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A LITERATURE SURVEY OF THEORIES AND METHODS OF PREDICTING CHARACTERISTICS OF MATERIALS

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COLUMBUS, OHIO

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UNITED STATES AIR FORCE
HOLLOMAN AIR FORCE BASE, NEW MEXICO

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Air Force Missile Development Center
Air Research and Development Command
United States Air Force
Holloman Air Force Base, New Mexico

FOREWORD

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ABSTRACT

A literature survey of theories and methods relating to strength and plastic deformation of materials has yielded almost 1800 abstracted references from various publications appearing between 1930 and 1957-1958. Primary emphasis was given to dislocation theories; absolute reaction rate theories; thermodynamic theories of fracture strength; relationships based on equations of state; and empirical relationships and parameters. The evaluation of the most promising theories and methods indicates that dislocation-type theories, or the parameter-type expressions, offer the greatest opportunity for ultimately predicting strength properties.

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LITERATURE SURVEY OF THEORIES AND METHODS OF PREDICTING CHARACTERISTICS OF MATERIALS

INTRODUCTION

The problem of describing the characteristics of materials is a long-standing one. When the additional goal is set of predicting material characteristics, almost insuperable difficulties are encountered. Many different lines of attack have been tried, to solve the problems encountered in describing or predicting material characteristics. The current approach has reached a degree of sophistication that leads to the conclusion that the basic mechanisms, the detailed atomic movements, the various interactions of elementary particles – all must be scrutinized in more detail in order to understand what is happening. This microscopic approach is necessary in order to understand the gross, macroscopically observed behavior, and embodies the scientific, long-range view.

On the other hand, the exigencies of the daily demands on engineers for practical and immediate solutions to his problems leave no alternative but to use empirical relationships, rule-of-thumb reasoning, or just plain horse sense. The two points of view on this general problem thus represent the two extremes that exist today in seeking to arrive at a solution to the problem of predicting material characteristics. The urgency under which one must work, then, will dictate the line of approach employed. This literature survey has attempted to plead both sides of the case – the plaintiff may receive the verdict applicable to himself alone. Therefore, for the purposes of a literature review in which the goal is to ascertain the potentially most useful theories and methods for predicting material properties, the guiding principle has been to re-examine all available work pertinent to the general problem. Then, on the basis of current developments in theory and methods and the opinions of experts in the field, and from the long-range perspective afforded by this literature review, an evaluation of the most promising theories and methods has been made.

SCOPE OF THE LITERATURE SURVEY

Obviously, complete coverage cannot be afforded a subject as prolific as characteristics of materials. It is recognized that such factors as heat resistance, corrosion resistance, strength at low or high temperatures, heat conductivity, etc., are all integral components of the over-all problem of material behavior. However, in view of such practical

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considerations as time, which must be faced in a 6-month literature survey, and in view of the vast amount of material already printed on the general subject, it is deemed advisable to limit the scope to the most fruitful areas. One of the most important areas would include the mechanical, or strength, properties; also, the selection should be directed primarily toward metallic materials. This latter choice is not as restrictive as it may seem at first glance, since the crystalline nature of metals is found duplicated in many nonmetallic substances, and the basic laws should be applicable equally to both. Furthermore, the term "strength", as used here, would be applied in the broad sense, in that the yield stress, the critical resolved shear stress, creep strength, the hardness, etc. – in fact, almost any index of a material's ability to resist plastic deformation – would be considered.

Some items have been excluded, rather arbitrarily, perhaps, but from the sheer necessity to draw the line somewhere. Included in a list of factors not covered specifically would be such items as fatigue, brittle-ductile transition behavior, age-hardening phenomena, recovery and recrystallization processes, and crack initiation and propagation. However, important articles on these subjects have been included in the main appendix. There is a good reason for the emphasis given here to strength properties. That reason is, if a material cannot pass the basic requirements of adequate strength under the specified conditions, then there is no great need to know the other properties.

As to the references themselves, each item deemed worthy of inclusion in this report has been entered in the main appendix, along with a brief abstract of its contents. The entries are listed alphabetically by the first author and are numbered consecutively. Here, again, the emphasis in selection has been on the broader aspects of the problem. Another guiding principle has been to document the experimental side, as well as the theoretical, as thoroughly as time and space would permit. This action was taken because of the great debt owed by theory to experiment, and because of the great importance such references would have in an experimental continuation of this program. It goes without saying that many references may have been left out – either by chance or design – that might be considered important. Be this as it may, there is no doubt that the references given in the articles covered here will lead to all additional references desired and many more. So, it should be a relatively minor task to locate a particular reference from the other quoted sources.

To facilitate the search for references on any particular subject, the main appendix of some 1800 entries has been broken down into four subsidiary categories. In addition, there is an author index in which are listed the references, by number, where the author's name appears. It is believed that the bibliography contained in the appendix will constitute an invaluable aid to the research worker in this field, and that the widest possible dissemination of this report should be made to interested parties.

BACKGROUND DISCUSSION

Early theories of the strength of metals were restricted mostly to simple substances, and to a relatively narrow range of temperatures. Fairly recently, some thought has been given to the case of more complex materials, as well as to a wider range of temperatures. In spite of the numerous attempts to develop a comprehensive theory, little progress was attained until the introduction of the concept of "dislocations" in the early 1930's. The flexibility of the dislocation theories, and the imaginative and fertile work of the many mathematicians and physicists who became interested in the possibilities of this concept, led to explanations of many metallurgical phenomena previously only vaguely understood. Important as this concept has proved, there still have been many alternative lines of attack on the basic problem of strength, such as the chemical, thermodynamic, electronic, atomistic, and mechanical. It can be seen that these various approaches embody the same goals, but that the points of view are somewhat different. Thus, all available theories have been reviewed so that no possible line of attack has been overlooked that may lead to a solution of the present problem.

In addition to the theoretical attempts to understand the basic factors affecting the strength of material, empirical methods have been developed to describe relationships between significant variables, such as temperature and stress. Although such ad hoc methods are not completely satisfying, they do have the advantages of relating the desired property to readily measurable experimental data, and, more important, they can be applied to the complex materials actually used in engineering applications. The outstanding development in this direction is the parameter involving time or strain rate and temperature, which correlates the strength properties rather successfully. However, it cannot be said that such parameters are completely empirical, because of their direct connection with the Boltzmann, or Arrhenius, rate equation, which connects a rate to an activation energy and temperature exponentially.

In the following paragraphs, those theories and empirical relationships that may be useful in describing material behavior at various temperatures will be discussed briefly. Then, areas that have been neglected or that need further consideration will be specified to some extent.

The outstanding importance of creep in metals stressed at high temperatures has led to a preponderance of theoretical work in this area. Schoeck(1396)*, Dorn(377), and Weertman(1672) have offered high-temperature dislocation theories of creep, based on the dislocation climb

*Reference numbers in parentheses refer to the bibliography in Appendix A.

mechanism suggested by Mott[1081]. Parker has claimed that Weertman's theory is the first to adequately take into account the important experimental facts. Seeger's ideas on the dislocation mechanisms of plastic deformation have stimulated those of Wiedersich[1697], as well as others. Older theories that have influenced ideas on creep are those due Orowan[1182], Mott[1082], and Nabarro[1110].

Bleakney[127] and Parker[1217] have examined the creep process in terms of intercrystalline cohesion, whereas Bochvar[146] theorized about intergranular shears. The absolute reaction rate theory has been applied to creep deformation by Kauzman[357], Nowick and Machlin[1137], and Dekhtyar[357], among others. A statistical formulation for creep of metals has been published recently by Bates, Ree, and Eyring*. Other approaches have been attempted, also. For example, Osipov and Fedotov[1203] have described creep in terms of self-diffusion coefficients and melting temperatures.

It can be seen that considerable latitude exists in the various approaches to a theoretical description of deformation at high temperatures. Theories that treat deformation from a more generalized standpoint than creep alone are also very numerous, with the emphasis at lower temperatures where thermal energy is not an appreciable factor. Such theories are important in any assessment of the literature on theories of strength, because it is possible that the basic ideas can be applied, without too many modifications, to other temperatures of interest. General theories that have had far-reaching influence in more modern formulations are due to Becker[89], Orowan[1174], Bragg[173], and Mott and Nabarro[1101], to quote a few. The dislocation concept in plastic deformation was explored thoroughly up to 1941 by Seitz and Read[1444], and the principles of plasticity theory were invoked by Hollomon and Lubahn[714]. Jaswon[758] has considered the problem of cohesion on an atomic scale. Other, rather extensive, treatments of the theory of metals have been given in books by Wilson and by Mott and Jones, primarily from the physicists' point of view.

A general review by Matthaes[1054] considered the relationships that exist among the various physical and mechanical properties of metals and alloys during plastic deformation. Numerous other authors have suggested alternative approaches to this problem. The rheological approach, embodied in the expression by Nutting[1140], appears to have extremely broad applicability. Examples are given by Dekhtyar[356], who established a relationship between bond energies and energies for diffusion; by Fastov[418] and Fürth[502], who utilized the methods of thermodynamics; by Gulyaev[617], who showed the periodicity of the strengthening influence of solute elements as related to valency; by Il'ina and Kritskaya[733], who relied upon X-ray measurements of bond strengths to describe the characteristic temperature of metals and alloys; and by Rovinskii[1360], Osipov[1195], and Dekhtyar[355], who expressed behavior in terms of electron-density configurations.

*Tech. Rep. 56, ONR (NR-032-168), June 15, 1956.

Factors that have definite influence on the realizable strength of metals have been systematized by many. Kornilov[854] considered strength and solubility relationships, whereas Andrews[39] classified properties according to a thermodynamic scheme. Ball[60] showed clearly the surprisingly important effects of subgrain size, and Biggs and Broom[107] considered the influence of ordering on strength properties. The hardness of pure metals was expressed by Westbrook[1690] as a function of temperature, crystal structure, specific heat, and the heats of fusion and transformation.

It may be noticed that the theories mentioned above depend, to some degree, on empirical laws – for example, the Hume-Rothery rules. Unfortunately, the science of metallurgy has not yet advanced to the stage where alloys can be designed on the drawing board, or with a computer. Thus, it is inescapable that the art of metallurgy today is still dependent on the rule of thumb, or empirical correlations, which are not based on fundamental metallurgical theory. Examples of empirical correlations relating tensile strength, temperature, and strain rate are due to Kanter[782] and to Clark, White, and Guarnieri[275]. Underwood[1620] has correlated hardness, creep, and tensile data to one straight line.

Zener and Hollomon[1777] and Hollomon and Jaffe[712] have proposed parameters involving strain rate or time and temperature, respectively, to correlate the flow stress and hardnesses of alloys. Larson and Miller[903] and Robinson, Tietz, and Dorn[1341] demonstrated that the time-temperature parameter could be applied just as well to stress-rupture data as to tensile data. The "velocity modified" temperature of MacGregor and Fisher[990] is akin to the parameter of Zener and Hollomon, and Rabotnov's parameter[1300] is useful in the case of isochronous stress-strain curves. The expressions involving strain rate describe the type of temperature- and rate-sensitive deformational behavior that is usually designated as viscosity, relaxation, or, more generally, thermal inelasticity[477]. The interrelationship of many of these parameters is obvious, which helps to emphasize the common origin of such expressions. The range of validity of the time-temperature parameter has been shown* to extend over rupture times as short as a fraction of a minute to more than a year and over a 700°F temperature range, for the Alloy S-590. This is indeed an impressive accomplishment for an expression involving only one constant.

Manson and Haferd[1043] have advocated their empirical expression that defines stress as a function of time and temperature. Since their parameter does not stem from the basic Arrhenius rate expression, it does not appear to have the significance of the other parameters listed above. Stowell[1527] attempted to lump together, in one equation, factors dependent on stress and strain, heating rate, and the time-temperature type of deformation. Under specified conditions, the expression can be simplified to a parameter similar to some mentioned above. It may be useful for rapid-heating rate tests.

*Underwood, E. E., unpublished research at Battelle Memorial Institute.

The preceding discussion was designed to give a brief survey of various kinds of theories and methods that have been advanced to describe plastic deformation. Conspicuous gaps in the coverage afforded by these theories are evident. For example, the marked influence of very small additions of a solute is not explained, nor is the existence of solution softening generally recognized. When several variables, such as strain, temperature, and aging, all change simultaneously, the problem of expressing such behavior analytically becomes hopelessly complex. No present theory can account for a creep rate that is governed by the instantaneous arrangement of dislocations, impurity atoms, and vacant lattice sites(227). Even N. F. Mott, who has done so much to advance dislocation theories of creep, says that they are "extremely tentative and may well have to be revised or abandoned(32)."

In spite of such shortcomings, progress in the theory of plastic deformation and strength has increased greatly during the past years, and further advances can be expected in the ensuing years.

DETAILED PLAN OF THE LITERATURE SEARCH

In order to get the most significant coverage of the literature, it was decided to start with articles appearing between 1930 and 1957. Most of the references of value today would fall in this period, and, when exceptional cases were noted, these could be included in the survey. Also, special volumes on meetings, reports, symposia, etc., and textbooks and specialized treatises dealing with strength of materials were included in the literature search, to insure that no important papers were missed.

The following sources were consulted:

(1) Chemical Abstracts

(2) Metallurgical Abstracts

(3) Abstracts of the Journal of the Iron and Steel Institute

(4) ASM Review of Metal Literature

(5) Metals Review

(6) Abstracts of Metallurgy of the USSR

(7) Transaction of the AIME

(8) Transactions of the ASM

(9) Acta Metallurgica

(10) Applied Mechanics Reviews

(11) NACA Bulletins, General Electric Company Bulletins, ASTM Bulletins, etc.

(12) Science Abstracts

(13) Proceedings from conferences on deformation, strength, creep, high-temperature behavior, etc.

(14) Textbooks and treatises on creep and strength

(15) Personal files already available at Battelle Memorial Institute.

Items (1), (2), (5), (7), (8), and (9) were checked as far into 1958 as possible, also. Other sources of information were consulted during the search period, including translations from Battelle Memorial Institute, National Research Foundation, Henry Brutcher, etc.

In addition to the above list, reports of special value to this investigation should be mentioned:

Report of a Conference on the Strength of Solids (1948)

A Symposium on the Plastic Deformation of Crystalline Solids (1950)

Imperfections in Nearly Perfect Crystals (1952)

Dislocations and Plastic Flow in Crystals (1953)

Creep and Fracture of Metals at High Temperatures (1956)

Dislocations and Mechanical Properties of Crystals (1957).

Collecting titles to references of possible value is a relatively easy and minor part of this task. More time-consuming is the next step – that of obtaining a suitable abstract for the reference. Depending on its importance, either a routine annotation was prepared for the record; a more thorough abstract was obtained from any of the abstract sources listed above; or the original article was read and evaluated, and an abstract prepared therefrom. The most time-consuming process of all is, of course, the full analysis given those articles of outstanding importance. All entries selected, regardless of importance, were then assembled in the main appendix, alphabetically by first author, and numbered consecutively. Evaluation of the important theories and methods is covered elsewhere in the report.

DISCUSSION OF IMPORTANT THEORIES AND METHODS RELATING TO STRENGTH PROPERTIES

Before plunging into detailed discussions of the theories and methods that are considered to be important to this literature survey, a brief outline of the main subdivisions will be given:

(1) Dislocation Theories. These are the results of the most modern theoretical developments, and are being exploited to an increasingly greater extent by scientists all over the world. They deal with detailed mechanisms, are very flexible, and are applied to a great diversity of physical phenomena. Quantitative predictions are now becoming possible in simple cases.

(2) Absolute Reaction Rate Theories. These more generalized theories do not depend so much on a detailed mechanism as do the dislocation theories. A "unit of flow" is postulated that conforms to thermodynamic criteria, and, depending on the detailed interpretation given, this "unit of flow" can be applied to the phenomenon of plastic flow.

(3) Thermodynamic Theories of Fracture Strength. These are based on the idea that the breaking of atomic bonds by fracture is analogous to the melting process. Great generality is to be expected from an approach along such lines, but the very fact that such generality is achieved makes it impossible to account for effects due to variations in microstructure, crystalline defects, etc.

(4) Relationships Based on Equations of State. Equations of state for solids are better known for the case where the selected variables are volume, temperature, and hydrostatic pressure. When variables such as stress, strain, strain rate, and temperature have been chosen, their functional relationship is known as a "mechanical equation of state". These equations are particularly attractive because they offer the possibility of predicting the mechanical properties of materials. However, the main stumbling block to the acceptance of such functions has been their dependence on the past history of the material.

(5) Empirical Relationships and Parameters. These parameters usually express a functional relationship between variables, such as strain, stress, strain rate, temperature, and/or time. Their greatest usefulness lies in the ability to predict behavior for the complex materials used for engineering purposes. However, their range of applicability is unknown, and calculated values extrapolated too far are uncertain.

Dislocation Theories of Plastic Deformation and Strength

Relatively speaking, the dislocation concept is new to the fields of plastic deformation and strength. However, the facility with which hitherto poorly explained observations could be rationalized; the extreme versatility with which the properties of dislocations could be applied to detailed mechanisms; the amenability of dislocations to mathematical analysis; and the experimental detection of dislocations have all helped in making this line of attack very popular nowadays. Unfortunately, the values of yield stress, for example, given by equations derived from dislocation models are indicated only to within orders of magnitude. The engineer desires numbers he can apply to the actual problems of everyday life. Furthermore, there are no all-encompassing dislocation theories involving strength properties, but mostly fragmentary explanations of mechanisms applicable only to isolated processes. Different types of failure (yielding, brittle fracture, shear fracture, fibrous fracture, fatigue fracture, etc.) have different underlying mechanisms, so that an "all-encompassing" theory is inherently impossible. However, at the present expanding rate of effort in this field, major breakthroughs can be anticipated in the next 10 years or so.

Modern dislocation theories of plastic flow stem from the papers of Orowan[1174,1175], Taylor[1575], and Polanyi[1272] in 1934. They described what is now known as an edge dislocation, which is characterized by the fact that its dislocation line, which separates the slipped portion of the crystal from the unslipped, is normal to the direction of slip. Depending on the orientation of the edge dislocation, they may be called either positive or negative. Another type of dislocation, known as the Burgers or screw dislocation, has the feature that its dislocation line is parallel to the direction of slip. Excellent review articles are available on the nonmathematical aspects of dislocations (see Appendix C), numerous papers have been published with a mathematical approach to the problem (see Appendix C), and many symposia held by specialists in the field of dislocations have been printed (see the six reports listed in "Detailed Plan of the Literature Search"). Earlier contributors to this field include Orowan, Mott, Nabarro, Frank, W. T. Read, Jr., and Cottrell. More recent workers are Seeger, Schoeck, Friedel, Leibfried, Hirsch, and Eshelby, among others.

For the purposes of this literature survey, only the most important theories, in the light of present-day knowledge, will be reviewed here. For convenience, they are considered under the headings of theories that pertain primarily to strain hardening, alloy hardening, precipitation hardening, and creep. Although this may seem to be a rather arbitrary classification, it is not intended as a hard-and-fast separation of distinct theories. Rather, it is found that these theories overlap and duplicate one another in varying degrees. The basic features or mechanisms, such as intersection of dislocations, jog formation, pile-up at barriers or obstacles, dislocation climb, and stacking faults, may appear in a few or all of the theories in the above-listed categories.

Strain Hardening

With increasing amounts of slip, further deformation becomes more and more difficult (i.e., the yield stress rises); this is strain hardening. The earliest quantitative dislocation theory that applied to strain-hardening phenomena was proposed by G. I. Taylor[1575]. The Taylor theory is discussed here in some detail because it has introduced into the theory of plasticity several concepts and mathematical methods that are of great importance, independent of the particular model of strain hardening to which they were first applied. Also, Taylor's model, although not giving a realistic picture of strain hardening, does contain the basic elements that are responsible for the additional hardening due to obstacles such as grain boundaries and inclusions. His idea was that the yield stress depends on the internal stresses opposing the movement of dislocations and that the dislocations create the stresses during plastic deformation. Taylor suggested that the dislocations do not pass completely through a crystal but interact elastically with one another and with obstructions such as mosaic boundaries, which prevent further motion. These immobile dislocations cause the internal stresses that raise the yield strength. Since plastic flow results from the movement of dislocations, any mechanism that causes a decrease in the mobility of dislocations causes work hardening. An expression relating stress and strain was derived for the case where slip begins at random points throughout the crystal and occurs by the separation of one positive and one negative dislocation at each of these points. (However, no separation occurs if the dislocation can arise at a surface or even an interface.) If the average length along the slip plane through which the dislocations move apart is L, and if the yield stress is assumed to be the same as the highest internal stress acting upon a dislocation when it is set in motion, then

$$\sigma = \alpha G \left(\frac{\gamma b}{L}\right)^{1/2} , \qquad (1)$$

where σ is the tensile stress; α is a constant; G is the shear modulus; γ is the plastic strain; and b is a vector (called the Burgers vector) that specifies the direction and distance by which atoms above the slip plane have moved relative to those below. This parabolic relation between stress and plastic strain was confirmed experimentally for metals crystallizing in the cubic system. L was hypothesized to be of the order of 10^{-4} cm, in agreement with the order of magnitude of faults found in metals and rock salt. The crystallographic nature of the faults is immaterial from the point of view of the theory. However, in Taylor's theory, no provision is made for

crystalline deterioration or the development of imperfections. It is a pure barrier theory; thus, if the strain is reversed, the dislocations should go back to their source, and there should be no strain hardening. This is contrary to observation. Further detailed analyses and criticism of this theory have been presented by Orowan[1189] and Cottrell[293].

Although Taylor's theory is no longer accepted, some of the general ideas are basic to later theories. Mott[1085] suggested a theory based on piling up of edge dislocations against obstacles in their slip plane. These obstacles were thought to consist primarily of sessile dislocations (a type of fixed dislocation that can move only by the transport of atoms to or from the perimeter of the fault by diffusion) randomly distributed in the crystal. At each obstacle, a group of n dislocations of the same sign is piled up and anchored by combining with a few dislocations on an intersecting slip system. The stress field of each group acts through large distances, n times farther than that of a single dislocation. An expression for the internal stress, σ_i, on each group of dislocations is derived, which, when combined with that for the plastic strain, gives a parabolic hardening law

$$\sigma_i = (G/2\pi)\,(n\gamma b/L)^{1/2} , \qquad (2)$$

where the terms are as before. A value for L, the spacing of the obstacles, can be obtained by postulating a dynamic generation (later discarded) of dislocation loops, from a source of length ℓ, which move a distance L. This gives

$$\sigma_i = G(\gamma b/2\pi\ell)^{1/2} . \qquad (3)$$

The following characteristics of this result may be seen. When ℓ is constant, a parabolic stress-strain curve is obtained; with a reasonable value of ℓ (about 10^{-4} cm), the resulting coefficient of work hardening is of the right order of magnitude; and the stress-strain relation is independent of L, which is one of the more serious deficiencies of the theory. Even though the intensity of strain hardening is roughly the same in many crystals of different orientations, strain hardening is probably mainly due to the decrease of the spacing between obstacles.

Mott's theory resembles that of Taylor, but differs in several respects: the newer theory pictures the dislocations as being locked; the strength of each group of dislocations is n times larger; and the spacing between them is correspondingly larger.

Other theories have contained alternative explanations of work hardening[173,218,815,911], but they either have been unable to stand the test of time, or the number of assumptions introduced has prevented their acceptance. However, two rather comprehensive reports have emerged lately, which attempt to give a more unified picture of the present status of experiment and theory. These are the papers by Orowan[1189] in 1954 and by Seeger[1425] in 1957. Orowan points out the generality of the phenomenon of strain hardening, and the attendant uncertainty as to its cause. He points out that a number of factors can contribute to strain hardening, and that the pure barrier pile-up theories cannot account for more than a small fraction of the hardening. In the case of polycrystalline metals, strain hardening can arise from the mutual interference of neighboring grains. However, the mechanism for intracrystalline hardening, e.g., in single crystals, is by no means clear.

A mechanism of strain hardening was first outlined by Taylor, and this has been treated above. Another possibility of strain hardening, discussed by Orowan, is that arising from the removal or inactivation of lattice defects that make the crystal soft. This possibility is not too probable. Without the presence of a multiplication mechanism, a crystal would harden extremely rapidly as the dislocations present initially were used up by slip. However, the number of dislocations needed for producing large amounts of plastic deformation is far too high to be present initially in the crystal. An alternative scheme embodies the idea of an initial stock of Frank-Read sources (dislocation double mills) with different widths. As deformation proceeds, the double mills with widest spacing (and correspondingly lowest operating stresses) are used up first, and the mills with smallest spacings would go last. Although this mechanism for the origin of strain hardening cannot be ruled out completely, it is not entirely satisfactory.

More probable is the creation of lattice "injuries" acting as obstacles to slip in the course of deformation. One way of producing lattice imperfections other than dislocations during slip is the generation of vacancies; similarly, excess (interstitial) atoms may come into the lattice. Twin and kink(1180) lamellae may, and in general will, arise locally, particularly in a polycrystalline material. Other mechanisms of hardening are the cutting of dislocations by slip taking place in a plane pierced by them, and the intersection of stacking faults by crossing slip planes. These latter two mechanisms may play a more significant role in the hardening process than the others, so they will be described in more detail later.

The lack of satisfactory explanations for multiplication mechanisms of dislocations was one of the major problems in the theory of plasticity. Either new dislocations must be created during slip, or a dislocation must be able to produce large amounts of slip. This difficulty was circumvented when it was realized that a dislocation loop need not lie entirely in one plane. Whenever a dislocation loop does not lie wholly in one slip plane, any part of it that lies in a certain slip plane may sweep over the plane many times without disappearing. Sources that can supply many dislocations have been called dislocation mills. Various types of dislocation mills are described by Orowan, including the slip-deflection mechanism and the "Z-mill", a dislocation sheared through the middle, which resembles the letter Z. The present status of the problem may be summed up in the following way: Most crystals of moderate size contain flaws from which slip can start at a low stress. Once slip has started, there are numerous ways, topological or dynamical, in which new dislocations or dislocation mills can arise.

The principle of strain hardening due to dislocations cut across by slip may be illustrated in a simple way. Consider two blocks sliding upon one another. The surface of contact is the slip plane. Now, an elastic thread (dislocation) is imagined to pierce both blocks perpendicular to the slip plane, and, if slip occurs, the upper and lower halves of the thread will be displaced correspondingly. The connecting portion of the thread which lies in the slip plane represents the connecting dislocation between the ends of the two segments. The tension of this connecting dislocation increases the shear stress required for further slip. If the number of immobile dislocations traversing a slip plane is n per unit of its area, their intersection gives rise to an additional shear stress n times greater than the force needed with one. Since the number of dislocations traversing any slip plane increases in the course of plastic deformation, the yield stress must also rise, i.e., strain hardening must occur.

If the mechanism by which n increases with increasing deformation were known, and a relationship between n and the plastic strain could be established, the rate of strain hardening due to the intersection mechanism and the corresponding stress-strain curve could be calculated. However, at present, any such calculation would require a number of highly arbitrary assumptions that could hardly be justified by any agreement of the result with observed stress-strain curves.

The intersection mechanism can explain the difficult problem of why latent slip planes, intersecting the operative slip zones, harden before they would be expected to. Another phenomenon explicable on the above basis is the Bauschinger effect in single crystals, although it now appears to be due to other causes. Another mechanism of hardening, pointed out first by Seitz(1443) and also by Nabarro(1113), deals with the mechanism of intersection of screw dislocations, which produces strings of vacancies or of interstitial atoms.

A newer mechanism of strain hardening, which may be of considerable importance in heavily deformed face-centered-cubic crystals, involves a type of defect known as a stacking fault*. The contribution of stacking faults to the general theory of slip, and in particular to that of strain hardening, is believed to be of great importance. A stacking fault, as its name implies, is merely an irregularity in the sequence of stacking of octahedral planes in a close-packed-cubic crystal. Calculations show that the extensive development of stacking faults can occur only at fairly high applied stresses, in a strongly distorted state of the crystal. The effect of intersecting slip upon a stacking fault is to generate two mixed edge-screw dislocations, which move apart as the intersected edges of the fault move apart by slip. No slip across the fault can occur until the shear stress is high enough to produce these two dislocations and move them apart. This process probably requires the piling up of dislocations at the stacking fault before it can be broken through.

*W. T. Read, Jr., Dislocations in Crystals, McGraw-Hill Book Company, Inc., New York (1953), 110-113.

If a strongly cold-worked face-centered-cubic crystal contains several intersecting sets of stacking faults, it will be strain hardened in a way that resembles Taylor's theory of hardening. The difference is that the obstacle walls are not pre-existent, but are generated by slip, and that they are not impermeable to slip, but can be penetrated at a sufficiently high stress. Furthermore, it is not necessary to assume the piling up of dislocations in the cells between the fault walls, as in the Taylor theory; intersecting walls of stacking faults could produce internal stresses high enough to explain the observed yield stress. It should be repeated, however, that hardening by the intersection of stacking faults is likely to be important only in strongly deformed face-centered-cubic metals. Under these conditions it may be the dominant factor in hardening.

An ambitious attempt to explain theoretically the dislocation processes governing the plastic properties of close-packed metals was undertaken by Seeger[1425] in 1957. He stated that the present state of the theory would permit only a semiquantitative interpretation of the experimental facts. Furthermore, there would be no attempt to derive the stress-strain curve of a crystal from first principles because of the complexity of dislocation patterns and behavior. Rather, the goal of devising a theory of cold work and work hardening would be directed toward finding the fundamental processes hidden behind the individual behavior of crystals.

The first step in a theory of work hardening is to develop a theory of flow stress, i.e., to determine the resolved shear stress, τ, under which extensive plastic flow in an unstrained crystal begins. The next step is to determine how the dislocation arrangement changes with strain, and, in some cases, with time. Combining this with the theory of flow stress gives the slope $\theta = d\tau/d\epsilon$ of the stress-strain curve as a function of strain, ϵ, and strain rate, $\dot{\epsilon}$; i.e.,

$$d\tau/d\epsilon = \theta(\epsilon, \dot{\epsilon}) \quad . \tag{4}$$

The equation of the stress-strain curve, $\tau = \tau(\epsilon)$, for a given strain rate is obtained by integration. Equation (4) is considered to be the fundamental relation of the theory of work hardening. It should be noted here, however, that Equation (4) is incorrect because the slope of the stress-strain curve is not determined by the instantaneous values of strain and strain rate. Also, integration of Equation (4) cannot give the equation of the stress-strain curve.

The program outlined above by Seeger cannot be carried through completely because of insufficient knowledge. However, the individual features of the dislocations in various metals, even though different, can be rationalized, at least for the face-centered-cubic metals. This is done in terms of the magnitude of a single quantity, namely, the stacking-fault energy, γ. The dislocations with which we are mostly concerned are "extended" ones, and the degree of extension is determined by a quantity containing γ. The stacking-fault energy, γ, is defined as the surplus free energy of a stacking fault of unit area. Theoretical arguments based on the increase in energy

of the conduction electrons and measurements of the energy of coherent twin boundaries give order-of-magnitude estimates of the stacking-fault energy and show rather good agreement.

The "surface tension" of the stacking-fault energy opposes the elastic repulsion between the partial dislocations and binds them together at a finite equilibrium distance. The dimensionless parameter that determines the equilibrium extension is $\gamma c/Gb^2$, where G is the shear modulus, c is the separation between neighboring glide planes, and b is the distance between neighboring atoms in the glide plane. If the parameter is larger than 10^{-2}, the metal is considered to have a high stacking-fault energy (e.g., aluminum) and the partials are close together; if less than 10^{-2}, the stacking-fault energy is considered to be low (e.g., copper), and the partials are well separated.

Next, Seeger turns to an account of the principal experimental results on stress-strain curves of face-centered-cubic single crystals. The results can be summarized in terms of three separate regions of the stress-strain curve. There may, or may not, be a region of easy glide (Stage I), depending on the crystal orientation and the impurities present. Most characteristic for these crystals is the stage of rapid work hardening (Stage II), which follows the easy-glide region. In this region, the ratio of the work-hardening coefficient to the shear modulus is practically independent of the applied stress and temperature, not very dependent on the crystal orientation, not sensitive to the impurity content, and of the same order of magnitude for all face-centered-cubic metals. The understanding of the rapid work hardening in this stage seems basic to an understanding of the plastic deformation of face-centered-cubic metals. At larger strains (Stage III), the slope of the stress-strain curve diminishes with increasing strain. The stress, τ_3, at which this stage begins depends markedly on temperature and on a kind of "dynamic recovery" – a term coined by Diehl to emphasize the effects of temperature during deformation.

The explanation of the easy glide observed in Stage I is that no Lomer-Cottrell dislocations, a particular form of immobile dislocation, are formed in some crystal orientations, permitting unperturbed easy glide. Easy glide is assumed to take place primarily in only one glide system, but there may be some dislocation movement in other glide systems. Most dislocations during easy glide slip out of the crystal and only a small fraction is held to contribute to work hardening. The Lomer-Cottrell dislocations act as obstacles to the glide of screw dislocations. In other orientations of the crystal, the resolved shear stress in certain secondary glide systems is large enough to result in some Lomer-Cottrell dislocations being formed, and, with increasing plastic deformation, the slip distance in all directions is limited by Lomer-Cottrell dislocations. Stage II, rapid work hardening, is fully developed if Lomer-Cottrell dislocations of all (three) types possible in the primary glide system are formed in significant numbers. The linearity of Stage II is explained as a result of continued formation of

Lomer-Cottrell barriers. This gives rise to a decrease of the slip distance with increasing strain and to small dislocation groups of essentially constant size, piled up against the barriers and distributed randomly. The geometrical arrangement of the groups is thought to be more or less statistical, in a pattern such that groups of opposite sign stabilize each other to some extent. As a consequence, the flow stress is proportional to the density of dislocations intersecting the glide plane. It should be noted here that the very fact that stacking-fault formation does not occur in this picture shows how very special the assumed mechanism is. In all probability, Lomer-Cottrell dislocations are only one of many types of obstacle produced by deformation.

The general picture of the dynamical recovery occurring in Stage III starts with the dislocation arrangement built up in Stage II (which is essentially independent of temperature and strain rate). At a sufficiently high stress and temperature, the dislocations can undergo processes that had been suppressed at lower stresses and temperatures. For example, they may allow the dislocations to climb around obstacles that held them up in Stage II; another possibility is that these processes enable some dislocations of opposite sign to annihilate each other and to reduce the internal stress fields. This results in a reduction of the work hardening.

Although the work-hardening coefficient decreases, this effect is merely one of superposition on the continuing hardening process from Stage II. The flow stress is found to be composed of the temperature-dependent contribution, τ_S, of the dislocation forest and the temperature-independent contribution of the stress fields of the dislocations lying in the primary slip plane, τ_G. The increase in the flow stress, i.e., the hardening of the primary slip systems, is mainly due to the increase in τ_G, rather than in τ_S.

This general discussion of the stress-strain curve, although couched primarily in terms of face-centered-cubic metals, is applicable to hexagonal close-packed metals and alloyed single crystals, when their specific characteristics are considered. Although instances of discrepancies from this general treatment may arise, they can be accounted for, except when the data are as yet too limited to permit any clear-cut explanations. Seeger's picture drawn for the hardening mechanism still lacks certain details. They can best be filled in by theoretical and experimental studies of additional properties of the deformed crystals.

Alloy Hardening

So far, the most promising approach to an understanding of hardening in alloys is one employing dislocation models. The "hardening" considered in this section will include that due to alloying in single-phase solid solutions and not that due to particle effects in polyphase alloys. Actually, depending upon the degree of dispersion, these two cases can be treated from a common point of view, and this will be done whenever applicable.

There is at this time no theory that will permit, a priori, the prediction of mechanical properties of an alloy; the available theories are actually rather primitive, since direct observation of dislocations is still rather limited. Theories cannot predict, nor explain fully, the effects of temperature, stress, or chemical species on strength properties. However, there are certain general trends, confirmed experimentally, available to guide theoretical developments. These behavior patterns may be listed as: (1) the addition of a second element to a pure material almost always increases its strength; (2) the strength increases with increasing amount of the added element, then may decrease later; and (3) the scale of dispersion of a second phase has an effect on the strength of an alloy.

The more important dislocation theories of alloy hardening may be considered on the following basis:

(1) Those theories that assume that solute atoms cause internal stress in the matrix, and that hardening is due to the resistance that these stresses offer the movement of dislocations

(2) Theories that are based on interactions between solute atoms and dislocations

(3) Theories in which the passage of dislocations is hindered by discrete aggregations of atoms, inclusions, or particles.

The basic treatment upon which theories assigned to Section (1) above are based is that due to Mott and Nabarro(1100), as modified later by Mott(1082). The case considered is that for which the wavelength, Λ, of the internal stress field, σ_i, is small compared with the limiting radius of curvature of the dislocation. The local stresses around dissolved atoms have a "wavelength" $\Lambda \approx \frac{d}{c^{1/3}}$, where d is the interatomic spacing and c is the solute concentration. In this case, the dislocation is hardly bent by these local stresses, so that the appropriate average value for the internal stress turns out to be

$$\sigma_i \approx G\epsilon c \log (1/c) \quad , \qquad (5)$$

where ϵ is the strain around the dissolved atoms, and the other terms are as before. The length of the dislocation line is estimated from the relative magnitudes of the amplitude of n^2 loops of the dislocation line and the wavelength of the stress field. The positions of equilibrium of the dislocation line occur at intervals of about Λ in the solid solution. From statistical considerations of the force on single loops of the dislocation line, an equivalent uniform stress, σ_i/n, is derived for the dislocation line. This stress should be the zero-point yield strength, σ, of the material. Substituting for σ_i and n, the approximate expression is obtained:

$$\sigma \approx 2.5\ G\epsilon^{4/3}\ c \qquad (6)$$

for solutions with solute concentrations varying from 0.001 to 0.01.

The equation predicts a stronger solution-hardening effect than is observed experimentally, and this may be due to an underestimation of the length of the coherent piece of dislocation. In their earlier treatment, Mott and Nabarro assumed a much greater length, which leads to a smaller yield strength

$$\sigma = G\epsilon^2\ c \ . \qquad (7)$$

There is some evidence that the hardness of polycrystalline solid solutions changes as the square of the change of lattice spacing, but this relationship is not always clearly defined. Some of the disagreement between theory and experiment can be explained on the basis that a valency effect exists in addition to the size-factor effect. Thus, it has been shown that solute atoms whose valencies differ from that of the solvent have a greater hardening effect, for the same size factor, the greater the difference in valencies.

Theories pertaining to Section (2) above are based on interactions between solute atoms and dislocations. There are at least four important types of interactions that are found between solute atoms and dislocations. They are called, after Cottrell(295), elastic interaction, electrical interaction, chemical interaction, and geometrical interaction. When a solute atom replaces a solvent atom in a substitutional solution, or enters a vacant site in an interstitial solution, the hole it enters may be the wrong size or shape. Work must be done to alter the dimensions of both the hole and the atom; and, if a stress field alters the dimensions of the hole, the work done in inserting the atom may also be altered. Calculations of this interaction for the case where the dislocation provides the stress field have been made for several cases(110,933).

Mobile solute atoms will drift, in the presence of an inhomogeneous field such as the stress field of a dislocation, toward those places where they have lowest energy. The segregation produced in this way is an equilibrium state of distribution for the solute atoms, since its formation involves a lowering of the free energy of the system. One of the more important theories stemming from the segregation of solute atoms around dislocations is the theory of the sharp yield point due to Cottrell(286).

Under an external force a dislocation surrounded by an atmosphere of solute atoms starts to move and leave the latter behind. A force is then exerted, pulling the dislocation back to its original position at the center of the atmosphere. If the applied force is less than this anchoring force, the dislocation cannot move. The dislocation can move, however, if the atmosphere moves with it, but only at a speed equal to the speed of migration of the solute atoms in the atmosphere.

In many cases the rate of straining is too high or the temperature is too low for the atoms to keep up with the dislocation. However, to produce plastic flow, the dislocations must first be pulled away from their atmospheres, and to do this the applied force must exceed the anchoring force. Because of the strong affinity between a dislocation and its atmosphere, this applied force will be larger, in many cases, than the force needed to keep the dislocations in motion once they have escaped from their atmospheres. The material can then exist in either of two conditions – the strain-aged condition or the overstrained condition. In the former case, the dislocations are anchored and the deformation is purely elastic, whereas in the latter case, the dislocations are free to move. The conversion from the first to the second condition coincides with the beginning of plastic deformation in the material. When the dislocations escape from their atmospheres, the force needed for movement is smaller, so the material suddenly becomes softer and yields under a decreasing stress at the beginning of plastic deformation. This is the explanation of the phenomenon of the sharp yield point observed in body-centered-cubic metals with certain impurities, notably carbon or nitrogen.

The theory has been applied quantitatively to the yielding of iron containing carbon or nitrogen(302), and has stimulated the investigation of yielding in other metals. In spite of several modifications to the theory(289), some discrepancies are apparent, as Orowan has pointed out(1189), and some experimental contradictions have arisen (see discussion to Reference 289). However, the basic ideas appear to be widely accepted and applied to many diverse phenomena. Schoeck and Seeger, in a paper presented at the Fall Meeting of the Metallurgical Society of the AIME, in October, 1958, proposed an alternate mechanism of interaction based on the Snoek effect, which had been applied to the yield phenomenon previously by Nabarro(1109) and Crussard*. Here, the interstitial atoms jump to neighboring sites that are now preferred because of the stress field of the dislocation. These jumps can take place in times that are orders of magnitudes smaller than it would take to form Cottrell atmospheres. Excellent experimental verification is claimed for the magnitude, temperature dependence, and concentration dependence of the flow stress calculated from this model.

*C. Crussard, Métaux et Corrosion, 25 (1950), 203.

Electrical interactions, between a solute atom and a dislocation, are known to play a strengthening role in metals, and calculations have been made of the interaction effects(306). A comparison of electrical and elastic interactions shows, in alloys of copper, that the latter are 3 to 7 times larger than the former. So, unless the effective charges on solute atoms are substantially larger than the values used in the calculation, the electrical interaction is relatively unimportant, except possibly at the center of a dislocation.

Chemical interaction is the name of the mechanism suggested by Suzuki(1546) to account for the heterogeneous distribution of solute in faulted and unfaulted regions. The heterogeneous distribution of the solute atoms results in a hardening atmosphere, similar to the Cottrell atmosphere in body-centered-cubic metals. In a face-centered-cubic solid solution, thermodynamic equilibrium will in general require the concentration of solute to differ from that in the close-packed hexagonal structure of the faulted layer. From consideration of the free-energy curves of the matrix and the faulted material, and assuming that the proportion of the phases remains fixed, the equilibrium concentrations can be found. Cottrell has extended Suzuki's theory by removing the constraint on the proportions of the phases. Further experimental verification of Suzuki's theory has been obtained by Hibbard(683) and Flinn(451). His theory appears to be an important extension of the ideas on interactions of dislocations.

The fourth type of interaction with dislocations is called "geometrical interaction", and is associated with the presence of a dislocation in an ordered alloy. The interaction is a result solely of the slip displacement caused by the dislocation. In a crystal with long-range order, a unit perfect dislocation in the lattice of atomic sites is only a half-dislocation in the superlattice. It must therefore always be attached to a stacking fault in the superlattice, i.e., to an antiphase domain boundary. The fault has surface tension due to the energy of its "wrong" bonds and it exerts a force on the dislocation line at its boundary. Quantitative aspects of the hardening expected from this source have been discussed by Ardley and Cottrell(43). For the β-brass superlattice, the stress to move a dislocation would have to be about 3×10^9 dynes/cm^2.

The motion of dislocations through short-range ordered solutions has been discussed by Fisher(435). Since there is no superlattice in these, unit dislocations in the lattice of atomic sites are perfect and there are no long-range faults to pull these dislocations in pairs. However, because the distribution of neighboring atoms is not random, the passage of a dislocation along a slip plane will destroy the short-range order between the atoms across the plane. As in the case for long-range order, the stress, τ, to move the dislocation is given by

$$\tau = \gamma / b \quad , \qquad (8)$$

where γ refers to the energy, per unit area of the plane, associated with the degree of order across it, and b is the length of the Burgers vector. Although γ is smaller for short-range than for long-range order, in an alloy with intense short-range order the stress to move dislocations can approach the magnitude of 10^8 dynes/cm^2. Both types of ordering should play a definite role in the development of a theory of hardening, but the magnitude of their effects is not expected to be too important.

Precipitation Hardening

The third major subdivision of dislocation theories pertaining to alloy hardening deals with precipitation hardening, or the hardening associated with hard, discrete particles. Two papers by Mott and Nabarro(1100,1101) have provided a detailed treatment of solid-solution hardening and precipitation hardening, i.e., of cases where the solute atoms are dispersed at random, either singly in solution or as clusters in precipitates. Later, these authors emphasized that the dislocation line passing through the alloy is flexible(1074,1107); it is akin to a stretched string, which vibrates and radiates elastic energy as it moves and is "plucked" by the solute atoms as it passes. The amount of energy dissipated by the plucking process depends on the distribution of the solute atoms and increases when they are clustered together, as in precipitates. Orowan pointed out* that, when the distance between clusters increases beyond a certain range, it becomes possible for sections of the dislocation line to bulge between neighboring clusters and then expand into the slip plane on the other side, thus bypassing the clusters. For a fixed composition, there is thus a critical distance between clusters at which the hardening is greatest, as is observed in precipitation-hardening alloys. Theory gives the distance as typically about 50-atom spacings, which is reasonable.

The approach adopted by Mott and Nabarro in their theory of dispersion hardening was based on residual stresses. The stresses are considered to arise from the misfit of the precipitate in the matrix and the resultant elastic accommodation. The dislocations producing slip must be pushed through those regions in the slip plane where the stress is adverse to their motion. They estimate the average magnitude of the stress and identify this with the yield stress due to the precipitate.

The value of the stress, σ, is

$$\sigma = G\epsilon f \quad , \qquad (9)$$

*E. Orowan, Discussion in Symposium on Internal Stresses in Metals and Alloys, Institute of Metals, London (1948), 451-453.

where G is the rigidity modulus, ϵ is the resultant strain in the precipitate, and f is the volume fraction of the solute atoms in the alloy. The implication in their original theory is that the dislocations may pass completely through the precipitate particles, but later work favors the idea of flexible dislocations, mentioned above.

For the case where the radius of curvature of the flexible dislocation, ρ, is approximately equal to the mean spacing of the precipitate particles, Λ, the argument is that each segment of the dislocation of length Λ must be separately forced through the local adverse stress regions between the precipitate particles. At this stage of hardness, the relation describing the critical dispersion is given as

$$\Lambda \approx b/\epsilon f \quad . \tag{10}$$

Several criticisms can be directed at this theory in its present state(645). In the first place, this method would require that the strength remain high at the value $G\epsilon f$, even when the spacing exceeded the critical spacing. This is contrary to the customary behavior. Furthermore, this residual-stress theory is too qualitative, since it is rather difficult to assign values to the parameters. Also, Equation (9) must be judged deficient from the value of ϵ which is necessary for a sufficiently large yield stress at maximum hardness.

Orowan* proposed a particularly simple and straightforward method for computing the yield stress due to precipitates in terms only of the spacing of the particles. He considered that dislocations would be held up by internal stresses at precipitate particles and that it would be necessary to force them between the particles. Loops of dislocations would then be left encircling the precipitate particles as the dislocation line moved past them. The yield stress estimated from this model is

$$\sigma = 2\ Gb/\lambda \quad , \tag{11}$$

where λ is the spacing between two particles (or obstacles) and the other terms have the same meanings as before. Orowan concluded that, since λ increases with increased aging time, this might explain the decrease in yield stress of overaged alloys. Equation (11) is the same in form as that developed by Mott and Nabarro; however, the assumptions and interpretations are distinctly different. One important distinction is that the Λ of Equation (10) represents the length of an independently mobile dislocation segment, and belongs essentially to a two-dimensional picture, whereas the λ of Equation (11) is the spacing between particles in three dimensions. Orowan's treatment implicitly denies the validity either of Equation (9) or of its interpretation as the yield stress and replaces Equation (9) with

*E. Orowan, loc. cit.

Equation (11) entirely. However, the applicability of the Mott-Nabarro criterion of a dislocation being forced across a region of adverse internal stress (which is really G. I. Taylor's original idea) is not denied. At sufficiently high internal stresses, the Taylor-Mott-Nabarro criterion (yield stress = adverse internal stress) would apply, although not in the form of Equation (9).

A minor extension to Orowan's theory was suggested by Geisler to the effect that coherency strains around particles make the effective spacing smaller. Orowan's theory can then be applied over the entire hardening range, instead of only in the overaging range. The drop in yield stress at early aging times is explained on the basis that λ is larger because of the smaller amount of precipitate available. The calculated yield stress at maximum hardness agrees in order of magnitude with that observed. Also, the yield stress in the overaged region is of the same order as in the solid solution, as would be expected.

Another theory of dispersion hardening was advanced by Fisher, Hart, and Pry(443). However, in this case, they are concerned with incremental strain hardening, and not the yield strength, as in the previous two theories. They show that an appreciable hardening increment is obtained, as a result of strain, due to the stresses from trapped dislocation loops around particles, as originally described by Orowan.

The loops encircling the precipitates are shown to exert a shear stress on the rest of the surrounding slip plane, which stress is of opposite sign to that which caused the slip. By certain simplifications, the final expression for the maximum value of the stress increment is obtained,

$$\tau_h = K\tau_c\ f^{3/2} \quad , \tag{12}$$

where K is a constant, τ_c is the limiting shear strength of either the precipitate or the matrix, whichever is weaker, and f is the volume fraction of the precipitate. Some agreement with experimental results was claimed, but actually the data used, for particle radii and volume fraction, were calculated and not measured. Under its present state of development, this theory seems in need of further clarification.

Creep

Creep may be defined as the plastic deformation that can occur under a constant applied stress. It is an important part of any study of plastic deformation, and is not, as sometimes thought, confined only to high temperatures. In discussing theories of creep, we will be concerned primarily with dislocation theories that explain macroscopic behavior in terms of the structural processes on an atomic scale. There are two main processes to consider: transient creep and viscous creep. The former is a decelerating component, the rate of which depends on the applied stress and disappears with time; the latter is a constant-rate process that depends primarily on the applied stress. This important distinction was made clear by Andrade(22) in 1914. The term "steady-state creep", however, is ambiguous in that either viscous or transient creep may appear to be a steady-state creep. Normally, the term "steady-state creep" is meant to apply to viscous creep.

The basis upon which all formal theories of creep have been built was laid down by Becker(89), starting in 1925. Becker's purpose was to use thermal stresses for explaining the discrepancy between the high theoretical value and the low observed value of the yield stress. The contributions of Orowan(1182) led to the present activation theory of transient creep, and the main ideas embodied in this treatment are:

(1) At the beginning of creep, the applied stress is equal to the yield stress, so the activation energy is vanishingly small. This is the reason for an infinitely high initial creep rate, even at the lowest temperatures.

(2) The flow rate during creep is limited because thermal fluctuations are needed to supply the difference between the applied stress and the yield stress.

(3) As the creep strain increases, the yield stress also increases, rising progressively farther above the applied stress, and the activation energy increases accordingly. The increasingly large thermal fluctuations that are thus needed cannot be accomplished as frequently as the small ones that were sufficient earlier, and the rate of flow slows down. If a stage is reached where the yield stress no longer rises, the activation energy becomes constant and steady-state creep is observed.

Becker proposed the following formula to relate the creep rate, $\dot{\epsilon}$, with the stress, σ, and temperature, T:

$$\dot{\epsilon} = C_{\exp}\left[-\frac{V(\sigma_0-\sigma)^2}{2GkT}\right], \qquad (13)$$

where C is a constant, σ_0 represents the theoretical yield stress of the crystal, and V is the volume in which a stress fluctuation occurs. Equation (13) does not represent viscous creep; Becker emphasized very sharply that this is an entirely different process of atomic rearrangements ("amorphous plasticity"). For this reason, it cannot explain the transient component of creep, the rate of which falls from infinitely large to zero in the course of time at constant stress and temperature. The deceleration occurs because of strain hardening or some other progressive change of the material during flow.

Orowan(1182) introduced strain hardening into Equation (13) by assuming that σ_0 increases during deformation by an amount $\phi(\epsilon)$, which is a function of the strain, ϵ; the revised formula gives

$$\dot{\epsilon} = C_{\exp}\left[-\frac{V(\sigma_0 + \phi(\epsilon) - q\sigma)^2}{2GkT}\right], \qquad (14)$$

where q is a stress-concentration factor. Equation (14) was subsequently found to be unsatisfactory, and this was attributed to the failure of the "mechanical equation of state", of which Equation (14) is a special case.

At the present time(1191), the mechanism of creep is held to be as follows. Although the details of the mechanism are not yet clear, there is no doubt that transient creep is a consequence of thermal vibrations, superimposed on a sufficiently high applied stress, which result in slip. During further creep, the material hardens and thermal vibrations are then less and less frequently able to produce local slip; this is the cause of the gradual disappearance of transient creep. The applied stress must always be high enough to cause at least a small amount of sudden plastic strain before transient creep can be observed – and this is why transient creep occurs even at the lowest temperatures. Then, if the applied stress is sufficient to cause slip without any thermal contribution, additional local slip can occur, at points where the applied stress is not quite high enough, by means of very slight thermal fluctuations.

Viscous creep is believed to be produced by at least two different mechanisms, and often the two act simultaneously. The first type of viscous creep is called recovery creep. After the load is applied, the rapid plastic deformation produces strain hardening, which raises the yield stress to the level of the applied stress and thus resists the load. However, at a high enough temperature, thermal recovery gradually reduces the strain hardening. In order to carry the applied load, therefore, the material must strain harden further until the amount of strain hardening lost by recovery is replaced. This means that additional plastic strain is continually required to make up for the strain hardening removed by recovery.

The second important type of viscous creep is due to sliding between the grains of a polycrystalline metal when a stress acts at a sufficiently high temperature. At low temperatures, the grain boundary is a strong part of the structure; it resists the slip in the grains. At high temperatures, however, the boundary becomes soft and viscous and is an element of weakness. Of course, this aspect of the creep process is bypassed when single crystals are dealt with, which may be necessary for purposes of simplifying the experimental and theoretical problems.

Mott and Nabarro(1101) used the elastic properties of dislocations to develop a theory of creep exhaustion – that is, creep in which the slowing down of the extension is due to the exhaustion of easily moved dislocations. They point out that dislocations move in a potential field that changes during

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work hardening and stress application, and that the internal stresses that must be overcome for plastic flow are primarily determined by the energy a dislocation must acquire to pass a precipitate particle. They thought that the potential field should undergo less change with strain in age-hardened materials, which should be simpler to work with, providing, of course, that no metallurgical changes occur during the creep test.

Their analysis indicates that the average distance between precipitated particles is of prime importance. The dislocations will be retarded by the particles but will advance beyond the particles in the regions between them, giving rise to a wavy dislocation. The wavelength of the dislocation line would be equal to the distance between particles. An approximate calculation of the energy, $E(\sigma)$, required to activate one loop of the dislocation, so that it could escape from the particle that anchors it and thus move freely forward until another particle is encountered, is given by

$$E(\sigma) = C\,(\sigma_i - \sigma)^{3/2} \quad , \qquad (15)$$

where σ_i is the internal stress. The exponent 3/2 arises from the assumption that the internal stress field is sinusoidal rather than constant, as was assumed in the Becker-Orowan theory. The creep rate works out to be

$$\dot{\epsilon} = N a \Lambda\, p \nu \exp\left[-\frac{C(\sigma_i - \sigma)^{3/2}}{kT}\right], \qquad (16)$$

where N is the dislocation density; a is the elongation per unit slip process; Λ is the distance between precipitated particles; p is a multiplicity factor to account for an avalanche of dislocations; and ν is the frequency of oscillation of a dislocation loop. It was found that experimental values of yield strength were not in accord with predictions based on Equation (16). Mott and Nabarro concluded that the internal stress must be dependent on temperature.

Since σ_i is not necessarily constant, but may represent a range of values, the initial part of the creep curve could be accounted for by the theory, because regions requiring low stresses to activate dislocations would gradually be exhausted as the strain proceeded. The exhaustion theory of transient creep based on this concept gives

$$\dot{\epsilon} = CT^{2/3}\,(\ln \nu t)^{2/3} \quad , \qquad (17)$$

where ϵ is the strain and t is the time.

The exhaustion theory was further developed by Mott(1082) and compared with the results of Davis and Thompson(339) on precipitation-hardened polycrystals of copper with silver. The data conformed closely with the time law expressed in Equation (17), but a serious discrepancy was noted in the value of ν, the frequency of vibration of a loop of dislocation against its obstacle. Orowan(1188) pointed out the theoretical insufficiency

of the exhaustion type of theory, which was later recognized by Mott(1086), who said, "...following Orowan, we consider that exhaustion creep, though it may occur, will mainly be included in the instantaneous extension: the phenomena observed...by Davis and Thompson occur because creep is slowed down due to work hardening".

With the further development of the dislocation theory, more and more details of plastic deformation could be explained. It now seems possible(1396) to give a detailed structural interpretation of the different processes that are rate controlling during creep in simple structures and in the early stages of creep. Since creep is thermally activated, those deformation processes will be considered in which thermal activation takes place and which may be rate controlling. With respect to dislocation mechanisms, there are three possibilities conceivable in which this could be the case. The rate-controlling process can be

(1) The formation of dislocations, or

(2) Their movement through the lattice, or

(3) Their rearrangement or annihilation in a recovery process.

The formation of dislocations has been a major problem in dislocation theory of plastic deformation. Now, it is generally believed that dislocations are always present and that they form three-dimensional nets in annealed metals. The dislocation segments between the nodes of the net are potential Frank-Read sources, which can produce a large number of dislocation loops under a critical stress. Since thermal fluctuations over the distances the dislocation loop has to move are extremely unlikely to occur, only those sources can operate for which the applied stress is practically equal to the critical stress. Therefore, the production of dislocations will generally be an athermal process, although there are certain cases where secondary processes, which are thermally activated, may make the formation of dislocations possible from Frank-Read sources(293, 1546). Early theories based on the generation of dislocations were proposed by Kochendörfer(817) and Laurent(911), but did not obtain popular acceptance because other mechanisms appear more likely to be rate controlling. Their theories have the merit that most of the important variables were considered, whereas other theories tend to be oversimplified.

The movement of dislocations through the lattice can be impeded by a wide variety of obstacles, and many explanations are available to explain different experimental observations. Some of these have been discussed previously, so will not be dealt with again.

A dislocation encounters a frictional resistance to movement, even in a perfect lattice. This Peierls force(1250) is relatively slight in soft metals and is usually neglected, although it has been tentatively identified with the low activation energy for creep in aluminum single crystals below 400 K[379]. In harder crystals, however, it is in many cases the high value of this frictional stress that makes a hard crystalline material hard. There are essentially three other types of obstructions that are important in hindering dislocation movement: the stress fields of other dislocations in parallel glide planes; the forest of other dislocations that the moving dislocation has to cut and the jogs formed thereby; and the impurity atoms that are dragged along by the dislocation.

The stress fields in the first type above interact with one another at fairly long range, whereas in the second type the characteristic feature is that they exert no long-ranged force on the moving dislocation. Thermal fluctuations in the first type of obstruction generally do not help to overcome the internal stresses, whereas, in the second type, thermal activation can contribute considerably toward the intersection process. Also, the activation energy to intersect obstacles should decrease linearly with the applied stress. The third possibility of impeding moving dislocations by interaction with impurity atoms or point defects has been discussed previously. Movement by this process is helped by thermal fluctuations.

The discussion of rate-controlling processes during plastic deformation leads next to a consideration of the recovery process[216]. In the preceding paragraphs, the movement of dislocations in their glide planes was described. During deformation, the crystal work hardens and finally all of the dislocations may get stopped at some obstacles. If the back stress of the piled-up groups on the Frank-Read sources is high enough to prevent further formation of dislocations, deformation will stop, unless the applied stress is increased or unless recovery takes place. This recovery can be due to a rearrangement of dislocations whereby a reduction of the internal stresses may be obtained or to an actual annihilation of dislocations by the combination of two of opposite signs. For this to happen, the dislocations must leave their glide planes, and this is done differently by edge and screw dislocations. The edges can leave their glide planes by climb[1081] and the screws by cross slip[1085].

The movement of an edge dislocation perpendicular to its glide plane is called climb. To move in one direction, the dislocation absorbs vacancies, and to move in the other, it gives off vacancies (or absorbs interstitial atoms). Since these defects must diffuse away, climb can be observed only at temperatures where self-diffusion occurs with reasonable speed. On the other hand, no diffusion is necessary for a screw dislocation to escape from its glide plane, since it can escape by cross slip (i.e., slip from one slip plane to another). The dislocation-climb hypothesis of recovery seems very far from certainty. The climb process is very likely to be a factor, but it may well be a relatively secondary factor.

Another recovery process has been proposed as a possible explanation of "work softening"[308] in face-centered-cubic metals. The sessile

dislocations described by Lomer and Cottrell[288] cannot move and therefore form obstacles for the glide movement of other dislocations in the same glide planes. There exists the possibility that these sessile dislocations, which stop piled-up groups of dislocations, may break down under the combined action of stress and thermal fluctuations, having the same effect as a recovery process.

In the preceding sections, possible rate-controlling processes during creep were examined. There are thermally activated deformation processes that can be rate controlling during creep; on the other hand, the movement of a dislocation itself can be thermally activated; furthermore, recovery processes may be rate controlling. At high temperatures, viscous creep is controlled by self-diffusion-type processes; at low temperatures, it does not exist. At low temperatures, only transient creep exists, and its mechanism is some kind of slip activation, without diffusion being essentially involved. In the following paragraphs, some of these processes will be examined in terms of their application to actual theories of creep, or to specific mechanisms in the cases where theories do not exist.

The primary structural change observed during creep of pure metals at high temperatures consists of subgrain formation. With increasing deformation, the angle between the subgrains increases, whereas the dislocation density in the grains stays constant. In viscous creep, the subgrains obtain an equilibrium size and no work hardening occurs. Another feature of viscous creep is the equality of activation energies for creep and self-diffusion.

Dorn[376] has proposed an expression to describe the observed stress and temperature dependence of the creep rate;

$$\dot{\epsilon} = C_{exp} \left[-\Delta H_d / kT \right] \phi(\sigma) \quad , \tag{18}$$

where $\phi(\sigma) = C' e^{\beta\sigma}$ at high stresses, and $= C'' \sigma^{\alpha}$ at low stresses, and ΔH_d is the activation energy for self-diffusion. Polygonization is explained as the climb of dislocations out of their slip planes and the formation of small-angle boundaries. If this takes place during viscous creep, the rate-controlling process is expected to be climb, which, in turn, is dependent on the rate of self-diffusion.

Theoretically, the jog energy, ΔH_j, should be included with ΔH_d, giving the activation energy for creep $\Delta H_c = \Delta H_d + \Delta H_j$. However, if ΔH_j is small compared with ΔH_d, it can be neglected, and this is generally found to be the case. Climb under creep conditions in face-centered-cubic metals is then thought to occur in the following manner: Vacancies given off by jogs will diffuse to other dislocation lines, where they become elastically attached[1415] to a half dislocation. There they will diffuse along the dislocation line with considerably higher speed until they are annihilated at a jog. If the distance between intersection jogs is comparable to the distance over which the vacancies have to diffuse to the dislocation line, the latter time will be long compared with the time to find a jog. The rate-controlling process will then be only volume diffusion, and hence we find that $\Delta H_c = \Delta H_d$.

Dorn's work at lower temperatures revealed the existence of discrete plateaus in the activation energies for creep in aluminum single crystals(379). Over the entire temperature range of 78 to 800 K, three plateaus of activation energy were found, which were constant over a range of temperatures, stresses, and strains. These plateaus are thought to correspond to three unique processes, which have been ascribed tentatively to three rate-controlling mechanisms: (1) the 35,500-cal/mole activation energy, obtained at the highest temperatures, is identified with a dislocation climb process; (2) the 28,000-cal/mole activation-energy process, occurring over the intermediate temperature range, is attributed to a cross-slip mechanism; and (3) the 3400-cal/mole process observed below 400 K may be identified with the Peierls energy. Similar values of activation energies were found for polycrystalline samples of aluminum, but displaced to lower temperatures. This suggests that turbulent slip in polycrystals can block the easier creep processes, forcing creep to continue by the more difficult higher activation-energy processes. Undoubtedly, this is why the more difficult creep processes are found to occur over lower ranges of temperatures in polycrystalline aluminum than in single-crystal aluminum.

The most complete analysis of viscous creep based on dislocation climb has been made by Weertman(1672, 1677, 1679). The first paper(1672) uses Mott's mechanism of dislocation climb, and makes the assumption that the rate-controlling process is the diffusion of vacancies between dislocations that are creating vacancies and those that are destroying them. The obstacles are assumed to be created by the Lomer-Cottrell mechanism. In the second paper(1677), Weertman considers the case where dislocation climb does not require the production of immobile dislocations. Instead, the pile-up is assumed to occur between dislocations in the same slip system, in the manner suggested by Mott(1093). Climb by the leading dislocation of each group will lead to their annihilation; viscous creep will occur through their continual replacement. In the third paper(1679), two processes other than dislocation climb are assumed to be rate controlling. In the first, the dislocations are considered to move in a viscous manner, with their velocity of motion proportional to the force exerted on them. The second mechanism makes use of the Peierls stress, where the motion of dislocation lines over Peierls stress hills is the rate-controlling process.

The equations developed for these particular cases have some features in common, with the creep rate being proportional to stress at a power of about 3:

Case 1 (Dislocation climb):

$$\dot{\epsilon} = C(\sigma^{\alpha}/kT) \exp(-\Delta H_d/kT) \quad , \qquad (19)$$

where C is a constant, α = 3 to 4, and the other terms are as before.

Case 2 (No immobile dislocations produced):

$$\dot{\epsilon} = A\sigma^3 \sinh(B\sigma^{1.5}/kT) \exp(-\Delta H_d/kT) \quad . \qquad (20)$$

Case 3a (Viscous motion):

$$\dot{\epsilon} = \sigma^3 b^2/\mu AB \quad , \qquad (21)$$

where b is the length of the Burgers vector, μ is the shear modulus, A is a temperature-dependent constant, and B is a constant.

Case 3b (Peierls stress):

$$\dot{\epsilon} \approx D\,\sigma^{2.5} \exp(-\Delta H_d/kT) \exp(\pi\sigma\,\Delta H_d/2\tau\,kT) \quad , \qquad (22)$$

where τ is the Peierls stress.

Equation (19) applies particularly to face-centered-cubic metals, Equation (20) to hexagonal crystals, Equation (21) to metal alloys at low stresses, where a microcreep mechanism may be rate controlling, and Equation (22) to brittle materials having a large Peierls stress (such as in nonmetallic crystals). The results agree fairly well with the appropriate material, especially at lower stress; for example, in Equation (19) the relationship between $\dot{\epsilon}$ and σ is obeyed over about 3 orders of magnitude of the stress out of 4, whereupon $\dot{\epsilon}$ increases more steeply at higher stresses. Possible explanations for this behavior are that at higher stresses the sessile dislocations may break down or that piled-up screw dislocations may escape by cross-slip.

The comparison of Equation (22) with experiments on high-purity zinc single crystals shows good qualitative agreement at all stresses; at higher stresses the experimentally observed increase of $\dot{\epsilon}$ with σ is also seen in the theoretical curve, because of the increased importance of the exponential σ term at higher stresses.

Weertman's analyses are deficient in several respects, but these shortcomings are not necessarily permanently fatal to the theory. Such factors as primary creep are disregarded; the necessity for mechanical jogs is overlooked; node formation is neglected; and the assumption of constant Frank-Read sources is unrealistic – it does not give the observed stress dependence. More serious, perhaps, is that the currently fashionable dislocation-climb process is far from having been proved, and that theories based on this mechanism are yet on shaky ground. Although his models need more detailed analyses, some agreement can be said to have been attained with experiment. As more pertinent experimental observations are made of the actual dislocation mechanisms, more realistic assumptions can be made in theoretical treatments.

Absolute Reaction Rate Theories

A number of creep theories have been proposed that are based on the rate theory developed by Eyring(415) and his associates. The theory of rate processes utilizes the methods of statistical mechanics and involves the concept of "activated" complexes or units, and has been successfully applied to a wide variety of chemical and physical rate processes.

Kauzmann(787) and Dushman, Dunbar, and Huthsteiner(392), working independently, were the first to apply rate theory to the flow of metals. In their theories, which are essentially identical, flow of metals is considered to take place by the movement of flow units in a periodic potential field. The "units of flow" are regarded as generalized elementary structures within a solid, whose motions constitute the shear process. It is assumed that, in order for two units of flow to pass one another, an energy barrier must be overcome, so that the unit shear process cannot take place unless the units of flow become activated. These theories are quite similar in final form, the logarithm of the strain rate being proportional to the stress. The difference lies mostly in the description of the flow units and other details of the postulated mechanism. Only a few representative theories will be discussed here because of their similarity.

When an external shear stress is applied, Kauzmann assumes that the activation energy for motion of units of flow in the direction of shear is lowered by an amount proportional to the applied stress, and that in the opposite direction is raised by an equal amount. The theory predicts a viscous creep rate

$$\dot{\epsilon} = CT \exp\left[-\Delta F/kt\right] \sinh\left[qA\ell\,\sigma/kT\right] \quad , \qquad (23)$$

where ΔF is the free energy of activation, q is a stress-concentration factor, A is the area of the projection of a flow unit in the slip plane, and ℓ is half the distance between two potential minima. The term $qA\ell$ must vary with temperature and stress in order to provide agreement between theory and experiments. The Kauzmann theory goes no further than the Becker theory in elucidating the mechanism of plastic flow in metals. It is worthy of note, insofar as it presents another approach to the subject, but the interpretation of various terms involved (e.g., the entropy term contained in ΔF, and $qA\ell$) is vague.

Saibel(1383) applied reaction-rate principles to such phenomena as creep and fracture. He obtained expressions for the creep rate, as well as for the rate of propagation of fracture cracks in metals. Seitz and Read(1444), Machlin and Nowick(1137,1138), and Feltham(428) applied the Kauzmann theory to the motion of dislocations, which they specified as the units of flow. Using theoretical reasoning similar to that used by Kauzmann, Seitz and Read derived an equation for transient flow and obtained

$$\dot{\epsilon} = N\lambda^2/t \exp\left(-\Delta H/kT\right) \sinh\left(qA\ell\,\sigma/kT\right) \quad , \qquad (24)$$

where N is the density of dislocations cutting across a plane that is normal to the slip plane and extends in the slip direction; λ is the slip distance associated with the passage of a dislocation; t is the time required for the transition of an activated dislocation to pass from one equilibrium position to the next; and ΔH is the change in energy required for the unit process. The viscous flow is given by

$$\dot{\epsilon} = A \exp\left(-\Delta H/kT\right) \quad , \qquad (25)$$

where A is a constant. They consider the creep curve to be resolved into these two component curves — a transient and a viscous part. However, they believed at that time that there was good evidence against this type of resolution being generally applicable. Their modification of the Kauzmann theory does not lead to a satisfactory expression for the creep rate; also, values cannot be assigned to some of the terms, nor can they be determined experimentally.

The expression developed by Nowick and Machlin(1138) takes into account the work hardening of the lattice that has already occurred before the steady-state stage of creep. The internal stress fields resulting from such hardening are assumed to reduce both the effective shear stress and the rate of generation of dislocations. The reduced form of their equation (as well as Feltham's) for the creep rate, under reasonably large values of stress, is

$$\ln \dot{\epsilon} = C + \ln T - A/T + B\sigma/T \quad , \qquad (26)$$

and has the same form as that derived by Kauzmann.

A theory of fracture in creep-rupture tests, proposed by Machlin and Nowick(1026), is also based on the application of the general reaction-rate theory. They assume that creep to rupture is a rate process governed by the maximum shear stress, but do not speculate as to the nature of the unit process or physical mechanism involved. An expression relating the time to rupture to the applied stress and temperature is derived and gives

$$\log t_r = \frac{A + BT - D\sigma}{T} \quad , \qquad (27)$$

where t_r is the time to rupture, T is the absolute temperature, σ is the applied stress, and A and E are material constants. D is defined as log D = E + FT, where E and F are material constants. The evaluation of the numerous material constants requires that many tests be made. The authors report that a given material may have three different sets of constants, depending on the temperature and stress and the occurrence of microstructural changes during tests. This would appear to be a severe limitation to the practical application of the derived expression.

Eyring and his school are still working in this area and have come out recently with a statistical mechanical theory of plasticity involving the virial theorem and absolute reaction rates.* Their statistical formulation for plastic deformation is based on the relative displacement of a "system of atoms". These domains or patches are displaced along a shear surface as a series of relaxations obeying a generalized absolute reaction rate equation. The interpretation of the exact nature of these domains, the cause of their creation, and the manner in which they slip are matters for conjecture, but, to conform to current concepts, they are called "dislocation domains". These dislocation domains involve the dislocation and the atoms that are associated with it in its movement from one relaxation site to another occurring during the deformation process.

The equation resulting from the application of their theory gives, at higher stresses,

$$\dot{\epsilon} = (\beta/2) \exp (\sigma/2g\sigma_m) \quad , \qquad (28)$$

where $\dot{\epsilon}$ is the secondary creep rate and σ is the applied stress, β is proportional to the relaxation time and is essentially constant, σ_m is the local microstress that is influencing the dislocation domain movement, and g is related to the velocity of sound. $2g\sigma_m$ is the important variable, and its variation with tensile strength, hardness, alloying, and cold working, as well as with annealing and recovery, is claimed to conform to expected behavior. However, the objections raised with regard to the theories discussed previously still seem directly applicable to this later theory.

Thermodynamical Theories of Fracture Strength

These types of theory are based on the idea that the breaking of atomic bonds by fracture is analogous to the loosening that occurs during melting. Born[159,161] and Fürth[502,505] suggested an approach to the problem of fracture in terms of melting that is closely dependent on thermodynamic quantities. Assuming the maximum normal-stress criterion of fracture, and

*Bates, J. L., Ree, T., and Eyring, H., "A Statistical Formulation for Creep of Metals", Tech. Rep. 56, ONR, June 15, 1956.

no plastic deformation, Fürth[502,503] developed a relation between breaking strength and the energy of melting that yields values of strength in fair agreement with those observed experimentally. His equation for the tensile strength, F, of an isotropic body at low temperatures is

$$F = Q\rho \, \frac{1-2\mu}{3-5\mu} \quad , \qquad (29)$$

where O is heat of melting per unit mass, ρ is the density, and μ is Poisson's ratio. Experimental data for ten metals showed agreement with theory within 7 per cent. Later, Fürth attempted to relate his theory with that proposed by Bragg[173], by assuming that the block structure in an intrinsic feature of the crystal lattice. This idea was attacked by Patterson[1232] on X-ray grounds, but defended by Wood[1717], who stated that Patterson's objections were not conclusive. Aroesta[46] points out that Fürth's results have been criticized because rupture strengths are associated with surface phenomena. By assuming that melting is dependent not only on block size, but also on the degree of atomic misfit between the blocks, Aroesta relates the theory to yield strength, which is less surface dependent. Suzuki[1545] applied a thermodynamic model to the tensile breaking strength of an internal-stress-free polycrystalline specimen at 0 K. The formula derived is the same as Fürth's.

Saibel[1379,1380,1381] has formulated a thermodynamic theory of fracture, assuming a relation between fracture and the latent heat and volume change of melting. The criterion of fracture was that of a critical strain energy per unit volume. His theory is based on the assumptions that all of the strain energy is available for the abolition of cohesive strength, the heat of fusion is uniformly partitioned throughout the material, and the energy required is that part of the energy of fusion associated with the change in volume on passing from the solid to the liquid state. Thus, the criterion for fracture can be expressed in the form

$$U = J\,Q\,\Delta V/V \quad , \qquad (30)$$

where U is the strain energy per unit volume, J is the mechanical equivalent of heat, Q is the latent heat of fusion, and $\Delta V/V$ is the change in volume per mole on passing from the solid to the liquid phase. Saibel's calculations indicated that, if no plastic deformation occurs prior to fracture, the breaking strength will correspond to the value obtained from the theoretical calculations. If plastic deformation occurs, the fracture stress is reduced to the magnitude experimentally observed, and fair agreement is obtained between his calculations and the experimental values. Consequently, it was concluded that plastic flow precedes all fractures.

In a recent paper by Osipov and Fedotov[1203], it is shown that several mechanical properties of metals are related to the energy required to melt them. This quantity, ΔW, differs from that used by Fürth, and others, in that to the heat of melting is added the additional energy required to bring

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the specimen from the test temperature to the melting point. Apparently, this additional energy is responsible for the good linearity demonstrated between hardness at higher temperatures and ΔW. Although this paper is not on as theoretical a level as the papers by Fürth, for example, they are close enough in principle that a suitable theory should be readily developed. Further work along this line should be instigated, since the results appear quite promising.

Whether such theories can correctly embrace the influence of metallurgical structure, by which means the strength of some alloys can be varied widely, is not apparent. It is also not clear whether the thermodynamic approach can account for the surface effects noted by Griffith(593) and others. Zener(1771) has criticized the thermodynamic criterion for fracture of metals on the grounds that the strain energy absorbed prior to fracture is dependent on test conditions and is also structure sensitive. The thermodynamic quantities are not dependent on these factors. Therefore, he believes that these theories contradict the established principles regarding fracture. The interesting findings of Osipov and Fedotov may alter these conclusions somewhat, if further experimental or theoretical justification for their results is found.

Relationships Based on Equations of State

From the engineering standpoint, the equation of state probably represents the most desirable solution to the problem of predicting material behavior. If an expression were valid that related the instantaneous values of the variables strain, strain rate, temperature, and stress, for example, then new data could be calculated for any other set of conditions or type of test. Expressions relating this particular set of variables have been called "mechanical equations of state" by Hollomon(708), in obvious analogy with the equations of state for gases or solids(391,549), examples of which are, respectively,

$$PV = nRT \quad , \tag{31}$$

where P is the pressure, V is the volume, n is the number of moles, R is the gas constant, and T is the absolute temperature; and(1488)

$$P = P_0(T) + P_1(T)\left(\frac{V_o - V}{V_o}\right) + P_2(T)\left(\frac{V_o - V}{V_o}\right)^2 + \dots \quad , \tag{32}$$

where P is the hydrostatic pressure on the solid, with V and T as before, and P_o is the pressure that must be applied to a solid to reduce its volume to V_o, the volume at absolute zero under no pressure. For the more complicated case where a solid undergoes stresses other than simple pressure, or strains other than a mere change in volume, the equation of state is a set

of relations giving the stress at every point of the solid as a function of the strains and the temperature.

The existence of a mechanical equation of state means that the flow stress depends only on the instantaneous strain, strain rate, and temperature, and not on their past history. The range of validity of a mechanical equation of state yet remains to be established, although data already reported cast considerable doubt that it will be very widely applicable. However, the influence of the changes on the flow properties may be sufficiently slight in some cases that the concept of a mechanical equation of state will be of some practical utility.

One of the more comprehensive critical reviews of the literature pertaining to the mechanical equation of state was written by Zener and Hollomon(1779) in 1946. Their conclusions on the pros and cons of this subject were hampered by the lack of suitable experimental evidence, and this situation has not improved materially in the intervening years.

Hollomon and Lubahn(714,715) attempted to derive a general relation for the combined effects of strain, ϵ, strain rate, $\dot{\epsilon}$, and temperature, T, on the stress, σ, required for plastic flow. They deal, in turn, with the relationships between ϵ and σ; ϵ, $\dot{\epsilon}$, and σ; and ϵ, $\dot{\epsilon}$, T, and σ. They then suggest that all these variables are related in the following way:

$$\sigma = CG^T (\dot{\epsilon}/\dot{\epsilon}_o)^{DT} \exp (E - FT \ln \dot{\epsilon}/\dot{\epsilon}_o) \quad , \tag{33}$$

in which the constants, C, D, E, F, G, and $\dot{\epsilon}_o$ are independent of all the variables concerned, and the strain rate and temperature are constant in arriving at that strain at which the stress is determined. At constant strain rate and strain, Equation (33) predicts that the logarithm of the stress should vary linearly with the temperature, and this behavior appears to be followed very generally. Also, the available data indicate that there are two distinct ranges of temperature in which the material constants in Equation (33) are different – i.e., a low-temperature range and a high-temperature range. This behavior suggests that there are two different mechanisms of deformation – at low temperatures, deformation occurs primarily by slip, and at high temperatures, the deformation occurs primarily by rotation at the grain boundaries.

For the case where the strain rate and temperature are not held constant during the test, the validity of the empirical relationships obtaining under variable conditions was investigated. Hollomon and Lubahn conclude that their general relation should be an equation of state in which the stress at a given strain should not depend on the past history of the temperature or the strain rate. However, they did not expect an equation of state to be valid whenever structural changes such as phase transformation and recrystallization occur, as is pointed out also by Sylwestrowicz(1561).

Many other proposals have been advanced for relating the important variables in plastic deformation. Anderson[20] introduced the time variable explicitly in his general relation denoting stress as a function of strain, time, and strain rate. He attempted to show that the phenomena of various mechanical tests conform to the laws of dynamics, and that all equations describing special testing operations are derivable from one equation. Wyatt[1735] showed that transient creep at low temperature and stresses obeyed an equation of state and confirmed this by experiment; and Graham[563] gave an expression that is a special case of the equation due to Hollomon and Lubahn. Further, he obtains an alternative expression relating stress, time, strain, and temperature that is akin to the Nutting equation[1140], generalized to include temperature,

$$\sigma/\sigma_s = \epsilon^m (t_s/t)^{nT} \quad , \qquad (34)$$

where σ_s, m, t_s, and n are constants. The results of Carreker[232] with platinum were described satisfactorily by Equation (34). Equations of state for zinc single crystals in creep were reported by Thompson[1558] and Gilman[542], and Wiedersich[1697] showed that a modified form of Seeger's equation relating strain rate to temperature and stress described the data obtained by Dorn, et al., with high-purity aluminum[1603].

Many such examples as above are available in the literature. In spite of the well-known arguments against the existence of a general equation of state for solids[380,1182], it appears that there is good experimental evidence for the validity of more limited relationships. Further work with the Boltzmann superposition theory[771] and with incremental- rather than total-strain equations may extend the validity of these equations to a point where they are of real practical use in forecasting the results of any given experiment.

Equations of state have been confirmed either at low temperatures, where recovery is not appreciable, or at high temperatures (in the absence of phase changes, etc.), where recovery proceeds rapidly along with hardening. Perhaps this line of demarcation between the high- and low-temperature regions of plastic deformation has not been drawn too clearly in formulating equations of state for solids. In any event, it appears that a mechanical equation of state represents a possibility of great theoretical and practical importance. Although the basic postulates are extremely attractive in principle, the verification has lagged in practice. The frequent reports in the literature of cases where an equation of state is obeyed over restricted ranges of variables lends credence to the idea that such an expression may exist for the more general case, could we but see it and formulate it correctly.

Empirical Relationships and Parameters

A generally valid equation of state and its experimental verification has not been obtained; however, relationships have been found in many cases over a more limited range of the variables stress, strain, time, strain rate, and/or temperature. Frequently, two variables are involved in such a way that they appear in the form of a combined function or parameter. Thus, for example, Zener and Hollomon[1778] proposed that the stress-strain relation $\sigma(\epsilon)$ in steels at low temperatures depends upon strain rate and temperature only through a single parameter P, such that

$$\sigma = \sigma (P, \epsilon) \quad , \qquad (35)$$

and that this parameter has the form:

$$P = \dot{\epsilon}\, e^{Q/RT} \quad , \qquad (36)$$

where Q is the heat of activation for the deformation process.

Other parameters can be systemized in functional notation according to the following scheme, which emphasizes the interrelationship of these expressions.

Zener-Hollomon parameter[1778]	$Z = Z(\dot{\epsilon}, T)$	Tensile tests
Hollomon-Jaffe parameter[712]	$P = P(t, T)$	Hardness tests
Larson-Miller parameters[903]	$P_1 = P_1(\dot{\epsilon}, T)$ $P_2 = P_2(t, T)$	Creep and tensile tests
Dorn θ-parameter[1341]	$\theta = \theta(t, T)$	Creep and tensile tests
MacGregor-Fisher velocity-modified temperature[990]	$T_m = T_m(\dot{\epsilon}, T)$	Tensile and creep tests
Rabotnov parameter[1300]	$P_c = P_c(\sigma, t)$	Creep and tensile tests

The Hollomon-Jaffe parameter[712] and Dorn's θ-parameter[1341] both have the form

$$P = te^{-Q/RT} \quad . \qquad (37)$$

Equation (37) was applied by Hollomon and Jaffe to the room-temperature hardnesses of steels tempered for different times and temperatures, and by Dorn to the creep strain obtained under constant stress for various combinations of time and temperature. Larson and Miller[903] proposed parameters of the form

$$P_1 = T\,(C - \log \dot{\epsilon}) \qquad (38)$$

and

$$P_2 = T\,(C + \log t)\ , \qquad (39)$$

which were derived simply from the extremely general Arrhenius rate expression,

$$\text{Rate} = \text{Constant}\ \exp\,(-Q/RT)\ . \qquad (40)$$

MacGregor and Fisher(989,990) developed an expression, similar to that by Zener and Hollomon, in terms of a parameter T_m, termed the "velocity-modified temperature". Their derivation was based on the Kauzmann(787) analysis of the dependence of creep rate on stress and temperature. MacGregor and Fisher proposed that in general the flow stress is a function of the strain and the strain-rate-modified temperature of flow:

$$\sigma = \sigma\,(T_m, \epsilon)\ , \qquad (41)$$

where T_m has the form

$$T_m = T(1 - K \ln \dot{\epsilon}/\dot{\epsilon}_o)\ , \qquad (42)$$

where K and $\dot{\epsilon}_o$ are constants. This relation also holds for either tension tests or creep tests and over a wide range of temperatures. The similarity of Equation (42) to Equation (38) is apparent, and is also seen when Equation (36) is rearranged.

Rabotnov's parameter(1300) relates creep data to the tensile test in the form of isochronous stress-strain curves. In essence, he postulates that the tensile stress is a function of the tensile strain and a creep function P_c, such that

$$\sigma = \sigma(\epsilon, P_c) \qquad (43)$$

and

$$P_c = \sigma_c(1 + at^{1/3})\ , \qquad (44)$$

where σ_c is the (constant) creep stress, t is the time to a selected creep strain, and a is a material constant.

These parametric relationships have been applied in many cases to creep, creep-rupture, tensile, and hardness data, and very satisfactory results have been obtained (see, for example, the discussion to Reference 510 by J. Miller). Those cases where unfavorable results were obtained(510,869) can usually be traced to an inapplicable constant, for example, a blanket use for all materials of C = 20 in Equations (38) and (39). Other expressions and parameters have been proposed(1043,1527) that appear to have only empirical significance. It is believed that the

parametric expressions listed above offer the greatest probability of successful application to practical problems; and furthermore, through the close interconnection with the Arrhenius rate expression, they may possibly achieve a more respectable theoretical status at a later date.

Empirical expressions devised to account for material behavior under various combinations of stress, strain, strain rate, temperature, and time are extremely numerous (see Appendix C). One of the more recent empirical attempts to correlate high-temperature creep and rupture data is that due to Conrad*. For the rupture time, t_r, and the minimum creep rate, $\dot{\epsilon}_s$, he gives

$$\dot{\epsilon}_s \approx \frac{K}{t_r} \approx A\ \exp\,(-\Delta H_D/RT)\ \sinh\,[\sigma/\sigma_o(T)]^n\ , \qquad (45)$$

where K, A, $\sigma_o(T)$, and n are constants, and ΔH_D is an activation energy for diffusion. Better fit of this expression with experimental data is claimed than with the Larson-Miller parameter, but four adjustable constants are employed versus one in the Larson-Miller expression, and in addition an arbitrary value of 20 is assumed for their constant. Under these circumstances, it is not surprising that Equation (45) should appear in the better light. Kanter(782) proposed a relation between high-temperature tensile tests such that

$$(\dot{\epsilon}/\dot{\epsilon}_o)^n = \sigma/\sigma_o\ , \qquad (46)$$

where n is a function of temperature, and $\dot{\epsilon}_o$ and σ_o are constants determined at the convergence of the curves for different temperatures. Interestingly enough, he found that activation energies found by his approach are of the magnitude of the heat of melting, rather than of the heat of vaporization.

Correlations between different mechanical properties are also quite numerous (see Appendix C). Examples of these include direct, experimentally observed relationships between, for example, hardness and tensile strength or rupture strength and tensile strength. Periodic variations of strength with atomic number of solute also appear to be useful(617). However, cognizance of these relationships in the present report stems primarily from their potential practical applications, in the event the theoretical approach is not followed in any subsequent research problem. To illustrate what can be done with the variables hardness, tensile strength, and rupture strengths, attention is called to the correlation proposed by Underwood(1620). By comparing tensile and rupture strengths with hot hardnesses, at the same parameter value [Equation (39)], a straight-line

*H. Conrad, Westinghouse Research Laboratories, Scientific Paper 6-94701-1-P9, March 26, 1958.

relation is obtained between hardness and strength, which accounts also for the effects of time and temperature of test. Such correlations may ultimately be shown to have theoretical justification, but, until then, they may be used for engineering purposes. A very definite role of these various property interrelationships is to guide theoretical developments, since, in the last analysis, theory must conform to experimental observations.

EVALUATION OF THEORIES AND METHODS

From the detailed discussion given in the preceding text, it can be seen that there have been many theoretical attempts to describe the strength of metals. These theoretical attempts may be considered as falling into the following broad classifications: dislocation theories, absolute reaction rate theories, and thermodynamic theories. Because of their inability to account for specific effects, theories based on thermodynamic criteria and on absolute reaction rates are rejected as being too general to afford a basic understanding of the underlying processes occurring during plastic deformation. Therefore, dislocation-type theories are held to represent the most promising avenue for further theoretical and experimental research in this general area. However, this does not imply that early results can be expected in the prediction of material properties. A general description of the present situation is that dislocations are recognized as representing the most important element in the mechanism of plastic deformation; their properties, and the way of interaction between different dislocations, are well known, but the arrangements and interplay of dislocations in different processes are largely unknown as yet.

Having selected those theories based on the dislocation concept as the most promising, a preference rating of specific theories will be made. It is extremely difficult to subdivide theories in an arbitrary manner and then consider their parts as separate entities. However, an attempt will be made to indicate the best portions of those theories according to the organizational scheme adopted in the text.

The G. I. Taylor theory, as modified by Mott and Orowan, is believed to be the fundamental theory at the present time for explaining strain hardening. Details and interpretations have changed, but Taylor's basic ideas are still valid. Seeger, Friedel, and others have suggested improvements and have stressed new mechanisms (some of which are unproved), but these are still within the basic framework.

The theories of Mott and Nabarro, the Cottrell-Suzuki interactions, and Fisher's short-range ordering effect appear to be the most applicable to those various aspects of alloy hardening covered by their theories. There is no all-inclusive theory that is applicable to the entire subject.

Precipitation hardening is closely linked with the preceding categories, but the treatment afforded by Orowan of precipitation hardening seems to be the most realistic. The modifications and extensions contained in the Mott and Nabarro treatments, and the Fisher, Hart, and Pry theory should also be considered.

In the field of creep theories, the 1947 paper by Orowan on the thermal activation of transient creep and his 1956 paper appear to give the basic treatment. The theories of Weertman for viscous creep need modification, but follow experimental observations most closely. Numerous other contributions of merit are found in papers by Mott, Nabarro, Schoeck, and Dorn, but these also include items not applicable today, or else not firmly established.

Of the methods available for predicting strength properties, the most promising appear to be those expressions employing parameters. The Larson-Miller parameters are equivalent to the others listed in the text that relate either strain rate and temperature or time and temperature. Rabotnov's relation using a parameter for stress and time should also prove useful.

Also very promising is the periodicity, first investigated systematically by Gulyaev, of the strengthening due to solute elements as a function of their atomic numbers. Closely related to the periodic behavior are the relationships demonstrated by Osipov and Fedotov. Since both mechanical properties and latent heats in general vary with atomic number, perhaps some relationship between the two should not be unexpected.

A final recommendation of a prediction method is based on the idea of a mechanical equation of state. The success enjoyed by the parameter-type expression gives reason to hope that a more inclusive relationship may be found. The equation developed by Hollomon and Lubahn seems the most general, but may need overhauling when sufficient experimental data are obtained. The general rheological approach contained in the Graham-modified Nutting equation should also prove worthy of more extensive testing.

SUMMARY OF CONFERENCES WITH CONSULTANT, PROFESSOR E. OROWAN

In three full-day conferences with Dr. Underwood in Pasadena, in La Jolla, and in Columbus at Battelle Memorial Institute, the present status of the physical understanding of the phenomena of plasticity and strength was reviewed and separation of the comparatively secure fundamental lines from hypotheses in the workshop stage was attempted. As a side line,

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Professor Orowan read a large number of Russian papers supplied in translation by Dr. Underwood and gave written or oral comments on them. The main points that emerged from the conferences are as follows:

(1) Plasticity

The usual reason for the great discrepancy between the high molecula cohesion and the low observed yield stress of crystalline materials is the presence of dislocations. These represent the most important element of the structure of real crystals as far as their plastic behavior is concerned. The structure and interaction of dislocations are fairly well known; to understand the plastic properties of materials, however, the arrangement of the dislocations and their interplay during the process considered must be known.

The yield stress (stress required for plastic deformation after a certain preceding deformation) may be determined either by the stress required for moving dislocations in the absence of obstacles (frictional stress driving stress, Peierls-Nabarro force) or by the obstacles in the way of the dislocations. Foreign atoms in interstitial solution may be adsorbed at dislocations and anchor them to the lattice (Cottrell locking), or one type of atoms in a substitutional solid solution may be concentrated in certain parts of a dislocation, with similar effects. Such adsorption phenomena seem to be the cause of most, but hardly all, yield phenomena. The obstacles hindering the movement of dislocations may be hard precipitated particles, stress fields around them, dislocations piercing through the slip plane, sessile dislocations, stacking faults, etc. They may be overcome by the dislocation cutting through them, or by dislocation bulges being extruded between obstacles.

Strain hardening is due in general to the increase in the number of obstacles produced by plastic deformation and the increasing difficulty of driving slip across them. Its quantitative treatment will be possible only if the rate of increase of the number of obstacles during slip, as well as the exact nature of the obstacles, is known. A special type of hardening is that upon which the hypothesis of G. I. Taylor was based; it is due to the piling up of slip at relatively impenetrable barriers. Such a component is present probably in most cases of strain hardening, but its relative significance is usually small.

Solution hardening seems to have two main causes: first, the internal stresses around larger or smaller atoms that do not fit between their neighbors; second, valency or ionic types of bonding forces between neighboring atoms, which also increase the driving stress of dislocations. Precipitation hardening is due to the resistance of the precipitated particles to being cut or sheared by dislocations, and to the internal stresses in the lattice around them. Overaging is a consequence either of easier dislocation-bulge extrusion with increasing spacing of the particles or of the

reduction of internal stresses by the breaking away of particles from the matrix. The adsorption of atoms at dislocations has been mentioned already; similar adsorption may take place at stacking faults also ("Suzuki effect").

Transient creep is due to thermal-stress fluctuations superposed on the applied stress; its slowing down with time is a consequence of increasing strain hardening. Viscous or hot creep is due to atomic-rearrangement processes of the self-diffusion type. These processes may lead to thermal softening and, under stress, to recovery creep; or to viscous flow at the grain boundaries; or to the movement of interstitial atoms or vacancies or of atoms from or into grain boundaries, all of which may give rise to viscous creep when taking place under stress.

(2) Fracture

Brittle fracture in fully brittle materials is a crack-propagation process by cleavage; it is usually governed by the Griffith equation, which is an expression of the second law of thermodynamics. If the material has some ductility, internal stresses developed by plastic deformation (e.g., where dislocations pile up) may be superposed on the applied stress and may cause cleavage fracture. Finally, fracture-like separation of bodies into fragments may take place exclusively by plastic deformation, as when a wire of pure gold or indium necks and separates at sharp needlepoints in the center of the neck.

(3) Russian Work on Mechanical Properties of Materials

Perhaps the only interesting work found was that concerned with empirical relationships between the thermal and mechanical properties of materials. Most of the other papers were second or third rate; in general, the present level of Russian work in this field is incomparably lower than was that in the 'twenties and 'thirties. Dislocation theory is practically nonexistent; it seems to have been scorned for political reasons until a few years ago, and the recent publications are mostly either unimpressive second-hand reviews or amateurish concoctions. Many papers are published on hot creep testing, mostly without serious substance. It seems that the good workers have been drafted into industrial production, and scientific work has come to a near standstill.

EEU:MFA:REM:GKM/all

APPENDIX A

ANNOTATED BIBLIOGRAPHY OF THEORIES AND PROPERTIES OF MATERIALS

(1) Acera, L. H

Elasticity and the Transition Zone of Steels (In Spanish)

Inst. hierro y acero 4 (1951) 220-226

Factors affecting elasticity and transition temperature. Results of experiments on the relationship between values of elasticity, ductility, and tensile strength.

(2) Achter, M. R., and Smoluchowski, R.

On the Role of Grain Boundaries in Creep

Acta Met. 4 (1956) 331-332

Rate of creep is influenced by the availability of dislocations and the ease with which they can move across the grain boundary In bicrystals, a grain boundary parallel to a plane of high density would provide a better fit between the lattices of the two grains than a low-density plane, and would facilitate creep

(3) Adams, M. A.

The Plastic Behaviour of Copper Crystals Containing Zinc in the Surface Layer

Acta Met. 6 (1958) 327-338

Tensile tests have been made on Cu crystals containing various concentrations of Zn in the surface layer Crystals containing small amounts of Zn, after a small prestrain and an anneal at 200 C, showed a yield point, while in crystals of higher surface Zn content the yield point was absent. Previous deformation affected the yielding behavior of both lightly and heavily zincified specimens. Critical shear stress measurements showed that a lightly zincified surface strengthens a Cu crystal more effectively than a heavily zincified surface; removal of the surface layer from a lightly zincified crystal caused a large decrease in strength and a disappearance of the yield point. The results are consistent with the idea that the first Frank-Read sources to become active in Cu crystals are those which lie near the surface.

(4) Adams, M. A., and Cottrell, A. H.

Effect of Temperature on the Flow Stress of Work-Hardened Copper Crystals

Phil. Mag. 46 ser 7 (1955) 1187-1193

Changes in the flow stress of copper crystals due to changes in the temperature of deformation have been measured. The change of flow stress with temperature is closely proportional to the flow stress itself. These results are discussed briefly in terms of recent ideas of dislocation processes sensitive to temperature. The effect of increasing the temperature of deformation is to produce a yield drop, similar to those observed in aluminium crystals during work softening.

(5) Akulov, N. S., and Galenko, P. P.

Theory of Plastic Deformation of Metals (In Russian)

Doklady Akad. Nauk S.S S.R. 103 (July 1955) 387-390 (Translated by British AERE Lib/Trans. 672, August 1956)

Uses concept of "blocks" as elements which behave as units in plastic deformation. They consider the case where displacement of blocks is irreversible and calculate the area of the hysteresis loop using the Rayleigh-Preisach theory for magnetic hysteresis.

(6) Akulov, N. S., and Miryasov, N. Z

A New Method of Studying the Plastic Deformation of Ferromagnetic Crystals (In Russian)

Zhur. Tekh. Fiz. 18 (1948) 389-394 (Physics Abstr 53, 80)

The "deposition lines" on ferromagnetic crystals are connected in a definite way with the crystallographic directions. These lines also determine the degree and character of the residual stresses in the crystal and, consequently, enable the distribution of the latter to be referred to the crystallographic directions. The existence of two independent systems of deposition lines was proved, each of which characterizes a definite mechanism and degree of residual deformation. When the plastic deformation of the crystal is increased, qualitative and quantitative changes of the character of the deposition figures are found. The results of these observations make possible a systematic investigation of the magnitude of the plastic deformation for ferromagnetic single- and polycrystals under a complex system of stresses The new method was found to be much more sensitive and to supply a far more complete description of the plastic deformation than any other method.

(7) Alexander, B H., Dawson, M. H., and Kling, H. P.

The Deformation of Gold Wire at High Temperature

J. Appl Phy 22 (1951) 439-443

Gold wires were subjected to small tensile stresses at high temperatures and the strain-time relationship, coefficient of viscosity, and surface energy were determined. The creep curves obtained were similar to those for metals at lower temperature except that the minimum creep rate ∝ applied stress, i.e., the flow was viscous. Theories to explain viscous behavior of metals were discussed

(8) Alexander, B. H, Kuczynski, G. C., and Dawson, M. H.

Relations Between Diffusion and Viscous Flow in Metals

Article in Physics of Powder Metallurgy, McGraw-Hill Book Co., New York (1951) 202-213

When Cu wires wound on heavy Cu cylinders are heated, the radius of the sintered neck which forms bears a 5th power relationship to the wire diameter at temperatures up to 1070 C, indicating that sintering occurs by volume diffusion In creep tests on Au wires at 970 C, however, deformation occurs according to a viscous-flow law. It is assumed that there is concentration of vacancies near the curved surfaces of the necks and that the volume diffusion is caused by the diffusion of vacancies The same atomic mechanism leads to viscous flow in the large mosaic blocks in the Au wire under creep loading.

(9) Allen, N P.

Cohesion and Fracture in Metals

Article in The Fracture of Metals, Inst. of Metallurgists, London (1950) 5-28

Crystal structure, plastic and brittle fractures, and fractures due to their combination. Discusses the structure of metals, metallic bonds, and dislocations. Modern research uses knowledge of the forces within a metallic lattice to find out how a crack of atomic dimensions should behave Work is also being done on factors which influence the rate of the speed of the crack

(10) Allen, N P

Introductory Paper

Proc. N P.L Symposium on Creep and Fracture of Metals at High Temperatures (1956) 1-18

Progress made since 1946 in the study of plastic deformation is reviewed. The behavior of creep-resisting alloys over long periods, the influence of method of manufacture, and studies of new alloys are discussed

(11) Allen, N P., Hopkins, B. E, and McLennan, J. E.

The Tensile Properties of Single Crystals of High-Purity Iron at Temperatures from 100 to -253 C

Proc. Roy. Soc (London) 234A (1956) 221-246

Single crystals of high-purity Fe of various orientations were tested in tension at temperatures from 100 to -253 C. The results showed that: (1) in the early stages of deformation slip lines were straight, and corresponded to one of the planes [110], [112], and [123] wavy slip lines developed at a later stage of deformation; (2) the values of the critical shear stresses for the three operative slip systems were very similar, the ratios being close to unity at all temperatures; (3) down to -124 C all the crystals were ductile, giving chisel-edge fractures and 100 per cent reduction in area; at -196 C, depending on the orientation of the stress axis, the behavior covered the whole range from fully ductile to completely brittle; between these limits, mixtures of slip, twinning, and cleavage were obtained; at -253 C most of the crystals broke by cleavage without prior deformation except near [011], where twinning, or a small amount of slip, preceded cleavage; and (4) the yield point and the critical shear stress for slip increased with decreasing temperature of test.

(12) Allen, N P., Schofield, T. H., and Tate, A.E.L.

Mechanical Properties of α-Solid Solutions of Copper, With Zinc, Gallium, Germanium, and Arsenic

Nature 168 (September 1, 1951) 378-379

The ultimate tensile strength, the resistance to plastic deformation, and perhaps also the 0.5% proof stress of these alloys appear to be almost entirely governed by their electron-atom ratio.

(13) Altmann, S. L., Coulson, C A , and Hume-Rothery, W.

On the Relation Between Bond Hybrids and the Metallic Structures

Proc. Roy Soc (London) 240 (1957) 145-159

The failure of existing theories to account for the type of crystal structure of a given metal is emphasized It is suggested that, particularly when the number of bonding electrons is high, the metallic bond has greater directional characteristics than are generally assumed, and that those can be related to the symmetries of known hybrid bonds. Consideration is given to the fcc, bcc, and cph structures of the transition metals, and it is shown that hybrids suggested by the crystal structures can be correlated with the known electron characteristics of these metals.

(14) Amelinckx, S.

Slip Lines and Etch Pits

Phil. Mag 44 (1953) 1048-1049

Experiments with relatively large crystals of pure Al which were recrystallized, then polished electrolytically, deformed and etched, lead to the conclusion that slip lines are characterized by the occurrence of rows of dislocations along them, and provide evidence for the validity of the Frank-Read mechanism [Phys. Rev. 79 (1950) 722]. Dislocations were found to be clustered and not distributed uniformly along slip lines, as is to be anticipated in accordance with Mott's theory of work hardening [Phil. Mag. 43 (1952) 1151].

(15) Amelinckx, S.

The Direct Observation of Dislocation Patterns in Transparent Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 3-51

Methods which allow the direct microscopical observation of dislocation lines are described and the decoration mechanism is discussed. The nature and crystallography of the precipitation are considered. The method was used to study the geometry of dislocation patterns in deformed and annealed NaCl single crystals. Singularities in the patterns of the dislocation nets were analyzed in terms of Burgers vectors. Direct evidence was found for the climb of single dislocations and of networks. The pinning of dislocations by precipitates and by locked dislocations was observed.

(16) Amelinckx, S.

Dislocation Patterns in Potassium Chloride

Acta Met. 6 (1958) 34-58

Dislocation patterns observed in "single crystals" of KCl, as grown and after deformation, are analyzed. Large areas covered by regular square and hexagonal networks are found. Singularities in the networks are explained in terms of Burgers vectors and the genesis of the nets is considered. In particular, evidence is presented for the stability of a [100] dislocation with respect to dissociation into two a/2 [110] dislocations. It is found that a small driving force coming either from a third crossing dislocation, or from purely geometrical circumstances, and which tends to bring the two combining a/2 [110] dislocations into a parallel position, is sufficient for the formation of a segment of a [100] dislocation. Evidence for the formation of "holes" at the intersection point of two singular dislocations with the same Burgers vector is also presented. It is suggested that the networks are sometimes decorated more than once A systematic use of this phenomenon might be of some value in studying the evolution of networks during anneal. Dislocations which moved during the anneal accompanying the decoration leave traces of particles behind them, suggesting that certain parts of the dislocation line are more effective in causing precipitation. The density of the decorating particles depends on the orientation of the line with respect to the Burgers vector; screws seem to be less easily decorated than edges.

(17) Amelinckx, S., and Maenhout-van der Vorst, W

A Slip Source in Potassium Chloride

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 55-56

A photograph of a slip source is shown, and its structure is analyzed.

(18) Amelinckx, W., Bontinck, W., Dekesyser, W , and Seitz, F

On the Formation and Properties of Helical Dislocations

Phil. Mag. 2 (1957) 355-378

The factors influencing the development of helical dislocations in CaF_2 (Bontinck and Amelinckx, ibid , 94) are studied at temperatures near and below 700 C. Climbing dislocations having a strong screw component assume a helical or spiral prismatic form The model of F-centers

in CaF_2 and their equilibrium characteristics are discussed. Helical dislocations should be generated in many materials in a variety of circumstances and, if they occur near the surface, they should be capable of generating whiskers which grow from the base Controlled climb in any material may be produced by appropriate temperature gradient if the production or annihilation of lattice defects at the dislocations engender climb.

(19) Ancker, B., Haslett, H., and Parker, E R.

Relationship Between Small-Angle Dislocation Boundaries and Creep

J Appl Phy 27 (1956) 333-340

The relationship between the small-angle boundary density, creep strength, and room-temperature tensile properties of 99-95% Ni was investigated. Specimen bars were given controlled prestrains, followed by recovery at 800 C for 1 hour Creep tests under constant stress at 700 C were halted at strains of 1 and 2-1/2%. Half of the bars were then tensile tested, and the duplicate series used for X-ray examination of the substructure by an adaptation of the Laue method [Barrett, Trans AIME 161 (1945) 15] The linear relation of flow stress to mean density per grain of small-angle boundaries was confirmed. Increased amounts of prestrain resulted in decreased initial creep-strain rates. The shape of the creep curve may be made to vary as a function of the initial density small-angle boundaries; primary creep can be eliminated by introducing small-angle boundaries of a certain type of density The creep-induced substructure is characterized by the large number of parallel, small-angle boundaries, and differs from that developed by an equal amount of room-temperature deformation plus recovery. Consideration of the processes of creep, self-diffusion, stress-induced generation of vacancies and their migration suggests that creep deformation at high temperatures involves dislocation climb. A mechanism for the production in creep of short parallel boundaries is proposed in terms of the interaction of dislocations from a Frank-Read source with those piled up at a barrier Removal of these boundaries by tensile tests is discussed.

(20) Andersen, A G.H

Stress-Strain-Time Phenomena in Mechanical Testing: A Study of the Stress-Strain-Time Functions of Metals in Simple Monotonic Tension

USAEC Publ., ORNL-1114 (1952) 93 pp

It is shown that stress can be expressed as a function of strain δ and time t according to:

$$(\sigma)_v = \int_0^{t_n} [v(f_\delta)_v + (f_t)_v]\, dt \text{ or } \frac{d(\sigma)_v}{d\delta} = (f_\delta)_v + \frac{1}{v}(f_t)_v .$$

where v is the strain rate, $(f_\delta)_v$ is the part of the total change in stress that can be assigned statistically to effect of strain alone, during an infinitesimal period, and $(f_t)_v$ is the part of the total change in stress during an infinitesimal period that can be assigned to the relaxing effect of time alone The total change in stress is given by $d(\sigma)_v = (f_\delta)_v\, d\delta + (f_t)_v dt$. The hypothesis is developed that stress is a functional of strain that reduces to functions of the independent variables: strain, time, strain rate, and variations in strain rate, i e ,

$$\sigma(t) = F[\delta(t)] = \int_0^{t_n} (f_t + vf_\delta + af_v + af_a + \ldots)\, dt, \text{ where } a = \frac{dv}{dt}$$

It is shown that the phenomena of various mechanical tests conform to the laws of dynamics, and that a general equation representing stress as a function of the independent variables, strain, time, and strain rates can represent the phenomena All equations describing special testing operations are derivable from one equation:

$$F[\delta(t)] = \sigma(t) = \sigma(\delta, \dot{\delta}, \dot{\delta}, \delta, \ldots, t) = \int (f_t + vf_\delta + af_v + \dot{a}f_a + \ldots)\, dt$$

(21) Andrade, E. N. da C.

Viscous Flow in Metals

Proc. Roy. Soc. (London) 84A (June 9, 1910) 1-12; Physik. Z. 11 (August 15, 1910) 709-715

The flow of a lead wire loaded beyond its elastic limit becomes viscous after a time, i.e., the extension is proportional to the time. The variation of the rate of flow with the load was studied by the use of a "hyperbolic weight" sinking into a liquid, the form of the weight being so designed that the upthrust at any moment varied inversely as the length, and directly as the sectional area of the wire, thus maintaining constant stress. Experiments were carried out on Pb, fuse wire (Sn 21 5, Pb 78.5%), and Cu, the results showing that all these metals are subject to viscous flow right up to their breaking points Extension is divided into three parts: (1) immediate extension on loading, (2) an initial flow which gradually disappears – termed the β-flow, and (3) the viscous flow – a constant flow throughout the extension. In Cu the immediate extension is large and the viscous flow small in comparison with Pb. The formula

$$l = l_0(1 + \beta t^{1/3})e^{kt} ,$$

where β is a measure of the β-flow and k a measure of the viscous flow, represents the extension-time curves very closely. For very large values of the stress β tends to become constant. The "fluidity" (k/stress) curve is roughly hyperbolic with one asymptote parallel to, and the other steeply inclined to, the stress axis

(22) Andrade, E. N da C

Flow in Metals Under Large Constant Stresses

Proc. Roy. Soc. (London) 90A (July 1, 1914) 329-342

The 1910 work is continued to determine if the empirical laws for Pb are applicable to other metals, and also to investigate the effect of temperature on the flow. The metals investigated were Pb, Sn, Fe, Cu, Hg, a Pb-Sn alloy, brass, and German silver. It was found that, without exception, all the pure metals gave extension-time curves which closely correspond to the equation

$$l = l_0(1 + \beta t^{1/3})e^{kt} ,$$

with the deviations less than 2%. In the equation, l_0 represents the immediate length on loading, β is a measure of that part of the flow whose rate decreases as the time increases, and k measures the final or viscous flow. The values of these constants depend upon the temperature and at a given temperature with increasing stress, β tends toward a constant value while k increases at a rate which itself increases to a constant value. The main result of this part of the work shows that metals of widely different nature obey the same general laws of flow over a range of temperature. Small quantities of impurities do not affect the general type of extension-time curves. Duplex alloys show an anomalous behavior At a certain stage of the flow produced at certain temperatures the wire softens instead of showing the hardening which is common to the pure metals. At other temperatures, however, alloys were found to behave normally. By subjecting to a high preliminary stress either in tension or torsion, wires can be put into a state in which they will flow viscously from the start of subsequently applied smaller stresses Photomicrographs of strips of soft Fe extended at different temperatures showed that slip bands were formed with equal distinctness and frequency, regardless of whether the extension took several minutes or was produced immediately On the basis of the co-existence of the crystalline and amorphous phases an explanation of these various phenomena has been worked out. When a wire is loaded, there is an immediate stretching owing to a slip between, and inside, favorably disposed crystals An immediate redistribution of stress then takes place, with the result that other less favorably placed crystals begin to slip and give rise to the β flow There is a limit to the ultimate number of lamallae which can be produced, corresponding to the production of elementary crystals This is represented by the limit to which β tends with increasing stress If the amorphous material is capable to flow it gives rise to the viscous or k flow. At low temperatures the amorphous phase is hard, but as the temperature rises, it softens at a relatively greater rate than the crystalline material This is obviously no limit to the viscous flow

(23) Andrade, E N. da C

Flow of Metals

J. Inst. Metals 60 (1937) 427-445

Flow is most easily observed in the liquid state, but the structure of the liquid state is still obscure. Nevertheless, it is possible on simple lines to formulate a theory of liquid viscosity, which both gives the observed viscosity of simple liquids and accounts for the temperature variation. In this connection, viscosity of liquid metals is important, because of the simplicity of the molecular state The flow of solids is best formulated, from which it is clear that the velocity of flow is of fundamental significance. The perfect crystal lattice does not offer a basis for any theory of the flow of solids; the only successful attempts to construct a mechanism to explain plastic behavior are based on the assumption of flaws, or dislocations, in the lattice, which are propagated along preferential directions when external stresses are applied Thermal fluctuations must also be invoked. Further investigation of the nature of the inherent flaws is of importance, not only for physical theory but also for metallurgical practice

(24) Andrade, E. N da C.

Creep of Metals

Engineering 161 (March 8, 1946) 233-235

Historical survey and review of empirical laws of creep Discusses familiar $e = \beta t^{-p}$ law and suggests $\beta = A[(\sigma_1-\sigma_2)^n - (\sigma_3-\sigma_1)^n]$ where σ_1, σ_2, and σ_3 are principal stresses

(25) Andrade, E N. da C.

Metal Crystals and Metal Strength

Proc. Roy Inst. (London) 33 (1947) 237-250

The breaking strength of a perfect crystal is considered, and the mechanism of plastic deformation of single crystals is described in terms of structure.

(26) Andrade, E N. da C.

The Flow of Metals

J. phys. radium 8 (1947) 313-326

The phenomena of flow and creep in metals are reviewed To simplify the experimental results a constant stress is essential and two ways of achieving this are described. Under these conditions, metals exhibit two flow regimes, one temporary, the other permanent, and their relative importance in the case of any metal depends upon the temperature The flow of single-crystal metals is characterized by certain planes and crystalline directions of slip, by slight shear stress, and by marked hardening due to strain. These phenomena are explained by a theory based upon dislocations propagated through the crystals. The state of the surface of the single crystal plays a considerable role in the theory, and it is considered that the deformation of single crystals can suggest a mechanism for the flow of ordinary metals

(27) Andrade, E N da C

The Creep of Metals

Paper from Report of a Conference on Strength of Solids, Phys. Soc (London) (1948) 20-26

A brief review is given of creep phenomena, with special reference to creep under constant stress, the effects of recrystallization, "martensitic" phase changes, rotation of crystallites, grain-boundary flow, and the creep of single crystals. Three methods for maintaining constant stress on specimens under axial tension during testing are proposed

(28) Andrade, E. N da C

Creep of Metals and Recrystallization

Nature 162 (September 11, 1948) 410

Results of some experiments on creep of pure Pb which show that recrystallization during creep has a fundamental effect upon the form of the creep curves This metal, although normally stable at atmospheric temperature, recrystallizaes under stress Possibility of an analogous explanation of the creep behavior of other metals

(29) Andrade, E N da C.

The Physics of the Deformation of Metals

Endeavour 9 (1950) 165-177

Discusses in general terms structure-sensitive and structure-insensitive properties of metals. A description of plastic flow, creep, dislocations, etc , is given

(30) Andrade, E. N da C

The Flow of Metals

J Iron Steel Inst 171 (1952) 217-228

Reviews knowledge about creep of metals under stress Creep behavior of Pb, Sn, Cu, Fe, Cd, solid Hg and many other materials is very similar if allowance is made for temperature, and can be expressed by a simple equation The physical mechanism of creep is discussed

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(31) Andrade, E N da C

Critical Shear Stress and Temperature

Phil Mag. 43 ser 7 (1952) 1218-1221

As regards the mechanical behavior of single crystals, there is a contrast between metals of hexagonal crystal structure, which in general possess one set of glide planes, and the metals of cubic crystal structure, having many glide planes It has, however, been found that the pure fcc metals, Au and Ag, show the hexagonal type of "easy glide" at low temperature when the glide is not large. With suitably chosen conditions, glide in cubic crystals can, apparently, be restricted to one set of glide planes without even local interference by other sets, and then the behavior is hexagonal in character. The critical shear stress shows no distinction between the two types of metals. Graphs of critical shear stress of the metals Bi, Zn, Cd, Cu, Mg, Ag, Au, Pb, and Hg against the ratio of temperature, T, to T_m, the melting point of the metal, i e , T/T_m (= θ), show no suggestion of grouping according to crystal structure, but follow a very similar course. A plot of σ, the shear stress, against θ shows that for Au, Ag, Cd, and Zn, Orowan's law $\sigma = \sigma_0 - BT^{1/2}$ holds within the range θ = 0 05-0 4, but for high temperature the experimental values are higher than the law indicates

(32) Andrade, E N da C.

Concept of Creep

Paper from Creep and Recovery, Am. Soc Metals, Cleveland, Ohio (1957) 176-198

Physical distinction between primary, beta, and secondary, k, flow, behavior of cubic and hexagonal metals, useful characteristics of shear method; behavior of surface grains; significance of temperature relative to melting point

(33) Andrade, E N. da C , and Chow, Y S

Glide Elements of Body-Centered Cubic Crystals, With Special Reference to Effect of Temperature

Proc Roy Soc. (London) 175 (1940) 290-315

The glide elements of single crystals of bcc Na have been determined at various temperatures Experiments with Na, Fe, and Mo show that the spacing of the glide planes increases markedly as the temperature is raised. It has been found that, for equal strain, the crystallite rotations, as evidenced by the asterisms, are much greater at low temperatures where the hardening is greater, which supports the view that hardening is intimately connected with the rotation of crystal fragments The breaking up of the asterisms into discrete spots which has been found with Na and K is shown to be due to recrystallization The general implications of the results are discussed

(34) Andrade, E. N. da C., and Jolliffe, K. H

The Flow of Polycrystalline Metals Under Simple Shear

Proc Roy. Soc (London) 213A (1952) 3-26

Creep of three polycrystalline metals, commercial Pb, pure Pb, and Cd, were investigated under conditions of simple shear by a method in which a constant couple is applied to an annulus cut in a thicker disk of the metal For comparison, normal tensile tests were carried out on wires of the same metals Cause of the elimination of permanent creep under the conditions of simple shear, and a variety of experimental results explained in terms of intracrystalline and boundary effects

(35) Andrade, E N da C., and Kennedy, A J

A Surface Effect in the Creep Behavior of Polycrystalline Lead

Proc Phys Soc (London) 64B (1951) 363-366

Results of some experiments with pure Pb containing 0.05% Te This alloy undergoes transient creep only, i e , the creep equation is $\ell = \ell_0 (1 + \beta t^{1/3})$. Plots of β against stress were prepared for wires of four different diameters, grain size being very nearly the same in each case The plots did not coincide, but could be made to do so if corrected on the assumption that a thin surface layer was offering effectively no resistance to creep. This surface effect is interpreted as being due to a lesser constraint on the surface region as regards slip. X-ray studies revealed a change in type of structure 0 1 mm below the surface

(36) Andrade, E. N da C., and Roscoe, R

Glide in Metal Single Crystals

Proc. Phys. Soc (London) 49 (1937) 152-176

Experiments carried out on hardening and recovery of Cd crystals, and in Pb crystals on the spacing of glide planes which has been shown to be independent of a range of factors, and so to have a physical significance. The results relating to hardening can be explained by a hardening on individual glide lamellae which is proportional to the glide, and it is suggested that the mechanism of the permanent hardening is mainly a rotation of crystallites in the lamellae

(37) Andrew, J H , and Lee, H

The Work Hardening and Aging of Steel

J. Iron Steel Inst 145 (1942) 153P-211P

Experimental work was undertaken with a view of proving or disproving the hypothesis that the cold working of iron and steel gives rise to the formation of the alpha phase It is shown that carbon is dissolved during the work-hardening process, and that under certain conditions both austenite and martensite may form A new theory of quench aging is suggested, and the subject of strain aging is also dealt with The close correspondence between the changes produced in steel by cold work and by quench hardening is strong evidence in favor of the suggestions made. A new theory of the yield is developed, while the changes undergone during the extension of the tensile test piece are shown to be dependent upon the total elongation and the condition of the carbide in the steel.

(38) Andrew, R P

A Correlation Between the Tensile Test and the Creep Test

Abs Dissert, Univ Cambridge, No. 1953 (1950-1951) 73 pp

Results of tensile tests on high-purity Al were predicted from results of creep tests under various loads The very close agreement between the predicted and actual experimental results supports the hypothesis of a unique relationship between stress, strain, and rate of strain within the ranges studied, in the case of high-purity Al The maximum load in the tensile tests increased linearly with the log rate of extension, and the relation between the applied load and log time to fracture, in the creep tests, was also linear, the two gradients were equal in magnitude but opposite in sign The relationship between the gradients agreed with the result that the creep curves for various loads coincide when plotted with the nondimensional abscissae t/T_F, where t is the time and T_F the time to fracture

(39) Andrews, K W

Principles Involved in the Formation of Iron Alloys

Metal Treatment and Drop Forging 19 (1952) 425-489

Empirical relationships developed from a study of experimental facts: (1) principles of classification, (2) semiquantitative study of phase diagrams from a thermodynamic viewpoint, (3) explanation of formation of alloys and their constitution and properties in terms of electronic theory of atomic structure, and (4) application of thermodynamic methods to the transformation in binary and ternary alloys

(40) Arantes, A A

Limitations in the Use of Hardness Tests as a Method of Investigation of the Mechanical Properties of Tempered and Annealed Steels (In Portugese)

Bol da assoc brasil Metais 12 No. 43 (1956) 135-143

Analysis of the relationships between hardness, tensile strength, impact value, and wear resistance of various steels showing the inadequacy of hardness tests as a method of investigating mechanical properties, even when the chemical composition of the steel and its Jominy curve are known

(41) Arbtin, E., Jr , and Murphy, G

Correlation of Vickers Hardness Number, Modulus of Elasticity and the Yield Strength for Ductile Metals

USAEC Publ ISC-356 (1953) 28 pp

Indentation, scratch, and dynamic methods of hardness testing are reviewed The investigation is based on a hypothesis of Cardullo [Mech Eng 46 (1924) 638], that a relationship of the form $H = CE^m L^n$ exists between the hardness number H, the modulus of elasticity E, and the compression elastic limit L. The materials studied included Al brass, Cu, Mg, steel, Ta, Sn, and Zn, and covered a wide range of moduli of elasticity DPN were determined, using three different loads and three loading times for each material the mechanical properties measured were the modulus of elasticity, the yield point, and the ultimate tensile strength Strength-hardness relationships are presented for three ranges of modulus of elasticity No discernible relationship existed between the yield point and the DPN The foregoing relationships appear to be in general agreement with similar results presented elsewhere the present equations were limited by the small number of points used, and by the accuracy of the hardness values

(42) Ardley, G W.

On the Effect of Ordering Upon the Strength of Cu_3Au

Acta Met. 3 (1955) 525-532

Single crystals of Cu_3Au were obtained with different antiphase domain size and degree of long-range order The critical resolved shear strength and electrical resistivity were measured at room temperature The resistivity measurements enabled the domain size to be deduced, and, as this increased, the strength first increased and then decreased to a value lower than the initial (disordered) strength The strength decreased as the long-range order increased The change in strength of crystals equilibrated at 375 C and then quenched to lower temperature was also obtained as a function of time at the lower temperature. The relaxation times for attaining the equilibrium long-range order at different temperatures were in agreement with previous estimates. The variation of strength with domain size was found to fit a theoretical relation given by Cottrell Some results were also obtained on the change of strength with temperatures as a crystal annealed to equilibrium at 300 C was heated to 680 C The strength increased with temperature up to the critical temperature, dropped sharply during disordering, and then increased with temperature again up to a maximum before finally decreasing The maximum strength in the disordered region was strain-rate dependent, and jerky flow was observed below this temperature It is believed that this is a strain-aging effect.

(43) Ardley, G. W , and Cottrell, A H

Yield Points in Brass Crystals

Proc. Roy Soc. (London) 219A (1953) 328-341

It is suggested that the yield point in these crystals is caused by N in the material The conditions for producing yield point in fcc metals are discussed in relation to the "atmosphere" theory of the yield point, which supposes that dislocations in crystals become anchored by solute atoms, which segregate to them, and that the material gives way suddenly and softens when these dislocations are pulled away from their atmospheres at the beginning of plastic deformation

(44) Arkharov, V , Borisov, B S., and Mardeshev, S.

Diffusion-Caused-Hardening as a Factor of High Temperature Deformation (In Russian)

Research on Heat Resistant Alloys 2 Moscow (1957) 120-124

Points out that diffusion interchange does not necessarily relieve strain. Only the movement of an atom from an interstitial site to a vacant lattice site actually causes relief of local microdistortion Reasons that at high temperatures diffusion-caused-hardening can become an important factor in high-temperature strength

(45) Arkharov, V I , Kolesnikov, G. N , and Orlov, A. N

Possible Development of the Dislocation Theory (In Russian)

Doklady Akad. Nauk S.S.S R 92 no. 4 (October 1, 1953) 751-754 (NSF tr-212)

A theory of edge dislocations is developed, designed to eliminate two fundamental difficulties of the current theory, viz , the very high energy required to produce a dislocation, and the very large number of dislocations which must be present in a crystal before the application of forces The theory is based upon consideration of a system of dislocations comprising two pairs of edge dislocations (+ and -) and eight pairs of screw dislocations (left- and right-handed), arranged so that the dislocations in different slip planes will, pairwise, have common frontal planes The activation for the generation of a dislocation is broken up into elementary parts, and equals the self-diffusion activation energy, and in the crystal, before the application of deforming forces, there is a sufficiently large concentration of self-diffusion-type disturbances in the regularities of the lattice The ideas developed are somewhat more general than those due to Seitz [Phys Rev 79 (ii) (1950) 890].

(46) Aroesta, H

Theory of Melting and Yield Strengths

Phys Rev (1955) 1723-1724

Fürth's theory of rupture strength (Phil Mag 40 (Ser 7) (1949) 1227), based upon fusion, has been criticized (see Frenkel, "Kinetic Theory of Liquids", London: (1946) 101) as yielding fortuitous results largely because rupture strengths are associated with surface phenomena The theory is now related to yield strength, which is less surface-dependent. Fürth's theory assumes that melting is due to the breakup of a block structure, it is here assumed that the mechanism is dependent not only on block size but also on the width between blocks where the atoms are misfits, and may be expected to enter the mechanism first

(47) Auld, J H , Coyle, R. A , Marshall, A M , and McKinnon, N. A

X-Ray Microscopy of As-Grown and Deformed Single Crystals of Aluminum

Trans. AIME 209 (1957) 360-361

The microfocus X-ray method of Schulz [ibid. 200 (1954) 1082] was used to study the slip deformation and strain hardening of single crystals of pure Al both in the state as grown by the strain-anneal method, and after they had been subjected to increasing amounts of plastic strain Although many as-grown crystals showed no sign of any macroscopic defects, some showed defects similar in structure to those reported by Kelly and Wei [ibid 203 (1955) 1041] to occur in crystals grown from the melt, while others showed a more regular appearance

(48) Averbach, B L.

The Structure of Solid Solutions

Mass Inst. Technol , Dept Met (USAEC) NYO-7054 (Nov 1955) 36 pp

Sizes of atoms in solution, strain energy, strength, local atomic arrangements, changes in vibrational spectrum in alloy formation

(49) Averbach, B L , Bever, M B., Comerford, M R., and Leach, J. S. Ll.

X-Ray and Calorimetric Investigations of Cold Working and Annealing of a Gold-Silver Alloy

Acta Met 4 (1956) 477-484

The energy stored in filings of a 75Au-25Ag alloy is released during the recovery and recrystallization processes Most of the stored energy is associated with the presence of low energy boundaries introduced during deformation; average specific interfacial energy for these boundaries was calculated

(50) Averbach, B. L., Cohen, M , Allen, S , Comerford, M F., and Houska, C

Fundamentals of Cold Working and Recrystallization

Mass Inst Technol (USAEC) NYO-7075 (June 1955) pp 3

An X ray study of recovery and recrystallization in an alloy containing 75% Au, 25% Ag was combined with calorimetric data to obtain pertinent information on mechanism by which energy is stored in deformed metals

(51) Bacon, R , and Smith, C S.

Single Crystal Elastic Constants of Silver and Silver Alloys

Acta Met. 4 (1956) 337-341

The elastic constants of single crystals of Ag and of dilute alloys of Mg, Zn, Pd, Cd, In, and Sn in Ag have been measured by the ultrasonic pulse-echo method. For all solutes except Pd, there is a large fractional decrease, upon alloying, in the shear constant $(C_{11} - C_{12})/2$, and a relatively small decrease in the short-range crystal forces because of a local weakening of nearest-neighbor repulsive bonds, and an increase in the long-range electrostatic forces because of the increase in the average ion-core charge The two shear constants increase upon alloying with Pd, and a similar interpretation is not inconsistent with this result

(52) Bailey, R W

Note on the Softening of Strain-Hardened Metals and Its Relation to Creep

J Inst Metals 35 (1926) 27-43

Postulates strain hardenings and simultaneous partial softening by annealing as a basis for explaining the mechanisms of creep

(53) Bailey, R W

Utilization of Creep Test Data in Engineering Design (Creep of Lead Tubes Under Compound Stress)

Proc Inst. Mech. Engrs (London) (1935) 131 131-269

A rational treatment of the subject of creep is attempted, particularly directed to the requirements of design General expressions for creep under any system of stress are given, which include the case of tension, and permit the results of tensile creep tests to be utilized in the design of parts under complex stress General relationships are suggested for creep in the direction of three principal stresses, X, Y, and Z (considered positive when tensile) representing any stress system The expressions are similar in form, e.g , the tensile creep rate C_x in the direction of X is represented by

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$$C_x = \frac{A}{2}\left[\frac{1}{2}(X-Y)^2 \frac{1}{2}(Z-X)^2 \frac{1}{2}(Y-Z)^2\right]^m \left[(X-Y)^{n-2m} \quad (Z-X)^{n-2m}\right]$$

where A, m, and n are constants. For simple tension (Y = O, Z = O) $C_x = AX^n$. Values of m and n are derived. The distribution of stress in important engineering parts under compound stress is determined. The paper also includes results for the axial, circumferential (twist) and diametral creep of pipes under combined internal pressure and axial stress, and internal pressure and axial torsion.

(54) Bailey, R. W

A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures

J Appl Mechanics 21 (1954) 309-322

Treats methods of extrapolating creep data. Advocates his method of maintaining creep stress constant and varying temperature. Gives his expression for the creep curve (which includes a factor for "thermal action") dε/dt = $A_0 \sigma^n t^{-p}$, where ε is strain, σ is stress, t is time, and A, n, and p are material constants, with values depending on the particular stage of creep. The coefficient A contains the thermal-action effect.

(55) Bainbridge, D., Li, C., and Edwards, E. H

Recent Observations on the Motion of Small Angle Dislocation Boundaries

Acta Met 2 (1954) 322-333

The motion of small-angle dislocation boundaries in zinc crystals was investigated in the temperature range -196 C to 400 C. Boundaries were made to move by the application of a shear stress acting in the direction of the Burgers vector of the edge dislocations comprising the boundary. The character of this motion was found to vary markedly with temperature. Motion proceeded at a constant rate under a constant stress at elevated temperatures. At +20 C movement was discontinuous, the boundary advancing through an appreciable distance during each jump. At -176 C, motion appeared to be steady, however, at both 20 and -196 C a continuously increasing stress was required for continued movement. The boundary angle remained constant during motion at high temperature. At lower temperatures, the magnitude of the angle decreased, and the boundary assumed a more complex shape through interaction with structural defects. Small-angle boundaries of like sign in proximity to one another coalesced during short-time annealing treatments at 400 C to form a single boundary. Closely spaced boundaries of like sign could be made to unite at any temperature by the application of a stress, thus establishing a mechanism for the formation of a substructure in the absence of appreciable thermal energy. Boundaries of unlike sign were united through their stress-induced motion and the angle of the resultant boundary equalled the algebraic sum of the angles of the constituent boundaries. The results of boundary motion experiments were compared with the results of simple shear tests on single crystals of zinc. The similarities suggested that motion of dislocations through the structural barriers of the crystal rather than generation of new dislocations may be the factor which determines the yield strength.

(56) Bakarian, P W and Mathewson, C H

Slip and Twinning in Magnesium Single Crystals at Elevated Temperatures

Trans AIME 152 (1943) 226-254

The mechanism of plastic deformation in high-purity magnesium up to 300 C was investigated in a series of compression tests including representative orientations of the crystal relative to the stress axis. The results indicate that slip on the basal plane in the original material twinning on the (102) plane, slip on the basal plane of the twinned regions, and fracture (or cleavage) along the (101) plane are the only mechanisms operating during compression stressing, prior to the entrance of general crystal breakup. The dominance of these several mechanisms has been classified into three fields of orientation.

(57) Bakish, R., and Robertson, W D

Structure-Dependent Chemical Reaction and Nucleation of Fracture in Cu_3Au Single Crystals

Acta Met 4 (1956) 342-351

Cu is selectively removed from Cu_3Au by $FeCl_3$ from imperfections originating during crystal growth. Selective removal of Cu also occurs from local areas in slip clusters apparently unrelated to growth imperfections. Under applied stress, both sites of reaction become nuclei of fracture cracks which propagate only in the presence of stress and reagent, the path is normal to the stress axis and is independent of crystallography. This indicates that the deformation at the leading edge of the crack is highly complex. It is proposed that fracture occurs as a result of selective removal of Cu from the zone of complex deformation at the leading edge of the crack.

(58) Balicki M

A Study of Work Hardening and Reannealing of Iron

J Iron Steel Inst 151 (1945) 181 224P

Armco-iron wires were given 12 different degrees of work hardening and annealed in vacuum. The following properties were determined: hardness, electrical resistivity, elastic limit from the bend test, plastic limit, ultimate stress, uniform elongation, springiness, thermoelectric properties and microstructure. The changes induced by reannealing confirm the presence of three phenomena: strain aging, recrystallization, and crystal growth. The main change, that of recrystallization of a work-hardened wire, is shown by all the curves as occurring in the same range of temperatures (which is contrary to the findings of Tammann), this suggests that all the changes are a result of the same fundamental cause. The recrystallization range is lowered when the degree of work hardening is increased. From the change in the course of the curves which characterize work-hardened iron, three regions of plasticity were distinguished.

(59) Ball, C J

Surface Distributions of Dislocations in Metals II

Phil Mag 2 (1957) 977-981

The analysis described in I [Hirsch and Ball, ibid., 46 (1955) 1343] is extended to boundaries containing dislocations of three systems, and it is shown that the rotation axis of such a boundary can lie anywhere on the surface of a cone. A single boundary plane corresponds to each direction of the rotation axis. The theory cannot explain the experimental evidence on misorientations in Zn unless slip occurs in nonbasal directions or on planes not hitherto reported, at high temperatures. The experimental evidence for fcc metals is insufficiently precise to test the theory.

(60) Ball C J

The Flow Stress of Polycrystalline Aluminum

Phil Mag 2 ser 8 (1957) 1011

An X-ray microbeam technique was used to measure subgrain size and range of misorientations in one original grain in a series of specimens, tensile tests being carried out to measure flow stress. There is a strong correlation between flow stress, and subgrain size t, a plot of σ vs $t^{-1/2}$ giving a straight line. The strength of the boundaries does not appear to depend on boundary angle. The variation of σ with temperature was also measured and, from this, it is suggested that the strength controlling factor is elastic interaction.

(61) Ball C J

Nature and Effect of Substructure in Polycrystalline Aluminum

Paper from Dislocations and Mechanical Properties of Crystals John Wiley and Sons Inc New York (1957) 353-358

Subgrain-size decreases with increasing deformation and approaches a limiting value which increases linearly with the temperature of deformation. The types of stress free low angle boundaries that can be formed without climb with dislocations of one, two, or three systems have been calculated. If dislocations of only one or two systems are present, the possible rotation axes are [100], [111], and in the plane (110).

(62) Ball, C J and Hirsch, P B

Surface Distribution of Dislocations in Metals

Phil Mag 46 ser 7 (1955) 1343-1352

It is shown that a boundary containing dislocations of two systems can, in general, form on two, and only two, planes which have simple indices and that the rotation axes are simple crystallographic directions. Most of the experimental evidence on misorientations in deformed crystals can be explained in terms of such simple boundaries.

(63) Balluffi, R W., Rosi, F D., and Seigle, L L

Self-Diffusion of Metals and Associated Phenomena Progress Report

USAEC Publ SEP-151 (1954) 4 5

The stress/strain characteristics of single crystals of dilute alloys of Cu Al, Cu-Ge, and Cu Si were determined as a function of concentration. The critical shear stress increased considerably with alloying content, the yield point was better defined at higher alloy contents and with the highest contents a double yield point was found. Strain aging suggested that this yield phenomenon was a result of the Cottrell mechanism of anchoring dislocations by solute atoms. All alloy crystals displayed a two-stage hardening process, characterized by a low linear hardening rate followed by a high parabolic rate, for similarly orientated crystals the extent of the first stage increased markedly with alloy content whereas the shear hardening of both stages decreased. For similarly orientated crystals of identical solute concentration the two-stage hardening curves showed that in the order Cu-Ge, Cu-Si, Cu Al (1) the critical shear stress decreased, (2) the extent of the first hardening stage decreased, and (3) the degree of strain hardening in both stages increased. The most significant difference occurred in going from Si to Al. It appears that variations in the diffusion rates of the solutes may be a significant factor in explaining these differences.

(64) Balluffi, R W., Rosi, F D, and Seigle, L. L.

Self-Diffusion of Metals and Associated Phenomena Progress Report

USAEC Publ. SEP-151 (1954) 5

A study has been made to establish a correlation between the stress-strain characteristics and the nature of slip-band formation in metal single crystals, the effect of variables influencing plastic flow, such as orientation, composition, and temperature have also been investigated. A study of the effect of crystal orientation on the plastic properties of Cu and Ag showed (1) stress-strain characteristics are strongly dependent on orientation, and at certain orientations two stages of shear hardening occur; (2) low, linear hardening rates occurred when slip was on a single system, a high, parabolic rate was always associated with slip in several systems, the greater the number of intersecting slip planes, the greater the degree of shear hardening and (3) the first stage of low hardening rate is terminated by the occurrence of secondary slip, and the extent of this stage decreases as the initial orientation of the crystal approaches a stage for multiple glide. It appeared that the onset of stage two was associated with a resolved shear stress which was independent of crystal orientation.

(65) Balluffi, R. W., and Seigle, L. L.

Growth of Voids in Metals During Diffusion and Creep

Acta Met 5 (1957) 449-454

A study was made of the thermodynamic conditions under which voids may grow from suitable nuclei in a metal by a mechanism of vacancy aggregation under the influence of stress and vacancy supersaturation. The results are applied to the intergranular void formation observed during creep experiments and also void formation during Kirkendall diffusion. In the case of creep it is postulated that nuclei may grow into voids by receiving stress-motivated vacancy currents from nearby grain-boundary sources. In the case of Kirkendall diffusion it is shown that the development of stress in the diffusion zone depends directly upon the existence of a vacancy supersaturation.

(66) Barnes, R. S.

The Climb of Edge Dislocations in Face-Centered Cubic Crystals

Acta Met 2 (1954) 380-385

An edge dislocation of type a/2<110> may be made in a fcc crystal by inserting two {110} planes perpendicular to the Burgers vector. The atomic movements involved in the climbing of such a dislocation from one {111} plane to another produce extension or shrinking of the extra {110} planes. It is concluded that climbing is still possible, though more difficult, when the dislocation is dissociated into Shockley partials. A straight line will be unable to climb unless the environment contains a large excess of point defects, but this restriction is removed if the dislocation possesses jogs. Surface markings may be produced by dislocations climbing out of the crystal, and it is suggested that this may be the explanation of some anomalous "slip" steps observed by Forty and Frank [Proc Roy Soc (London) 217A (1953) 262]. The possible importance of climb in various physical phenomena is stressed.

(67) Baron, H. G

Stress/Strain Curves of Some Metals and Alloys at Low Temperatures and High Rates of Strain

J. Iron Steel Inst. 182 (1956) 354-366

Tensile tests were carried out on some metals and alloys at temperatures of 20, -78, and -196 C, using strain rates of 10^{-3} and 10^{+2} sec. The strain rate and temperature have a marked effect on Fe and the softer ferritic steels. In dynamic tests below a critical temperature, all the ferritic materials exhibit a type of premature failure in which the strain is entirely localized to a short neck. It is shown that this is a consequence of the adiabatic nature of this test. The variation of upper yield stress with temperature and strain rate appears to obey an activation energy relationship over part of the range of stress. Within this range the activation energy for yielding varies with the stress in the manner predicted by Cottrell and Bilby. The divergence from theory at low stresses may be due to simultaneous strain aging, while at high stresses, brittle fracture of twinning eventually intervenes before the upper yield point is reached.

(68) Baron, V. V., and Savitsky, E. M

The Influence of Temperature Upon the Strength of Brittle Metallic Materials (In Russian)

Doklady Akad Nauk S S S.R 94 (2) (1954) 269-272

The ultimate tensile strength and compressive strength of Si and Ge and of brittle metallic compounds of the NiSi, Ni_2Si, Cu_3Si, CoSi, and $CoSi_2$ types were determined at various temperatures up to their melting point. In contrast to the ductile metals, the strength of which decreased with temperature according to an exponential law, the brittle

materials showed an initial increase of strength up to a maximum occurring for ultimate tensile strength at temperature T = 0 8 - 0 6T_m (where T_m is the melting point) and for compressive strength at T = 0 5 - 0 7 T_m. After reaching the maximum, the strength of the brittle materials declined along a curve represented by the equation $M_1 = M_2 \exp[-\alpha(t_2 - t_1)]$, where M_1 and M_2 are mechanical properties at temperatures t_1 and t_2 respectively, and alpha is a constant. Hardness of both the ductile and the brittle materials decreased with increase of temperature.

(69) Barrett C S

Imperfections From Transformation and Deformation

Paper from Imperfections in Nearly Perfect Crystals, John Wiley & Sons, Inc., New York (1952) 97-125

A stacking fault is produced when an atom layer in a crystal is displaced to a position destroying the regular sequence of the layers; they can be detected and analysed by X-ray-diffraction patterns made with polycrystalline metals oscillating through small angles. They can also be determined, though less reliably, by X-ray line broadening in powder patterns. Plastic deformation causes faulting in some Cu-Si, Au-Cd, Ag-Sn, and Ag-Sb alloys, and possibly in Cu-Zn, Cu, and Ag at low temperatures, but not in Al or the Al alloys, 24S-T. Faulting accompanying transformation in Co, Li, and Li-Mg alloys is ascribed to strains due to the martensitic type of transofrmation. The more fundamental characteristics of crystal distortions due to plastic flow are briefly reviewed, these include elastically bent glide lamellae, distortion around slip bands, rotational slip, deformation and kink bands, deformation twins, martensitic (diffusionless) transformations both spontaneous and strain induced, grain-boundary and subboundary flow, and strain gradients near grain boundaries.

(70) Barrett, C S

Effects of Temperature on the Deformation of Beta-Brass

Trans AIME 200 (1954) 1003-1008

High-purity beta brass specimens were homogenized at 700 C, then cooled and deformed in compression at low and high rates of strain at temperatures of -195 and +625 C. No deformation twinning could be observed. deformation-band spacing increased steadily from a minimum value at -195 C up to ~425 C, thereafter, it widened rapidly. Impact hardness decreased moderately with increased temperature from -195 to +20 C, increased moderately from +20 to 385 C, and fell continuously and rapidly between 400 and 625 C. Current theories of these effects are discussed, and it is concluded that below 425 C and also somewhat above the critical temperature for disordering, the state of order, rather than thermally activated flow processes, controls the impact behavior. It is suggested that it is predominantly local order rather than the number of domain boundaries that controls hot impact hardness, and that the reverse is the case at room temperature. The degree of local order affects the energy required for dislocations to be generated, to cross imperfect domains, cut domain boundaries and antiphase strings, and to surmount obstacles.

(71) Barrett, C. S

Effect of Pressure on the Plastic Deformation of Ni and Al

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 238-240

Increasing the pressure increases the flow stress. If pressure is decreased, flow stress decreases. There is a slight transient immediately upon reloading after the pressure is changed, but there is clearly a difference in flow stress. In all cases, the crystal fractures by necking down; the type of fracture did not change under pressure.

(72) Barrett, C S

Yield Points in Al and Ni Single Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 419-422

Investigation of the yield points that appear upon reloading after prior plastic deformation and unloading. The yield point appears only if there has been previous plastic flow; the magnitude of the yield-point effect increases with the flow stress at the time of unloading; the specimen must be subjected to a reduced load to show the effect.

(73) Bartenev, G M

The Elasticity of Crystals Near the Melting Point (In Russian)

Zhur. Fiz Khim 24 No. 12 (1950) 1437-1441

On the basis of his theory of phase fluctuations (ibid., 22 (1948) 587; 23 (1949) 1075) according to which a solid near the melting point contains small regions of mass in which liquid is produced by thermal fluctuations, Bartenev examines the rigidity modulus of a solid near the melting point, showing that if the regions of liquid are assumed to be spherical, randomly distributed, and without resistance to shear, their existence reduces the actual rigidity modulus G to a value $G_N (1-\alpha)^2$, where G_N is the value to be expected by extrapolation of the modulus/temperature curve from lower temperature and α is the mass fraction of liquid present, given approximately at temperature T by the relation [Bartenev, ibid., 24 (1950) 1016] $\alpha = kT_sT/\mu\gamma(T_s - T)$, where k is Boltzmann's constant, γ is the latent heat of fusion, and T_s is the melting point. Comparison with Kornfel'd and Shestikhin's values [Doklady Akad Nauk S.S.S.R 36 (1942) 52] for the rigidity moduli of Sn and ice near the melting point confirms this relation.

(74) Bartenev, G M

The Time- and Temperature Dependence of the Strength of Solid Bodies (In Russian)

Izvest Akad Nauk S.S.S R Otdel Tekh Nauk 9 (1955) 51-61

A theory of time/temperature dependence of the brittle strength of solids is developed from (1) existing ideas about the mechanism of fracture, and (2) an assumption of the passage of atoms through a potential barrier in the process of fracture It is shown that a safe load exists, below which fracture is impossible The theory also describes the phenomenon of static fatigue in the absence of a surface active medium and chemical processes In practically the whole interval of change from a safe to a theoretical critical load the time temperature dependence of strength gives approximately linear relationships for log t versus P and log t versus 1/T - where t is the time of fracture, P is the load, and T the absolute temperature. The theory agrees with the experimental formula of Busse-Zhurkov better than with that of Holland and Turner Finally, it explains the time dependence of strength in the presence of a surface-active medium.

(75) Basinski, Z S.

Theory of Work-Hardening

Paper presented at 2nd Symposium on Melting, Diffusion and Related Topics Ottawa (October, 1957)

A theory of work hardening is proposed for fcc metals in which the main obstacles are provided by the "forest" of dislocations; the theory appears to apply also to bcc metals, but in that case at low temperature, the mechanical properties are dominated by a large Peierls-Nabarro force

(76) Basinski, Z S.

Activation Energy for Creep of Aluminum at Sub-Atmospheric Temperature

Acta Met 5 (1957) 684-686

The conclusion of Sherby, et al (ibid , 219), that the activation energy for creep of Al is independent of stress and strain, is examined for conditions where the effects of annealing and dislocation climb are negligible It is concluded that the activation energy for creep cannot be determined using only the change in strain rate with temperature Variations in elastic modulus and either strain rate or the temperature dependence of flow stress must also be considered

(77) Basinski, Z. S.

The Instability of Plastic Flow of Metals at Very Low Temperatures

Proc Roy Soc (London) 240 (1957) 229-242

The discontinuous yielding of superpurity Al, Al alloys, and Ta was studied at 4 2 K The effect can be explained if the release of energy during deformation heats the material sufficiently to produce unstable conditions of flow At room temperature, the amount of heat liberated is too small to produce any appreciable softening of the material but the decrease in specific heat at low temperature implies that the same energy will produce a much greater local rise in temperature If the flow-stress/temperature curve has an appreciable slope at low temperature, unstable conditions will arise when the decrease in flow stress caused by the local heating becomes greater than the increase due to the deformation itself A localized portion of the specimen will then flow catastrophically under decreasing stress until the load is relaxed to a lower value Once this has happened however, and flow has ceased, the material will cool down and the load must be increased to at least its former maximum value before deformation is resumed At sufficiently low temperature, all metals should exhibit this behavior

(78) Basinski Z S.

Ductility of Iron at 4 2 K

Acta Met 5 (1957) 763-764

Points raised in Smith and Rutherford's communication (ibid , 761) are discussed Reference is made in particular to the serrations in stress/strain curves, nonuniform deformation, and brittle fracture

(79) Bassi G.

Cross-Slip in Copper (In German)

Z. Metallk 48 (1957) 190-192

A single crystal and a bicrystal - in the form of cubes with 12 mm sides - of spectrographically pure Cu were given cyclic treatments of 5% compression followed by annealing at 200 C for 3 days. Cross slip, which was observed after a few such cycles increased and assumed a more irregular and wavy form with increasing number of cycles It is considered that the phenomenon is associated with the increasing number of vacancies formed by such cycling The vacancies provide an obstacle to slip; when a primary-slip line encounters a group of vacancies it fails to penetrate them and is diverted to a secondary-slip system but reverts to the original plane after a short distance; with increasing number of vacancies this process occurs more frequently Such a process also accounts for the prevalent cross slip in alpha brass, where full annealing often produced porosity (arising from the condensation of vacancies) owing to dezincification; intense cross slip is common in the neighborhood of such forces, consequent upon the high concentration of vacancies around them

(80) Batdorf S B , and Budiansky, B

Polyaxial Stress-Strain Relations of a Strain-Hardening Metal

J. Appl Mechanics 21 (1954) 323-326

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A plastic stress strain law of anisotropic strain hardening type is developed on the basis of the polycrystalline nature of metals and the mechanism of plastic deformation The principal source of error is the neglect of the interaction between neighboring grains and the assumption that each grain has only a single slip system

(81) Bateman C M

Residual Lattice Strains in Plastically Deformed Aluminum

Acta Met 2 (1954) 451-455

Flat tensile test pieces of polycrystalline high purity Al and commercial purity Al were extended 1-20% and residual lattice strains were measured using a black reflection X ray method The results are compared with Greenough's theory [Proc Roy Soc (London) 197A (1949) 556] according to which the strains are due to an intergranular stress system A discrepancy between the theoretical predictions and the experimental results is found in each case It is suggested that the theory while apparently valid for wires, may be inapplicable to these test pieces

(82) Bateson S

Critical Study of the Optical and Mechanical Properties of Glass Fibers

J Appl Phy 29 (1958) 13 21

Previously suggested that the increase in strength of the fiber with decreasing diameter was caused by an increased rate of cooling as the diameter decreased Further investigation suggests a modified flaw theory with the following basic principles (1) the flaws themselves need not be visible but should be considered as structural defects which are potential origins of fracture; (2) the flaw frequency and distribution is a governing factor in determining strength surface properties of rods or fibers rather than the relative "seriousness" of individual flaws and (3) thermal history plays the dominant role in flaw formation and distribution

(83) Bausch, K

Investigation of Slip under Shear in Single Crystals of Tin

Z Physik 93 (1935) 479-506

Single crystals of Sn were so mounted by soldering in a Polanyi extensometer that shears in the slip planes and slip directions were operative In the slip planes (110) and (100) slip occurred in the direction [001] whatever the direction of application of the tensile stress in the planes The initial parts of the hardening curves followed the cosine law of shear stress in subsequent parts intensified hardening was present In the plane (110) slip also occurred in the direction [111]; in the plane (100) slip also occurred in the direction [010] The mechanism of plastic deformation of crystals is discussed in considerable detail

(84) Bauser M , and Dehlinger U

Creep Experiments on Aluminum Single Crystals Under Incremental Loading (In German)

Z Metallk 45 (1954) 618-621

Single crystals of 99.998% Al were creep tested at 20 C under incremental loads of 1 6 g/mm^2 each applied for 10 60 min After a given number of increments the crystals were unloaded reannealed and again subjected to creep. The small creep elongations were measured by an interference technique The shapes of the strain hardening curves obtained are, at least up to the onset of the tertiary stage of creep independent of the average rate of loading and of the previous history of the specimen In the transient stage the crystals obey the Andrade creep law; the creep rate a Ct^{-m}, with the exponential m 1 1-1 4 The factor C is independent of the total load and of the duration of the previous increment, and is inversely proportional to the strain-hardening parameter; in the linear part of the curve C 1 x 10^{-4}, when t is in min The results are discussed in relation to the dislocation exhaustion theory of Mott and Nabarro [Phys Soc Rep Conf on Strength of Solids (1948) 1]

(85) Bechtold J H

Effects of Temperature on the Flow and Fracture Characteristics of Molybdenum

Trans AIME 197 (1953) 1469-1475

The flow and fracture characteristics of annealed Mo were studied between 195 and +970 C by tension tests at a constant rate of extension The results indicated (1) a "brittle zone" below 75 C, characterized by the lack of measurable ductility and bright transgranular cleavage type fracture, (2) a "transition zone" extending from -75 to +150 C characterized by a rapid decrease in yield point and a simultaneous increase in ductility with increased test temperature and a change from bright transgranular fracture to a dull, fibrous fracture (3) a "ductile zone" extending from 150 to 900 C, characterized by low yield point and a dull, fibrous fracture (4) an "unstable zone" above 900 C which is due to thermal instability of the microstructure developed during test Strain markings resembling mechanical twins are observed in the brittle zone; these may be related to the brittle-fracture strength There is equivalence of temperature and strain rate in the transition zone through the Zener Hollomon parameter

(86) Bechtold, J H

Tensile Properties of Annealed Tantalum at Low Temperatures

Acta Met 3 (1955) 249-254

Tensile tests on annealed 99 9% Ta were made at temperatures of 195 to 1400 C. The yield strength increased rapidly from room temperature to -195 C Pronounced upper and lower yield point were found at most temperatures and some evidence of strain aging was observed at 200 to 400 C The increase in yield strength is attributed to the ordering of interstitial atoms into preferred sites around dislocations, and it is shown that for the bcc metals, Fe Mo, Cr, and W, the temperature at which the yield strength rises rapidly also corresponds to the internal friction peak associated with interstitial ordering The formation of condensed atmospheres of solute atoms around dislocations, believed to be responsible for the production of sharp yield point, occurs at considerably higher temperatures Unlike other bcc metals, Ta does not undergo a ductile-to-brittle transition in the temperature range where the yield stress increases sharply, and the metal remains ductile down to -195 C This appears to be a consequence of the very high stress required for internal fracture in Ta, possible reasons for which are the high solubility of O(preventing segregation of oxides at grain boundaries) or the absence of mechanical twinning

(87) Bechtold, J H , and Shewmon, P G.

Flow and Fracture Characteristics of Annealed Tungsten

Trans ASM 46 (1954) 397

W, like Mo, has a bcc crystal structure and experiences a change from ductile to brittle behavior with decreased test temperature When fine-grained, annealed W is tested in uniaxial tension a transition in ductility occurs between 150 and 450 C Except for the temperature at which brittleness occurs, the effect of temperature on the tensile properties of W is similar to the effect of temperature on the tensile properties of other bcc metals

(88) Becker, J J., and Hobstetter, J N

Plastic Deformation of Single-Crystals of Copper

Trans AIME 197 (1953) 1231-1234

Single crystals of Cu which were compressed 1-10% showed very similar structures, the most striking feature of which was the accuracy with which the pattern of slip lines of the smaller deformation was preserved at the higher deformations Increasing deformation resulted in the formation of heavy clusters of slip and cross slip lines at the original slip and cross slip lines Regions which were practically free from slip lines remained conspicuously so Boundaries of clusters of slip lines went off at slight angles to the lines themselves. Attempts to produce slip on a single system, by deformation in several types of rotating-grip machines, were unsuccessful X-ray examination showed that the occurrence of conspicuous slip and clustering was favoured by an orientation near (100); specimens with orientations far from this exhibited little or no cross slip. Thus the detailed nature of plastic deformation in Cu single crystals appears to depend more on the orientation of the specimen than on the exact means of deformation; it is complicated far beyond the naive idea of a "glide ellipse" on the classical slip plane

(89) Becker, R

On the Plasticity of Amorphous and Crystalline Solids (In German)

Physik Z 26 (1925) 919-925

The author seeks to explain the whole province of the plastic deformability of solid bodies by means of the three basic phenomena of atomic interchange, stress fluctuations, and strengthening Atomic interchange is shown to determine the plasticity of amorphous bodies and to enable the deduction of a quantitative connection between viscosity and diffusion For crystalline bodies atomic interchange is of great significance, while the flow velocity may be determined by spontaneous variations of stress The existence of the temperature dependence of plasticity, derived from theoretical considerations, has been established by experiments on W The proof has been obscured by the very slight temperature sensitiveness of crystalline substances with respect to their plastic properties All three of these fundamental phenomena appear simultaneously during the viscous flow of metals above their recrystallization temperature.

(90) Belbeoch, B., and Guinier, A

Relation Between Structures and Properties During Age Hardening in Al-Ag Alloys (In French)

Acta Met. 3 (1955) 370-379

The variation of hardness during the age hardening of an Al-Ag alloy are correlated with the structure variations studied with small-angle X-ray scattering

The transition between cold hardening and warm hardening corresponds to the appearance on the X-ray patterns of many long and blurred streaks which are characteristic of very small $AlAg_2$ precipitates During warm hardening the hardness increased with the growth of the precipitates and the streaks become short and intense When the precipitates have become large and perfect, the scattering vanishes During cold hardening the patterns have rings, the alloy containing "G P zone" However, the evolution of the zones as revealed by X-rays is not directly correlated with the variation of hardness The diameter of the rings on the patterns decreases steadily as the annealing progresses, while the hardness variations are reversible with some thermal treatments (particularly reversion) It might be concluded

A 9

that the hardening is determined by zones of very small size These are masked on the patterns by larger zones The conclusion is verified by measurements of absolute diffuse intensity

(91) Bell R L , and Cahn, R W

The Nucleation Problem in Deformation Twinning

Acta Met 1 (1953) 752-753

Results indicate that there are three characteristic stages in twinning: (1) the creation of an initial wedge shaped twin, (2) the spread of this twin across the crystal and (3) the thickening of the twin lamella, generally accompanied by the creation of new twins

(92) Bell R L., and Cahn, R W

Dynamics of Twinning and the Interrelation of Slip and Twinning in Zinc Crystals

Proc Roy Soc (London) 239 (1957) 494 521

Zn crystal wires in which the basal plane was nearly parallel to the wire axis were found to twin at abnormally high stresses No single critical resolved shear stress exists; resolved shear stresses near 3 7 kg/mm^2 were common for short crystals, while longer crystals (which often fractured at the instant of twinning) had an average critical stress of 2 9 kg/mm^2

(93) Belyaev, A N

An Investigation of Elastic After-Effects in the Linear-Stressed State (In Russian)

Izvest Akad Nauk S.S S R , Otdel Tekh, Nauk, No 4 (1957) 70-74

The dependence of the direct and aftereffects on instantaneous elastic deformation was investigated under repeated loading at a stress below the elastic limit Both effects were proportional to the applied stress Repeated loading of a specimen without an intervening temper leads to a decrease in the direct effect but has no marked influence on the aftereffect The phenomenon is explained by a rise in the remaining oriented microstresses resulting in microplastic deformation This begins at not too low a stress, e g , for Al at stresses greater than 3 kg/mm^2 Preliminary plastic deformation significantly increases the elastic aftereffect

(94) Benedicks, C

Which are the Most Fundamental Properties for Describing the Strength of a Material? An Attempted Explanation (In Swedish)

Jernkontorets Ann. 129 (1945) 557-570

A general review of the stress-strain relationships of metals - particularly of steel - leads to the description of four parameters of the stress-strain figure as being the most important ones Elastic and plastic stresses are defined and their relation to hardness as usually measured is examined; tenacity is defined as the sum of elastic and plastic deformation Two parameters for limiting stresses and two for limiting strains are required to describe the strength of a metal adequately

(95) Benthem, J P

Note on the General Stress-Strain Relations of Some Ideal Bodies Showing the Phenomena of Creep and of Relaxation (In English)

Netherlands Nationaal Luchtvaartlaboratorium Report S426 (1954) S15-S23

General stress-strain relations of isotropic linear bodies and viscosity phenomena which may accompany plastic deformation

(96) Berghout C W

The Relation Between the Electrical Resistivity and the Yield Strength of Deformed Copper

Acta Met 4 (1956) 211-213

Some observations are made and discussed in terms of dislocation theory on the relations between resistivity and yield stress at -195 C of Cu deformed and annealed at various temperatures When the resistivity is proportional to the concentration of dislocations, the yield strength depends markedly on the position of the dislocations This is a good example of the difficulties attending the theory of work hardening

(97) Berghout, C W

Influence of Elastic Deformation on the Mobility of Vacancies in Copper (In French)

Paper from Diffusion in Metals, Philips Tech Biblio., Eindhoven (1957) 133-115

Vacancies are produced by cold working. Their precipitation is studied by its influence on electrical resistivity Influence of deformation on the activation energy of diffusion is shown.

(98) Bergman, G.

The Elastic Properties of Metals and the Resonating Valence Bond Theory

Acta Met. 6 (1958) 110-115

The elastic properties of metals with fcc and hcp structures are derived on the basis of the resonating valence bond theory of metals developed by Pauling It is found that reasonable agreement between calculated and observed elastic moduli cannot be obtained on the basis of the Pauling theory in its simplest form In this form the theory requires that the lengths of the bonds formed by a given atom are in a definite relationship to each other It is found, however, that quite good agreement can be obtained if the theory is supplemented by the reasonable assumption that the individual bonds can also undergo deformations that are not interrelated The supplementary assumption in effect allows the strong bond-bond interactions in the Pauling theory to be weakened

(99) Bernshteyn, M. L

Steels and Alloys for Service at High Temperature (In Russian)

Metallurgizdat, Moscow, U S.S.R (1956) 239

Theory of heat resistance; data on the properties and treatment of heat-resistant ferrite, pearlitic and austenitic steels and heat resistant Ni, Co, Cr, Ti, and Mo-based alloys Results of the study of the structure of heat-resistant steels and alloys

(100) Beshers, D. N

On the Distribution of Impurity Atoms in the Stress Field of Dislocation

Acta Met 6 (1958) 521-523

It is shown that impurity atoms distributed in the stress field of a dislocation obey Fermi-Dirac statistics. This result is applied to experimental situations, and the binding energy of an impurity to a dislocation is determined

(101) Besseling, J F.

A Theory of Plastic Flow for Anisotropic Hardening in Plastic Deformation of an Initially Isotropic Material

Nat. Luchtvaartlab. Amsterdam, Rep. (S410) (1953) pp 30

A theory of plastic deformation based upon the conception of a material as being composed of various portions, successively taking part in plastic yielding It describes the anisotropic behavior of the material in hardening In uniform loading it gives stress strain relations which are equivalent to the relations of a deformation theory, based upon the second invariant of the deviator of the stress tensor Immediately after uniform loading the stress strain relations are in accordance with the isotropic flow theory, derived from the same stress invariant The predictions of the theory concerning the anisotropy introduced by the plastic deformation of a hardening material are in close agreement with the Bauschinger effect, measured in some torsion tests on Cu tubes Some of the consequences of the theory in cases of non-uniform loading are discussed, and the superiority of the new theory with respect to existing flow theories is demonstrated

(102) Betteridge, W

Tertiary Creep of Nimonic 80A

Proc N P L. Symp. on Creep and Fracture of Metals at High Temp. (1956) 299-307

Short-period low-stress torsion creep tests were carried out at intervals during normal tensile creep experiments on Nimonic 80A. The results indicate the creep curves can be represented by the sum of two terms, the first of which relates to the primary stage of creep, the second to the tertiary stage. The form of the second term suggests that the number of strain-promoting centres increases linearly with tensile strain

(103) Betteridge, W

The Extrapolation of the Stress-Rupture Properties of the Nimonic Alloys

J Inst Metals 86 (1957-1958) 232-237

Four methods proposed for the extrapolation of the stress-rupture properties of high-temperature alloys have been examined and are compared with regard to their application to the nickel-base alloys Nimonic 80A and Nimonic 90 The best results were obtained by using a time/temperature parameter of the form: $(T-T_a)/(\log t-\log t_a)$, where T is the temperature t the time to rupture, and T_a and t_a are constants Values of the constants are given for the two alloys mentioned and for Nimonic 100, and the master curves of stress against the above parameter are plotted

(104) Betteridge, W , and Franklin, A W

An Investigation of the Structural Changes Accompanying Creep in a Tin-Antimony Alloy

J Inst Metals 80 (1951) 147-150

A Sn + 5% Sb alloy was used for a microscopical study of phenomena occurring during creep at room temperature In addition to general slip within the grains and flow at the grain boundaries it is shown that localized strain within the grains occurs in directions associated with boundaries between adjacent grains. It is also suggested from this work and from an examination of a pure Al sample strained in creep at 250 C that the "cell structure" observed by X ray examination is a result of the breakup of the grains by slip bands and by local strains

(105) Bever, M B , and Ticknor, L B

A Method for Determining the Energy Stored During Cold Working of Metals

J Appl Phy 22 (1951) 1297-1298

New calorimetric method employs the fact that heats of solution are small in some metallic systems, especially compared to heats of solution of metals in aqueous media Initial work was carried out with Sn as solvent and additions of Ag and Au-Ag alloy in the annealed and cold-worked states

(106) Bhattacharya, S., Congreve, W K A , and Thompson, F C

The Creep-Time Relationship Under Constant Tensile Stress

J Inst. Metals 81 (1952) 83-92

Constant stress tests on Cu, Zn, Sn, Cd, Pb, Al, and the Pb-Sn eutectic All the results are consistent with the equation: $\epsilon_t = \epsilon_0 + at^k$, where ϵ_t and ϵ_0 are, respectively, the total and the initial strain, t is the time, and a and k are constants Once the primary stage is completed, the creep strain $\epsilon_c = at^k$, a relationship which is not affected by the crystal lattice, temperature, applied stress or prestrain The results are in accord with the constant-temperature relationship $\epsilon = bS^n$, where S is the stress and b and n are constants Combining the two relationships, it would appear that metals obey the Nutting-Scott Blair equation: $\epsilon = At^kS^n$, which also describes the flow of many nonmetallic substances If $\epsilon_c = at^k$, then the product of creep rate and time, i e , $(d\epsilon_c/dt)$ t = [illegible], gives, when plotted against time on a double log scale, a straight line parallel to that obtained for the creep-time relation ship itself when similarly plotted This prediction of the power law equation is confirmed The technique is important, in that it obviates the necessity of deriving ϵ_0

(107) Biggs, W D , and Broom, T

The Yield Strength of Partly Ordered Cu_3Au Wires

Phil Mag 45 (1954) 246

The dependence of yield stress on the size of ordered domains has been investigated by tensile deformation of polycrystalline wires of Cu_3Au. In agreement with a prediction by Cottrell, it was found that the yield stress was greatest when the estimated domain size was about 50 A.

(108) Bibet, O L.

Importance of Plasticity to the Phenomena of Metal Fracture (in French)

Rev soudure; Lastijdschrift 6 (1950) 20-30

Theories of fracture, dislocations, mechanism of cold hardening, and their influence on the brittleness of metals are discussed Selection of steels for welded structures is based on these considerations

(109) Bilby, B A

The Theory of the Discontinuous Yield Point

Sheet Metal Inds. 27 (1950) 707-718

When a metal is subjected to tension and a load extension graph is obtained, the graph may either curve smoothly away from the initial linear portion of the curve or may show a sharp discontinuity plastic flow often continuing for a time at loads lower than that required to start it The latter type of curve, where the yielding is discontinuous, is discussed on the basis of the dislocation theory of plasticity

(110) Bilby, B A

On the Interactions of Dislocations and Solute Atoms

Proc Phys Soc (London) 63A (1950) 191-200

An extension of the reciprocal theorem of Colonetti is given and with it a general expression derived for the elastic energy of a multiply-connected solid containing sources of internal stress and subjected to external forces The expression is used to estimate approximately the interaction energy between parallel edge dislocations with arbitrary slip vectors, between parallel screw dislocations and between an edge dislocation and a solute atom causing a spherical distortion of the lattice

(111) Bilby, B A

Types of Dislocation Source

Rep. Conf Defects in Crystalline Solids Phys. Soc (1955) 123 133

The nature of dislocation sources in a three-dimensional "chicken wire network" of dislocation lines is analyzed Besides plane sources which give rise to successive loops of dislocation in the same lattice plane (the Frank Read source) there are also conical sources which produce dislocation loops in successive lattice planes They are the slip equivalent of a twinning source On the hypothesis of a network of dislocations all lying in the various {111} planes and with ⟨110⟩ Burgers vectors an analysis is made of the abundance ratio of the two types of sources A range of answers is obtained for this essentially statistical problem, according to the detailed assumptions made, but the abundance ratio is in all cases of order unity The operation of cone sources produces fine or homogeneous slip over a thick slip zone, such as is known to occur in creep. The rarity of homogeneous slip at room temperature cannot be put down to the absence of appropriate sources The reasons for this rarity are not known, but a wider path must be cleared through the crystal when a conical source operates, which involves overcoming more obstacles Moreover, the ability of piled-up dislocations to punch their way through obstacles is likely to be smaller when the dislocations are not coplanar The concept of the surface dislocation is next introduced This is a surface separating volumes of lattice in different states of strain; a tilt boundary, for instance, is a special case of this. The quantitative description of such a dislocation and of the tensor which takes the place of the fixed Burgers vector, is given briefly The application of these ideas to the substructure generated by pressing a conical tool into the basal plane of a Zn crystal and to three-dimensional mosaic arrays in NaCl is explained The theory of surface dislocations has now been published in extenso [Bilby and Smith, Proc Roy Soc (London) 213A (1955) 263]

(112) Bilby, G A , Bullough, R , and Smith, E

Continuous Distributions of Dislocations: A New Application of the Methods of Non-Riemannian Geometry, Part II

Proc Roy. Soc. (London) 231A (1955) 263

When describing a crystal containing an arbitrary distribution of dislocation lines it is often convenient to treat the distribution as continuous, and to specify the state of dislocation as a function of position Formally, however, there is then no "good crystal" anywhere, and difficulties arise in defining Burgers circuits and the dislocation tensor The dislocated state may be defined precisely by relating the local basis at each point to that of a reference lattice The dislocation density may then be defined, it is important to distinguish this from the local dislocation density

(113) Bilby, B A , and Entwisle, A R

The Formation of Mechanical Twins

Acta Met 2 (1954) 13-19

It is suggested that the nucleation of mechanical twins is controlled by large local stresses which are set up in a crystal around inhomogeneities of various kinds An examination is made of the stress fields around two types of inhomogeneity arising during plastic deformation, the bounded slip band, and the kink band. It is shown that in hexagonal metals, twin nuclei on planes containing the slip direction of the dislocations in the inhomogeneity are unlikely to be formed The theory is compared with available data on these metals, and critical experiments are suggested to distinguish between this hypothesis and that which proposes a macroscopic critical resolved twinning stress

(114) Bilby, B A , and Entwisle, A R

Dislocation Arrays and Rows of Etch-Pits

Acta Met 4 (1956) 257-261

Arrangement of pits in α-brass was found to be consistent with the assumption that each corresponds to an individual dislocation Arrangement is correlated with that predicted for linear groups of dislocations piled up under shear stress.

(115) Bilby, B A , Gardner, L. R T , and Smith E

The Relation Between Dislocation and Stress

Acta Met 6 (1958) 29-33

Read has recently derived for the special case of simple bending a relation between the lattice curvature and stress gradient in a solid containing dislocations It is shown that this relation follows at once from the fundamental relation in the theory of continuous distributions of dislocations As a further example the relations between the stress gradient, dislocation density, and lattice curvature in twisted cylindrical bars are given. It is also shown that the properties of linear dislocation arrays used by Read follow from the general expression for the dislocation tensor of a surface dislocation

(116) Bilby, B A., and Smith, E.

Continuous Distributions of Dislocations Part III

Proc Roy Soc (London) 236A (1956) 481-505

The theory of the continuously dislocated crystal is extended It is shown that the general equations of the theory of Nye are applicable in full only when the lattice curvature (and so also the dislocation density) is small The correct equations for large curvatures are formulated The relation between the fundamental node theorem of dislocation theory and certain theorems of the theory of generalized space is considered in some detail It is also shown that when the lattice lines of the dislocated crystal are treated as a system of independent congruences of curves, the tensor describing the local dislocation density may be expressed in terms of certain invariants connected with the system of congruences For the rotation case, a relation between the dislocation density and Ricci's coefficients of rotation is derived

(117) Bingel, J

The Atomic Lattice Strength of Crystals and Metals as a Definite Fraction of the Modulus of Elasticity (In German)

Arch Metallkunde 1 (1947) 300-304

The strength of the ideal atomic lattice of fcc crystals was calculated by Madelung's lattice potential and Born's electrostatic potential methods as a definite component of the modulus of elasticity The method is then extended to metals, especially Cu

(118) Bingel, J

A New Aspect of the Theory of Work-Hardening of Metals (In German)

Z Metallk 42 (1951) 309-315

Current theories of the strain hardening of metals are based on slip processes Suggests that all the phenomena can be adequately interpreted on the basis of the stress-raising effects of the molecular notches which exist within the metal crystals General equations of this form are developed and are discussed in terms of experimental observations on the work hardening and crystallite size of various metals It is considered that the results are applicable, also to the phenomena of precipitation hardening, where the notch effects result from the precipitated particles being highly dispersed throughout the matrix

(119) Bishop, J F W

A Theoretical Examination of the Plastic Deformation of Crystals by Glide

Phil Mag 44 (1953) 51 64

Proofs are given of theorems stated in Bishop-Hill theory of crystal distortion Mathematical relations are established for deformation of crystals by simultaneous shears, and possibly of enforcing an arbitrary strain by glide is examined Uniform stress states not exceeding critical shear stresses in glide directions are discussed, and a geometrical picture of stress and strain states is developed

(120) Bishop J F W

A Theory of the Tensile and Compressive Textures of Face-Centered Cubic Metals

J Mech and Phys Solids 3 (1955) 130-142

A review of tensile and compressive texture results for fcc metals shows that previous theories did not account for the different textures developed by metals of similar lattice structure Although it is appreciated that every grain in a polycrystalline specimen does not undergo the macroscopic strain and that consequently there will be a small scatter in orientation, this is neglected in the present theory and the macroscopic strain taken as a good first approximation for each grain From the maximum work principle [Bishop and Hill, Phil Mag , 42 (ser 7) (1951) 414], the stress system and operative glides can be found The resultant shear magnitudes determine the rotation of the lattice relative to the specimen axis Lattice rotations for a 1 78% compression were calculated for incremental positions of the cubic axis relative to the compression axis This predicted the general trend of the textures except for the (111) component of the brass-type compression texture The effect of work hardening is treated qualitatively in the theory If latent glide systems do not harden more rapidly than the active systems, the shear magnitudes will be as nearly equal as the constraints permit. If latent systems harden more rapidly than active ones, the largest shear magnitudes will be the maximum possible Al, Cu, and Ni show similar hardening on latent and active planes, whereas greater hardening of latent planes has been reported for Cu-Al and Cu-Zn solid-solution alloys According to the present hypothesis, Al, Cu, and Ni should show a different type of texture from that of the Cu alloys Orientations worked out for a 15% compression with the two types of hardening agree qualitatively with the trends observed in the metals having the appropriate hardening characteristics

(121) Bishop, J F W , and Hill R,

A Theory of the Plastic Distortion of a Polycrystalline Aggregate Under Combined Stresses

Phil Mag 42 ser 7 (1951) 111-427

A general relationship between stress and plastic strain in a polycrystalline aggregate is derived for any metal in which individual crystals deform by slipping over preferred planes under a critical shear stress. Shows that a plastic potential exists which is identical with the yield function. Upper and lower limits are obtained for approximate calculation of this function for any applied system of combined stresses.

(122) Bishop, J F, W and Hill, R

A Theoretical Derivation of the Plastic Properties of a Polycrystalline Face-Centered Metal

Phil Mag 42 ser 7 (1951) 1298-1307

It is conjectured that the work done in plastically deforming a polycrystal is approximately equal to that which would be done if the grains were free to deform equally. In conjunction with the principle of maximum plastic work, this enables the yield function of an aggregate to be calculated. This is done for an isotropic aggregate of fcc crystals, following a determination of the stresses needed to produce multislip.

(123) Blackman, M

On the Relation of Debye Theory and the Lattice Theory of Specific Heats

Proc Roy Soc (London) 181A (1943) 58-67.

In the Debye theory of the specific heat of solids the value of θ calculated from elastic constants, namely, θ_D (elastic), should be the same as that found from specific-heat data, θ_D (specific heat). The ratio of these θ values for crystal lattice is calculated here at a temperature $T \approx \theta_D$ on the basis of lattice theory; it is shown that the ratio is remarkably near unity for crystals of the NaCl type provided the crystals are not very anisotropic. In the case of other crystal types, the agreement is in general less good, the value of unity holding only in isolated cases

(124) Bland, D R.

Associated Flow Rule of Plasticity

J Mech. and Phys Solids 6 (1957) 71-78

The flow rule at singular points on a yield surface is found by considering the actual yield surface as the limit of a sequence of regular surfaces. Confirms the work hardening and linearity of hypothesis of Drucker

(125) Blank, H

Transient Creep in Face Centered Cubic Metal Crystals (In German)

Z Metallk 49 (1958) 27-39

Transient creep in single crystals of Al, Cu, and Ni studied at and above room temperature, using method of load increments. Creep behavior at room temperature is very similar for these three metals, the creep rate rising rapidly to a maximum value a_m during a time interval t_a after loading, and decreasing afterwards according to the law $a = C_1/(C_2 + t)^m$. The creep laws (hyperbolic, logarithmic, parabolic) are connected with the different parts of the stress-strain curve for fcc crystals. There are differences in the temperature-dependence of creep behavior between Al, Cu, and Ni. A formula connects the slope of the stress-strain curve with certain quantities deduced from the experimental parameters describing creep-rate as a function of time. Transient creep obeys the equation $\dot{A} = C\ t^{-m}$, $m > 0$. If $m = 1$, get logarithmic creep; if $m < 1$, parabolic; and for $m > 1$, designated hyperbolic

(126) Blank, H.

Theory of Transient Creep in Metal Crystals (In German)

Arch Eisenhüttenw. 29 (1958) 301-308

Attempt to deduce the formulas for transient creep from a displacement model. A certain relation exists between the model and the hardening properties of fcc crystals. Creep occurs in dependence on a parameter and results in parabolic, hyperbolic, or logarithmic velocity laws. Starting conditions for creep are developed mathematically. At higher temperatures elastic influences produce superhyperbolic curvature.

(127) Bleakney, H H.

Intercrystalline Cohesion and the Stress-Rupture Test

Proc ASTM 47 (1947) 575-589

Evidence bearing on the causes of intercrystalline failure of metals when stressed at elevated temperatures is presented. Existing theories of intercrystalline cracking are stated, and criticized. A hypothesis is suggested to explain certain kinds of intercrystalline failures; on this basis, a program of investigation is suggested

(128) Bleakney H H

The Ductility of Metals in Creep Rupture Tests

Can J Technol 30 (1952) 340-351

Creep rupture tests on wires of Cu, Al, and Ag of various purities are described. Tests conducted at various temperatures and strain rates, some of them in vacuo, gave reductions in area and the time to fracture. The results for OFHC Cu showed that the reductions in area decreased with increasing time to fracture; the reduction in area also decreased substantially with increase of atmospheric pressure. The ductility was increased by reducing the temperature of testing. The embrittlement of the Cu tested at atmospheric pressure is attributed to absorption of O during the test; other tests confirmed this. Similar tests on Ag and Al of various purities showed that the ductility is greatly reduced by increase in impurity content. Results obtained by other workers with Pb and Fe confirm that the brittle intercrystalline cracking frequently observed in creep rupture tests is caused by the presence of impurities. The "mechanical" theory of grain-boundary weakness which postulates that the boundaries are weaker than the grains at high temperatures and low strain rates, is discussed in the light of the results obtained; it is concluded that the theory is inconsistent with these results and with other knowledge of the behavior of metals

(129) Bleakney, H H.

An Evaluation of the Recovery Theory of Creep

Can J Technol 33 (1955) 56 66

Phenomenon of creep-rupture embrittlement may not be inconsistent with the recovery theory. Suggests the opposing influences of strain-hardening and thermal softening are fundamental forces in creep.

(130) Bleakney, H H

Tensile Fracture of Ductile Materials

Can Metals 20 (February, 1957) 60, 62-64

Discussion of difference between theoretical and observed cohesive strengths. Al and mild steel studied; three modes of fracture and their mechanisms described. Data suggest that true stress at fracture is not experimentally determinable by methods known at present

(131) Blewitt, T H

Deformation of Copper Single Crystals at 300 and 78 K

Phys. Rev 91 (1953) 1115-1121

The plastic deformation of Cu single crystals, under tension, was studied at 78 and 300 K. A slight temperature dependence of the critical shear stress was found, and for shear strains < 0.25 the stress-strain relationship was linear and independent of temperature. This linear relationship persisted for higher strains at 78 K. The annealing at 300 K of crystals deformed at 78 K produced a decrease of electrical resistance accompanied by a phenomenon suggestive of strain aging. The magnitude of the recoverable resistance was dependent on the strain varying faster than linearly. A measurable decrease of electrical resistance was not found for strains <~0.30. The results are interpreted in accordance with the theory of dislocations, and suggest that some modification is required in Mott's theory of work hardening, which requires that the stress should be proportional to the square root of the strain; a linear relationship between stress and strain would necessitate the rather stringent requirement of the Frank-Read generator varying inversely as the strain

(132) Blewitt, T H , Coltman, R R , Holmes, D K , and Noggle, T S.

Mechanism of Annealing in Neutron-Irradiated Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons Inc , New York (1957) 603-623

The determination of the number of defects produced during irradiation is considered and the problem of the very different behavior of different metals is mentioned. The various interpretations put on the annealing spectrum, which arises from low-temperature irradiation, are discussed in detail in terms of migration by an interstitialcy process

(133) Blewitt, T H , Coltman, R R., and Redman, J. K

Work Hardening in Copper Crystals

Paper from Defects in Crystalline Solids, Phys Soc , London (1954) 369-382

Cu single crystals deformed at 42 K showed the easy glide and linear portion of stress-strain curves expected for fcc metals at low temperatures. Parabolic relation between flow stress and electrical resistance was found. The effect of deformation on the slip lines of Cu and the change in the deformation mechanism at low temperature were also investigated. A model for plastic flow similar to Mott's theory was discussed to explain the results

(134) Blewitt, T. H , Coltman, R R , and Redman, J. K

Low-Temperature Deformation of Copper Single Crystals

J. Appl Phy 28 (1957) 651-660

Describes the tensile deformation of 99.999% Cu single crystals at 4.2 and 77.3 K. At 4.2 K deformation proceeds by three different mechanisms (i) at low flow stresses, ordinary glide occurs; (ii) at intermediate stresses, discontinuous slip occurs; each discontinuity in the flow curve corresponds to the release of 30 slip lines, each containing 10^4 dislocations; (iii) at high flow stresses, mechanical twinning occurs. Twinning occurs by the formation of a twin nucleus which results in a decrease in the flow stress. The nucleus grows and completely fills the crystal. There is no evidence that slip occurs in the twinned region until after the sample has been filled with twins, and then discontinuous slip occurs

(135) Blewitt, T H , Coltman, R R., and Redman, J K

Mechanism of Annealing in Neutron-Irradiated Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 179-207

Single crystals of Cu were deformed at 4.2 and 77.3 K. At 4.2 K, after a large strain produced by normal slip, jerky flow, called discontinuous slip, occurs. From the study of reactor-irradiated crystals, slip lines, each containing 10 dislocations, were released to form each jerk of the discontinuous flow. For samples of certain orientation the region of discontinuous flow was followed by a region of deformation twinning. The fact that deformation twinning was taking place was verified by X-ray methods

(136) Blewitt, T H , and Koehler, J S

The Lamellar Nature of Slip and Its Implications

Paper from Symposium on Plastic Deformation of Crystalline Solids, Pittsburgh (1950) 77-86

The following researches relating to crystal slip are summarized and discussed: (1) the work of Heidenreich and Shockley [Rep Conf. on Strength of Solids, Phys Soc. (London) (1948) 57] and of Brown [Nature 163 (1949) 961]; (2) slip phenomena shown by $AuCu_3$; (3) the work of Treuting and Brick [Trans AIME 147 (1942) 128] and that of Sachs and his co-workers relating to slip in alpha-brass [Z Physik 41 (1927) 116; 50 (1928) 161]. Slip is considered to occur in three or more stages as follows; in the first stage, slip occurs by glide on slip steps. Initially these steps have a minimum separation of ~1μ, the glide at each step being $\sim 10^{-5}$ cm. In the alpha-brasses the primary slip steps cluster. This first stage continues until a minimum spacing is reached which is dependent on temperature. In Al this minimum is 2μ at room temperature and falls to 1/2μ at very low temperatures. In the second stage of deformation, glide occurs on laminae between the primary slip steps; the laminae have a minimum spacing of 200-800 Å. In the case of $AuCu_3$ the glide lamina in the second stage is much less than the glide step in the primary stage (approximately 1/6). The laminae show clustering in Al. Higher stages of slip have been found in initially ordered $AuCu_3$ and in alpha-brass. The spacing and glide decrease in alloys as the specimen passes from one stage to the next. Several lines of further research are suggested. In the discussion, Koehler pointed out that the linear horizontal region in the stress-strain graph is characteristic of single crystals of all alloys, and is associated with hardening due to impurity atoms. It occurs in $AuCu_3$ probably owing to the alloy not containing exactly the correct ratio of Au:Cu atoms. In alloys, slip seems to occur on one slip system and then on another; in pure metals, macroscopically at least, simultaneous glide is frequently observed on two slip systems

(137) Blin, J

Small Angle Scattering of X-Rays by Cold-Worked Metals

Paper from Defects in Crystalline Solids, Phys Soc (London) (1955) 420-422

Intensity of scattered rays is used to study the defects created in Cu, Ni, Al, and Zn by plastic deformation. The change in density due to cold work can be explained by vacancies, but less readily by dislocations alone

(138) Boas, W

The Interaction Between the Crystals of an Aggregate During Plastic Deformation

Proc Seventh Intern Congr Appl Mech 1 (1948) 356-364

The relation of the interaction to physical and mechanical properties of metals and alloys is discussed. Concludes that when an aggregate of crystals is subjected to plastic deformation, the extent of deformation varies from crystal to crystal and also within the individual crystals. The deformation is continuous at grain boundaries. It seems that this continuity of deformation is fundamental for any theory of the stress-strain curve of polycrystalline materials based on the tensile curves of the crystals composing the aggregate

(139) Boas W

On the Inhomogeneity of Plastic Deformation in Metals

Helv Phys Acta 23 (1950) 159-166

Microscopic inhomogeneity of plastic deformation in metals and alloys is due to crystal anisotropy and the presence of crystals of different structures. The importance of the inhomogeneity in relation to the theory of the deformation of crystal aggregates is described. Macroscopic inhomogeneity is produced by common methods of deformation

(140) Boas, W

Stored Energy and Lattice Defects in Cold-Worked Metals

Paper from Defects in Crystalline Solids, Phys Soc (London) (1955) 212-221

Measurements of changes in internal energy, electrical resistivity, density and hardness which occur during annealing of Cu and Ni deformed at room temperature indicate that almost all the energy stored in Cu is due to dislocations, but vacancies make a significant contribution to that stored in Ni.

(141) Boas, W.

Lattice Defects in Plastically Deformed Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 333-344

In all metals investigated, irrespective of the heating rate and of whether deformation occurs by tension, compression, or torsion, there is a rapid evolution of energy at the high temperature and of the curve showing the release of energy. This energy release is always associated with recrystallization, as has been proved by metallographic and X-ray methods. It is accompanied by changes in hardness, density, and electrical resistivity. This energy is derived from the disappearance of the dislocations created by deformation.

(142) Boas, W , and Hargreaves, M E

On the Inhomogeneity of Plastic Deformation in the Crystals of an Aggregate

Proc Roy Soc (London) 193A (1948) 89-97

The variation of plastic deformation in Al specimens consisting of large crystals was determined by measuring elongation and hardness at various points after tensile deformation. The deformation varied from grain to grain, and also within each grain. Deformation near the boundary was greater or smaller than at the center according to whether the neighbor was more or less deformed – there is not necessarily inhibition of slip near grain boundaries. Results are of importance for calculation of the stress-strain curve of aggregates from those of single crystals. It is suggested that a mechanism other than slip operates near the grain boundaries during deformation, and even within the crystals during large extensions.

(143) Boas, W , and Honeycombe, R W K

The Plastic Deformation of Noncubic Metals by Heating and Cooling

Proc Roy Soc (London) 186A (1946) 57-71

Several pure metals were subjected to cyclic thermal treatment between 30 and 150 C. Specimens of Zn, Cd, and Sn showed signs of plastic deformation, which were evident after a small number of cycles, and which become more pronounced as the number of cycles increased. On the other hand, the phenomenon was not observed in Pb. Evidence is brought forward to show that this deformation is due to the anisotropy of thermal expansion in the crystals of noncubic metals. Some possible theoretical and practical implications of the phenomenon are discussed

(144) Boas, W , and Ogilvie, G J

The Plastic Deformation of a Crystal in a Polycrystalline Aggregate

Acta Met. 2 (1954) 655-659

Microscopic evidence is given that during plastic deformation of a polycrystalline aggregate the crystals both at the surface and in the interior are deformed inhomogeneously. In addition, it is found that slip is not always confined to {111} planes but may also occur on {100} or {110} planes. The relation between these results and the current theories of the distortion of polycrystalline aggregates is discussed

(145) Boas, W , and Schmid, E.

Relation Between Temperature and Plasticity of Aluminum Crystals (In German)

Zeits. Physik 71 (September 26, 1931) 704-714

Tensile tests on Al crystals in the temperature range 185 to 600 C have shown that the behavior of the crystal alters in a marked manner at about 400 C. Up to this point the normal translation described by Taylor and Elam continues to take place. No dependence on temperature of the difference of the hardening of the active and latent octahedral slip systems can be found. There is no increase in elongation with increased temperature up to this point, and the elastic limit does not become more definite. The relation between the hardening and the temperature is much like that which has been found for hexagonal metallic crystals. Above 400 C a new translation mechanism begins, viz., slip along the cube surfaces in the direction of the surface diagonals. Details are given of the behavior of crystals with different orientations.

(146) Bochvar, A A

Dependence of Mechanical Properties of Alloys on the Composition and Structure (In Russian)

Bull acad sci U.R.S.S Classe sci tech. (1946) 743-752

Property composition diagrams of binary alloys are subject to radical change of shape at higher temperatures. The increased resistance to shear owing to insertion of extraneous atoms into the lattice of a metal diminishes with rising temperature. Additivity and linear relation between hardness and composition in systems with a solid-solubility gap is contradicted in the system Al-Si. In other systems, linearity is found at ordinary temperature but does not hold at higher temperatures. Hardness-lowering and plasticity-raising effects of abnormal magnitude are found in cast polycrystalline two-phase alloys quenched from a high temperature and tempered. As the usual dislocation mechanism cannot account for the fact that the mixture has a much higher plasticity than its more plastic component, and explanation must be sought in intergranular shears at the boundaries of phases. Alternatively, the phenomenon may be interpreted by changes in mutual solubility at grain boundaries with varying temperature which affects the ease of intergranular displacement. In general, healing of shear rifts through mutual solution, proper to mixtures and absent in pure solids, is apt to account for the appearance of enhanced plasticity in binary two-phase solids. That the effect was found only in Al-Zn alloys may be related to the particularly pronounced temperature variation of mutual solid solubility in this system. Evaluation of mechanical properties of an alloy must involve consideration of its structure not only in the sense of constituent phases, but also with regard to the heterogeneous particles suspended in the grain and responsible for many peculiarities of its mechanical behavior.

(147) Bochvar, A A

Dependence of High-Temperature Properties of Aluminum Alloys on Their Composition and Structure (In Russian)

Izvest Akad Nauk S S S R Otdel Tekh. Nauk 10 (1947) 1369-84

Time-dependent hot hardness of Al alloys studied with the load varying from 10 seconds to 1 hour. The diameter of indentation d as a function of time T followed the equation: $d = aT^n$. These tests placed alloys in the same order with respect to mechanical properties at elevated temperature as long-time creep tests. Results were considered suitable as a simple and rapid test-temperature substitute for creep testing in the study of new alloys.

(148) Bochvar, A A

Different Mechanisms of Plasticity in Metallic Alloys (In Russian)

Izvest Akad. Nauk S.S S R (May, 1948) 649-653

A new approach for the explanation of the mechanism of plasticity of alloys at high temperatures, emphasizing the predominant influence of the character of the interaction of the existing phases of the heterogeneous system.

(149) Bochvar, A A

Creep Resistance of Alloys as Function of Their Composition (In Russian)

Izvest Akad Nauk S S S R Otdel Tekh. Nauk no. 1 (1957) 136-138 (Brutcher Translation No 3945)

Discusses two principal theories of creep resistance – the one, attributing it to the formation of multicomponent solid solutions (Rotherham, Kornilov), and the other, to the formation of a multiphase structure (Delbart, Cottrell, and Bochvar). Refinement of author's theory, that creep resistance is improved by a heterogeneous structure, is described and an attempt is made to unite the two viewpoints given above.

(150) Bolsworth, C , Halling, J , and Barton, J W

The Use of Paraffin Wax as a Model Material to Simulate the Plastic Deformation of Metals I – A Preliminary Investigation Into the Mechanical Properties of Paraffin Wax

J Iron Steel Inst 185 (1957) 375-383

Compression tests at various strain rates and temperature (0-35 C), tension and compression creep tests, and extrusion tests were made on paraffin wax specimens. The results indicate that many features of the mechanical properties are analogous to those of metals. Thus, the wax exhibited temperature dependent work hardening, a yield point, and either ductile or brittle behavior, depending on the strain rate and temperature. The pattern of deformation on extrusion agreed closely with that obtained for Pb, and also with that computed from plane strain theory. A method of etching the wax to distinguish deformed and undeformed regions was developed. The advantages of wax as a model material are ability to produce accurate patterns of the mode of deformation and information relating applied forces and the extent of deformation, ease of machining and forming, and correlation of microstructure with extent of deformation.

(151) Bohnenblust, H F , and Duwez, P.

Some Properties of a Mechanical Model of Plasticity

J Appl Mechanics 15 (1948) 222-225

An analysis of a mechanical model leading to the computation of the change in potential energy of a metal due to work hardening.

(152) Bohnenkamp, K , Lücke, K , and Masing, G.

Measurement of Latent Deformation Energy of Drawn Copper Wire (In German)

Z. Metallk 46 (1955) 765-770

Determination of latent deformation energy by a differential method. The heaviest heat evolution occurred with a decrease in the yield point and the electrical resistance, and was associated with recrystallization.

(153) Böklen, R

The Relationship Between the Derived Hardness and the Tensile Strength of Metallic Materials

Z Metallk 40 (1949) 372-374

By the use of suitable conversion factors, which are peculiar to the type and condition of the metal or alloy under investigation, approximate values can be obtained for the tensile strength (σ_B) of the material from Brinell hardness determinations. If, however, the ultimate Meyer hardness value (H_{MD}) is used in place of the Brinell hardness, it is seen that the ratio, u, of tensile strength to hardness, is almost constant, and independent of the degree of cold work and thermal treatment of the material. As H_{MD} approximates to the Ludwik hardness value (H_L) obtained by the use of a 90-degree cone indentor, tensile strengths can be easily obtained from such hardness values, since $u = \sigma_B/H_{MD} \approx \sigma_B/H_L \approx 0.3$. Some 180 examples from published literature are quoted to support this thesis; among them are steels, copper, and Duralumin after various heat treatments.

(154) Böklen, R

The Relationship of Cylinder Impression in a Material and the Stress/Strain Curve (In German)

Metall 9 (1955) 1074-1076

When a flat circular punch, of diameter, D, and under a load, P, penetrates a metal surface, the mean pressure H_z for plastic penetration is not widely different from the value $3\sigma_s$, where σ_s is the yield strength of the metal. Experiments with flat and with spherical-ended cylindrical punches, using a specially designed apparatus to measure the depth of penetration, t, show for t/D values between 1-2 and 25 per cent there is a close relationship between the $H_z/3$ plot and the stress-strain curve of the metal; in some cases the two curves coincide, in other cases the $H_z/3$ curve is parallel to but displaced above or below the stress-strain curve.

(155) Bollenrath, F , and Troost, A

Correlation Between Stress and Deformation Gradient Part 2. Influence of Shape and Size (In German)

Arch Eisenhuttenw 22 (1951) 327-335

Theoretically investigates and diagrams a new method for designating the influence of irregular stress and deformation distribution upon the hindering of plastic deformation. The terms used are indexed. Practical application is suggested.

(156) Bol'shanina, M A

Work-Hardening and Recovery as Basic Phenomena in Plastic Deformation (In Russian)

Izvest. Akad Nauk S.S.S.R Ser Fiz 14 no. 2 (1950) 223-231

The view is put forward that the course of plastic deformation is determined by work hardening, which increases with increasing strain, and by recovery, or relaxation at a rate depending only on temperature.

(157) Bontinck, W , and Amelinckx, S.

Observation of Helicoidal Dislocation Lines in Fluorite Crystals

Phil Mag 2 (1957) 94-96

After a thermal treatment of synthetic fluorite crystals at 1100 C in a reducing atmosphere with excess Ag, decorated helix-shaped lines were observed. A mechanism for the production of such helical dislocations is suggested, based on the climb of dislocations of mixed edge and screw character. Closed loops were also found, being attributed to the intersection of windings of the helix with other dislocation lines.

(158) Bordoni, P G.

Ultrasonic Investigation on Solid State at High Temperature (In Italian)

Ricerca sci 25 (1955) 847-859

Elastic and anelastic behavior of metals near their melting point. The dissipation of elastic energy, when it is not affected by any relaxation phenomena, increases with temperature, and a close connection was found between this increase and creep.

(159) Born, M.

Thermodynamics of Crystals and Melting

J. Chem Phys. 7 (1939) 591-603

The Helmholtz free energy, A, of a rigid body is a function of temperature, and of the six homogeneous strain components. If the crystal is to be rigid, three inequalities must be satisfied for the derivations of A with respect to the six strain components, for a regular (cubic) lattice. This enables one to limit the P-T range for which the crystal is stable. The violation of the condition $C_{44} > 0$, that the crystal resist shearing, is interpreted as leading to melting. It is expected that this method, properly improved, will be capable of accounting for the properties of strength, sliding and breaking of crystals. We have only to treat another stress component in the same way as we have done here with the pressure; we have to calculate the limit of stability with increasing temperature for a finite stress X_x (breaking) or X_z (sliding).

(160) Born, M

The Thermodynamics of Crystal Lattices I. Discussion of the Methods of Calculation

Proc Cambridge Phil Soc 39 (1943) 100-103

A brief general discussion of the difficulties and assumptions involved in the mathematical procedure for calculating the temperature dependence of the elastic constants for a crystalline solid.

(161) Born, M , and Fürth, R.

An Attempt to Calculate the Tensile Strength of a Cubic Lattice by Purely Static Considerations

Proc Cambridge Phil Soc 36 no 4 (1940) 454-465

The stability of a cubic lattice, homogeneously deformed by a force acting in the direction of one axis, with respect to additional small forces acting in any other arbitrary direction is investigated, and numerical calculations are made for the fcc lattice. The tensile strength of the lattice is determined from the stability conditions. In common with other theoretical treatments, the lattice strengths thus calculated are approximately one hundredfold larger than the experimental values. The discrepancy is thought to arise from the fact that the theory neglects to take into account the heat motion of the atoms.

(162) Born, M , and Huang, K

Dynamical Theory of Crystal Lattices

International Series of Monographs on Physics, Oxford University Press, New York (1954) 430 pp

Atomic forces, lattice vibrations, elasticity, stability, thermodynamics of lattices, free energy, optical effects, dielectrics, and piezoelectric properties are treated.

(163) Boros, J. K

Study of Kikuchi Line During the Plastic Deformation of Aluminum Single Crystals (In German)

Z. Metallk. 48 (1957) 281-288

The occurrence of Kikuchi lines on the surface of annealed single crystals of pure Al and their extinction by static and dynamic loading were studied. The lines found on the initial crystals cannot be extinguished by dynamic loading without slip lines representative of simple or multiple slip appearing on the surface of the crystal, and they do not necessarily disappear when there are slip lines inclined to the electron beam. Under static loading the lines may disappear, but reappear when some of the surface material is removed; this does not occur when dynamic loading is employed. The results are discussed in relation to the difference in dislocation density near the surface and in the interior.

(164) Borzdyka, A M

The Effect of Alloying Elements on High Temperature Creep Strength of Chrome Nickel Austenite (In Russian)

Doklady Akad Nauk S.S.S.R 63 (1948) 265-267

Creep resistance was determined at 600 and 700 C for a series of alloys within the composition range 15-17% Fe, 10-28% Cr, and 8-60% Ni. The addition of Ni has no beneficial effect on the creep resistance in the austenitic range, while the creep resistance increases with the percentage of Cr. The results are explained in terms of lattice stresses produced by alloying.

(165) Borzdyka, A M

Character of Curves of Composition vs Properties of Metallurgical Solid Solutions at High Temperatures (In Russian)

Doklady Akad Nauk S.S S.R 65 (April 1, 1949) 505-507 (Brutcher Translation No 2343)

Isocurves of creep, hardness, and electrical resistance obtained between 0-1000 C for the Fe-Ni and Fe-Cr-Ni systems. Results indicate that the "classical" scheme for the variation of the properties of solid solutions with composition is valid only in the range from room up to moderately high temperatures. At elevated temperatures, the curves tend to flatten out.

(166) Borzdyka, A M,

Evaluating the Long-Term Plasticity of Steel and Other Alloys at High Temperature (In Russian)

Zavodskaya Lab. 22 (1956) 225-229

Considers the quantitative characterization of plastic properties of steels and other alloys under tension, long times, and high temperatures. Special reference to V S. Ivanova's concept of "plasticity resource". Data on plasticity of medium alloy pearlitic steels at 500 C and high alloy austenitic steels at 650 C considered. From these and other data it is concluded that the true resource of plasticity is best characterized by the total elongation during the first and second stage of creep, since it is the moment of transition from the second to the third stage that predetermines subsequent fracture.

(167) Bottone, S

On a Relation Subsisting Between the Atomic Weights, Specific Gravities, and Hardness of the Metallic Elements

Chem News 27 (May 2, 1873) 215-216

Moh's scale of hardness found to be unreliable, so other methods for determining relative hardness were developed: (1) pressure required to force a plunger 1 cm into a "cake of metal"; (2) for brittle materials, the time required for a revolving soft iron disk to cut the material to a constant depth. Obtained a "calculated" hardness by dividing specific gravity by atomic weight, and compared with his (normalized) hardness values. Very close agreement noted for 21 materials (common metals plus diamond). Author "has noted with astonishment the extraordinary power which a mere trace" of impurity has in raising or lowering the hardness.

(168) Boulanger, Ch

Mechanism Responsible for the Plateau Observed in the Tensile Curves of Annealed Steels (In French)

Compt rend 230 (1950) 1072-1074

This phenomenon is discussed in the light of the theory of dislocations. Annealed steels are connected with the general case of cold-worked and aged alloys by invoking a mechanical effect determined by the change in specific volume which accompanies the gamma to alpha transformation, followed by aging during cooling.

(169) Boulanger, Ch

Contribution to the Study of Plastic Deformation of Iron and Soft Steels (In French)

Rev mét. 47 (1950) 547-556

Tensile-test data obtained at different temperatures using small wire specimens. By this means, very slight changes in metallic structure are revealed. In the case of iron, because of a very thorough purification, it was possible to eliminate all behavior characteristics of steels and then to make this behavior reappear by cementation (using N, C, or O). Results and the mechanism of plastic deformation.

(170) Boulanger, Ch , and Crussard, C

Mechanical Hysteresis of Metals at High Temperature (In French)

Métaux & Corrosion 31 (1956) 203-213

Investigates influence of polygonization on the modulus of elasticity and on internal friction, heats of activation, critical temperatures, and the form of stress-deformation cycles

(171) Boulanger, Ch , and Crussard, C

Study of Mechanical Properties at Very High Temperatures (In French)

Rev. mét 53 (1956) 715-727

Friedel, Boulanger, and Crussard have put forward a theory [Acta Met 3 (1955) 380] that the mechanical properties at high temperatures result from the superposition of two factors: (1) the phenomenon of cold work, leading to the creation of defects (dislocations, etc) in the crystal lattice and at the same time to their partial elimination by diffusion or recrystallization, and (2) the true effect of existing defects in the given state This theory was based on the results obtained from stress-deformation cycles of light alloys from room temperature to 1500 C Creep measurements and free damping at 10 cps were also made The results showed the existence even at high temperature of an elastic modulus and internal friction independent of the amplitude of the deformation, but a function of the state of the metal before the application of the stress and not of the dislocations thereby created The viscous character of a metal at high temperatures is not due to the crystal structure itself; defects are required, such as dislocations or vacancies in the structure It is probable that this viscosity comes from the migration of the defects by diffusion The results obtained are valid only for a metal in the stable state; if the metal is in the process of evolution under the effect of the temperature, its capacity for viscous deformation increases enormously The influence of polygonization is considerable and greatly increases the deformability of the metal at small amplitudes

(172) Boulanger, Ch , Delbart, G , and Ravery, M

Relation Between Internal Friction and Resistance to Creep of Steel as a Function of Microstructure (In French)

Compt rend 233 (1951) 794-796

Internal friction and modulus of elasticity were measured at different temperatures between 300 and 700 C for Cr-Mo steel of four different microstructures: (1) ferrite-pearlite, (2) martensite, (3) fine-grained bainite, and (4) coarse-grained bainite. The curves for the four structures appeared in the same order as those obtained for creep tests The results show that viscous flow takes place at the grain boundaries

(173) Bragg, W L.

A Theory of the Strength of Metals

Nature 149 (1942) 511-513

Proposes a criterion for the onset of slip in a metal The effect of plastic deformation by cold working is to break down each of the crystalline grains into "mosaic fragments" Variations in the elastic limit are ascribed to differences in size of the fragments and increasing resistance to stress corresponds to a decreasing fragmentation size. Derives an expression for the shearing of the same general type as given by G I Taylor

(174) Bragg, W L.

Some Problems of the Metallic State

Iron and Steel (London) 18 (1945) 531-535; and Engineering 160 (1945) 433-435

A general lecture, dealing with the nature of metals and the mechanism of deformation, with particular reference to his approximate theory of the elastic limit of polycrystalline metals

(175) Bragg, W L.

Cohesion of Metals (In French)

Rev met 42 (1945) 187-193

Discusses the origins of the cohesion of metals Fragmentation produced by cold work increases the resistance to deformation. Dislocation conceptions presented by means of a bubble raft

(176) Bragg, W L.

Effects Associated With Stresses on a Microscopic Scale

Paper from Symposium on Internal Stresses, Inst. Metals (1948) 221, Discussion 432-462

A formula for the limit at which a metal when sheared ceases to behave elastically and begins to undergo plastic deformation is established It is based on the consideration that a slip process confined to a limited volume of the metal should on the whole represent a local release of energy The

formula yields estimates of the elastic limit which are of the same magnitude as those actually observed in cold worked pure metals

(177) Bragg W L.

The Yield Point of a Metal

Paper from Report of a Conference on Strength of Solids, Phys Soc (London) (1948) 26-30

Theoretical analysis of the fact that slip alters the state of strain as it proceeds so that one must consider the altered state in the region behind it as well as the pre-existing strain in the region it has not yet reached Slip must take place in multiples of the interatomic distance and that it occurs as an individual process in each crystal element, the surrounding matrix remaining fixed The process of slip is reminiscent of ionization by collision in gases If the strain is so great that energy is realized by the slip of each individual element, a "discharge" of slip will proceed across the crystal

(178) Bragg, W L.

The Strength of Metals

Proc Cambridge Phil Soc 45 (1949) 125-130

A derivation of expressions for the yield stress of a cold-worked metal in terms of its structure and elastic constants, using the Dean and Wilson model of a dislocation the mathematical treatment of which excludes the region of intense strain at the center of a dislocation The value of the radius to be assigned to this region is derived from a consideration of the point where the expression for the strain energy corresponds to complete disorder, or the latent heat energy and is found to be slightly more than 1 atomic diameter for all metals On the basis of X-ray line-broadening experiments, estimates of the ultimate shear strength for several metals can be made

(179) Bragg, W L

Slip in Metals

Physica 15 (1949) 83-89

A quantitative investigation of the "mechanical properties" of a two-dimensional bubble structure is reported On the basis of a calculation of the attractive and repulsive forces between bubbles, Poisson's ratio for the structure can be calculated and compared with experimental results on an extended or compressed raft Young's modulus may also be calculated, and experimentally verified to within 5% The discussion lays stress on the elastic limit, and reports experiments on the critical strain for the case where a dislocation starts at a free edge and runs right across the "crystal" Results are shown graphically, the critical strain being plotted against bubble size, and compared with theoretical estimates calculated according to various assumptions The observed critical strains lie within limits calculated by reasonable theoretical treatments

(180) Bragg, W L., and Lomer, W M

A Dynamical Model of a Crystal Structure-II

Proc Roy Soc (London) 196 (1949) 171-181

A quantitative study of the mechanical properties of two-dimensional bubble rafts attempts to relate their plastic properties to those of metals Plastic deformation proceeds by the motion of dislocations which, in perfect crystalline rafts, are produced in pairs in the body of the raft or singly from the edge The observed shear strains can be explained in terms of the forces between the bubbles, and it seems, therefore, that the very low shear strengths of metallic single crystals cannot be explained in terms of dislocation creation but must be a consequence of the initial presence of faults of some kind Bubbles have quite high values of critical strain if the crystal is essentially perfect, so it appears unlikely that stresses cause a metal to slip by creating dislocations in an initially perfect structure. Although the bubble model does not represent the dynamic behavior of a real lattice, its behavior is interesting, if only because it shows that calculations of the "theoretical strength" lead in fact to values in good accord with observation

(181) Braun, A

The Relationship Between Hardness and Tensile Tests (In German)

Schweiz Arch angew Wiss. u Tech 20 (1954) 56-58

Elasticity, hardness increase, and heterogeneity factors most responsible for load dependence in hardness testing Correlation between hardness and tensile tests is difficult in mathematical terms because the geometrical foundations are different Attempts are described to analyze the relation between load and hardness value in terms of elasticity, cold working, and structural heterogeneity It is concluded that the indentation hardness test measures properties which cannot be revealed in tensile tests

(182) Braun, A

Rheological Aspect of Hardness (In French)

Rev. mét. 55 (1958) 470-474

Three categories of the properties of solids are distinguishable, viz elasticity, plasticity, and viscosity Analysis of the behavior at local deformations set up by stresses to which the solid offers a resistance (which is designated hardness) shows the necessity of defining hardnesses related to three categories mentioned above Their significance flows from their relation with the respective constants of elastic, plastic or viscous matter a relation which the author calls "hardness function" and which shows also whether these hardnesses are dependent on experimental conditions This conception of specific hardnesses allows one to envisage a more detailed analysis of the various rheological properties of a solid, by means of appropriate hardness measurements and by making use of rheological models

(183) Breen, J E., and Weertman, J

Creep of Polycrystalline Tin

Trans AIME 203 (1955) 1230-1234

Creep rate studied as a function of temperature and stress in constant stress experiments Temperature was varied from room temperature to almost the melting point of Sn. Two activation energies for creep of Sn were calculated from the data: 26,000 cal/mole at high temperatures and 11,000 cal/mole at low temperatures It is suggested that the discrepancies between the creep activation energies and those of self-diffusion can be accounted for if self-diffusion takes place predominately by Zener's ring mechanism rather than through vacancy or interstitial movements

(184) Brenner, S S.

Plastic Deformation of Copper and Silver Whiskers

J. Appl Phy. 28 (1957) 1023-1026

Studied by rapidly reducing stress after yielding Whiskers exhibit extremely sharp yield points and extensive easy "glide" regions due to propagation of Lüder's bands It is unlikely that sharp yield points are caused by dislocation pinning. Propagation of Lüder's bands often becomes obstructed, giving rise to repeated yielding in plastic region Nature of these obstructions and mechanism of Lüder's band propagation are not clear

(185) Brick, R M , Martin, D L., and Angier, R P

Effects of Various Solute Elements on the Hardness and Rolling Textures of Copper

Trans. ASM 31 (1943) 675-698

Added Ni, Zn, Al, Mn, Si, As, Mg, Co, Sn, Sb, to Cu. Straight line relationship found between solution-hardening and work-hardening characteristics of the different solutes The different solutes produce hardening effects which depend primarily on the difference in atomic volume of solute and solvent or, relatedly, upon the parameter change of the solvent or the extent of solid solubility.

(186) Bridgman, P W

The Stress Distribution at the Neck of a Tension Specimen

Trans ASM 32 (1944) 553-574

By approximating to the contour of a tension specimen at the neck by a circle and by using a circle to approximate the lines of principal stress in the neighborhood of the neck, the distribution of stress across the neck has been found which rigorously satisfies the conditions of plasticity in the conventional form of von Mises The same solution also applies with an error of only a few % when strain hardening occurs of the amount found under actual conditions The solution differs qualitatively from the stress distribution in an elastically strained specimen In the plastic specimen, the tension is greatest on the axis and least on the periphery; the stress system consists of an axial tension, uniform all the way across the neck, plus a hydrostatic tension, which is zero on the periphery and increases to its maximum values on the axis There appears to be a close connection between the "cup and cone" fracture often observed and the stress distribution at the neck The brittle fracture on the axis is associated with the hydrostatic tension prevailing there, while the shearing fracture nearer the outer surface is connected with the shearing stresses which become important near the outer surface.

(187) Bridgman, P W

Flow and Fracture

Trans AIME 162 (1945) 569-583

Flow and fracture are admittedly complicated phenomena of which we are yet only partially masters There is not even universal agreement as to the details of the language best adapted merely to describe the phenomena, to say nothing of any theory Certain points of view, however, are widely held, and there are certain general expectations as to what sort of procedures will prove permissible The importance of stress history in connection with fracture is emphasized; a hydrostatic pressure, for example, will produce no flow, but very different results may follow by increasing in succession the three components of stress into which the hydrostatic compression may be resolved Results obtained when stress is applied to a specimen under hydrostatic pressure are described.

(188) Bridgman, P W

The Rheological Properties of Matter Under High Pressure

J Colloid Sci 2 (1947) 7-16

A study of rheological properties of matter, whereby are understood those properties which play a role when a body receives permanent alteration of geometrical configuration without fracture. Such permanent alterations of shape follow the application of shearing stresses In the case of solids, permanent deformation does not occur until the shearing stress rises above some threshold value, the relevant property of the solid being designated generically as plasticity The study of hydrostatic pressure effects is of considerable significance as to the underlying mechanisms.

(189) Bridgman, P W

Fracture and Hydrostatic Pressure

Paper from Fracturing of Metals, Am Soc Metals, Cleveland (1948) 246-261

Results of experiments show remarkable increases in ductility for mild steels at high hydrostatic pressures and a progressive change in the character of the fracture Ductility imparted to completely brittle materials such as copper containing 8% phosphorus, and minerals such as limestone and rock salt Glass does not acquire ductility, but it is extremely sensitive to surface conditions. Fundamental implications of these results

(190) Bridgman, P W

The Thermodynamics of Plastic Deformation and Generalized Entropy

Revs Modern Phys 22 (1950) 56-63

The previous extension of the methods and definitions of classical thermodynamics to irreversible phenomena is further extended to the case of a metal showing hysteresis between stress and strain. The analysis confirms the earlier conclusion that it is possible to generalize the entropy concept so as to apply it to intrinsically irreversible processes, provided that the latter are simple enough to be characterized in terms of a small number of macroscopic measurements.

(191) Brock, P.

A Note on the Influence of Grain-Boundary Flow in the Creep of a Lead-0 5 Per Cent Tin Alloy

Inst Metals 83 (1955) 191

The effect of grain size on creep rate and the effect of stress and grain size on grain-boundary sliding have been demonstrated on two similar specimens. One specimen, tested at a stress of 300, crept 51% in 32,000 hours, whereas another specimen, tested at 500 psi, crept only 28% in the same time, as a result of recrystallization occurring during the test

(192) Brook, G B , and Sully, A. H.

Some Observations on the Internal Friction of Polycrystalline Aluminum During the Early Stages of Creep

Acta Met. 3 (1955) 460-469

A torsional-pendulum apparatus was constructed to allow internal-friction measurements to be taken during the tensile creep at constant load of super-purity and commercial-purity Al wires Measurements were made at room temperature, 250, and 350 C It is believed that only partial recovery of the internal friction due to deformation occurred in such specimens, the slow decrease being attributable to a decrease in grain-boundary internal friction The results are discussed in terms of dislocation theory The fall in internal friction during creep was ascribed to polygonization, and X-ray evidence supported this conclusion

(193) Broom, T

The Effect of Temperature of Deformation on the Electrical Resistivity of Cold-Worked Metals and Alloys

Proc Phys Soc (London) 65B (1952) 871-881

Apparatus used to draw wires of Al, Cu, Ni, Fe, 50-50 Ag-Au, 75-25 brass, and Ag_3Mg at temperatures between -183 and 100 C, and to measure their resistances at the temperature of drawing Results suggest that a unified theory of effect of deformation on resistivity of both pure metals and alloys can be based on stacking faults

(194) Broom, T , Mazza, J. A , and Whittaker V N

Structural Changes Caused by Plastic Strain and By Fatigue in Aluminium-Zinc-Magnesium-Copper Alloys Corresponding to D T.D 683

J. Inst. Metals 86 no. 1 (1957-1958) 17 23

High-purity Al alloys containing 6% Zn, 1% Mg, and 1% Cu were used for metallographic investigations of tensile and fatigue phenomena Catastrophic softening on certain planes were observed in the late stages of both tensile and fatigue tests. This softening is associated with structural changes such that the planes can be revealed by etching polished sections from the interior of specimens The planes are identified as those upon which extensive slip has occurred Various factors concerning their development are considered Possible mechanisms for the formation of bands of heavy slip in fully hardened alloys are discussed

(195) Brophy, G. R

The Characteristics of Deformation of Steel Under Constant Load at Elevated Temperatures

Trans Am Soc Steel Treating 20 (1932) 58-66

The idea is proposed that creep is a strain hysteresis which may be mathematically predicted for long periods from tests conducted for a few hours

(196) Brown, A F

Fine Structure of Slip Zones

Nature 163 (1949) 961-962

Slip-lines in Al single crystals have been shown by electron microscopy to consist of finer lines which are boundaries of elementary glide lamallae 200 to 800 A thick, which have slipped over each other about 2000 A Variation of temperature, type, and rate of deformation showed that the slip unit is approximately the same, the difference being in the grouping of the elementary lines into clusters (slip zones) Also, unetched electropolished Al shows a furrowed surface of the same order as the observed lamallae thickness.

(197) Brown, A F

Slip Bands and Hardening Processes in Aluminum

J Inst. Metals 80 (1951) 115-124

Slip bands in Al increase in number during plastic deformation and, at the same time, further slip occurs within each band. At higher temperatures and lower rates of deformation, as well as with increasing strain under all conditions, the latter process becomes increasingly predominant This is interpreted on the basis of the fine structure of slip bands resolved by the electron microscope Differences in density and inner structure of slip bands formed under different conditions are compared with differences between stress-strain curves

(198) Brown, A F.

Surface Effects in the Plastic Deformation of Metals

Advances in Physics 1 (1952) 427-479

Evidence as to the nature of slip in metals, revealed by examination with the optical and electron microscopes, and by interferometry is reviewed The appearance of slip bands on the surface of a plastically deformed metal is evidence that the deformation is not homogeneous, but is concentrated on a relatively few atomic planes This conclusion is considered valid only in the later stages of deformation, and that the first stage of strain is much more nearly homogeneous. Surface finish affects not only the appearance of internal processes but also the processes themselves In cases of nonhomogeneous deformation, this is probably also not continuous in time, slip on an active slip plane tends to a limit which is reached either gradually or suddenly The processes which stop slip on active planes produce hardening of the metal Slip can restart on or near former slip planes owing to mechanisms activated by temperature and stress, and can continue until fracture Slip bands, the sources of hardening, are also places of weakness

(199) Brown, A F

Deformation of Metals Without Apparent Slip Bands (In French)

Compt rend 1[er] congr intern microscopie electronique, Paris (1953) 380-385

The dislocation theory has not yet been able to explaine one of the most remarkable facts of metallic deformation - that of the appearance, on the surface, of avalanches of slip in the form of slip bands By means of the electron microscope and other techniques it has been possible to study the conditions for the diminution and disappearance of these bands, and the results may help in choosing between the various mechanisms already proposed for the formation of dislocation avalanches In general the results support dynamic mechanisms in preference to static mechanisms

(200) Brown, A F

Some New Problems Arising From Electron Microscope Studies of the Plastic Deformation of Metals

Rev. [illegible] (1956) 12 (IX) 501 506

In studying the plastic deformation of metals, it must be known whether the surface phenomena observed truly represent deformation processes occurring in the interior Methods of subsurface examination of metals using the electron microscope, are discussed Aspects include the geometry of internal deformation slip in transparent crystals; effect of slip on ordered alloys etching techniques for revealing slip; precipitates are indicators of deformation and the use of radioisotopes as markers

(201) Brown A F and Honeycombe R W K

Micro Slip in Metal Crystals

Phil Mag 42 ser 7 (1951) 1146 1149

Al crystals the surfaces of which were prepared for examination by electropolishing, show extremely fine slip bands (displacements of 150 A or less) after small plastic deformations of about 0 5 to 2%. The more familiar coarse bands involving displacements of the order of 5000 A appear subsequently However, if the metal surface is mechanically polished prior to electrolytic polishing, the coarse bands occur in the earliest stages of deformation Two possibilities are, first, that the microslip is a phenomenon restricted to the vicinity of the surface and is highly dependent on the nature of it second, that the fine slip may be typical of initial slip processes within the metal, but is almost entirely suppressed as the deformation proceeds

(202) Brown, Norman

Effect of Order-Disorder on the Strength of Beta Brass

Paper presented at AIME Fall Meeting, Chicago (November, 1957)

The effect of order on the mechanical strength may be viewed from two aspects. (1) the size of the antiphase domains and (2) the degree of order Cottrell predicted that maximum strengthening occurs for an intermediate domain size Data by Broom and Biggs on $AuCu_3$, and apparently data by Brown and Green on beta brass, substantiated the theory New data on beta brass appear to contradict the Cottrell theory The additional data consist in varying the quenching rate by varying the quenching medium or the specimen size The new data show that the previously observed maximum strength produced by a water quench from 445 C is shifted to quenching lower temperatures as the quenching rate was decreased and that the curve of yield point versus quenching temperatures reaches a plateau beginning at T_c when the quenching rate was greatest. The above results are interpreted to mean that the maximum strength is associated with the quenching-in of a maximum number of imperfections and/or disorder and not with the quenching-in of a critical domain size Electrical resistivity measurements support this view-point.

The second aspect of the work consists in determining the yield point of beta brass as a function of temperature With decreasing temperatures, the yield point shows a sudden twofold increase in the neighborhood of T_c and reaches its maximum value at 200 C Part of the sharp increase near T_c is associated with short range order A simple theory shows that the strengthening in the region of long-range order is less than that predicted for a unit dislocation moving alone and much greater than that expected from the movement of a super dislocation having the equilibrium spacing The maximum in yield point observed at 200 C is explained by the change in coherence of the super dislocation. The variation of elastic modulus with temperature is not sufficient to account for this maximum.

(203) Brown, N and Herman, M

Interaction of Dislocations and Long-Range Order (Technical Note)

Trans AIME 206 (1956) 1353-1354

Long-range order produces superdislocations, consisting of two partial dislocations separated by an out-of phase region The mutual repulsion of the partial dislocations is balanced by the surface tension of the out-of-phase domain boundary joining the dislocations Expression for equilibrium spacing is derived

(204) Brown, N , Washburn, J and Parker, E. R

Relation Between Initial Creep Rate and Resolved Shear Stress in Zinc Single Crystals

Trans AIME 197 (1953) 1229 1230

Investigation to establish some reproducible relation between initial creep rate and resolved shear stress at higher stress levels where the total creep strain is not limited Successive stress/strain curves for pure shear strains - from the same single crystal of 99.995% Zn, annealed 1 hour at 260 C before each test show (1) complete recovery of mechanical properties, and (2) an increment of stress along the yield point, [illegible] approximately proportional to the total strain, [illegible] where [illegible] is the total stress Thus, if [illegible] is the initial creep rate and [illegible] is the strain at the instant loading is completed, [illegible] A number of successive tests confirm this linear relationship. It is suggested that [illegible] may be the stress at which dislocations are able to break through substructure boundaries this seems to be consistent with the rather sharp transition from microcreep to macrocreep which occurred when a critical stress level was reached in Chalmers' experiments on Sn

(205) Bruckner, W H

The Micro-Mechanism of Fracture in Ferrite

Acta Met 2 (1953) 168-169

From a study of twins, cleavages, and the associated microareas of recrystallization, it is postulated that when the propagating twin meets an effective barrier, its energy may be diverted into producing slip and thereby initiating cleavage fracture Photomicrograph shown of the twin-slip-cleavage sequence

(206) Brunner, H , and Grant, N J

Calculation of the Contribution Made by Grain-Boundary Sliding to Total Tensile Elongation

J Inst, Metals 85 (1956) 77-80

Severe stress concentrations occur at the triple points whenever grain-boundary sliding takes place An equation is derived which permits calculation of the elongation of a tensile specimen caused by sliding along any particular grain boundary.

(207) Brunt, N A

Plastic Deformation of Crystals According to Taylor's Theory (In Dutch)

Metalen 3 (1949) 169-175

Theory of dislocations The generation and movement of dislocations under the influence of the stress field and the possibility for explaining the work hardening in metals, by this theory Finally, the more general treatment of the problem, as published by J. M Burgers, is mentioned

(208) Bulnov, N N

The Structure of Slip Markings on the Surface of Deformed Aluminum Alloys (In Russian)

Fiz. Metal i Metalloved Akad Nauk S S.S.R., Ural' Filial, 2 no 3 (1956) 477-483

The structure of slip markings by means of the electron microscope was studied on polycrystalline alloys of Al Deformation is localized not only on visible slip bands but also in the spaces between them Each slip marking includes slip processes on a number of atomic planes; the distribution of slip among these planes is not uniform The amount of slip per slip bands varies in different parts of the specimen, and even at different parts of the same band Intersections of slip bands of different systems are likely to be sites of incipient cracks Al alloys, when cooled quickly, behave as hexagonal metals, i e , deform on only one set of slip planes until large deformations are reached

(209) Bulnov, N. N., and Shashkov, O. D.

An Investigation of the Structure of Deformed Aluminum-Copper Alloy by Means of the Electron Microscope (In Russian)

Fiz. Metal i Metalloved Akad Nauk S S.S.R , Ural' Filial, 2 no 3 (1956) 484-488

Polycrystals of Al-4% Cu were quenched and aged so that platelets of the θ' formed in a network throughout the piece Specimens polished before deformation gave the usual patterns of slip lines intersecting precipitates, which give information about slip on the surface Specimens polished after deformation gave a pattern of distorted precipitate plates and provide information about deformation within the bulk of the material At high deformations (75 to 95%) slip is concentrated not only into visible slip bands but also into the spaces between them Also, the appearance

of slip on the surface is a reliable indication of the geometry of deformation in the interior. Comparing the appearance of slip bands on quenched and on age-hardened Al 4% Cu with those on pure Al, those on the alloy in both conditions are straighter, narrower, and farther apart Replicas of fracture surfaces show that, although the fracture of the hardened alloy is brittle in character, the fracture surfaces provide clear evidence of being mainly composed of slip planes The concentration of particles on fracture surfaces is much less than normal It is suggested that intensive slip may have locally the effect of high temperature, i e , it may redissolve some precipitates. This opinion is confirmed by micrographs of intensive slip lines on nonfracture surfaces the region around them seems impoverished in precipitates

(210) Bullen, F P

Metallographic Observations During Reversed Straining of Polycrystalline Zinc

Australia, Commonwealth, Dept Supply, Aeronaut Research Lab., Rept SM 218 (1953) 32 pp

Cantilever strip specimens of annealed Zn were bent by electromagnetic oscillation. Deformation at the lowest strain amplitudes used (about 0 1%) is localized at grain boundaries, and appears as a thickening progressing with increasing number of cycles. A substructure which became evident at the later stages of testing was found to have persisted from the hot-working treatment stage in preparing the specimens Grain-boundary migration becomes marked, and there is eventual intercrystalline fracture Increasing strain amplitude introduces deformation by slip and twinning in the grains, but boundary migration is restricted Little relative displacement between the grains is produced An explanation is advanced in terms of the occurrence of localized strain at grain boundaries by cyclic grain-boundary slip in order to relax stresses introduced by anisotropy of elastic strain of adjacent grains

(211) Bulygin, I P., and Lashko, N F

On the Theory of Metals in the Process of Plastic Deformation I - Recovery of a Pure Metal (Aluminum) II - Recovery of an Aged Aluminum Alloy (In Russian)

Zhur Tekh Fiz. 24 no. 2 (1954) 231-240, 241-249

(I.) The process of "block formation" which Lashko proposed [see e g , ibid , 20 (1950) 1025] as part of the mechanism of breakdown of metals during creep is compared with the process of fragmentation due to Wood and with polygonization All are recognized to be phenomenologically the same X-ray Laue photographs from single grains show the development of asterism up to ~1% strain. As strain increases the asterisms become less intense, and a pattern of sharp spots develops, showing that the original grain has broken up into a large number of almost perfect crystallites with orientations scattered over a range of several degrees. Experiments at higher speeds of deformation and other temperatures give similar qualitative results The dimensions of the blocks, however, increase with increasing temperature of deformation and decrease with increasing speed of deformation. (II.) Results of pure Al are summed up as follows: recovery takes place in creep by conversion of the grains into blocks, the boundaries of which are either former slip bands or former kinks. In either case some process of diffusion is necessary Thus, the process of recovery in alloys where diffusion may proceed either more or less readily than in pure metals is studied. In particular, it is interesting to see what happens in supersaturated solid solutions where the diffusion processes are accompanied by precipitation. In general, raising the temperature of deformation speeded up the change from slip to block deformation. At sufficiently high temperatures the form of deformation passed directly from slipless flow to irregular blocks without the intervention of a period of normal slip. Conclusions are (1) The absence of enhanced precipitation in the "slipless flow" range shows that such deformation is not, as has been suggested elsewhere, a diffusion process but involves slip too fine to be resolved by the microscope. (2) Some of these fine slips will grow to "critical size", which is defined as the size such that further slip on that plane results in a decrease of free energy These slips then grow to be visible slip lines (3) The transition from deformation by intersecting systems of slip lines to block formation requires diffusion (it did not, e.g., occur in deformation at 200 C) (4) Kinks are not a feature of deformation of the Al alloy

(212) Bunge H J

Deformation Anisotropy of Ordered Solid Solutions (In German)

Z. Metallk. 49 (1958) 40-42

Alternations of the long-range order parameter by plastic deformation are considered If there exists any kind of order (positive or negative short-range order, long-range order) in a solid solution, the symmetry properties are altered after deformation. This is also true for polycrystalline materials

(213) Burdukskiy, V V , and Oding I A.

The Process of Damage in Metals During Creep (In Russian)

Izvest Akad Nauk S S S R Otdel Tekh, Nauk no. 5 (1956) 137-151

Microcracks grow by coalescence and precipitation of vacancies The speed of coalescence depends on time and the initial concentration of vacancies But the rate of creep depends on this concentration also thus, a relationship is established between damage in metals and creep Equations are produced from theoretical considerations finally arriving at the experimental equation connecting stress and time of fracture An empirical exponential relation between the time to destruction τ_f, and the stress, σ which was successfully used in recent experimental work (cf C A. 50, 1553a), $\tau_f = Be^{-\gamma\sigma}$ where B and γ are constants was derived analytically

(214) Burgers, J M

Some Consideration on the Fields of Stress Connected With Dislocations in a Regular Crystal Lattice

Proc Koninkl Ned Akad, Wetenschap. 42 (1939) 293-325 378-399

(I) The theory of plastic deformation due to G I Taylor, is extended to the case of deviations from the ideal structure of the three-dimensional type Their nature is discussed, and equations are derived for the fields of stress associated with various types on the basis of the ordinary theory of elasticity for isotropic bodies (II) By a more rigorous treatment, expressions are derived which are sufficient to investigate the fields associated with simple dislocations in nonisotropic bodies. It is found, however, that in a large number of cases the difference between the formulae for the isotropic substance and those for the regular, crystalline substance completely vanishes. Describes a screw dislocation in terms of a displacement vector

(215) Burgers, J M

Geometrical Considerations Concerning the Structural Irregularities to be Assumed in a Crystal

Proc Phys Soc (London) 52 (1940) 23-33

The geometrical and mechanical properties of some types of lattice dislocations have been investigated. It is shown that plane systems of simple dislocations can break up a crystal into crystallites of the kind discussed by Bragg

(216) Burgers, W G.

Recrystallization and Grain Growth in Solid Metals

Paper from L'Etat Solide, Rept 9th Solvay Conf , Edited by R Stoops Brussels (1952) 73-166

Discusses recent results concerning structural changes taking place in metals during heat treatment, insofar as they have influence on the number, size, shape, state, or orientation of the constituent crystallites

(217) Burgers, W G.

Plasticity of Crystals

Chapter 5 from Elasticity, Plasticity and Structure of Matter, by R. Houwink, 2nd Edition, Harren Press, Washington, D. C. (1953) 73-127

Thorough consideration given to such matters as strain hardening, recovery, and recrystallization, and creep of polycrystalline metals Plastic deformation of single crystals discussed, as well as the theoretical work devoted to explaining the discrepancy between the actual and theoretical strength values. Various theories of slip in crystals are reviewed This chapter was written originally in 1937 so the older theories are given more complete coverage than can be found in more modern books.

(218) Burgers, W G., and Burgers, J M

Model for the Elucidation of Some of the Phenomena Presented by Crystalline Substances Upon Plastic Deformation

Second Report on Viscosity and Plasticity, sec 5. Acad. Sci Amsterdam (1938) 200-218

A theory of strain hardening, whereby dislocations are considered to form by the combined action of stress and thermal agitation at places where a notch effect exists and causes a local stress concentration The dislocations created at these places run into the crystal until they meet obstructions, where they accumulate and cause crystallite rotation It is also suggested that these dislocations collectively produce a stress field which counteracts the local stress at the notch, thus making the production of further dislocations more difficult. In this way an explanation of strain hardening is built up.

(219) Burgers, W G., and Lebbink F J

Lattice Distortions in Sheared Aluminum Single Crystals

Paper from Selected Topics in X Ray Crystallography From the Delft X Ray Institutes, Interscience Publishers, New York (1951) 146-158

In not too severely deformed single crystals, plastic deformation is indicated by elongation of the Laue interference spots (so-called "asterism") pointing to the occurrence of curved or broken-up lattice domains which may have either a local character or spread over areas of larger size Experiments on this type of diffraction phenomena Al single crystals were subjected to careful deformation by "pure shearing" and the occurrence of asterism in the Laue photographs of the deformed crystals was analyzed and interpreted in connection with the supposed mechanism of the shearing process

(220) Burke E C , and Hibbard, W R Jr

Plastic Deformation of Magnesium Single Crystals

Trans AIME 194 (1952) 295-303

Studied by tensile tests at room temperature, utilizing and improved preparation and testing technique Consistent critical resolved shear-stress values for basal slip were obtained The advent of pyramidal slip at room temperature was rationalized upon the basis of grip constraints A bend-twinning hypothesis is advanced as an explanation of mechanical twinning which occurs as a complex stress-relief mechanism

(221) Burke, J E and Turkalo, M

Deformation of Zinc Bicrystals by Thermal Ratcheting

Trans AIME 194 (1952) 651-656

Phenomenon of "thermal fatigue" proposed by Boas and Honeycombe. The possibility was investigated that an additional mechanism might cause plastic deformation during thermal cycling - a "thermal ratchet" that depends upon a combination of grain-boundary flow to relax the stress that develops between differently oriented grains upon raising the temperature and transcrystalline slip to relax the oppositely directed stress which develops on lowering the temperature. Theoretical analysis is followed by details of experiments on Zn bicrystals.

(222) Buttner, F H , Funk, E. R , and Udin, H

Viscous Creep of Gold Wires Near the Melting Point

Trans AIME 194 (1952) 401

Gold wires are found to creep viscously up to approximately 5.5×10^5 dynes/cm^2 around 1 100 K. Beyond this point, an additional slip mechanism appears The average coefficient in the viscous range at these temperatures is $18.9 \pm 7 \times 10^{12}$ poises This observation and other visual observations made during the experiments agree with Herring's predictions

(223) Cahn, R. W

Recrystallization of Single Crystals After Plastic Bending

J Inst Metals 76 (1949-50) 121-143

Experiments with deformed crystals to determine under what conditions a special type of recrystallization occurs which leads to discontinuous asterism in the Laue patterns. Bent single crystals of Zn, Mg and Al are particularly liable to this type of recrystallization. The structures of bent and of annealed specimens show that the annealed specimens consist of many crystallites separated by straight boundaries perpendicular to the slip planes The theory of the phenomenon is discussed, and it is concluded that it is the result of the motion of dislocations during annealing The bearing of the results on the general theory of recrystallization is briefly considered

(224) Cahn, R W Bear, I J , and Bell, R. L.

Some Observations on the Deformation of Zinc at High Temperatures

J Inst Metals 82 (1954) 481-489

Microbeam X-ray diffraction technique for determining orientation relationships between neighboring units of substructure Causes and mechanism of cell development

(225) Caisso, J

Cold Working and Recovery of Aluminum Single Crystals Subjected to Low Tensile Stresses (In French)

Publs sci et tech ministère l'air Inst recherches sci et tech Centre-Quest No 316 (1956) 46 pp

The phenomena observed consist essentially of a disorganization and a rearrangement of the crystal structure one or the other can become predominant Depending on the strain, three distinctly different stages are found in the tensile curve Agreement is obtained with Jaoul's observations and Mott's theory of cold work

(226) Calnan, E A.

Laue Asterism and Deformation Bands

Acta Cryst. 5 (1952) 557-563

Nature of lamellar regions in relation to current ideas on inhomogeneous deformation. Experimental data using Al crystals

(227) Calnan, E A., and Burns, B. D

Some X-Ray Observations on the Nature of Creep Deformation in Polycrystalline Aluminum

J Inst Metals 77 (1950) 445-455

Back-reflection Laue patterns were taken from the same series of locations on a large-grained Al testpiece after successive amounts of creep deformation at 250 C From analysis of the asterism and movement of the reflection spots relative to the stress axis, it appears that early creep deformation is associated with slip processes Later stages are characterized by presence of numerous fine units or cells formed from the previously distorted material.

(228) Calnan, E. A. and Clews, C J B.

Deformation of Body-Centered Cubic Metals

J Appl Phy 22 (1951) 1508

Discusses recent results of Opinsky and Smoluchowski Operative slip systems for unequal and equal critical shear stresses are shown in diagrams

(229) Calnan, E. A., and Clews, C J. B.

The Prediction of Uranium Deformation Textures

Phil Mag. 43 ser. 7 (1952) 93-104

Tension, compression, and rolling textures were derived for the orthorhombic metal alpha-uranium From a consideration of the relative importance of the slip and twinning mechanisms, it is possible to differentiate between the textures developed after slight and severe deformations at both room and elevated temperatures

(230) Campbell, J D.

The Dynamic Yielding of Mild Steel

Acta Met. 1 (1953) 706-710

It is proposed that dynamic yield will occur when the density of dislocations released from Cottrell atmospheres reaches a critical value The yield stress (or time to yield) in any given type of dynamic test, $\sigma = f(t)$, can then be found from the Cottrell-Bilby theory of yielding [Proc Phys Soc. (London) 62A (1949) 49]. The theory is applied to the rather meagre experimental data, and reasonable agreement is obtained. The criterion does not apply to testing times of ~1 sec or more, where experiment indicates the existence of a static yield stress The change may be due to the redistribution of interstitial solute atoms under stress, for which the relaxation time is known to be ~1 sec

(231) Carlsen, K. M , and Honeycombe, R. W K.

Plastic Deformation of Aluminum-3.5% Copper Alloy Single Crystals

J Inst. Metals 83 (1954) 449-454

Long crystals of an Al-3.5% Cu alloy, prepared by the strain-anneal method, have enabled a comparison to be made of specimens of identical orientation after three different heat treatments (1) Crystals of the air-cooled solid solution resembled pure metals, in so far as plastic deformation occurred on well-defined slip planes and the stress/strain curves were orientation dependent. The deformation continued on the chosen system, suitably orinted alternative systems not becoming operative until heavy deformations were reached. (2) In contrast, the fully hardened crystals did not show visible slip nor did they undergo the change in shape expected from deformation on a single set of planes, furthermore, the stress/strain curves were independent of orientation (3) The behavior of the overaged crystals fell between these two extremes The work hardening of the aged and overaged crystals was greater than that of the solid-solution crystals, particularly when tested at -196 C At room temperature the air-cooled solid-solution crystals, on interruption of the deformation, gave stepped stress/strain curves, which are explained in terms of accelerated aging on the slip planes Differences in the rate of work-hardening in the solid solution and in the aged crystals are discussed in terms of the barriers which may prevent movement of dislocations.

(232) Carreker, R P.

Plastic Flow of Platinum Wires

J Appl Phy 21 (1950) 1289-1296

Creep behavior of annealed Pt wires at constant stress and temperature is reported for a wide range of experimental conditions 78 to 1550 K, 900 to 40,000 psi, 0 001 to 0.1 strain, and 10^{-1} to 10^{-6}/min strain rate Empirical equations are given which describe the results satisfactorily

The relation between activation energy and stress is inconsistent with the Becker-Orowan theory of creep (which predicts $Q^{1/2} \propto \sigma$) and with a theory applying nucleation theory to slip bands (which predicts $Q^{1/4} \propto \sigma$).

(233) Carreker, R P , Guard, R W , and Lenhart, R E.

Investigations of Deformation and Fracture of Metals

G E Research Lab , U S. OTS, PB 111838 (May, 1955) 25 pp

Plastic deformation behavior of pure metals as a function of temperature and grain size, correlations of the stress, strain, and strain rate were made on a phenomenological basis for both tensile and creep tests and the resulting data applied to examination of current concepts of deformation.

(234) Carreker, R P , Jr , and Hibbard, W R , Jr

Tensile Deformation of High-Purity Copper as a Function of Temperature, Strain Rate, and Grain Size

Acta Met 1 (1953) 654-663

Polycrystalline wires of Cu were heat treated to five different grain sizes and tensile tested over a wide temperature range The variation of yield point, ultimate tensile strength, and % elongation with temperature is shown graphically for various grain sizes Grain size was found to affect the yield point considerably but to have relatively little effect on ultimate tensile strength, the effect of grain size was most important at low temperatures The yield point varies slightly with temperature but there is a marked increase in the rate of strain hardening at low temperatures Some results on variation of flow stress with grain size at room temperature are compared with Wood's theory of a limiting crystallite size for Cu and with the critical stress needed to activate Frank-Read sources

(235) Carreker, R. P., Leschen, J G., and Lubahn, J D.

Transient Plastic Deformation

Trans A I M E 180 (1949) 139-146

Nucleation theory applied to slip bands predicts transient deformation phenomena after sudden stress changes Creep tests and tensile tests on specimens of Pb, Cu, and an Al alloy confirm the existence of these transients The results show the alterations in strain rate accompanying various stress changes, and it is shown that cyclic loads or temperatures in creep tests produce appreciably greater strains than do constant conditions, unless the duration of the transient effects is much less than the length of the cycle

(236) CarroCao, Guiseppe

Principles for the Study of the Technological Process of Plastic Deformation (In Italian)

Met ital. 44 (1952) 347-353

Principles for homogeneous and isotropic metallic substances in which the plastic deformation starts when the stress reaches a critical value.

(237) Castro, R., Gueussier, A , and de Lacombe, J

Prior Cold Work and Mechanical Strength of the Austenitic Stainless Steels at Elevated Temperatures (In French)

Fourth International Congress on Industrial Heating, Paris (1952) (180) 11 pp

Influence of C, Mo, W, and Ti on resistance of 18-8 to softening after cold working. Parallelism between the mechanical behavior at high temperature and resistance to softening after cold working: theoretical and practical conclusions. Establishes critical duration of loading or critical temperature beyond which the favorable effect of the cold work disappears.

(238) Chalmers, B

Micro-Plasticity in Crystals of Tin

Proc Roy Soc (London) 156 (1936) 427

Experiments are described on the isothermal stress-strain-time relations of single crystals of tin of two grades of purity, the stress being pure tension and the strain being measured to 10^{-7} Creep is found to occur under all stresses, its initial rate being proportional to stress for small stresses The rate of creep increases much more rapidly with increased stress (macrocreep). Microcreep decreases with time in a roughly exponential manner, and macrocreep remains constant for a considerable time The phenomena are considered from the point of view of the current theories concerning the mechanical strength of metallic crystals, and it is shown that microcreep can be accounted for by an extension of G. I Taylor's theory of fault propagation

(239) Chalmers, B.

Precision Extensometer Measurements on Tin

J. Inst. Metals 61 (1937) 103-118

Creep experiments on single crystals, bicrystals, and polycrystalline Sn, in which strains of 10^{-7} were measured. The results show that the change of orientation across a crystal boundary affects the mechanical properties of the boundary. The relation between recovery and creep and the forms of the creep curve are discussed. A rather sharp transition from microcreep to macrocreep occurs at a critical stress level

(240) Chalmers, B.

The Influence of Difference of Orientation of Two Crystals on the Mechanical Effect of Their Boundary

Proc Roy. Soc (London) 162 (1937) 120-127

Cylindrical specimens of tin were prepared, consisting of two crystals with a longitudinal boundary in the direction of the axis of the test piece. The 001 axis was perpendicular, and the 101 axis at 45° to the axis of the specimen. This symmetry about the axis ensures that the resolved shear stress is the same on corresponding planes in different cases but leaves the angle A between the 001 axes of the crystals under control. The critical tension required to produce a small arbitrarily defined extension varied regularly with the angle A, being a minimum for A = O (i e , a single crystal) and a maximum for A = 90°. It is concluded that the boundary has no inherent strength and that the results are best explained as the effect of a transitional lattice. The evidence is against the existence of an amorphous layer or intercrystalline cement.

(241) Chalmers, B.

The Plasticity of Polycrystalline Solids

Article from A Symposium on the Plastic Deformation of Crystalline Solids, OTS, U. S Dept. Commerce (1950) 193-196

Many investigators believe that the best approach to the understanding of plasticity is to study first the behavior of single crystals and then to use this information to elucidate the more complex case of a polycrystalline aggregate. Progress that has been made from this point of view and the difficulties that arise when an attempt is made to interpret polycrystalline plasticity in terms of single-crystal data.

(242) Chalmers, B.

The Properties and Effects of Grain Boundaries

Chapter from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc., New York (1952) 441-450

A distinction is made between properties and the effects of grain boundaries; effects of boundaries on plastic deformation; possibility of noncrystallographic mode of deformation. Strength (shear and normal) and fusion (chemical and electrochemical)

(243) Chalmers, B. and Davis, R. S.

Experimental Indications of Surface Sources

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 232-233

The behavior of the Schultz picture obtained from a slightly stretched Al single crystal supports the proposal that during the early stages of deformation the origins of the dislocations are Frank-Read sources of which one end is free to move on the crystal surface. The behavior at the crystal boundary in a bicrystal suggested that sources of a different type may be important in polycrystalline specimens.

(244) Chalmers, B., and Martius, U M

Slip Planes and the Energy of Dislocation

Proc Roy Soc (London) 213A (1952) 175-185

The characteristic slip directions and planes in metal crystals can be explained and predicted by taking into account the dependence of the energy of a dislocation on its plane. The reason for the existence of alternative slip systems, particularly at high temperatures. The energy of a dislocation is considered as a function of the parameter β, which is defined as the ratio of the Burgers vector to the interplanar spacing ($\frac{b}{h} = \beta$), and it is shown that the observed slip system corresponds to the lowest possible values of β in all the crystal types that have been studied

(245) Chang, H. C , and Grant, N J

Observations of Creep of the Grain Boundary in High Purity Aluminum

Trans AIME 194 (1952) 619-625

The salient features of creep at elevated temperature are: (i) grain-boundary sliding and migration, which take place in successive steps as a function of time, and (ii) the resultant deformation in the grains. A creep curve obtained between two reference marks across a grain boundary

shows that the period during which active boundary sliding takes place is characterized by the creep rate increasing to rather high values before the period of grain-boundary migration occurs, this latter resulting in a decreasing creep rate. Etch pits, scratches, and needle indentations on the grain surfaces exert a strong influence on the course of boundary migration, mainly as an attracting effect, and surface energy around the irregularity is suggested as a very important factor in this phenomenon. The effect of grain-boundary sliding is not restricted to a thin layer of several interatomic distances thick, but extends to a rather large volume along both sides of the heavily slid boundary. Boundary sliding causes two types of deformation within the grains, viz., (1) fairly straight "folds" or bands, caused by sliding the opposite grain boundary, and (2) "subgrain" formation, particularly at the triple point of three grain boundaries; lattice bending is believed to play an important role in both phenomena.

(246) Chang, H C., and Grant, N J

Inhomogeneity in Creep Deformation of Coarse Grained High Purity Aluminum

Trans AIME 197 (1953) 1175-1180

Local strain measurements were made across the grain boundaries and in different regions of various grains during creep. The following conclusions were made: (1) a cyclic behavior is exhibited both across grain boundaries and in the grains, the periodicity of the former appears to increase as creep progresses, but the deformation/cycle increases; (2) at 400 F boundary sliding becomes noticeable only in the later stages of creep, but at the higher temperature it is very significant from the start of the test; (3) it is unlikely that a single activation process can be considered for creep, and (4) any equation intended to define a conventional creep curve must be considered to be a statistical summation of equations describing the various component processes of creep.

(247) Chang, H. C , and Grant, N J.

Grain Boundary Sliding and Migration and Intercrystalline Failure Under Creep Conditions

Trans. AIME 197 (1953) 305-312

The processes of boundary sliding and migration were studied microscopically in high-purity Al. The direction of boundary sliding is governed, primarily, by the direction of the shearing stress acting on the boundary surface. The driving force which controls the direction of boundary migration is a combination of strain energy and surface energy, the latter being the more important at high temperatures. The movement of the grain-boundary triple-point appears to depend on the processes of grain-boundary sliding and migration. Alloying elements and excess phases restrict the amount of migration. A theory is presented regarding the grain boundary under creep conditions, which explains the intercrystalline failure of commercial alloys and leads to the conclusion that an optimum grain size should exist for good high-temperature properties of high-purity materials.

(248) Chang, H C., and Grant, N. J

Mechanism of Creep Deformation in High-Purity Aluminum at High Temperatures

J Inst. Metals 82 (1954) 229-235

Creep of very coarse-grained high-purity Al was studied up to 595 C over a stress range from 50 to 1200 psi. Simultaneous observations and measurements of localized strains on polished specimen surfaces were made by means of a high-temperature microscope. The sequence of the development of various deformation modes, heavy slip bands, kink bands, and subgrains, was followed. Slip is the fundamental mechanism of deformation for both single-crystal and polycrystalline materials even in high-temperature creep. Component creep curves (measured between two closely spaced markings), obtained across grain-boundary-affected slip bands show a periodic behavior, the significance of which is discussed. Subgrains are shown to be formed under conditions where slip development is restricted. Two types of subgrains, one caused by deformation bands and the other by kinking bands, are observed and discussed.

(249) Chang, H. C , and Grant, N J

Some Observations on the Structure of Grain-Boundary Fracture-Surfaces

Trans AIME 206 (1956) 1241-1247

Metallographic and X-ray studies were made of the fracture surfaces of annealed Al-20% Zn alloy after creep testing at 500 F at 2300 psi. The intercrystalline fracture surfaces were made up of facets - of cells in the form of valleys; deformation markings occurred on the plateaus and valleys of these cells. The fracture surfaces produced in room-temperature tensile tests showed a cold-worked layer, and by creep tests either a heavily deformed layer or a recrystallized layer, or both, depending on the grain-boundary orientation and the history of the crack progress

(250) Chang, H. C , and Grant, N J

Mechanism of Intercrystalline Fracture

Trans AIME 206 (1956) 544-551

On the basis of microscopic observations during creep tests and a knowledge of the interaction between grains and grain boundaries, a mechanism of intercrystalline fracture and propagation of the fracture is proposed

(251) Chang, H C , and Grant, N J

Mechanism of Grain Boundary Sliding

Trans AIME 206 (1956) 169-170

An Al-20% Zn solid solution alloy was subjected to creep at 500 F at stresses of 2000 to 5000 psi. All specimens showed appreciable grain-boundary sliding accompanied by "fold" formation and offset of the triple point - as shown by high-purity Al. Grain-boundary sliding is accompanied by fold formation in the grain on which the new boundary surface is created; this is the means whereby the grain can accommodate boundary sliding. Thus, there is bulk movement of two grains along a mutual boundary. It is likely that one grain of the two involved in the sliding process is oriented more favorably for slip to occur in it, and this supposition is supported by evidence of the greater amount of deformation in one grain as compared to the other in the sliding couple

(252) Chang, T S , and Kesler, C E

Correlation of Sonic Properties of Concrete with Creep and Relaxation

Proc ASTM 56 (1956) 1257-1272

This paper presents a method of relating the properties of concrete that can be obtained from sonic testing to the creep behavior in compression and flexure and relaxation behavior in compression. Valid nonlinear mechanical models are selected to represent concrete in creep and relaxation and their coefficients are statistically related to the sonic properties. A simple procedure is also developed to relate the creep of one concrete beam to another under different loading. The results presented provide a means of predicting creep and relaxation behavior of concrete from a relatively simple sonic test.

(253) Chauduri, A R., Chang, H C , and Grant, N J

Creep Deformation of Magnesium at Elevated Temperatures by Nonbasal Slip

Trans. AIME 203 (1955) 682-688

Tests were run at 500 and 700 F at stresses of 148 to 786 psi. Based on the measurements and theoretical calculations, the crystallographic elements for nonbasal slip were determined. Deformation resulted in a nonbasal type of slip appearing as wavy traces which were dependent on the angle between the surface of observation and the plane containing both the axis of tension and the slip direction. The observed glide plane did not coincide with any low-index plane and was nearly perpendicular to the plane of maximum resolved shear stress. This cooperative form of slip between at least two planes indicates that the slip plane was a corrugated surface formed by suitable amounts of glide occurring in a consecutive manner

(254) Chechulin, B. B

On the Statistical Theory of Brittle Strength (In Russian)

Zhur Tekh Fiz. 24 no. 2 (1954) 292-298

Theories of the brittle strength of solids due to Weibull [Proc Roy Swedish Inst. Eng. Research no. 151 (1939)] and to Frenkel and Kontorova [Zhur Tekh. Fiz. 11 (1951) 173] are reviewed. In these it is assumed that brittle failure is due to the distribution throughout the solid of defects which result in its disruption on loading. It is shown that the fundamental defect of these theories is the lack of a theoretically well-founded random distribution function for the defects. Using a Pearson distribution function of the third kind, Ch re-solves the equation of Frenkel and Kontorova and obtains a more accurate solution. Weibull's solution is shown to be a special case accurate when the number of defects is large

(255) Chechulin, B. B.

Study of Microscopic Nonuniformity of the Plastic Deformation of Steel (In Russian)

Fiz. Metal i Metalloved Akad Nauk S.S.S.R., Ural' Filial 1 no. 2 (1955) 251-260

Character of plastic deformation of metals as contrasted with deformation of usual isotropic bodies. Distribution of deformations of real polycrystalline metals, position of grain axes during plastic flow or creep

(256) Chen, C W , and Machlin, E S

On the Mechanism of Intercrystalline Cracking

Acta Met 4 (1956) 655-656

Experiments on bicrystals of pure Cu have shown that grain-boundary shear is necessary for the production of boundary voids. A mechanism is proposed in which tensile stresses are developed at jogs in the boundary during slip.

(257) Chen, C W , and Machlin, E. S.

On a Mechanism of High Temperature Intercrystalline Cracking

Trans AIME 209 (1957) 829-835

Formation of voids at grain boundaries is considered to be primarily responsible for brittle failure of metals at elevated temperature. Voids once nucleated grow either by vacancy condensation or plastic yielding or both

(258) Chen, N K , and Maddin, R

Plasticity of Molybdenum Single Crystals

Trans AIME 191 (1951) 937

In the extension of Mo single crystals at room temperature, the slip planes were found to be of the type {110} and the slip direction <111>. Theories of plasticity of bcc metals are examined, and an explanation based upon planes of highest atomic density seems to explain the plastic behavior observed here.

(259) Chen, N K., and Maddin, R

Slip Planes and the Energy of Dislocations in a Body-Centered Cubic Structure

Acta Met 2 (1954) 49-51

It is assumed that the experimentally observed slip on {112} and {123} planes of a bcc structure is the result of slip movements on alternating segments of two nonparallel {110} planes. Revised values of the parameter beta used by Chalmers and Martius [Proc Roy Soc. (London) 213A (1952) 175] are calculated on this basis, and remove the former discrepancy between observed and theoretical slip planes of bcc materials. The model provides an explanation for the possible occurrence of slip on "high-indices" planes

(260) Chen, N K., and Pond, R B.

Dynamic Formation of Slip Bands in Aluminum

Trans AIME 194 (1952) 1085-1092

Experimental apparatus by which progressive formation of slip bands can be recorded while specimen is undergoing deformation. Qualitative and quantitative data on dynamic formation of slip bands are presented concerning propagation of slip bands, spacing of slip bands, and their relations to strain hardening. Views on formation of slip bands. A mechanism of the unit process involved in formation of a slip band is proposed

(261) Chenea, P F

Stress Calculations for Design for Creep Conditions

Paper from Utilization of Heat Resistant Alloys, Am Soc. Metals, Cleveland (1954)

Factors affecting a workable theory include equations of motion or equilibrium, kinematics of the deformation, and equations of state and dissipation relations. For creep in tension, the simplest class of models from the standpoint of theory is that which results in a linear differential equation between the stress and the strain.

(262) Chenigny, R., and Syre, R.

Creep of Aluminum Alloys (In French)

Rev mét 46 (1949) 682-686

A study of the fundamental characteristics. Method of investigation and data

(263) Chit'kov, A. A

Testing of Metals for Relaxation at High Temperatures (In Czech)

Hutnické listy 10 (August 1955) 450-455

Two theories for reconciling relation between creep and relaxation; differences between measured relaxation values and those calculated from creep values, Czech methods of measuring relaxation according to Barr and Bardgett

(264) Christian, J W, and Spreadborough, J

Stacking Faults in Cold-Worked Cobalt-Nickel Alloys

Phil Mag 1 (1956) 1069-1075

X-ray diffraction experiments were made on the powdered alloy containing 50 to 65 % Co, and accurate line-profile measurements were made using Co radiation. These measurements were also made after annealing at various temperatures, and the stacking-fault parameters were obtained from the shifts of the $K\alpha_1$ peaks. The results are compared with similar work on alpha-brasses [Warren and Warekois, Acta Met 3 (1955) 473] both showing that measurable stacking faults are removed gradually as the annealing temperature is raised. A possible correlation between production of faults and both the large work-hardening capacities and the abnormally large increases in electrical resistivity after cold working of alloys, is discussed.

(265) Christian, J W, and Spreadborough, J

Stacking Faults and Dislocations in Copper-Aluminum and Cobalt-Nickel Alloys

Proc Phys Soc (London) 70B (1957) 1151-1164

Stacking-fault densities in heavily cold-worked Cu-Al and Co-Ni alloys have been measured from the peak shifts using Paterson's theory. Fourier coefficients of the broadening function due to faults are calculated for the {111} and {200} lines, assuming equal density of faults on all {111} planes, and these enable the strain-broadening function to be evaluated from the measured coefficients.

(266) Christy, R W

Creep of Silver Bromide at High Temperature

Acta Met. 2 (1954) 284-295

Transient and steady-state creep rate of single crystal and polycrystalline specimens stressed in compression was investigated with emphasis on steady-state creep of single crystals. Concludes that Mott's mechanism for the limitation of steady-state creep at high temperatures by self-diffusion is able to explain the observed results. The Nabarro mechanism (plastic deformation without slip by diffusion of lattice defects) apparently does not contribute significantly to creep under these experimental conditions.

(267) Chubb, W

Contribution of Crystal Structure to the Hardness of Metals

Trans. AIME 203 (1955) 189-192

A hot-hardness testing machine is described and illustrated. The experiments show that the hardness changes caused by allotropic transformation are related to the type of transformation. The relative magnitude of the property change appears to be a characteristic of the crystal-structure change. The bcc crystal structure is always the softer structure when it is involved in a transformation with the fcc and hcp lattices, which have approximately the same structural strength. Highly complex lattices, although less dense, contribute even more to the strength of the metal. However, several other factors, such as melting point, are involved in the strength of a metal, so that it does not follow that a fcc metal must always be stronger than a bcc metal.

(268) Churchman, A T

The Yield Phenomena, Kink Bands and Geometric Softening in Titanium Crystals

Acta Met. 3 (1955) 22-29

Single crystals of titanium grown by a modification of the strain-anneal technique show discontinuities in the stress-strain relationship when containing 0 1 wt. % oxygen and nitrogen The discontinuities are explained as a manifestation of the yield phenomenon modified by geometric softening taking place during the formation of kink bands An explanation of fragmentation is suggested for materials which form kink bands

(269) Churchman, A. T , and Cottrell, A. H.

Yield Phenomenon and Twinning in α-Iron

Nature 167 (1951) 943-945

The question of whether single crystals of Fe show the yield phenomenon required by the dislocation theory has been controversial for many years Recently, however, the authors have observed the phenomenon, at room temperature, in lightly carburized Armco Fe single crystals On lowering the test temperature to -77 C, the yield points in the single crystals become more marked By lowering the testing temperature to -190 C, the yield phenomenon is replaced by deformation twinning Twinning is also produced, in single crystals, by impact loading at room temperature, but is not produced in coarsely polycrystalline specimens at -190 C Just as the yield point of Fe can be removed permanently by eliminating C and N, or temporarily by plastic deformation, so twinning can be affected in the same way The stress needed to produce twinning or the yield phenomenon is increased by strain aging Some of the effects observed can be explained on the basis of the steep dependence of the upper yield stress on temperature which also supports Orowan's theory of brittle fracture

(270) Clarebrough, L M

Lattice Defects and Plastic Deformation

J Australian Inst Metals 1 (1956) 90-110

Literature review giving some of the current ideas concerning nature of dislocations and role they play in plastic deformation of metals. [illegible] structure of dislocations including edge and screw types. Evidence from experiments on crystal growth, low angle boundaries, and metallic whiskers, parts played by dislocation mechanisms in plastic deformation in forming large slip steps, lattice defects, and dislocations.

(271) Clarebrough, L M , Hargreaves, M E , and West, G W

The Release of the Energy Stored in Deformed Nickel

Phil Mag [illegible] ser 7 (1953) 913-915

Certain possibilities suggested by previous work on Cu have now been tested by measuring the energy released in Ni as the temperature increases, together with the changes in resistivity and hardness. About 40% of the energy stored in torsional working is released between 200 and 300 C and is associated with the major decrease in resistivity. No hardness change occurs in this range. There is a gradual release of a further 20% up to about 550 C, when another sudden release occurs associated with a rapid decrease in the hardness. The lower temperature release is attributed to the disappearance of vacancies and the higher temperature release to recrystallization.

(272) Clarebrough, L M , Hargreaves, M E , and West, G W

The Release of Energy During the Annealing of Deformed Metals

Proc Roy Soc (London) 232 (1955) 252-270

Using apparatus and techniques previously described, measurements have been made of the release, during annealing, of the energy stored in cold-worked specimens of pure and arsenical Cu and Ni Hardness, electrical resistivity, and density determinations were also carried out For all the materials, for all types of deformation (compression, tension, and torsion) and for all heating rates, a sudden release of energy corresponding to recrystallization is observed. It is concluded that for all materials the value of energy associated with recrystallization is probably due to the disappearance of the dislocations created by deformation and for pure Cu this is the only mechanism involved However, for arsenical Cu and for Ni additional mechanisms are responsible for the liberation of a large proportion of the stored energy before recrystallization In arsenical Cu the rearrangement and annihilation of dislocations is probably responsible for the first stage of the release of energy It is suggested that the difference in behavior between this material and pure Cu is due to "Cottrell" locking of the dislocations by As atoms In Ni the disappearance of vacancies created by deformation is responsible for the release of energy in the first stage The second stage is probably associated with the rearrangement and annihilation of dislocations

(273) Clarebrough, L. M., Hargreaves, M. E , and West, G. W

Density Changes During the Annealing of Deformed Nickel

Phil Mag. 1 ser 8 (1956) 528-536

Changes were measured by a differential method and are correlated with earlier measurements of stored energy, electrical resistivity, and hardness There are two sudden increments in density, the first is attributed to the disappearance of vacancies and the second to recrystallization These are superimposed on a gradual increase in density attributed to recovery There is a considerable discrepancy between the densities of dislocations calculated from the stored energy measurements and from the density measurements

(274) Clarebrough, L. M , Hargreaves, M. E , and West, G. W

The Density of Dislocations in Compressed Copper

Acta Met. 5 (1957) 738-740

The changes in stored energy, macroscopic density, and electrical resistivity associated with the annealing of deformed copper have been measured Three independent estimates of the density of dislocations in the deformed material are obtained by combining these results with the best available theoretical values for the energy, density, and resistivity changes associated with dislocations The estimates from the energy and density measurements are in good agreement, but those from the resistivity measurements are approximately sixty times greater This discrepancy may be due to the presence of stacking faults in the deformed copper

(275) Clark, C. L., White, A. E., and Guarnieri, G J

A New Application for the Short-Time High Temperature Tensile Test

Trans. ASM 26 (1938) 1035-1050

Five steels tested between 550 and 1300 F at rates of elongation of 0.005-0.2 inch/min Correlated tensile strength versus strain rate (straight lines on log-log plots), as well as tensile strength versus time for fracture (on log-log plots) A critical temperature was found by plotting tensile strength versus log temperature since two intersecting straight lines were obtained The magnitude of T_c gives an indication of the creep characteristics in its vicinity. This method may serve as an acceptance test in indicating whether or not steels of the same general type and composition possess the same creep strength.

(276) Clark, D. S., and Duwez, P E

The Influence of Strain Rate on Some Tensile Properties of Steel

Proc. ASTM 50 (1950) 560-576

Inability of impact tests to reveal the true influence of strain rate on tensile properties is demonstrated Fundamental requirements of a device by which strain-rate effects can be studied and details of apparatus constructed Results of static and strain-rate tests for three different steels.

(277) Clark, R., and Chalmers, B.

Mechanical Deformation of Aluminium Bicrystals

Acta Met. 2 (1954) 80-86

Specimens were composed of two symmetrically oriented crystals having a longitudinal common axis The stress/strain relation in the initial region of plastic deformation was linear, this part of the curve was extrapolated back to zero strain to define a yield stress The yield stress and the rate of work hardening increased with increasing orientation difference between the crystals and the linear region of the stress/strain curve became shorter

(278) Cochardt, A. W.

Nickel-Chromium Base Alloys Hardened With Refractory Oxide Additions

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Nichrome powder was mixed with the powders of alumina, titania, or silica, the oxide content ranging from 0.5 to 5 per cent Stress-rupture properties at 1600 F and hardness values were determined. It was found that, in all cases, additions of an oxide decreased the time to rupture This observation appears to be due to the formation of void layers around the oxide particles A mechanism is suggested, according to which an incoherent particle does not strengthen the matrix alloy if the surface energy between particle and matrix is greater than the surface energy of the matrix itself

(279) Cochardt, A., Schoek, G , and Wiedersich, H.

Interaction Between Dislocations and Interstitial Atoms in Body-Centered Cubic Metals

Acta Met. 3 (1955) 533-537

Theory of Cottrell and Bilby on the locking of dislocations is extended It was found that carbon atoms near an edge dislocation are spread out over all angles below the slip plane and are concentrated in the neighborhood of the slip plane rather than at positions just below the dislocation. A method is given for calculating the interaction between interstitial atoms in a bcc lattice and edge and screw dislocations The saturated concentration of interstitials is almost 6 at % for both types of dislocaton. The presence of the atmosphere reduces the elastic energies by about 20% for a screw and 10% for an edge dislocation

(280) Coffin, F. D , and Weiman, A L

Surface Effects and the Creep of Zinc Single Crystals, 1 Creep Characteristics of Clean and Oxide-Coated Crystals

J Appl. Phy. 24 (1953) 282-289

The ratio of creep rates after and before acid addition was much greater for oxidized crystals than for clean ones and greater at small extensions than at large ones. The results suggest that the strengthening effect of oxide is due to its carrying a part of the load unless the film is cracked. The high strength of the film which this implies is attributed to absence of defects. The rate increase for clean crystals is attributed to chemically produced heat. A new empirical creep equation is reported.

(281) Colonnetti, G

Elastoplastic Equilibrium as a Function of Time (In French)

Compt. rend 233 (1951) 717-718

Extends the theory of elastoplastic deformations, varying with time, of homogeneous bodies to heterogeneous bodies, which are, by definition, characterized by the coexistence of elements with different coefficients of creep.

(282) Conrad, H

An Investigation of the Rate Controlling Mechanism for Plastic Flow of Copper Crystals at 90° and 170°K

Acta Met 6 (1958) 338-350

The plastic flow characteristics of Cu single crystals at 90 and 170 K were investigated by means of incremental loading creep tests and change-in-strain rate tension tests for the purpose of determining whether the intersection of dislocations is the rate controlling process in low temperature deformation. The present results indicate that although the nature of the stress function is similar to that predicted by the intersecting mechanism, i e , strain rate = C exp B $(\tau - \tau_G)$, the constant B is relatively independent of temperature rather than proportional to the reciprocal of the temperature as required by the theory. This represents a serious objection to the theory. An analysis of the present data along with the data of previous investigators indicates some agreement with a rate controlling mechanism based on the formation of thermal kinks in dislocations lying in close-packed directions. Several difficulties associated with the application of this mechanism to plastic flow are discussed.

(283) Conrad, H , and Robertson, W. D

Effect of Temperature on the Flow Stress and Strain-Hardening Coefficient of Magnesium Single Crystals

Trans AIME 209 (1957) 503-512

Determines stress-strain curves for magnesium single crystals by incremental tensile creep test in temperature range of 78 to 364 K Empirical expression derived for strain rate γ in terms of strain-hardening coefficient, $\frac{d\tau}{dg} = h$, $\dot{\gamma} = C\exp(-\Delta H/RT)\exp B(T - h\dot{\gamma})$, where C and B are constants. The limiting stress for macrocreep of magnesium single crystals (the initial yield stress) was found to increase linearly with reciprocal of absolute temperature from 78 to 364 K. The strain-hardening coefficient is constant from 78 to 203 K and is independent of prior strain history.

(284) Constant, A., and Delbart, G.

Basic Principles of a Creep-Resistant Alloy

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 191-214

Essential part played in the resistance to creep by fine precipitates of additional phases, and the importance of heat treatment by which the nature, size, and distribution of these precipitates can be controlled, with special reference to Cr-Mo-V steel.

(285) Cook, M., and Richards, T. L.

Fundamental Aspects of the Cold Working of Metals

J Inst Metals 78 (1951) 463-482

Nature of the metallic state and metallic cohesion in terms of the electron theory of metals. The various mechanisms involved in plastic deformation include crystallographic slip, twinning, and kinking, and a shear mechanism to which particular attention is drawn because of its importance in many metal fabrication processes. Influence of plastic deformation on structure with special reference to the development of preferred orientation. The effect of deformation on fine structure as revealed by X-ray diffraction and the relation of work hardening and plasticity to structural changes brought about by cold working.

(286) Cottrell, A. H.

Effect of Solute Atoms on the Behaviour of Dislocations

Paper from Report of a Conference on Strength of Solids, Phys Soc., London (1948) 30-36

Solute atoms differing in size from those of the solvent can relieve hydrostatic stresses in a crystal and will thus migrate to regions where they can relieve the most stress As a result they cluster around dislocations forming "atmospheres" similar to the ionic atmospheres of the Debye-Hückel theory The conditions of formation and properties of these atmospheres are explained mathematically, the theory is applied to problems of precipitation, creep, and yield point.

(287) Cottrell, A H

Theory of Dislocations

Chapter 2 from Progress in Metal Physics, 1, Edited by B Chalmers, Interscience Publishers, Inc., New York (1949) 77-126

Discusses types of dislocations, elementary properties, and their interactions with one another Segregations of solute atoms around dislocations and slip-band formation are also treated Structural strain hardening, aging and annealing of worked metals, and precipitation hardening are accounted for in terms of the dislocation theory Creep and the origin of dislocations are touched upon briefly

(288) Cottrell, A H

The Formation of Immobile Dislocations During Slip

Phil Mag 43 ser 7 (1952) 645-647

A new mechanism whereby dislocations on intersecting slip planes in a fcc lattice can react to form immobile dislocations is proposed, which is more effective than that suggested by Lomer [ibid , 42 (1951) 1327].

(289) Cottrell, A H

The Yield Point in Single Crystal and Polycrystalline Metals

Paper from L'Etat Solid Rept 9th Solvay Conf , Edited by R Stoops, Brussels (1952) 187 313

The experimental and theoretical considerations leading to the theory of impurity locking of dislocations as an explanation of the yield phenomenon are reviewed Some recent data on metal single crystals are included, Evidence is presented that the upper yield point is less than the stress needed to release an isolated locked dislocation. Yield is believed to start at points of stress concentration, and small amounts of plastic flow occur locally before yield The stress concentration factor drops as this local flow proceeds but eventually passes through a minimum Proper yield then takes place Recent work on the removal of C from effective solid solution in Fe as a consequence of strain aging (as estimated by internal friction measurements) is described In the discussion, J H Hollomon reports a failure to achieve a yield point in Fe single crystals, W Koster a similar failure for quenched and aged mild steel, and N P Allen for Fe containing very little C Cottrell replies by pointing out that dislocation locking is a necessary but not a sufficient condition for yield

(290) Cottrell, A H

The Time Laws of Creep

J. Mech and Phys Solids 1 (1952) 53-63

Many empirical laws have been developed to give the relation between creep strain and time in the early stages of creep. The theoretical basis for these formulas is discussed with particular reference to transient creep, and some new dislocation models which show good agreement with experiment are developed Andrade's $t^{1/3}$ law can be incorporated only if work hardening is taken into account

(291) Cottrell A H

The Strength of Metals

J Chem Met Mining Soc S Africa 53 (1952) 177-181

The problems of creep and brittle fracture are discussed, and explanations of the yield and strain aging of mild steel are given in terms of the movement of dislocations and presence of foreign atoms

(292) Cottrell, A H

A Note on the Portevin-Le Chatelier Effect

Phil Mag. 44 (1953) 829-832

Substitutional solute atoms in Al usually diffuse too slowly to cause appreciable strain aging at room temperature However, the concentration of vacancies is increased by plastic deformation or by quenching, the rate of diffusion may increase sufficiently to cause strain aging during plastic deformation. A serrated stress-strain curve should then result These ideas are used to explain the Portevin-le Chatelier effect

(293) Cottrell, A H

Dislocations and Plastic Flow in Crystals

Oxford University Press, England (1953) 223 pp

Includes chapters on interpretation of slip in crystals elastic properties of dislocations dislocations in crystals theories of the yield strength, and work hardening, annealing, and creep.

(294) Cottrell, A. H

Theory of Dislocations

Chapter 5 from Progress in Metal Physics, IV, Edited by B Chalmers, Interscience Publishers, Inc , New York (1953) 205 264

Progress in the theoretical and experimental study of crystal dislocations since Cottrell's previous review of the subject ibid , 1 (1949) 77 is comprehensively reviewed A new development, the Frank-Read source, shows that certain geometrical arrangements of dislocation lines are able to create large numbers of new dislocations by a process not involving kinetic energy The Kirkendall diffusion effect, polygonization, work hardening, and annealing may depend on the creation and absorption of vacant atomic sites at dislocations Advances have been made in the elastic theory of dislocations, including the distribution of dislocations in slip bands, the energies of small-angle crystal boundaries, the effects of interatomic forces on the widths and mobilities of dislocations, and effects relating to the interaction of dislocations with each other, with grain boundaries and other elastic singularities The examination of the forms of dislocations in various crystal lattices has led to the recognition of "imperfect" dislocations lining the boundaries of sheets of stacking fault in the lattices Imperfect dislocations are probably important in determining slip planes, in deformation twinning and work hardening Observations on cross-slip, multiple slip, deformation bands, and the fine structure of slip bands have suggested new views concerning work hardening. Parallel dislocations on intersecting slip planes may run together to form immobile dislocations Other matters discussed include the dynamics of moving dislocations the growth of deformation twins dislocations in crystal boundaries and in slip bands, obstruction of dislocations at grain boundaries , mechanical hysteresis in polycrystals, the theory of the yield point and strain aging, and work hardening, annealing, and creep

(295) Cottrell, A H

Interactions of Dislocations and Solute Atoms

Paper from Relation of Properties to Microstructure Am Soc Metal Cleveland (1954) 131-162

The elastic, electrical, chemical, and geometrical interactions between dislocations and solute atoms are discussed The effects of such interactions between stationary dislocations and moving atoms, dislocations and stationary atoms, and moving dislocations and moving atoms, respectively, are analyzed in relation to experimental evidence

(296) Cottrell, A. H

Creep and Ageing Effects in Solid Solutions

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 141 152

The effects of atomic migration during creep in causing recovery or strain aging are reviewed If recovery occurs during creep, the creep resistance is reduced, if strain aging occurs, it is increased. Aging in substitutional alloys is accelerated during plastic flow Dislocation theory is applied to the calculation of the minimum temperature for strain aging during creep, and the theory is used to analyze data on the creep and aging of Al-rich solid solutions. Precipitation during creep is shown to be more effective in reducing the rate of secondary creep than is precipitation before creep.

(297) Cottrell, A H

The Intersection of Gliding Screw Dislocations

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 509-512

When two systems of moving dislocations meet and intersect each other, the screw-screw interactions mostly produce interstitials, whereas experiments suggest vacancies are formed in practice by plastic deformation. Other processes may lead to the formation of point defects by slip.

(298) Cottrell, A H.

On Radiation- and Quench-Hardening in Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 577-579

A disagreement with Friedel is discussed Cottrell suggests that point defects become incorporated into the dislocations rather than form cavities on them The hardening is attributed to the jogs formed on the dislocations by the defects

(299) Cottrell, A H

Theory of Brittle Fracture in Steel and Similar Metals

Trans. AIME 212 (1958) 192-203

The following topics are treated: fracture and plastic deformation, theory of the yield point; the nucleation of cracks by slip, the ductile-brittle transition in unnotched tensile specimens, notch brittleness long cracks and service failures

(300) Cottrell, A H , and Aytekin, V

The Flow of Zinc Under Constant Stress

J Inst Metals 77 (1950) 389-422

A general study of the flow of single crystals of pure Zn, under constant shear stress and of polycrystalline specimens, under constant tensile stress, Flow of the single crystals occurred by slip, while that of polycrystalline specimens involved at least four processes slip, twinning, cell-formation, and displacement along grain boundaries The nature of steady-state flow in single crystals has been examined from the point of view of the recovery theory of creep. Application of the theory to the softening of strain-hardened crystals during annealing experiments leads to the conclusion that the yield strength should decrease according to a logarithmic time relation Measurements of the recovery of Zn crystals have given results consistent with this relation and the values of the parameters in the recovery equation agreed with those obtained from the creep experiments

(301) Cottrell, A H , and Aytekin, V

Andrade's Creep Law and the Flow of Zinc Crystals

Nature 160 (1947) 328-329

Several modifications were made in Andrade's law in order to extend the results to single crystals Single crystal wires of zinc were extended in creep, under constant resolved shear stress Shear strain on the glide planes in the glide direction is plotted against time of loading, and it is shown that the results fit an equation of the form $\gamma - \gamma_0 + t^{1/3} + Kt$, where γ is the total shear strain at time t and γ_0 is the instantaneous shear on loading The constants for this equation in six tests are tabulated, and it is shown that for one case in which K = O the plot of γ against $t^{1/3}$ is accurately linear as required by the equation

(302) Cottrell, A. H., and Bilby, B A

Dislocation Theory of Yielding and Strain Aging of Iron

Proc Phys Soc (London) 62A (1949) 49 62

A theory of yielding and strain aging of Fe, based on the segregation of C-atoms to form atmospheres around dislocations, is developed The form of an atmosphere is discussed and the force needed to release a dislocation from its atmosphere is roughly estimated and found to be reasonable

The dependence on temperature of the yield point is explained on the assumption that thermal fluctuations enable small dislocation loops to break away; these loops subsequently extend and cause yielding to develop catastrophically by helping other dislocations break away The predicted form of the relation between yield point and temperature agrees closely with experiment

Strain aging is interpreted as the migration of C atoms to free dislocations The rate of aging depends upon the concentration of C in solution and the estimated initial rate agrees with experiment on the assumption that about 0 003% C is present in solution

(303) Cottrell, A H., and Bilby, B A

A Mechanism for the Growth of Deformation Twins in Crystals

Phil. Mag 42 ser 7 (1951) 573-581

By extending the recent theory of slip bands, proposed by Frank and Read, it is shown that a dislocation can move steadily from plane to plane in a crystal A theory of mechanical twinning, which is formally analogous to Frank's theory of crystal growth, is developed

(304) Cottrell, A H , and Churchman, A. T

Change of Electrical Resistance During the Strain Aging of Iron

J Iron Steel Inst. 162 (1949) 271-276

On aging the change in hardness starts more slowly than the change in resistance Otherwise, the two changes are similar and are attributed to the same structural change in the Fe for which the activation energy is 16-22 cal/mol The activation energy for the diffusion of C and N in alpha Fe is about 20 cal/mol. The results are consistent with the theory that the yield point and strain aging of alpha Fe are due to the migration of C and N atoms to dislocations

(305) Cottrell, A H , and Gibbons, D. F.

Thermal Hardening of Cadmium Crystals

Nature 162 (1948) 488-489

No yield point was detected prior to plastic deformation in Cd single crystals grown in an atmosphere of A, contrary to the experience of C. L. Smith [Nature 160 (1947) 466]. The similarity between thermal hardening and the yield point of Fe is discussed in relation to Cottrell's explanation of the latter in terms of the force required to tear a dislocation away from a cloud of solute atoms which have taken up positions to relieve the stress around a dislocation.

(306) Cottrell, A. H , Hunter, S. C , and Nabarro, F R N

Electrical Interaction of a Dislocation and a Solute Atom

Phil Mag 44 ser 7 (1953) 1064-1067

The electrical interaction, E_1, to be expected between an edge dislocation and a charged solute atom is deduced from the Signer-Seitz approximation for the energy of an electron in an unstrained lattice. For the alloys of Cu with Zn, Ga, Ge, and As, E_1 is 1/3-1/6 of the corresponding elastic interaction.

(307) Cottrell, A H , and Jaswon, M. A

Distribution of Solute Atoms Around a Slow Dislocation

Proc Roy Soc (London) 199A (1949) 104-114

The factors determining the average velocities of solute atoms attracted to a dislocation are discussed, and an equation is set up for the concentration of solute around the dislocation. This leads to a symmetrical distribution of a Maxwell-Boltzmann type round a stationary dislocation In the case of a slowly moving dislocation the distribution is given a series solution in Mathieu functions, and the nonsymmetry of this distribution causes a force on the dislocation, opposing its motion This force is calculated and shown to increase linearly with the speed of the dislocation at low speeds, and a critical range exists above which the motion is unstable and the dislocation accelerates. The characteristics of the plastic flow below this critical range are compared with those of microcreep in Sn crystals and are shown to be similar Quantitative agreement can be obtained by assuming plausible values for the density of dislocations and the rate of diffusion of solute atoms in An, but the need for further experiments on microcreep is emphasized.

(308) Cottrell, A H , and Stokes, R J

Effects of Temperature on the Plastic Properties of Aluminium Crystals

Proc Roy Soc (London) 233A (1955) 17 34

By changing the temperature of deformation during tensile experiments on single crystals, it is possible to separate reversible changes of flow stress with temperature from irreversible ones It is proposed that, under the combined influence of stress and temperature, sessile dislocations at the heads of piled-up groups of dislocations become unlocked; the piled-up groups then partly collapse and many dislocations are released for slip. The reversible changes of flow stress are interpreted in terms of the intersection of dislocation lines.

(309) Couling, S. L , and Roberts, C. S.

Grain Boundary Deformation in Fine-Grained Electrolytic Magnesium

Trans AIME 209 (1957) 1252-1256

Grain-boundary displacements were measured after creep at various temperatures and stresses. High temperature grain-boundary deformation in polycrystalline Mg is a two-stage process involving alternate boundary shearing and migration. Increasing test temperatures and decreasing strain rates favor increased strain from boundary deformation. In the limiting case, it appears that all the deformation would be localized at the boundaries. A mechanism which explains the observations is the alternation of anelastic boundary shears with the capture of these shears when the boundaries migrate to new positions.

(310) Coulomb, P , and Friedel, J.

On the Formation of Cavities Along Dislocations

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 555-572

Conditions under which vacancies in supersaturation may precipitate to form cavities are studied theoretically. Spherical cavities will be the most stable and the most easily formed. The cavities will grow to a critical size depending on the temperature and will prevent the dislocations from climbing and gliding.

(311) Cox, H L., and Sopwith, D G.

Effect of Orientation on Crystal Strength

Proc. Phys. Soc (London) 49 (1937) 134-151

The effect of different criteria of failure in indicating the failure of polycrystalline specimens is investigated. If elastic failure of polycrystalline specimens is determined entirely by the maximum resolved shear stress developed locally, the ratio of the yield in torsion to the yield in tension should be 0 500; whereas, if elastic failure is determined by the complete yield of all the crystals of the specimen, the value of this ratio should be about 0 577.

(312) Cox, J. J , Horne, G. T , and Mehl, R. F

Slip, Twinning and Fracture in Single Crystals of Iron

Trans ASM 49 (1957) 118-131

The slip, twinning, and fracture characteristics of single crystals of decarburized mild steel have been investigated at temperatures from +392 to -321 F. A critical shear stress law was found to be a valid criterion for slip at all temperatures A critical resolved shear stress for twinning was found on {112} planes in <111> directions; however, the direction of the applied stress must be considered. A burst phenomenon was observed in twin formation and prior slip was found to prevent or inhibit twinning at low temperatures.

(313) Cracknell, A , and Petch, N. J.

Frictional Forces on Dislocation Arrays at the Lower Yield Point in Iron

Acta Met. 3 (1955) 186-189

The equation σ_1 yield point $= \sigma_0 + k^* l^{-1/2}$, which relates the lower yield point σ_1 yield point of polycrystalline iron with grain diameter l, has been confirmed Here k* and σ_0 are constants and it is suggested that σ_0 depends on part upon the frictional forces exerted by solute atoms and precipitates on the dislocation arrays that propagate the yield In agreement, it is found that σ_0 increases when the solute atom concentration is increased by nitriding or by subcritical quenching and there is a further increase on aging, followed by a decrease on over aging. A linear relationship is calculated between σ_0 and the concentration of carbon + nitrogen in solution, and this is confirmed by experimental measurements

(314) Craig, G. B , and Chalmers, B

Effects of Grain Boundaries on the Plastic Deformation of Zinc Crystals

Can J Phys 35 (1957) 38-47

Investigation of tensile plastic deformation of single-crystal and tricrystal specimens of zinc by analysis of the external change and of the change in X-ray diffraction pattern It was demonstrated that the single crystals deformed by slip on the basal plane, but pyramidal as well as basal slip occurred in specimens containing grain boundaries.

(315) Crussard, C.

Influence of the Grain Size of a Metal on the Creep Rate (In French)

Compt. rend. 219 (1941) 681-683

Some contradictions to behavior expected above the equicohesive temperature are discussed, viz., that in some cases specimens with a large grain size creep as fast, or faster, than a specimen with a fine grain size. Experiments prove, contrary to the classical ideas, that above the equicohesive temperature the minimum creep rate passes through a minimum.

(316) Crussard, C.

A Study of Slip in Aluminum Crystals (In French)

Rev mét 42 (1945) 286-294

The influence of the speed and temperature of deformation on slip is reported. Shock loading in tension has been used to study plastic behavior at high rates of strain. Distinction is drawn between two types of plastic deformation, one slow and progressive, and the other rapid and spasmodic. This distinction is justified from observations on the appearance of slip lines, irregularities in the stress-strain curves, roughening on the specimen during elongation, and the study of chemical reactivity. Work hardening and annealing were also studied, and it is shown that it is necessary to know the previous mechanical and thermal history of a specimen before its work-hardening capacity can be predicted. The function of the intercrystalline boundary was examined, and distinction is drawn between the viscous flow which occurs at the boundary and the plastic flow due to slip. It is possible to explain the form of stress-strain curves for polycrystalline specimens

(317) Crussard, C.

The Role of Intergranular Boundaries and the Deformation of Metals: Application to Creep and Fatigue (In French)

Rev. mét. 43 (1946) 307-316

Grain boundaries constitute an obstacle to the deformation of crystals, but at high temperatures they become a weakness. The transition temperature can be called the temperature of equicohesion, which was investigated in the case of Al, Zn, and Mg. The different types of creep were classified according to the value of the heat of activation. The following general conclusions were drawn: (1) in the annealed state there is no amorphous film at the grain boundaries, (2) for small stresses there is a type of microflow that gives rise to internal friction, and (3) beyond the limit of microflow appears ordinary flow with work hardening, which has both intergranular and transcrystalline origins. In the discussion, P. Laurent questioned whether there are two heats of activation and whether the transcrystalline origin of microflow is not a more logical theoretical consequence than the intercrystalline origin. He stated that subpermanent deformations are the external manifestation of the heterogeneity of internal tensions and do not exist for single crystals deformed by pure shear and commented on some of Crussard's conclusions on pure Al

(318) Crussard, C.

Creep and Fatigue as Affected by Grain Boundaries

Metal Treatment 14 (1947) 149-160

Discusses equicohesion, study and classification of small deformations, and fatigue. The classical method of defining the equicohesion temperature of metal is to compare the minimum creep rates in coarse- and fine-grained test pieces. When a creep test is carried out above the equicohesive temperature, the creep rate is greater for the fine-grained specimens. In the case of hexagonal metals, when there is no recrystallization, the X-ray diagram has the appearance of cold-worked metal. For cubic metals, if the grain size is fairly coarse, each grain gives rise to a number of fragments formed by blocks or crystallites of perfect structure. For very small loads, deformation known as microcreep gives rise to a peculiar type of internal friction. Creep in excess of this results in strain hardening.

(319) Crussard, C

The Creep of Glass at High Temperatures

Sheet Metal Inds 25 (1948) 2471-2474, 2484

Creep curves for glass are compared with those for metals. Creep recovery is less pronounced in the case of metals, while for glasses the deformation is almost irreversible. The constant rate increases proportionally with the load, whereas for metals the increase is exponential. Since the same form of curve is found for metals, plastics, and glasses, the reason for creep cannot be existence of a particular structure

(320) Crussard, C.

A Method of Exact Analysis of the Shape of Stress-Strain Curves. Application of the Role of Intergranular Boundaries and Impurities (In French)

Article from Some Recent Developments in Rheology, United Trade Press, Ltd., London (1950) 53-62

By a method of differential analysis, similar to that employed by Lacombe for the creep curve, the stress-strain curve can be characterized by the exponent, m, in the equation $\sigma = \sigma_0 + A\epsilon^m$, where σ is the stress and σ_0 and A are constants.

(321) Crussard, C

Relationship Between the Exact Shape of the Tensile Curve of Metals and the Simultaneous Modifications of Their Structure (In French)

Rev. mét. 50 (1953) 697-710

Observations are made on polycrystals and single crystals of various metals. Equations are developed for predicting the elongation at which necking begins. An exact analysis of the stress/strain curves is necessary to obtain precise information on cold working and the structural modifications that accompany it. These curves are parabolic and are here considered in the form $\sigma = \sigma_0 + a\epsilon^m$, where σ is the tensile stress, ε the true strain, and σ_0, a, and m are constant. New hypothesis on deformation bands is presented

(322) Crussard, C.

New Rheological Model of Creep (In French)

Rev. mét. 55 (1958) 375-382

The creep curves for various materials, notably metals, are made up of a decelerating "transient" part, which dies away progressively to be replaced by a stationary regime. A correct mathematical analysis shows that the curves of transient creep can be represented by a function of time which is sometimes logarithmic, but most often parabolic with an exponent varying from 0.2 to 0.75 (0.3-0.4 for many metals and 0.5 for glasses). A new "rheological" model is proposed comprising viscous "centers of creep" which interact elastically on each other. Application of a force to one of these centers causes the appearance of a transient order and a stationary regime. The calculations worked out in this paper show that the transient regime is represented by a summation of exponential terms, to which the observed parabolic laws provide a very close approximation

(323) Crussard, C., and Friedel, J

Theory of Accelerated Creep and Rupture

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 243-262

The facts concerning the phenomena observed during creep are discussed with respect to the form of creep-rupture diagrams and to the causes of instability in or near intergranular boundaries. Rupture occurs through the slow formation of intergranular microcracks resulting from the production of an excess of vacancies by movement of dislocations. In pure metals, boundary migration is assisted by such vacancies, but in most alloys where migration is difficult the vacancies cluster in the grain boundaries to produce a crack. The mechanism of the growth of microcracks is discussed in detail, and the interaction between vacancies and a crack and the effect of surface tension are considered. A new theory is proposed for the recovery process in alloys whose creep resistance is due to the presence of a precipitate

(324) Crussard, C., and Guinier, A.

Symposium on the Mosaic Structure of Metals (In French)

Rev mét. 46 (1949) 61-71

The existence of mosaic structure has been investigated by means of X-rays, micrography, diffusion, and a study of the mechanical and electrical properties. The X-ray study showed that an undeformed metallic grain is not formed of a coherent network, but that there are regions of cohesion with dimensions of at least 1000 A. Some metallic crystals have very small disorientation of their planes; others are divided into distinct little blocks, and others have nearly continuous curvatures. The mosaic structures revealed by micrography can be explained, not by the internal structure of the metal but by a periodicity of surface conditions. In slowly solidified metals there is a lamellar periodic distribution of defects about 1 μ apart. In recrystallized metals the structure is considerably confused. The imperfections met with in a metallic crystal are varied and depend essentially on the method of treatment of the metal. The mosaic grains may become more or less perfect, the degree of perfection increasing from a cast to a recrystallized metal. Thus, the origin of mosaic structure as far as the mosaic grains and lamellae are concerned depends on the conditions of growth, chance or a certain periodicity alone determines it. But for zones of defects the case is more complicated, and a number of theories have been put forward. These are briefly examined, but no conclusions as to the predominating factor can yet be drawn

(325) Crussard, C., Plateau, J., and Morillon, Y

The Mechanisms of Rupture in Metals (In French)

Paper from Deformation and Flow of Solids, Edited by R. Grammel, Springer-Verlag, Berlin (1956) 117-128

The question of whether the plastic deformation observed in the rupture of metals is its cause or its consequence, is discussed. Experimental techniques and the results of low-temperature rupture tests are described in terms of 4 stages.

(326) Cuff F B, Jr, and Grant, N J.

The Effect of Cold Work on the Creep-Rupture Properties of a Series of Simple 18-8 Stainless Steels

J Iron Steel Inst 186 (1957) 188

Six stainless steels were tested at 1100 and 1200 F, with cold work varying from 0 to 35%. A relationship was found among composition, M temperature, recrystallization temperature, and rupture life

(327) Cupp, C R., and Chalmers, B.

A Study of the Plastic Deformation of Copper Single Crystals

Acta Met. 2 (1954) 803-809

The crystals were tested in tension, using a "soft" machine, and the stress was increased stepwise in increments. A delay time, found between the beginning of each stress increment and the resumption of plastic strain, was dependent on the period at constant stress before the stress was increased. The effect is thus a type of yield point phenomenon. Crystals annealed first in H showed a higher critical resolved shear stress than identical crystals which were annealed only in vacuo. H atoms in solution may thus affect the slip mechanism. Sharply defined easy-glide regions were found for crystals orientated for single slip, but easy glide ended long before multiple slip would have been expected.

(328) Danilov, V N

Problem of the Nature of the Hardening and Softening of Plastically Deformed Metals. I (In Russian)

Zhur. Tekh. Fiz. 25 (1955) 916-921

Relationship between hardening and the coefficient of thermoelectromotive force and lattice distortion. Temperature of recrystallization determined by measuring the thermo-emf

(329) Danilov, V. N.

Softening of Metals Subjected to Plastic Deformation (In Russian)

Metalloved i Obrabotka Metal no. 6 (1957) 15-16

The effect of deformation was measured by application of a thermoelectromotive force whose coefficient bears a direct relationship to metal strength, and by measuring microhardness.

(330) Dash, W. C.

Observation of Dislocations in Silicon

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 57-58

A technique has been developed to decorate dislocations in Si so they are visually observable with an infrared image tube in conjunction with a microscope. Si single crystals were grown by drawing from the melt contained in a quartz crucible. These were then etched during a period of several hours or overnight in a mixture of nitric, hydrofluoric, and acetic acids to produce deep pits at the points of emergence of the dislocations

(331) Dash, W. C

Evidence of Dislocation Jogs in Deformed Silicon

J Appl Phy. 29 (1958) 705-709

Trails extending from dislocations in plastically deformed Si have been observed by decoration and also by an etching technique which develops channels on a {111} plane. The trails extending from screws tend to follow parallel <110> directions; those from mixed edge and screw dislocations are generally not crystallographic. Cusps occur where the trails are joined to the dislocations. A type of work hardening is found wherein trails from one turn of a Frank-Read spiral obstruct the motion of subsequent turns. Trails are sometimes segmented or zig-zag and appear to be composed of small discrete sections. Reversal of the direction of motion of a dislocation when the applied stress is removed is indicated by inversion of cusps. The main features of these trails can be accounted for on the basis of nonconservative motion of jogs which inject vacancies or interstitial atoms into their paths

(332) Davenport, C. C

Correlation of Creep and Relaxation Properties of Copper

J. Appl Mechanics 5 (1938) A55-60

Creep tests and relaxation tests were carried out in torsion on copper tubes, which permit a verification of the various theories proposed for a deduction of the relaxation characteristics from creep tests alone. It was found that the relaxation time actually observed lies between the two values calculated for this quantity on the basis of the strain-hardening and the time-hardening theories

(333) Davidenkov, N. N.

Resistance to Breaking and Cutting

Izvest. Akad Nauk S.S.S.R., Otdel Tekh Nauk (May 1951) 751-768

Author's reply to discussion by G. V Uzhik [ibid., November 1950] Various questions of strength and plasticity are discussed

(334) Davies, P J

Creep and Recovery of Zinc Crystals

Abs Dissert Univ Cambridge, No. 1954 (1951-52) 209

The transient component of the creep of Zn single crystals, after rapid straining, was found to obey Andrade's $t^{1/3}$ law. Recovery measurements were made by successive stressing of a strain-hardened crystal to just beyond its yield point, the recovery varied linearly with the initial hardening and obeyed in a log time law, in agreement with the theory of Kuhlmann, Masing, and Raffelsieper [Z Metallk 40 (1949) 241]. Recovery was extremely rapid in the initial stages and was not due to a dynamical cause. Recovery rate is influenced by the previous stress history of the crystal. A recovery theory of creep, analogous to that of reversible creep, associated with the Boltzmann superposition hypothesis, is developed. Transient creep of Zn crystals at room temperature can be interpreted as a recovery flow

(335) Davies, P W

Fracture in Creep

Bull Inst. Metals 4 (1957) 24-25

Derives an expression, similar to McLean's, for the stress to fracture at the transition between triple-point cracking and that due to cavity formation

(336) Davis, E A

Creep of Metals at High Temperature in Bending

J Appl Mechanics 5 (1938) A29-31

A theory for plastic bending and equations for the creep due to bending are developed. Results of test on a Cr-Ni alloy are given to show the agreement between experimental and theoretical results

(337) Davis, E A

Creep and Relaxation of Oxygen-Free Copper

Trans ASME 65 (1943) A-101 – A-105

This paper contains results of creep and relaxation tests on OFHC Cu at temperatures up to 235 C. The effect of stress and temperature upon the strain rate has been noted and an effort has been made to correlate the results of the two different types of tests by using various theories of plastic deformation

(338) Davis, E A.

A Generalized Deformation Law

J Appl Mechanics 15 (Trans ASME 70) (1948) 237-240

According to Hooke's law, the magnitude of infinitesimal elastic strains depends upon two independent constants. Equations are developed which express the magnitude and the distribution of the strains in terms of two independent functions of the stresses. The equations are easily adaptable to the relations between the strain rates and the stresses in combined stress-creep tests. The author believes that two independent functions are necessary and that behavior under a state of combined stress cannot be predicted from data obtained in pure-tension tests.

(339) Davis, M., and Thompson, N.

Creep in a Precipitation-Hardened Alloy

Proc Phys. Soc (London) 63B (1950) 847-860

Measurements were made of the creep shown by polycrystalline wires of a hardened alloy (Cu + 3% Ag) both at room temperature and 90 K. Results are interpreted in terms of the Mott-Nabarro theory of transient creep. Agreement between theory and experiment is qualitatively satisfactory

(340) Davis, R. S., Fleischer, R L., Livingston, J D., and Chalmers, B.

Effect on Orientation on the Plastic Deformation of Aluminum Single Crystals and Bicrystals

Trans AIME 209 (1957) 136-140

Tensile stress-strain curves reported. Isoaxial bicrystal specimens were used with one crystal rotated 45° about the stress axis with respect to the other. The axial orientations were chosen so that one, two, four, six, or eight slip systems were initially equally favored. The 45° grain boundary did not raise the stress-strain curve of the bicrystal above that of the corresponding single crystal if two or more slip planes were initially equally favored

(341) Dayal, B , and Purushothaman, C.

Equation of State of Solids

J. Chem. Phys. 24 (1956) 1257 (Letter)

The equation proposed is:

$$PV = -\frac{A\,mn}{9}\frac{\Delta V}{V_0}\left(1 - \frac{m+n+3}{6}\frac{\Delta V}{V_0}\right) + \bar{\gamma}E$$

where A is the heat of sublimation, m and n are exponents of Furth's power law, $\bar{\gamma}$ is the average Gruneisen's constant, E is the thermal energy, and P and V are the pressure and volume, respectively.

(342) de Bruyne, N A

Metals at High Temperatures

Aircraft Eng 15 (1943) 223-226

Published data on the strength of metals at high temperatures are examined in relation to expressions used by Andrade and by Dushman for flow and fracture at high temperatures. Where the strain energy becomes appreciable, a correcting term is necessary to allow for interaction between strain energy and activation energy. A relationship of the type suggested by Becker and previously used by the author in describing viscous flow is applied to results obtained by Martin [J Inst. Metals 31 (1924) 124] for the ultimate strength of Al at high temperatures. Results obtained by Dickinson [J Iron Steel Inst 106 (1922) 103] on a number of commercial steels at high temperatures are given, plotted in the form of the log of time to fracture at constant stress against the reciprocal of the absolute temperature; they show a linear relationship.

(343) de Courcel, M.

Creep (In French)

Mét Constr Méc 83 (1951) 847-849, 851-852

Brief outline of the phenomenon of creep in single crystals and polycrystalline metals, giving results of tests on pieces susceptible to creep.

(344) de Lacombe, M J

A Method of Representing Creep Curves (In French)

Rev. mét. 36 (1939) 178-188

Discusses previously proposed analytical expressions for representing creep curves. The equation offered by the author $c = c_0 + at^m + bt^n$, where c = total elongation, t = time, and c_0, a, b, m, and n are constants, fits a wide variety of creep curves, since one term represents decelerating creep, another accelerating creep.

(345) Dean, W R , and Wilson, A H.

A Note on the Theory of Dislocation in Metals

Proc. Cambridge Phil Soc 43 (1947) 205-212

A mathematical contribution to dislocation theory using a simple model of the Bragg type. An expression is derived for the energy of a pair of dislocations in terms of the distance between them. On simplification, this energy $E = \frac{\mu S^2}{\pi} \log t/R$, where μ is the appropriate elastic constant, S is the slip distance, t is the distance apart of the dislocations, R is the arbitrary radius of the transition region at the centre of each dislocation, which is excluded to avoid stress terms rising to infinity. An order of magnitude of E is derived on the basis of Bragg's work. By equating the total energies of dislocations to the maximum energy density that Taylor and Quinney found could be imparted to copper by cold work it was found that the number N of dislocations per unit length on an interface between two mosaic elements is 0.9×10^7. Bragg's estimate from a two-dimensional model is given as something in excess of 1.7×10^7.

(346) Dehlinger, U

On the Theory of the Recrystallization of Pure Metals (In German)

Ann Physik 2 (1929) 749-793

The capacity of a metal to recrystallize is attributed to internal stresses in the boundary layers between slip planes caused by deformation. The subject is treated mathematically by making extensive simplified assumptions, similar to those of Prandtl, as to the nature of the forces which a crystal lattice exerts on the atoms at its boundaries and as to the necessary amount of energy required to remove stress — i e , the increase of temperature required. These calculations show that below a certain temperature the heat is sufficient only rarely to remove the interlocking, and, thus, recrystallization is almost infinitely slow. At a certain temperature, however, all stress is spontaneously relieved. According to the calculations this temperature should be higher with an increase in the number of deformed lattices, whereas experiment shows that the greater the deformation the lower is the temperature of recrystallization. Hence, it is assumed that the number of interlocking lattices is not a function of the degree of deformation. Further explanation appears to be required as to the part played by these interlocked lattices in deformation and recrystallization

(347) Dehlinger, U.

Plastic Properties of Materials (In German)

Metallwirtschaft 20 no. 7 (1941) 159-162

The mechanism of plastic deformation of a metal single crystal is discussed, and it is shown how this is affected by lattice discontinuity, such as a mosaic structure, by speed of stressing, and by temperature. A comparison is made between single crystals made from the melt and by recrystallization. A review is made of research on these lines on polycrystalline material. Metals having fcc, bcc, and hcp lattices are considered.

(348) Dehlinger, U

The Stresses in the Flow of Polycrystalline Materials (In German)

Z tech. Physik 24 no. 5 (1943) 140-143

The decrease in surface stress (observed by X-ray methods in a steel rod) after the yield point in bending has been exceeded is explained quantitatively in terms of a slow after-flow occurring at constant extension. The relationship between the after-flow and latent elastic stresses produced during the primary flow, the behavior of the glide planes involved, and the effects of the grain boundaries are discussed in detail.

(349) Dehlinger, U

Glide in Metallic Single Crystals (In German)

Z Metallk 37 (1946) 11-17

The atomic mechanism of glide in single crystals and the interaction of slip and plastic deformation in polycrystalline plasticity

(350) Dehlinger, U

Contribution to the Theory of Dislocations (In German)

Paper from L'Etat Solide, Rept 9th Solvay Conf , Edited by R Stoops, Brussels (1952) 415-425

The variation of energy of a dislocation approaching a mosaic wall (subboundary of edge dislocations) is derived as a function of its distance and position relative to the individual dislocations constituting the wall. Over extensive regions there is an attractive force if the dislocations are of like sign. The problem of a dislocation penetrating such a wall was discussed by other contributors. A H. Cottrell suggested that a reasonably low activation energy is attainable if the crossing dislocation line is inclined at a large angle to those being crossed. F. C. Frank's concept of "mosaic structure" as consisting of a 3-dimensional dislocation network was supported by recent American data on X-ray line broadening.

(351) Dehlinger, U

On A Theory of the Upper Yield Point (In German)

Z Metallk 49 (1958) 416-418

A mathematical analysis of the distribution of plastic deformation over a sample shows that, for the ideal plastic medium, this distribution is not uniquely determined by the external load. Plastic deformation is rather propagated inhomogeneously from small small statistical fluctuations of the initial distribution, i.e , from nuclei of plastic deformation. The behavior of these nuclei and the origin of a lower and an upper yield point are discussed.

(352) Dehlinger, U., Diehl, J , and Meissner, J

Creep Law of Polycrystalline Metals (In German)

Z Naturforsch. 11a (1956) 37-41

General linear law of the speed of plastic deformation and relationship between stress and elongation. Experimental proofs by tension-torsion tests with arbitrary rotation of axis of the stress tensor.

(353) Dehlinger, U , and Kochendorfer, A

The Flow of Polycrystalline Metal (In German)

Z Elektrochem 49 (1943) 228-233

The flow of a liquid is compared with that of a solid, and the influence of crystalline arrangement discussed in detail. It is shown that the effect of the grain boundaries in polycrystalline material is to impose on each grain inhomogeneous forces, leading to increased resistance to glide. Unrestricted glide occurs when external forces overcome this resistance, and, for cubic metals, several glide planes are used. Hexagonal structures are also discussed, and the general problem of plastic deformation is considered in detail

(354) DeJong, J J

Factors Bearing on the Creep of Metals and Alloys (In Dutch)

Ingenieur 64 (1952) 0 92 0 101

A critical review is given of the effect of internal and external structural factors on the creep of metals such as effect of grain boundaries and grain-boundary segregation, structural changes of phases (the similar effect of carbide transformations on creep and on temper brittleness is especially emphasized), formation of phases from supersaturated solution, superficial and internal oxidation, and diffusion of other gases. The importance, as regards high creep resistance, of lattice deformations of high stability as arising from age-hardening, internal oxidation, and mechanical deformation is particularly stressed.

(355) Dekhtyar, I. Ya.

Problems of the Heat Resistance of Alloys (In Russian)

Doklady Akad Nauk S S S R New Ser 73 (1950) 303-305

Analyzes the above on the basis of electronic theory. Investigation of diffusion in alloys indicates that its probable mechanism is filling of vacancy centers in the lattice by the diffusing atoms. If this is the case, it is of fundamental importance to the mechanism of creep.

(356) Dekhtyar, I Ya.

Diffusion and Bonding in Metallic Alloys (In Russian)

Zhur Tekh. Fiz. 20 (1950) 1015-1024

Survey of data of the activation energy E of self-diffusion and of the bond energy W (identified with the heat of sublimation) for pure metals shows a proportionality E = kW. Within the limits of uncertainty, k ≈ 2/3 for fcc metals, and for the single example of α -Fe, k = 0.85 for a bcc metal. The constancy of k for the same type of crystal indicates a common mechanism of self-diffusion through lattice vacancies. k was estimated for binary fcc alloys from diffusion data and theoretical calculations and found to be close to 2/3.

(357) Dekhtyar, I. Ya.

Some Relationships Between Diffusion and Mechanical Properties of Metals (In Russian)

Doklady Akad Nauk S S S R 80 (1951) 875-878

An expression is derived on the basis of rate theory for the activation energy of creep, $E = E_a^o - (\sigma_1 v_a/2) \coth(\sigma_1 v_a/2RT)$, in which E_a^o is the activation energy in the absence of stress, σ_1 is the effective internal stress acting on the mobile atoms, and v_a is the volume/atom. In form this is analogous to the semiempirical expression obtained by Vitman, Zlatin, and Shestopalov [Sborn posvyashch. 70-letiye Akad. A F Ioffe (1950) 331] for Pb, Sn, Al, Cu, and Fe. When σ_1 is small, E_a^o is approximately equal to the activation energy of the self-diffusion process. Using the expression derived by Dekhtyar and the data obtained by Vitman, et al , values of σ_1 for various external stresses (σ) have been calculated, for each metal, $\sigma_1 \gg \sigma$. The accelerating or retarding action of third elements on diffusion processes in a binary alloy can be explained by the presence of an effective stress (compressive or tensile) σ, with which is associated an additional energy $|\Delta W| = 1/2\,\sigma_a$, so that if the addition of the third element results in a change in activation energy from E_a^o to E_a, then $E_a = E_a^o \pm 1/2\,\sigma v_a$. On plotting published values of σ against ΔE_a (= $E_a^o - E_a$) for the diffusion of Zn in Cu-Zn and Ag-Zn in the presence of various impurities, a linear relation was obtained

(358) Dekhtyar, I. Ya.

Interatomic Interaction in Alloys Based on Elements of Period IV of the Mendeleev Periodic System (In Russian)

Doklady Akad. Nauk S.S S. R. 85 (1952) 583-586

The interaction between s and d electrons is considered, and for alloys of the transition metals the bond energy/atom is $W_o = 0.795e^2n^2/R_o$ for fcc lattices, while the compressibility $k = 1.4 \times 10^{11}n^2$, where n is the number of electrons forming a bond and R the least distance between atoms. Calculated values of k for Cu, Ni, Co, Fe, and Ni-Cu, Ni-Co, Fe-Co, Fe-Ni, Fe-Pt, and Ni-Mn alloys are compared with values obtained experimentally. The differences that occur in some cases are attributed to the approximate method of calculation and to the treatment adopted neglecting some types of energy. However, some relation of the type $W_o = kn^2$ must hold. In these alloys specific bonds of the metallic type do exist.

(359) Dekhtyar, I. Ya

Role of the Defects of the Crystal Structure During Certain Processes in Metals (In Russian)

Problems in the Physics of Metals and Metal Science, Izd.-vo Akad Nauk Ukrain S S S R. Kiev (1956) 53-76

Basic properties of the metal are determined by the function of the distribution of atoms in the crystal lattice. Treats diffusion of vacancies under creep conditions

(360) Dekhtyar, I Ya

Effect of Defects of Crystalline Structure on the Failure of Metals (In Russian)

Prochnost Metallov, Akad. Nauk S S S.R. (1956) 27-35

Theoretical equations previously derived and experimentally confirmed are analyzed in support of the concept that the process of slip and ultimate rupture of metals is as much a function of crystallization defects as other properties such as change in electrical resistance, diffusion, etc. By taking into account defects of vacancies alone, by ignoring the nature of their origin, the equation $\Delta l_3 = \delta n_o (At + 0.5 Bt^2)$ derived for the third stage of deformation, immediately preceding rupture, when the rate of vacancy formation is greater than that of their removal, was confirmed experimentally; δ and n_o are the initial stress and the number of vacancies, respectively, and t is the time before rupture. The theoretical equation previously derived (loc. cit) related t to the energy of activation of a vacancy ϵ_o, the product or unordered atoms at the formation of a vacancy m and the latent heat of fusion L, and the temperature T at rupture. One of the corollaries of this equation indicates that ln t versus 1/T is linear up to 0.8-0.9 T_s = melting point). The value of mL, approximately equal to the energy of activation of self-diffusion E_a, can be experimentally obtained from this linear section of the curve and ϵ_o calculated from the parameter $Q_o = \epsilon_o + mL$, where Q_o is the energy of activation of the process of slip. From this $c_o \approx 0.4E_a = 0.27\,E_s$ and $Q_o = 0.94\,E_s$(E_s = energy of sublimation)

(361) Dekhtyar, I Ya , and Osipov, K A

Failure of Metals at High Temperatures (In Russian)

Doklady Akad Nauk S S S R 104 (1955) 229-232

The ideas stated previously by the authors are extended with the following assumptions: (1) the fracture zone is the region in which the crystal lattice loses its stability most quickly and approximates to the liquid phase at the melting point; (2) fracture of the metal is connected with the formation in this zone of a certain critical number of nuclei of the liquid phase; and (3) for fracture in some region it is sufficient to bring this region into a state analogous to fusion. These conditions will be most significant at high temperatures, when there is increased movement of atoms and holes. The concentration of nuclei can increase either by migration and coagulation or by the formation and growth of new nuclei, mathematical analysis shows that the first process can be neglected. The rate of accumulation of nuclei in the fracture zone under the action of a stress and the thermal motion is analyzed to give the time to failure. At large stresses the time to failure is expressed by

$$t_p = B \exp(Q_o/kT)\exp(-\alpha\sigma),$$

where Q is the activation to energy for slip ($Q_o \approx 1.35\,E_a$, where E_a is the activation energy for self-diffusion), and B and α are essentially constant.

(362) Dekhtyar, I Ya , and Paderno, V N.

The Rupture Parameters of Metals at High Temperatures (In Russian)

Izvest. Akad Nauk S.S.S R, no. 5 (1956) 144-147

Formulae are given which describe the rupture of metals. The relationship between the basic parameters of the yield process (the energies of hole formation and of activation of constant creep) satisfies the condition $\epsilon/mL \approx$ constant, where ε = energy necessary for vacancy-formation, m = number of displaced atoms during the formation of a hole, and L = latent heat of fusion.

(363) Deruyttere, A. E., and Greenough, G. B

Cleavage Fracture of Zinc Single Crystals

Nature 172 (1953) 170-171

In order to test the criterion for cleavage, Zn single crystals were broken at -196 C in a tensile testing machine. The applied tensile stress (σ) and the resolved component of the stress perpendicular to the cleavage plane (N), at fracture, is in each case plotted against the angle between the direction of applied stress and the cleavage plane. N is not constant, and this is unlikely to be due to nonaxial loading. It is possible that N is affected by the plastic deformation which occurs before fracture, but the results make it clear that the criterion for cleavage fracture is not always one of a critical normal stress

(364) Dervusgtabm, A.

The Stress-Hardness Relation

ASTM Bulletin No. 215 (July 1956) 71-75

A theoretical and experimental study of the stress-hardness relation is treated in this paper. The theoretical study is based essentially on the Herz-Huber theory, and it is assumed that yielding occurred when the shear stress reached a maximum. Some important results were deduced from this theoretical consideration. Special instruments were designed and built for investigating the stress-hardness relation. The experimental results showed that stress and hardness as defined in this paper have a linear relationship, and the possibilities of using this method for determining the stress in already built structures are intimated

(365) Deshpande, R. C.

Inhomogeneous Deformation in Polycrystalline Metals

Trans Indian Inst Metals 10 (1956-1957) 131-137

Specimens of commercial Al containing only a few grains were deformed in tension and microhardness determinations made within grains and near grain boundaries. Local deformations measured; elongations of different portions of each grain determined; elongation varies in different grains and deformation not uniform; tendency to conform in elongation at grain boundaries, and nearly minimum near junction of three grains.

(366) Diehl, J

Tensile Deformation of Single Crystals of Copper. I. Strain Hardening Curve and Surface Phenomena. II. Inhomogeneities in Elongation and the Reproducibility of the Strain Hardening Curve (In German)

Z Metallk 47 (1956) 331-343, 411-416

(I.) 99.98% Cu single crystals, having orientations spread over the whole of the stereographic triangle, were deformed at room temperature in a Polanyi-type tensile machine, and the strain-hardening curves determined; slip-line formation due to such deformation was also studied. The strain-hardening curves cannot be interpreted in terms of any simple single equation, they show three characteristic and different regions: a relatively flat initial portion, an appreciably steeper middle section, and a final portion that tends to be concave to the strain axis. The detailed shape of the curves, including the transition zones between the various portions, are dependent on crystal orientation. The slip lines on the surface are appreciably finer than those occurring on Al single crystals deformed under similar conditions, and, therefore, are more difficult to resolve with the optical microscope, however, they are of similar nature to those occurring in most fcc metals. The first part of the strain-hardening curve appears to be associated with easy glide, the second with the occurrence of slip on secondary-slip systems, and the third with a modification of the secondary-slip process by the occurrence of recovery phenomena. The results are discussed in relation to the dislocation theory of strain hardening. Strain-hardening curves for various short sections of the gage length of Cu single crystals show variations between one another which do not average out over the total gage length. These inhomogeneities of strain affect the reproducibility of the over-all curve, and indicate variations in the critical shear stress and other characteristics of the strain-hardening curve. These are due, primarily, to pronounced variations in the coefficient of strain hardening in the easy-glide region as a consequence of fluctuations in the lineage structure of the single crystals resulting from slight variations in conditions during their growth.

(367) Diehl, J., Mader, S., and Seeger, A.

Slip Mechanism and Surface Phenomena in Face-Centered Cubic Metals (In German)

Z. Metallk. 46 (1955) 650-657

The literature on the formation of slip bands, and the temperature-dependence of such formation in Al are reviewed, and it is shown how the phenomena can be explained in terms of double cross-slip. Determination of the strain-hardening curves of single crystals of Al, Cu, and Ni, with simultaneous electron-microscope studies (using C replicas) of the surfaces of the crystals, confirm the validity of the strain-hardening curve to be correlated with slip-band formation. In fcc metals, slip bands are produced by double cross-slip of locked screw-dislocations. The relatively flatter third or last portion of the curve is associated with cross-slip and slip-band formation. Detailed differences in the curves for the three metals are associated with the different activation energies necessary for cross-slip in each metal, i.e., the different energies necessary to dissociate a screw dislocation into two half-dislocations at room temperature. It is low in Al so that double cross-slip occurs readily at room temperature whereas in Cu and Ni it is high and cross-slip occurs only at high strains

(368) Dienes, G. J

A Theoretical Estimate of the Effect of Radiation on the Elastic Constants of Simple Metals

Phys Rev 86 (1952) 228-234

An approximate theoretical treatment of change in elastic constants of simple metals caused by the presence of a given small fraction of interstitial atoms and vacancies. Elastic constants are calculated from interatoms potentials employing a simple exponential function for Cu and a Morse function for Na

(369) Dietze, H.-D.

Dislocation Structures in Face-Centered Cubic Crystals – II (In German)

Z Physik 131 (1951-1952) 156-169

An improvement of the Peierls treatment, in which the atomic nature of the force across the glide plane is considered. The interatomic forces are not assumed to be central but to have a Gaussian spread defined by a parameter/s, an elastic continuum corresponds to s = O. Considers that s = half the Burgers vector. Using a perturbation method, the dislocation structures and the Peierls-Nabarro constraining force of the lattice (called an "elastic limit") are given for the dislocations discussed in (I). The dislocation structures are practically unchanged by the more elaborate treatment.

(370) Dietze, H. D.

Temperature Dependence of the Structure of a Dislocation (In German)

Z Physik 132 (1952) 107-110

The effect of thermal vibrations of the lattice on the Peierls model of an edge dislocation is calculated, assuming these are independent of internal stresses. The width of the dislocation is increased as the temperature is raised, thus decreasing the "Elastic Limit" (Peierls Nabarro force)

(371) Dollimore, D and Gregg, S. J

The Strength of Brittle Solids

Research 11 (1958) 180-184

Use the Griffith crack hypothesis to explain the lowered strength of a brittle solid in a vapor, on the basis of the swelling produced by sorption of the vapor, rather than in terms of the reduction in surface energy consequent on sorption.

(372) Donnell, L. H

Plastic Flow as an Unstable Process

J Appl Mechanics 9 (1942) A-91 – A 102

Instead of occurring simultaneously over regions which are apparently uniformly stressed, plastic flow frequently proceeds in a discontinuous manner, as in the formation of wedge shaped plastic regions around the periphery of torsion specimens. This phenomenon is explained as an instability, brought about by stress concentrations which are caused by the discontinuous behavior of the material near the yield point

(373) Dorn, J E

The Effect of Stress State on the Fracture Strength of Metals

Paper from Fracturing of Metals Am Soc Metals, Cleveland (1948) 32-50

Attempts to correlate some of the existing knowledge on fracture of metals in order to ascertain what stress functions dictate the conditions for fracture. Data from various researches showing the effects of different stress and strain histories.

(374) Dorn J E.

Fracture of Ductile Metals

Iron Age 164 (July 7 1949) 90-95, 100

Influence of temperature, strain, and combined stresses on fracturing. Emphasizes need for more comprehensive data on rate of growth of microcracks

(375) Dorn, J E

Stress-Strain Rate Relations for Anisotropic Plastic Flow

J. Appl. Phy. 20 (1949) 15-20

A simple theory for stress-strain rate analyses during plastic flow of anisotropic sheet metals is proposed for the work-hardening range. The effect of orientation on yield strength in simple and biaxial tension is discussed for various types of symmetry. The theory appears to be approximately correct for mild steel plates that exhibit planar isotropy

(376) Dorn, J E

Some Fundamental Experiments on High Temperature Creep

J. Mech and Phys. Solids 3 (1955) 85-116

Theoretical analysis of published experimental data. Graphs, micrographs, tables, X-ray diffractograms. A critical analysis is made of published and unpublished high temperature creep data. High-temperature creep is given by $\epsilon = f(\theta)$ at constant stress (σ), where ϵ = creep strain, $\theta = t\exp(\Delta H/RT)$, t = duration of test, and ΔH = activation energy. Grain-boundary shearing obeys a similar relationship and has the same value of ΔH, which approximates to that for self-diffusion. Stress enters the equation, not as a function σ/T but as σ. It is suggested that creep is not due to thermal activation of dislocations over a barrier, but rather that it occurs as a result of the climb of dislocations by a self-diffusion process. After an appropriate decrease in stress the new creep rate is given by $d\epsilon/dt = S\exp(-\Delta H/RT)\,G(\sigma)$ at high stresses $G(\sigma) \simeq \sigma^n$ at low stresses. Transient phenomena encountered during loading or unloading further suggest that high-temperature creep is a dislocation-climb process

(377) Dorn, J E.

Some Fundamental Experiments on High Temperature Creep

Paper from Creep and Fracture of Metals at High Temperatures Her Majesty's Stationery Office London (1956) 89-133

At high temperatures, the creep strain, ε, appears to be a function, θ, of temperature, T, compensated time, t, namely $\theta = t\exp[-\Delta H/RT]$ and the stress. X-ray analyses and plastic properties reveal that the same structures are developed at the same values of θ following creep at the same stress. Thus, $\epsilon = f(t\exp[-\Delta H/RT])$ for the same stress. When the creep rate, $\dot{\epsilon}$, is evaluated as a function of stress σ, for the same structure $\dot{\epsilon} = S\exp[-\Delta H/RT]\,f(\sigma)$ where S depends on the structure and $S\,f(\sigma)$

$S\exp(B\sigma)$ $B\sigma \geq 1.1$

$S'\sigma^n$ $B\sigma \leq 1.1$

Although B and n appear to be insensitive to structural changes attending creep of annealed alloys, they decrease with increasing solute additions and cold working. Transients attending loading and unloading and the coincidence of the activation energy for creep, ΔH, with that for self-diffusion suggest that high-temperature creep might be ascribed to a dislocation climb process.

(378) Dorn, J. E

Spectrum of Activation Energies for Creep

Paper from Creep and Recovery, Am Soc Metals, Cleveland, (1957) 255-283

It is assumed that creep is a single, thermally activated process and the activation energies (ΔH) for creep of Cu and Al are calculated. ΔH is insensitive to stress and strain and of the preceding temperature-strain-time history. For Al, ΔH is constant from 500 K to the melting point, but in other temperature ranges different values of ΔH suggest that other creep processes occur and that existing theories of creep are inapplicable. For high-temperature creep, ΔH is the same for single crystals and polycrystalline aggregates and equal to ΔH for grain-boundary shearing. For Al alloys, ΔH is insensitive to small alloying additions or dispersions of intermediate phases. Generally ΔH = activation energy of self-diffusion. The effect of substructures and stress on creep rate is discussed

(379) Dorn, J E

A Survey of Recent Results on Experimental Determinations of Activation Energies for Creep

Paper from High Temperature Materials, Their Strength Potentials and Limitations, Fourth Sagamore Ordnance Materials Research Conference (1957) 30-63

Creep is defined as the time-dependent plastic deformation of materials under a constant stress. It takes place only when thermal fluctuations are sufficiently great to initiate activation of deformation, recovery or recrystallization mechanisms. Consequently, the creep rate depends on the stress and the temperature. At temperatures approaching the melting point and over a range of very low stresses the creep process is somewhat analogous to viscous flow of Newtonian liquids insofar as the creep rate is proportional to the applied stress and the activation energy approximates that for self-diffusion. But for higher stresses and over the entire range of temperatures so far investigated the creep rate increases much more rapidly than linearly with the stress. Furthermore the creep rate usually changes systematically with time under test. Inasmuch as the external variables of stress and temperature are held constant during any one test, the time-dependent changes in the observed creep rate must be attributed to changes that take place in the metal substructure during the course of creep. This report consists of a review of results that have already been published, followed by a brief survey of more recent and as yet unpublished data on activation energies for creep.

(380) Dorn, J E, Goldberg, A, and Tietz, T E.

The Effect of Thermal-Mechanical History on the Strain Hardening of Metals

Trans AIME 180 (1949) 205-224

An experimental investigation was conducted using commercially pure Al as the principal test material and high-purity Al, brass, Cu, and stainless steel for additional tests. Work was done between 292 and 78 K. The data show that flow stress for plastic deformation is dependent on the entire thermal-mechanical history. The mechanical equation of state for 25-0 Al gives results deviating as much as 35 % from the experimental data. Failure to conform to mechanical equation of state suggests an extensive study into recovery, strain aging, and mechanism of deformation. (1) Flow stress of plastic deformation is also a function of previous thermal-mechanical history of deformation. (2) At lower test temperatures higher work hardened states are obtained for the same total strains. (3) Simple history-modified strains do not yield equivalent work-hardened states. (4) Failure of the mechanical equation of state is perhaps partly due to a relaxation phenomenon of low activation energy which can proceed at low temperatures and high strain rates

(381) Dorn, J E., Pietrokowsky P, and Tietz, T E

The Effect of Alloying Elements on the Plastic Properties of Aluminum Alloys

Trans AIME 188 (1950) 933-943

Results of an extensive investigation of plastic properties of binary Al alloys in an attempt to clarify the general problem of solid-solution hardening. Effects of grain size, test temperatures, and alloying elements on true stress versus strain curves are shown. Al appears to contribute about 2 electrons per atom toward the metallic bond in its alloys. The flow stress is shown to be a simple function of lattice strain and average valence.

(382) Dorn, J E, and Shepard, L A

What We Need to Know About Creep

ASTM Symposium on Effect of Cyclic Heating and Stressing on Metals at Elevated Temperatures (1954) 3-28

Instead of attempting ideal creep tests which must exactly reproduce service conditions, the use of four high-temperature creep laws is proposed. These apply at temperatures above half the absolute melting point when recovery is rapid. The first law is based on evidence that for the same stress identical structures are produced at similar values of total strain, irrespective of temperature and time. Total strain, ε, is a function of σc, the constant stress, and θ, such that $\theta = \int_0^t e^{-\Delta H/RT}\,dt$, where ΔH = activation energy for creep and t = time. When the temperature is constant, $\theta = te^{-\Delta H/RT}$. The second law states that the activation energy for creep equals the activation energy for self-diffusion. ΔH can be obtained from two creep tests on a material at similar stress and temperatures, T_1 and T_2. To predict long-term creep at a lower temperature, T_3, for the same load, it is merely necessary to calculate $te^{-\Delta H/RT_3}$. Creep under varying temperatures can also be predicted. The third law relates to the effect of stress on creep rate, $\dot{\epsilon}$, and is given as $\dot{\epsilon} = S(\theta, \sigma c)\ e^{-\Delta H/RT}\,\phi(\sigma)$, where $\phi(\sigma)$ is the stress function and S is a parameter depending upon the metallurgical structure. The fourth law concerns the effect of structure on creep rate and is not yet fully formulated. It is shown that a high activation energy for creep promotes high creep resistance and that the elements with this property lie near the centers of the Transition Periods. W, Mo, and V have the greatest creep-resisting potentialities. These laws cannot be applied directly to precipitation-hardening systems because of the structural alterations during the test

(383) Dorn, J E., and Shephard, L.

Role of Subgrains in Creep

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The genesis of subgrains includes a study of single crystals, slip bands, deformation bands, kink bands and folds, role of polygonization, and the role of grain boundary shearing. The effect of these factors on subgrain structure was studied: strain, stress, temperature, temperature-compensated time, influence of stress changes, steady-state structures, and subgrains produced at low-creep stresses

(384) Dorn, J E, and Starr, C D.

Effect of Dispersions on Mechanical Properties

Paper from Relation of Properties to Microstructure, Am Soc Metals, Cleveland (1954) 71-94

Existing knowledge on the dependence of mechanical properties on dispersion in polyphase alloys is reviewed. Precipitation hardening is excluded. Deformation processes occurring in alloys composed of several ductile phases viewed as simple extension of processes that occur in single-phase polycrystalline aggregates. It is concluded that it is not possible to predict the mechanical properties of alloys containing two or more ductile phases. The plastic properties of alloys containing a hard intermetallic phase embedded in a ductile matrix depend upon the mean distance between the hard particles. Except when the brittle phase is continuous, the type of dispersion (lamellar or spheroidal) has little effect on strain hardening

(385) Dorn, J E, and Thomsen, E. G

The Ductility of Metals Under General Conditions of Stress and Strain

Trans ASM 39 (1947) 741-772

A review of theoretical treatments of the ductility and fracture of metals. The proposed criteria of failure are discussed in view of recent experimental results and applied to particularized stress systems assuming homogeneous isotropic material

(386) Drucker, D C

A Reconsideration of the Deformation Theories of Plasticity

Trans ASME 71 (1949) 587-592

Deformation theories of plasticity for strain-hardening materials are defined as those which postulate that the components of elastic and permanent strain are completely determined by the existing components of stress. The assumption is made that there is some criterion, in terms of stress, for loading or increase in plastic deformation. It is shown that, no matter what the loading criterion, these deformation theories of plasticity lead to the unacceptable conclusion that large (finite) shapes in the components of permanent strain may accompany infinitesimal increases in loading despite strain hardening. It is demonstrated that an incremental theory eliminates this undesirable feature

(387) Dugdale, D. S

Vickers Hardness and Compressive Strength

J Mech. and Phys Solids 6 (1958) 85-91

Hardness and compression tests reported for steels, Cu, brasses, Al, Pb, cast iron, and nylon. A simple empirical method for relating hardness to stress-strain curves is suggested. The correlation obtained leads to the conclusion that the Vicker's test is not at all sensitive to yield strengths corresponding to compressive strains >0.15. Concludes that indentation hardness evidently represents some kind of average of yield strength taken over a certain range of strains

(388) Dumbleton, M J, and Howlett, B W

Yield Points in Bending Experiments on Zinc Crystals

Proc Phys Soc (London) 65B (1952) 882-886

Yield points can be observed in unstrained Zn crystals by means of a bend test when this is arranged so that premature overstraining of specimen due to stress concentrations from grips, nonaxial loading, and handling, are avoided. Concludes that previous plastic deformation is not essential to appearance of a sharp yield in Zn crystals, and that failure to observe initial sharp yielding in tensile tests is due to limitations of experimental technique

(389) Dunn, C G, and Aust, K T

Dislocation Energy as a Driving Force for Boundary Migration

Acta Met. 5 (1957) 368-370

A bicrystal sheet specimen of Fe-Si was cold-rolled and then annealed for various time intervals. The grain boundary initially moved away from its center of curvature, but with continued annealing the direction of boundary migration was reversed. An estimate of 42,000 $ergs/cm^3$ was obtained for the difference in free-energy density across the boundary when the net driving force was zero. The above estimate, together with the measured difference in dislocation density across the boundary, gave a value of 14×10^{-4} ergs/cm for the energy of a single dislocation, which is in agreement with values reported in the literature. The results suggest a suitable method of experimentally determining the variation of energy of a single dislocation with density and distribution of dislocations.

(390) Dunn, C G, and Koch, E. F

Comparison of Dislocation Densities of Primary and Secondary Recrystallization Grains of Si-Fe

Acta Met. 5 (1957) 548-554

Single crystals of Fe-Si were cold rolled and annealed to obtain both primary and secondary recrystallization structures. The dislocation densities of the primary and secondary recrystallization grains were measured by an etch-pit method, which also disclosed considerable variation in etch-pit density. The average dislocation densities were 2×10^7 $lines/cm^2$ for primaries and 2×10^6 $lines/cm^2$ for secondaries, which indicates that primaries on the average are less perfect than secondaries. The effects of the observed difference in dislocation density on the driving force for growth in the initial and also in the later stages of secondary recrystallization were considered. The difference in dislocation density contributed approximately 8% to the driving force of a large secondary in the Si-Fe studied

(391) Dushman, S.

Cohesion and Atomic Structure

Proc ASTM 29 (1929) 7-64

There exists a relationship between at least four cohesional properties of the elements and electronic configurations of the atoms. The crystal structure of pure metals also shows a similar connection with electronic arrangement and cohesional forces

(392) Dushman, S., Dunbar, L W., and Huthsteiner, H.

Creep of Metals

J Appl Phy 15 (1944) 108-124

Results with wires of Al, Al-Mg, Pt, Ni-Mo, and Ag are described. Data from the literature are included for polycrystalline Pb and Sn, and for single-crystal Sn and Cd. The data are analyzed with reference to a theory of steady-state creep in terms of absolute reaction rates. Large negative entropies found

(393) Dwight A E

Allotropic Transformations in Titanium, Zirconium, and Uranium Alloys

Trans AIME 206 (1956) 162-163

Plot of Q_β versus atomic number shows periodic behavior. Q_β (heat of reaction) is obtained from the equation

$$\ln \frac{x_\alpha}{x_\beta} = \frac{-Q_\beta}{RT}$$

where x_α and x_β refer to the at % solute which can be held in solution at equilibrium in the α and β phases, respectively, at temperature T. Values were calculated at either 1073 or 1273 K and it was found that the α-stabilizers have $Q_\beta < 0$ while the β stabilizers have $Q_\beta > 0$

(394) Dragunova, I S, Zakharov, M V, and Sirota, N N

Comparing Young's Modulus With Other Mechanical Characteristics of Aluminum Alloys at Various Temperatures (In Russian)

Izvest Akad Nauk S S S R Otdel Tekh Nauk 2 (1957) 120-122

A definite relationship between the characteristics of heat resistance of alloys and Young's modulus observed at elevated temperatures (about 0.5 Tm). The greater the Young's modulus, the greater the heat resistance of alloys, therefore, the resonance method of determining Young's modulus may be applied to qualitative evaluation of the heat resistance of alloys

(395) Eborall, R

An Approach to the Problem of Intercrystalline Fracture

Proc N P L Symposium on Creep and Fracture of Metals at High Temperatures Her Majesty's Stationery Office, London (1956) 229-241

The properties of grain boundaries affecting the fracture of single-phase metals are discussed, and it is shown how large improvements in the fracture characteristics can sometimes be achieved by adding elements of high melting point and unfavorable size factor. It is concluded that the intercrystalline behavior may be affected by viscous sliding of the boundaries, by the fracture process itself, and by the hardness of the crystals

(396) Eckart C

The Thermodynamics of Irreversible Processes IV The Theory of Elasticity and Anelasticity

Phys Rev 73 (1948) 373-382

The traditional theory of the solid state is said to rest on two false assumptions. One is the principle of a constant relaxed (or standard) state. The other is the principle of relaxability-in-the-large, first formulated mathematically by DeSaint-Venant. It is shown that a principle of relaxability-in-the-small is sufficient for the geometry of strain — which then becomes a 3-dimensional Riemannian geometry. The kinematics of strain is next developed without introducing the principle of a constant relaxed state. A classical theory of anelasticity is established on this basis. The results are used to derive the equations for the waves of distortion and dilation in an ideal isotropic anelastic medium

(397) Edelman F and Drucker D C

Some Extensions of Elementary Plasticity Theory

J Franklin Inst 251 (1951) 581-605

Detailed investigation of yield or loading criteria for work-hardening materials, which lead to constant strain ratios under increasing stress when stress ratios are maintained constant. A choice of incremental stress-strain theories is offered with which results of simple or complicated combined loading tests may be correlated. Loading functions of isotropic as well as anisotropic types. Predicted results of some basic tests for several loading criteria

(398) Eder F X

Entropy and Strain Hardening (In German)

Arbeitstag Festkörperphysik II (1955) 41-44

A thermodynamic discussion of the Frank-Read dislocation theory shows that only 5% of the work done in producing dislocations in Al becomes latent in displaced centers; this agrees with the value of 3% found by Welber [(J Appl Phy 23 (1952) 876)]. The amount increases slowly with increase of the degree of deformation

(399) Edwards, C A, Phillips, D L, and Liu, Y H

The Yield Point in Steel

J Iron Steel Inst 147 (1943) 145P-172P

Some of the explanations which have been offered to account for the phenomena of the "upper" and "lower" yield points in mild steel during tensile testing have been examined. It is confirmed that the behavior of mild steel in this respect is an intrinsic property of the material, and is not due to the inertia of the testing equipment. It is also confirmed that the value of the yield stress is affected by the rate of loading. No support has been obtained for the hypothesis that the yield point is due to some kind of retardation in the ability of the metal to react to increasing stresses, if insufficient time is given for plastic deformation to be initiated, and that no yield point would be shown in mild steel if extremely slow rates of loading were used. The yield point in mild steel can no longer be attributed solely to the bcc lattice structure, since similar kinds of yield points have been found with alloys in which the solvent metals possess the fcc. It is believed that when a yield point is obtained it is associated with the presence in the metal of an element which is more soluble at high than at low temperatures, and with a treatment which causes this element to be precipitated on certain planes of slip within the crystals

(400) Edwards, E H, and Washburn, J

Strain Hardening of Latent Slip Systems in Zinc Crystals

Trans. AIME 200 (1954) 1239-1242

Zinc crystals were deformed in simple shear and it was found that anisotropic strain hardening occurred in which the inactive slip systems were hardened more than the active system. The formation of dislocation barriers by dislocation interaction was discussed as a possible explanation of hardening of the latent systems

(401) Edwards, E H, and Washburn, J, and Parker, E. R

Some Observations on the Work Hardening of Metals

Trans. AIME 197 (1953) 1525-1529

Single crystals of Cd, Cu, and Zn were tested in simple shear at -196 and +25 C, and the effects accompanying the stress-induced movement of dislocation boundaries were observed. The results lead to the following conclusions on the nature of work hardening: (1) some of the dislocations moving through a crystal during slip become piled-up against barriers, (2) duplex slip in single crystals and the more complex deformation in polycrystalline specimens are accompanied by a progressive formation of dislocation boundaries, these subboundaries act as the barriers mentioned above, and (3) the stress-induced movement of dislocation boundaries leads to merging of adjacent boundaries, creating boundaries of large angular magnitude, with resultant increases in their effectiveness for blocking movement of active dislocations

(402) Eisner, R.

Bending Creep of "Duplex" Zinc Single Crystals

Acta Met 2 (1954) 642-643

Zn single crystals were grown from the melt so that two separate crystals branched from a common seed and grew side by side. The crystals were creep tested under constant uniform bending moments up to three times the elastic limit. The curves were of the type $\eta = bt^m$, where η is the plastic shear strain at the tension surface, t the time in minutes, m varied from 0.20 to 0.32, and b was a function of the specimen's history and of the applied bending moment. Experiments on duplex pairs (using one crystal as a "control") were made to investigate the effects of stress reversal, etching, and electropolishing. The close similarity between the two crystals of a duplex pair was a consequence of the identical growth conditions, since this similarity did not exist between several pairs grown from the same seed

(403) Elliott, H A.

An Analysis of the Conditions for Rupture Due to Griffith Cracks

Proc. Phys Soc (London) 59 (1947) 208-223

The Griffith crack theory is extended by means of a more detailed consideration of the interatomic forces which resist the spread of a crack. Agreement is found with the experimental results of Griffith

(404) Elliot, H A

Stress Rupture in Glass (Letter)

J Appl Phy 29 (1958) 224

Effect of air on fracture in glass assumed to depend on diffusion of contaminant to the root of the crack. Uses $c = A \log t + B$ where c = crack length at time t, A and B = constants, and $1/F = kc^{1/2}$ (Griffith criterion) to get $1/F^2 = A_o \log t + B_o$, where F = applied stress, t = time to fracture, and A_o and B_o are constants. Good agreement with data obtained

(405) Ellis, W C, and Greiner, E. S.

Effect of Prior Strain at Low Temperatures on the Properties of Some Close-Packed Metals at Room Temperature

Trans AIME 194 (1952) 648-650

As temperature of deformation is lowered, flow strength and ultimate strength of a number of metals and alloys at room temperature are increased. Likewise, in materials in which lattice scattering predominates, electrical conductivity is decreased to a greater degree as temperature of deformation is lowered. Data for a number of commercial metals and alloys rolled at -195 C, illustrate the increase in strength properties that may be obtained by such treatment

(406) Engelhardt, W

Changes in the Concept of Permanent Deformation (In German)

Metall 6 (1952) 762-764

Brief review of the changes which have occurred during the last 30 years in the concept of crystal plasticity. The original purely mechanistic theory of deformation began to be superseded in 1925 by the Becker-Orowan theory — based on thermodynamics and statistics — and this was supplemented later by the concept of dislocations. Recent work on "spontaneous elongation", however, has necessitated a further alteration to theory, the statistical idea is retained, but the plastic flow is considered as a process combining a purely mechanical component with a thermal component.

(407) Epstein, B

Statistical Aspects of Fracture Problems

J Appl Phy 19 (1948) 140-147

Statistical theories of strength usually try to explain dependence of strength on specimen volume or length. Author attempts to give the general statistical viewpoint in order to eliminate faulty or wasteful efforts.

(408) Erdmann-Jesnitzer, F

Structure and Energy at Grain Boundaries of Metals (In Czech)

Hutnické listy 11 (1956) 424-433

Outlines electron theory of mutual action of the matrix and of foreign atoms in iron and steel

(409) Eshelby, J D

Uniformly Moving Dislocations

Proc. Phys. Soc. (London) 62A (1949) 307

An expression is derived for the displacements in an isotropic elastic medium that contains an edge dislocation moving with uniform velocity. The energy density in the medium becomes infinite as the velocity of movement approaches the velocity of shear waves. This velocity therefore sets a limit beyond which the dislocation cannot be accelerated by applied stresses. The atomic structure of the medium is next partly taken into account, following the method already used by Peierls and Nabarro for the stationary dislocation. The atomic structure is neglected only within a region that extends not more than a few atomic distances from the center. The method is also applied to a screw dislocation

(410) Eshelby, J D

The Equation of Motion of a Dislocation

Phys Rev 90 (1953) 248-255

The elastic field surrounding an arbitrarily moving screw dislocation is found, and a useful analogy with 2-dimensional electromagnetic fields is pointed out. Results are applied to a screw dislocation accelerating from rest and approaching the velocity of sound asymptotically. Applied stress needed to maintain this motion is found on the assumption that the Peierls conditions is satisfied near the center of the dislocation. General integral equation of motion is derived for a simplified dislocation model

(411) Eshelby, J D

The Elastic Interaction of Point Defects

Acta Met 3 (1955) 487-490

Summarizes the known results for interaction when they are idealized as centers of dilation in an isotropic elastic continuum and extends them to the case of cubic anisotropy

(412) Eshelby, J D

Scope and Limitations of the Continuous Approach

Paper from Symposium on Internal Strains and Fatigue in Metals, GM Research Lab Detroit, Michigan (September 1958)

In calculations relating to defects in a crystal lattice the solid-state physicist draws largely on continuous concepts familiar to the engineer Some topics relating to the two points of view are considered By way of the theory of continuous distributions of dislocations microscopic internal stresses may be traced to the lattice defects which are their source. A simple method for calculating the stresses in and around precipitations and transformed regions is outlined, in some cases it may be useful in dealing with the interactions between stresses on a microscopic scale Generally, however, such interactions have to be discussed in terms of energy changes

(413) Eshelby, J D., and Pratt, P L.

Note on the Heating Effect of Moving Dislocations

Acta Met 4 (1956) 560-562

It seems improbable that there can be appreciable local heating near the glide-plane, except perhaps at very high rates of loading

(414) Eshelby, J D., and Nabarro, F R N.

The Equilibrium of Linear Arrays of Dislocations

Phil Mag. 42 ser 7 (1951) 351-364

A method for finding the equilibrium positions of a set of like dislocations in a common slip plane under the influence of a given applied stress The case of a set of free dislocations piled up against a fixed dislocation by a constant applied stress is discussed in detail and the resulting stress distribution is compared with that produced by a crack with freely slipping surfaces

(415) Eyring, H

Viscosity, Plasticity, and Diffusion as Examples of Absolute Reaction Rates

J Chem Phys 4 (1936) 283-293

Since to form a hole the size of a molecule in a liquid requires almost the same increase in free energy as to vaporize a molecule, the concentration of vapor above the liquid is a measure of such "molecular" holes in the liquid The theory of reaction rates yields an equation for absolute viscosity applicable to cases involving activation energies where the usual theory of energy transfer does not apply This equation reduces to a number of the successful empirical equations under the appropriate limiting conditions. The increase of viscosity with shearing stress is explained, and an equation for the diffusion coefficient is obtained. The usual theories for diffusion coefficients and absolute electrical conductance should be replaced by those developed here when ion and solvent molecule are about the same size.

(416) Fast, J. D

The Influence of Impurities of the Properties of Metals (In Dutch)

Metalen 7 (1952) 48-50

Part I: Deleterious effects of inclusions on the mechanical properties of metals and alloys; also favorable effects Part II: Very useful effects (mechanical hardening, magnetic hardening, and resistance to creep at high temperatures) can be obtained with inclusions formed by precipitation from supersaturated solid solutions The same effects are deleterious if soft alloys (in the mechanical and magnetic sense) are desired. By studying the effects of C and N in pure Fe and in $FeMn_2$, a new explanation of magnetic aging of steel was obtained. Part III: Relationships between presence of inclusions and occurrence of dislocations Several strain-aging phenomena can be explained on the basis of Cottrell's theory, but others do not seem to fit this theory very well

(417) Fastov, N S.

On the Steady-State Creep Rate (In Russian)

Zhur Tekh Fiz. 20 (1950) 543-545

The only empirical quantitative relation so far established for the steady-state creep rate is $v = v_0 \sinh \sigma/\sigma_0$ where σ is the applied stress and v_0 and σ_0 are constants of the material It must be supplemented by a temperature factor, the suggested form of which is

$$\log v = a_0 - a_1/T + b_0 (1 - T_{crit.}/T)\sigma,$$

where all constants, including T_{crit}, can be determined experimentally This relation represents correctly the "reversal" of the variation of the creep rate in relation to stress at the "critical" temperature

(418) Fastov, N S

Thermodynamics of Plastic Deformation (In Russian)

Doklady Akad Nauk S S S R 78 (1951) 251-4

An expression for the free energy of a body undergoing plastic deformation with given end velocity is derived Expressions for the relation between yield point maximum elastic deformation and rate of deformation; for the relation between stress and deformation and its rate during plastic deformation and for the shape of the creep curve are developed The results agree well with experimental data

(419) Fastov N S.

Evolution of Heat During Plastic Deformation (In Russian)

Doklady Akad Nauk S S S R 83 (1952) 851-855

A mathematical discussion in relation to type of deformation (tension or torsion) By means of the equations derived energy converted to heat, energy due to residual stress, and energy due to work hardening may be calculated

(420) Fastov, N. S.

Equations of the Theory of Plasticity with Calculation of Change of Temperature (In Russian)

Doklady Akad Nauk S.S S R 85 (1952) 67-70

If plastic deformation is accompanied by a change in temperature, the shear stress is a linear function of temperature and a linear function of the shear deformation, so that calculation of the change in temperature is equivalent to calculation of the thermal expansion and of the linear dependence of the yield point on temperature In the region of elastic deformation, the shear stress is independent of temperature

(421) Fazan, B., Sherby, O D , and Dorn, J E

Some Observations on Grain-Boundary Shearing During Creep

Trans AIME 200 (1954) 919-922

Quantitative measurements of the contribution of grain-boundary shearing to the creep process were made for a high-purity Al in the temperature range 610 to 747 K under a stress of 250 psi The contribution of the grain-boundary shearing to the creep strain was found to depend upon a temperature-compensated time, $te^{-\Delta H/RT}$. The activation energy for grain-boundary shear is about the same as that for creep, and the contribution of the grain-boundary shearing to the creep strain follows the same primary and secondary stages as exhibited by the total creep strain Extensive polygonization is observed in the vicinity of grain boundaries. Grain-boundary shearing appears to occur by crystallographic mechanisms of deformation arising from bending and shearing of grain projections in the vicinity of the true-relaxed grain boundary. The relative contribution of the grain-boundary shearing to the total creep strain is independent of the test temperature, but, as shown by McLean [J Inst Metals 80 (1951-52) 507], it increases as the stress decreases

(422) Felbeck, D. K , and Orowan, E

Experiments on Brittle Fracture of Steel Plates

Welding J 34 (1955) 570S-575S

Tensile tests at room temperature on ship-plate specimens provided with brittle edge cracks of various lengths are described The fracture stress was found to be inversely proportional to the square root of the initial crack length The initial brittle crack did not propagate directly as such but first changed into a very short fibrous crack with considerable plastic deformation around its tip, and this changed back into a brittle crack The conclusion is drawn that the decisive factor in the brittle fracture of low-carbon steels is the high velocity dependence of the yield stress If a cleavage crack propagates slowly, it requires, under the conditions of the experiments, large local plastic deformations for producing the necessary triaxiality of tension; it becomes a really brittle crack only when it runs so fast that the high velocity of any plastic deformation at its tip raises the yield stress there nearly or fully to the level of the cleavage stress, so that a considerable triaxiality of tension and the corresponding intense plastic deformations are no longer necessary

(423) Feltham, P

The Plastic Flow of Iron and Plain Carbon Steels Above the A_3-Point

Proc Phys Soc (London) 66B (1953) 865-883

Apparatus is described for creep testing a variety of steels under constant stress at ~1000 C Metallurgical studies were made on the austenite grain size and on recrystallization during flow, yielding evidence of both intergranular and transgranular distortion The equation of steady-state creep is developed from other work, and empirical relations are determined between certain of the parameters These results are interpreted as arising from the remelting of small groups of atoms induced by dislocations piled up at obstacles such as grain boundaries The transient creep strain was found to obey the relation $\epsilon \sim t^m$ where m is 10-20% > 1/3 The value of the parameter β is also discussed

(424) Feltham, P.

On the Validity of Mott's Theory of the Beta-Flow in Polycrystals

Phil. Mag 45 ser 7 (1954) 9-12

Experimental evidence concerning the activation energy for transient creep is discussed, and it is concluded that if the Andrade equation is written in the form $\epsilon^3 = At$, in which ε denotes the transient strain the dependence of A on stress and temperature is governed by the same constant as for steady state creep Data for pure metals and alloys are tabulated and point to the essential correctness of Mott's interpretation of the beta-flow in polycrystals, in which the transient part of the flow is the sole type of flow up to the point at which its rate becomes that of the steady flow

(425) Feltham, P

On the Mechanism of High-Temperature Creep in Metals With Special Reference to Polycrystalline Lead

Proc Phys. Soc (London) 69B (1956) 1173-1188

On the basis of Mott's suggestions that transcrystalline deformation in creep takes place by fine slip and that the activation energy is that for the formation of screw dislocations impeded by jogs, expressions for the high-temperature transient and equilibrium creep rate are given in terms of applied stress, temperature, the grain size and the characteristics of the substructure The equations give a good interpretation of the known creep behavior of a number of metals as reported in the literature The synthesis is based primarily on Pb, as, in conjunction with the present experiments, the available literature provides a fairly comprehensive account of the creep of both single crystals and polycrystals of this metal

(426) Feltham, P

Relation Between the Initial Instantaneous Extension in Creep and the Yield Stress and Coefficient of Work-Hardening in Polycrystalline Metals

Nature 177 (1956) 632

Tensile stress of polycrystalline Pb is related to the initial tensile strain ε by the work-hardening law characteristic of polycrystalline metals of cubic symmetry.

$$\frac{\sigma^2}{\epsilon}\ X(T)$$

where X(T) is the temperature-dependent coefficient of work hardening Reasonable values yield $X = 3\ 2 \times 10^5\ kg/cm^2$ which is in agreement with the slopes of the two lines

(427) Feltham, P.

On the Representation of Rheological Results, With Special Reference to Creep and Relaxation

Brit J Appl Phys 6 (1956) 26-31

The remarkable similarity in the creep and relaxation curves of metals, ceramics, plastics, etc , suggests a common factor determining these properties. It is proposed that all such solids possess a number of relaxation centers with a log-normal distribution of relaxation times, thermodynamical justification for this distribution is advanced. Stress-relaxation data for Al are in agreement with the conclusions from this premise, while the creep data computed from the relaxation data fit Andrade's creep law, which is thus a corollary of such a distribution of relaxation times Other laws of deformation are reviewed.

(428) Feltham, P

The Activation Energy of High-Temperature Creep in Metals

Phil Mag 2 ser 8 (1957) 584-588

The activation energy is for the conservative motion of jogs along dislocations and is found to be about twice the latent heat of melting. The temperature dependence of the activation volume or stress-concentration factor, q, appearing in the expression

$$d\epsilon/dt = A \exp(-H/kT) \sinh(q\sigma/kT)$$

relating the equilibrium tensile creep rate, dε/dt, the temperature, T, and the applied tensile stress has been studied in the case of several pure metals subject to creep above about $1/2 T_m$, where T_m is the melting point On writing $q = nb^3$, where b is the distance of closest approach of atoms in the lattice, the relation

$$n = n_0 \exp\left[-\frac{Q}{kT}\left(1-\frac{T}{T_m}\right)\right]$$

was found to be valid in all cases, with $Q \approx \alpha T_m$ and α = 4 9 cal/mol/K, i e , Q is equal to about twice the latent heat of melting The increase of q with temperature is ascribed to the increase in the mean spacing between adjacent jogs in screw dislocations, and Q appears to be the activation energy for the conservative motion of jogs along dislocations. In fcc metals large values of n_0 are found to be associated with low stacking-fault energies, and vice versa

(429) Feltham P , and Meakin J D

On the Mechanism of Work Hardening in Face Centered Cubic Metals with Special Reference to Polycrystalline Copper

Phil Mag 2 ser 8 (1957) 105-112

Tensile specimens of polycrystalline copper were annealed for various periods so as to obtain variations in grain size and yield point The initial rate of work hardening of all specimens was linear up to strains of about 1.5% and independent of the magnitude of the yield stress This hardening appeared to be of the type responsible for the linear hardening which follows easy glide in single crystals, the theory of which has recently been developed by Friedel At higher strains parabolic hardening occurred In this stage the coefficient of work hardening X_p defined as the ratio $d\sigma^2/d\epsilon$, where σ and ε are the tensile stress and strain respectively, was found to obey the relation $X_p \propto G\sigma_y$, i e , it was proportional to the product of the shear modulus, G, and the tensile yield stress, σ_y This equation is derivable from Mott's theory, in which parabolic hardening is regarded as resulting from the action of the long-range stress fields of piled up dislocation arrays on Frank-Read sources in the grains

(430) Feltham P , and Meakin, J D

Work-Hardening in FCC Metal Crystals

Acta Met 5 (1957) 555-564

Work hardening and slip-band formation have been studied in Pb single crystals at 77, 193 and 295 K The metal was expected to show homogeneous glide on theoretical grounds. This was confirmed, the slip bands resembled those characteristic of Al Easy glide was not observed The initial stage of hardening was linear and was identified as being of the type treated theoretically by Friedel Evidence of the broadening of slip bands and of cross slip was not resolvable with the optical microscope at stresses significantly below the temperature-dependent critical stress at which this stage of hardening ends, but only in the subsequent stage This was also found to be linear, but the rate of hardening was low. The results show that manifestations of glide as observed on the surface may not be representative of the mode of slip within the metal Mechanisms of slip-band formation are proposed

(431) Fields, D S , Jr., and Backofen, W A

Temperature- and Rate-Dependence of Strain-Hardening in the Aluminum Alloy 2024-0

Trans ASM (Preprint) 51 (1959) 31 pp

Differential torsion testing was used to determine the strain-hardening characteristics at constant shear-strain rates of 0 08-24/minute and at -195 to 500 C Generally, high rates of strain hardening are found at temperatures less than 28 C, but little or no strain hardening occurs at temperatures greater than 200 C The shape of the stress/strain curve depends on the strain rate at 200 C At 500 C, an unexplained initial-yield effect obscured the behavior At 28 to 200 C, the effect of temperature on flow stress and strain rate at fixed strains is low because of strain aging during deformation, which also prevents the successful application of the Zener-Hollomon parameter for correlation of temperature and strain rate for fixed levels of flow stress

(432) Findley, W N

The Mechanical Equation of State With Special Attention to the Creep of Plastics

J Soc Plastics Engrs 6 no 10 (December 1950)

Attempts to apply the Hollomon mechanical equation of state to predict creep-time relations of plastics from stress-strain data Satisfactory agreement between predicted and actual creep-time curves was not obtained

(433) Finkel', V M

Distortions of the Crystal Lattice of Coarse and Fine-Grained Steel by Cold Plastic Deformation (In Russian)

Fiz Metal i Metalloved Akad Nauk S S S R , Ural' Filial 2 no 1 (1956) 189-191

Relation of intensity of lines to degree of deformation Effect of texture

(434) Fisher, J C

The Fracture of Liquids

J Appl Phy 19 (1948) 1062-1067

Fracture strengths calculated from nucleation theory for the rate of bubble formation agree satisfactorily with the maximum experimental values. Cracks form spontaneously and grow under negative pressure in subcooled liquids such as glass The fracture stress, σ of glass is proportional to $(E\ldots)^{1/4}$ where E is the elastic modulus The transition from high-temperature cavity-nucleated fracture to low-temperature crack-nucleated fracture is examined

(435) Fisher, J C

On the Strength of Solid-Solution Alloys

Acta Met 2 (1954) 9-10

The existence of short-range order (i e , any departure from a purely random arrangement) leads to a strengthening effect in a solid solution, since the motion of a dislocation destroys the short-range order across the glide plane If the energy of the disordered interface/unit area is γ, an additional stress [illegible] γ/b, is required to move a dislocation with Burgers vector of magnitude b along the glide plane An estimate for alpha-brass suggests that this effect is responsible for a significant fraction of its strength Long-range order need not lead to a strengthening effect, since the dislocations are associated in groups which recreate the ordered structure

(436) Fisher, J C

Approximate Steady-State Configuration of a Dislocation Mill

Acta Met 3 (1955) 413-414

The shape of a dislocation mill (single-ended Frank-Read source) is approximately calculated, neglecting energy dissipation It is found to be an Archimedes spiral, with spacing between turns Gb/τ (G shear modulus, b Burgers vector, τ applied shear stress) which [illegible] times the critical radius of curvature at the center of the spiral It is pointed out that a previous estimate of the number of loops generated by a Frank-Read source in a dynamic burst as 300 is incorrect; a better estimate is 10

(437) Fisher, J C.

Application of Cottrell's Theory of Yielding to Delayed Yield in Steel

Trans ASM 17 (1955) 451-462

According to Cottrell, dislocations in iron are pinned by adsorbed C, N, and other solute atoms Yielding occurs when dislocations are freed from their adsorbed solute atoms with the aid of thermal-energy fluctuations Based upon this model, the temperature and stress dependence of the delay time for the yielding of steel is calculated and is compared with experiment The temperature dependence of the yield stress also is calculated and found to be of the form (stress) x (temperature) = constant, in good agreement with experiment over a wide temperature range

(438) Fisher, J C

A Dislocation Model for the Origin of Fracture Cracks in Metal Crystals

Acta Met 3 (1955) 109-110

Combined movements of screw and edge dislocations can start a crack only if a normal stress is present across the screw dislocation. To prevent the crack closing and forming two edge dislocations a normal tensile stress is required across the slip plane Assuming a slip of several hundred interatomic distances, this stress is 10^{10} dynes/cm^2/m, i e , 1% of the elastic modulus, in agreement with the order of magnitude of observed fracture stresses for single crystals If a specimen is deformed by a tensile stress, a superimposed hydrostatic pressure would tend to close such a crack, thus increasing ductility, while a hydrostatic tension would tend to cause brittleness

(439) Fisher, J C.

Prismatic Loops as Frank-Read Sources

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 513-514

Numerical calculations are made In the discussion it is considered whether the vacancies will precipitate as spheres or platelets, which could then collapse to form dislocation loops

(440) Fisher, J C.

Theory of the High Temperature Strength of Alloys

Paper from High Temperature Materials, Their Strength Potentials and Limitations, Fourth Sagamore Ordnance Materials Research Conference (1957) 23-29

High-temperature behavior is relative It begins to be important at temperatures more or less proportional to the melting temperature It is characterized by time-dependent phenomena such as diffusion and recovery where thermal activation is important Insofar as resistance to plastic deformation is concerned, high-temperature behavior corresponds to the breakdown of the strengthening mechanisms that operate at low temperatures By shifting to materials with higher melting points, it is possible to postpone high-temperature behavior to higher operating temperatures However, to improve any given material, it is necessary first to understand the low-temperature strengthening mechanisms, how they begin to fail at elevated temperatures, and how it may be possible to delay their failure

(441) Fisher, J C

Elastic Interaction of Interstitial Atoms in Body-Centered Crystal

Acta Met 6 (1958) 13-18

The elastic distortions near interstitial atoms in bcc crystals are estimated by an atomistic relaxation process Through knowledge of the local strains, the elastic binding energy of a pair of interstitial atoms is calculated and is found to agree satisfactorily with Powers' experimental value of about 2 cal/mol In the appendix, the magnitude of the local strain produced by an interstitial atom is determined from the tetragonality of martensite to be approximately 0 19, and it is shown that the influence of C in increasing the free-energy of alpha-Fe (relative to gamma-Fe of the same composition) is largely accounted for by elastic strain energy

(442) Fisher, J C , Hart, E W , and Pry, R H

Theory of Slip-Band Formation

Phys Rev 87 (1952) 958-961

Summary of current state of knowledge regarding the structure of slip bands and the relationship between slip bands and work hardening The fine structure of slip bands on the surfaces of plastically deformed crystals, as described by Heidenreich and Shockley and by Brown, is explained in terms of the model of dislocation-loop generation proposed by Frank and Read The back-stress at an active Frank and Read source, produced by an expanding avalanche of about 300 dislocation loops is shown to be sufficient to stop dynamic-loop generation at the source Slip, therefore, occurs in avalanches separated in time Avalanches from other slip systems crossing a slip plane containing an active source lead to the observed stepped surface markings, with successive avalanches from the given source displaced relative to each other

(443) Fisher, J C., Hart, E. W , and Pry, R H

The Hardening of Metal Crystals by Precipitate Particles

Acta Met 1 (1953) 336-339

Dependence of the hardening effect is computed in terms of a model in which the precipitate particles cause the dislocations from an activated Frank-Read source to form closed loops about the particles Results of the analysis are shown to be in agreement with the relevant experimental data

(444) Fisher, J C , and Hollomon, J H

Wanted: Experimental Support for Theories of Plastic Flow

Paper from Symposium on Plastic Deformation of Crystalline Solids, OTS, U S. Dept Commerce (1950) 199-208

Surveys various theories of the time-dependent deformation of metals Andrades equation is applied to available constant-stress creep data and shown inadequate Discusses application of Hollomon and Lubahn's equation relating stress-strain-temperature rate Suggests that the "work of deformation" may be a better measure of the "quantity" of deformation than the strain, in searching for a history-independent relationship for deformation in metals

(445) Fisher, J C , and Hollomon, J H

A Statistical Theory of Fracture

Trans. AIME 171 (1947) 546-561

According to Zener and Hollomon (Trans. ASM 33 (1944) 163), in a two-phase alloy fracture is controlled by defects arising from particles of a second phase or inclusions introduced incidental to the manufacture of the material This concept alone is not completely satisfactory, and it has been suggested that slip bands behave viscously during deformation and can thus be sources of stress concentration If in steels the fracture process is determined by carbide particles, other included particles, and slip bands, the numbers concerned are of the order of 10^{10} per cm The effect of strain, size, and structure must therefore be approached statistically A statistical analysis is made which is capable of predicting the scatter of fracture-stress measurements for different specimens of a single material The analysis is based only on the assumption that fracture is caused by randomly oriented defects having the properties of cracks, and that the number of defects of a given size is an exponential function of the size The theory deals also with the effect of specimen size and of combined stress and plastic deformation. The agreement with experimental data is discussed.

(446) Fisher, J C , and MacGregor, C W.

Tempering Effects and the Mechanical Equation of State

Trans ASM 40 (1948) 302-312

The mechanical equation of state, which postulates that the stress in a metal undergoing plastic flow depends only upon the instantaneous values of temperature, strain, and strain rate, is only applicable to materials in which there is no phase change or other process which alters the composition or structure as a function of time It has recently been shown that the hardness of martensite tempered at constant temperature is a function of a single parameter, p, such that $p = T(1 + k \log_{10} t)$, where T the absolute temperature and t = time In a tension test on tempered martensite, the stress at a given temperature, strain, and strain rate is also a function of p, it being understood that the degree of tempering indicated by p is reached before the test begins and does not change during the test To confirm their hypothesis, they determined the true stress-strain curves for quenched and tempered specimens of 1045 steel and obtaining a smooth curve Some further tests were also made in which tempered specimens were strained, retempered and finally strained to fracture the curves obtained after the second tempering were all identical this treatment having removed the effect of the prior strain. The tempering process is independent of both strain and recovery These results suggest that the theory may also apply to the more general case where p varies during the test, the stress being a function of the instantaneous value of p

(447) Fisher, J C , and Rogers H C

Propagation of Luder s Bands in Steel Wires

Acta Met 4 (1956) 180-185

Annealed 1010 steel wires were deformed in tension at constant load by hanging weights on the wires Propagation was observed visually through the cracking of a brittle lacquer coating Luder's band fronts propagate with a velocity, V, that depends upon stress, σ, and temperature, T, through a relationship of the form

$$\log V = C - D/\sigma T$$

where C and D are constants

(448) Fisher, J F

Anistropic Plastic Flow

Trans ASME 71 (1949) 349-356

Experimental data concerning the plastic flow of anisotropic polycrystalline Al indicate that predictions of the anisotropic-flow theory are in good agreement with experiment and are significantly better than those of distortion-energy theory Caution is indicated in interpreting the results of combined stress tests by means of the latter theory.

(449) Fleeman, J , and Dienes, G J

On the Fredrickson-Eyring Theory of the Mechanical Behavior of Metals

J Appl Phy 21 (1950) 1193-1194

Some quantitative implications are derived from the Fredrickson-Eyring dynamical theory of metals (Frederickson and Eyring, Trans AIME 180 (1949) 382) and compared with experimental results obtained with steel It is concluded that the theory (1) predicts too much strain-hardening, (2) predicts a relaxation time for deformation recovery which is much too small

(450) Fleischer, R. L., and Chalmers, B

Size Effects in the Deformation of Aluminum

Trans. AIME 212 (1958) 265-274

Al single crystals and bicrystals of various cross-sectional dimensions were deformed in tension. Typical stress-strain curves, effects of changes in crystal dimensions; effects of growth rate used in preparation of crystals Macroscopic constraints at a grain boundary are responsible for the most prominent grain-boundary effect — the production of multiple slip.

(451) Flinn, P. A

Solute Hardening of Close-Packed Solid Solutions

Scientific Paper 6-94701-2-P10, Westinghouse Research Lab. (October 24, 1957) 11 pp

Calculations of the hardening contributions of local order according to Fisher and to Suzuki are made from experimental X-ray measurements Found that both types of interactions may make significant contribution to the strength of the solid solutions The Suzuki effect is expected to be dominant in dilute solutions, especially where the energy of a stacking fault varies rapidly with composition; the Fisher effect should be dominant in concentrated solutions if appreciable local order exists The largest Fisher interaction is probably considerably more important than the largest Suzuki interaction.

(452) Folberth, O. G , and Kochendörfer, A.

A Theory of Creep in Single Crystals (In German)

J Mech and Phys Solids 1 (1953) 244-257

A theoretical explanation in terms of dislocation theory is attempted for the empirical relationships established for creep in single-crystal and polycrystalline specimens It is possible to account for the temperature and resolved shear-stress dependence of the steady-state creep rate and the time dependence of the transient creep rate Extensions of creep laws to cover plastic behavior from creep to impact deformation are proposed

(453) Foley, F B

Factors Affecting Deformation and Rupture of Metals at Elevated Temperatures

Trans AIME 188 (1950) 845-850

At high temperatures metallic systems are considered to be in a disturbed state varying from near stability to great activity, from rigidity to fluidity, from strength to weakness Cast iron used as an example

(454) Foreman, A J E

Dislocation Energies in Anisotropic Crystals

Acta Met 3 (1955) 322-330

The energy/unit length of a straight dislocation of general type in an anisotropic crystal is derived The theory of Eshelby et al (ibid. 1 (1953) 251) is used to calculate E, an anisotropy factor, for particular cases in cubic and hexagonal crystals The variation of K with the direction of the dislocation line is found for {100}, {110}, and {111} planes of Al, Au, and Cu In all cases, the energy of a dislocation in a {110} plane is less than that of a dislocation in a {111} plane In the hcp structure, analytical solutions are obtained for screw dislocations, any dislocation in the basal plane, and for edge dislocations in the prismatic planes In Zn, K has its lowest value for basal-plane dislocations, but in Be, the K values for basal, prismatic, and pyramidal planes are almost identical

(455) Foreman, A.J E., and Lomer, W M

Dislocation Energies and Choice of Slip Plane in Face Centered Cubic Metals

Phil Mag. 46 ser 7 (1955) 73-76

Calculations of the energy of dislocations on various slip planes in Al, Cu, and Au indicate that the choice of slip plane is probably not controlled directly by this quantity It is suggested that the energy of the screw dislocation is lowered by dissociation in the close-packed plane, and that dislocations are trapped into this plane as they pass through the screw orientation. The possible importance of dislocation mobility is briefly discussed.

(456) Forty, A J

The Generation of Dislocations During Cleavage

Proc Roy Soc (London) 242 (1957) 392-399

The cleavage of NaCl and LiF crystals at a low rate of loading shows that a cleavage crack generates plastic deformation only if it is moving sufficiently slowly or can be brought to rest. Under these conditions the cleavage crack propagates discontinuously, and thus produces a range of velocities at which deformation might occur Plastic deformation occurs only in narrow zones around the positions where the crack stops; elsewhere, the crack runs freely producing a perfect cleavage. Interference patterns formed by light reflected from the two surfaces of the crack allow the deformation to be interpreted as the production of arrays of dislocation loops by the slowly moving crack Mechanical aspects of crack propagation are discussed

(457) Fouladi, A

Considerations on Creep (In French)

Métaux (Corrosion - Inds) 27 (1952) 69-74

Creep of metals at low temperatures and the mechanical properties of refractory alloys with regard to deformation and cracking, plastic deformations, superposition and repetition of strains, and resistance of refractory alloys to various loads are tested

(458) Frank, F C.

On Slip Bands as a Consequence of the Dynamic Behavior of Dislocations

Paper in Report of a Conference on Strength of Solids, Phys Soc (London) (1948) 46-51

Dislocations are considered to move with the speed of sound and to be reflected at free surfaces The problem then arises of why glide, once started, never stops It is suggested that the lamellae between which slip occurs are also rotated over each other through small angles, and that glide ceases when any plane becomes interlaced with dislocation lines to an excessive density It should sometimes be possible to produce a large change in the mode of slip in a single crystal by immersing it in a fluid of like or superior density, thus suppressing the surface reflection of dislocations.

(459) Frank, F C

Sessile Dislocations

Proc Phys Soc (London) 62A (1949) 202

The significance of the word "sessile" will be understood if it is remembered that it is derived from the Latin sedere, to sit. Sessile dislocations are contrasted with "glissile" dislocations, i e , those which can glide Atoms in twin-lattice positions fit correctly only on the appropriate composition plane of the main lattice Now, whereas a perfect dislocation can glide without changing the amount of misfit in a crystal, imperfect dislocations increase the misfits unless they glide in a composition plane Imperfect dislocations incapable of dissociating into glissile partial dislocations are sessile The only simple way in which they can move in the lattice is by diffusion processes in which they gain or lose atomic vacancies Sessile dislocations are important in matters of the strength of metals and crystal growth

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(460) Frank, F C

The Origin of Dislocations

Paper from Symposium on Plastic Deformation of Crystalline Solids, OTS U S. Dept Commerce (1950) 89-99

The following outline of the dislocation process is suggested some dislocations are present in every crystal under stress these move and undergo dynamic multiplication where there is an accumulation of dislocations they block each other's motion and now with increase of applied stress and stress concentration effected by the accumulation of dislocations, static generation of dislocations can occur by thermal agitation in regions of local stress these new dislocations may undergo some dynamic multiplication to an extent which decreases as the regions of relative perfection in the crystal diminish This scheme, it is considered, can explain the glide process with slip and deformation bands, kinking, etc with its paradoxical implication that deformation encourages further deformation in neighboring regions while demanding larger and larger stresses to bring it about

(461) Frank, F C

Crystal Dislocations Elementary Concepts and Definitions

Phil Mag ser 7 42 (1951) 809-819

The elementary concepts of crystal dislocation theory – in particular, the Burgers vector, perfect and imperfect dislocations, sessile dislocations, extended dislocations, twin and twinning dislocations – are defined in a manner independent of particular crystal lattices or models or special orientations of the dislocation

(462) Frank, F C

The Nature of the Real Crystal

J Inst Metals 85 (1956-57) 581-587

The imperfection of real crystals has been known since 1912 In 1934 a published symposium summarized the then-existing knowledge about the subject. The same year saw the introduction of the idea of crystal dislocations, which proved to be the essential concept for a more precise description of crystal imperfection. The present lecture traces the way in which this precision of knowledge has developed, culminating in methods of making dislocations visible, so that now in some few cases we can accurately see what the "mosaic structure" really is. Distinction has to be made between impurity-segregation substructures and disorientation substructures The nature of both is now understood So is the genesis of the former, but that of the latter only partially; it is discussed in detail for the case of growth from a pure melt

(463) Frank, F C , and Nicholas, J F

Stable Dislocations in the Common Crystal Lattices

Phil Mag ser 7 44 (1953) 1213-1235

The stability of dislocations in simple cubic, fcc, diamond, hcp, and bcc lattices is discussed on the assumption that the energy/unit length of a dislocation line is proportional to the square of the Burgers vector, it is shown that in each of these lattices there is only a finite number of Burgers vectors corresponding to stable perfect dislocations; Thompson's notation for describing the vectors of dislocations in a fcc lattice is explained Imperfect dislocations are discussed for those lattices in which they can occur, and the sets of Burgers vectors corresponding to isolated stable imperfect dislocations are derived Stable extended dislocations, consisting of arrays of imperfect dislocations separated by areas of translation-twin surface, are discussed

(464) Frank, F C , and Read, W T , Jr

Multiplication Processes for Slow Moving Dislocations

(Letter), Phys Rev. 79 (1950) 722-723

Purely topological reasoning can explain how a very large amount of slip can result from the motion of a single dislocation line, and the quantitative treatment is similar to the theory of crystal growth, allowance being made for mutual repulsion between turns Another process occurs when a part of a dislocation lies in one glide plane (the remainder lying outside the plane), and this is discussed for the case where the "endpoints" may be considered fixed. [See evidence offered by J J Gilman that dislocation loops do not come from existing Frank-Read sources in LiF Trans. AIME 209 (1957) 449]

(465) Frank, F C., and Read, W T , Jr

Multiplication Process for Slow-Moving Dislocations

Paper from Symposium on Plastic Deformation of Crystalline Solids, OTS, U S Dept Commerce (1950) 44-46

Describes the Frank-Read source. Slip bands observed in plastically deformed crystals indicate that on a typical slip plane there is ~1000 times more slip than would result from the passage of a single dislocation across the plane This phenomenon is attributed to the reflection and multiplication of dislocations which have acquired velocities approaching that of sound (Frank, Phys Soc , Report Conference on Strength of Solids (1948) 46) A recent theoretical estimate of the energy dissipated by a typical moving dislocation indicates that its terminal velocity is <1/10 the velocity of sound [Leibfried, Z Physik 127 (1950) 344] A topological argument analogous to the theory of crystal growth due to Frank is now briefly presented, suggesting how an unlimited amount of slip could result from the motion of a single dislocation line

(466) [illegible] and McLean, D

Polygonization in Copper

Phil. Mag. 1 ser. 8 (1956) 101-102

X-ray microbeam studies of Cu polygonized during creep at 400 C show that the process is not complete. A comparison with Al strained at 200 C (approximately the same temperature relative to the melting point shows that Al gives sharper spots and so polygonizes faster than Cu. However the difference in rate of polygonization (a factor of ~100) is not large enough to be due to the difference in the number of jogs present on dislocations in thermal equilibrium using the jog energies calculated by Schoeck and Seeger (a factor of 10^{25}) [Report Conference Defects in Crystalline Solids Phys. Soc. (1955) 340] and as it is unlikely that the concentration of vacancies differs sufficiently to account for the discrepancy, it is suggested that the number of jogs produced mechanically during the deformation of the Cu is 1/100 of the total number present in the Al

(467) Frederickson J , and Eyring, H

Statistical Rate Theory of Metals. I. Mechanism of Flow and Application to Tensile Properties

Trans. AIME 180 (1949) 382-414

A theory of the deformation of metals in tension is advanced in terms of the general statistical rate theory of chemical and physical processes In atomic or molecular processes involving an activation energy given by equations of the form $v = Ge^{-\epsilon/kT}$ the atoms or molecules involved must first come together to form an activated complex The units of flow in a crystalline substance are thus considered as systems of atoms and designated as domains The free energy of activation for movement of the rather large domains considered and the volume of the domains are linearly dependent on the temperature A stress-strain relationship for constant rate of strain is developed In a discussion of slip planes, deformation bands, and grain boundaries, it is concluded that the slip process consists of the movement of atomic domains into new conditions of equilibrium created by imperfections in the lattice structure It is shown that the theory accounts satisfactorily for strain hardening and the effects of temperature and strain rate on stress-strain relationships but not for the occurrence of blue brittleness in mild steel (See comments by Fleeman and Dienes)

(468) French, R. S , and Hibbard, W R , Jr.

Effect of Solute Elements on the Tensile Deformation of Copper

Trans AIME 188 (1950) 53-58

True stress-true strain data for Cu and Cu alpha-solid-solution alloys of Al, Be, Cd, Ni, Si, Sn, and Zn were obtained The strain-hardening coefficient is a function of yield strength but independent of solute element added. Approximately linear relationships were found between yield strength, and atomic per cent solute indicating that, of the elements studied, Sn was the most effective strengthener and Zn the least A linear relation was also found to exist between the DPHN and yield strength, showing that metallic hardness is a direct function of the true yield strength. The change in yield strength appeared to be, basically, a function of the change in lattice parameter produced by the solute addition

(469) Frenkel, R E., Sherby, O D and Dorn, J E.

Effect of Cold Work on the High Temperature Creep Properties of Dilute Aluminum Alloys

Trans ASM 47 (1955) 632-649

A study has been made of the effect of prior cold work on each of the significant parameters determining the high-temperature creep of Al and Al alloys with Mg or Cu. The high-temperature creep of cold-worked as well as annealed Al can be represented by the equation $\dot{\epsilon} = Se^{-\Delta H_c/RT}e^{B\sigma}$, where $\dot{\epsilon}$ = creep rate, ΔH_c = activation energy for creep, σ = applied stress, B = stress parameter, S = structure parameter ΔH_c is unaffected by previous cold work, and this fact disqualifies the commonly postulated model for creep based on the assumption that the rate-controlling process consists of thermal activation of dislocations over barriers The value of 1/B for initially cold-worked and partially recovered Al is greater than that for Al initially in the annealed state; as creep continues, 1/B appears to approach the value for the annealed metal S appears to be slightly larger for the cold-worked and partially recovered state than for the annealed state when compared at the same total creep strain and the same creep stress The principal effect of cold work on the creep resistance of Al appears to arise from the effect of increasing 1/B.

(470) Frenkel, R. E , Sherby, O. D , and Dorn, J E

Activation Energies for Creep of Cadmium, Indium, and Tin

Acta Met 3 (1955) 470-472

Creep tests at constant load were made on specimens of Cd, In, and Sn The plastic strain was a function of t exp($-\Delta H/RT$), where t is the time and ΔH the experimental activation energy for creep Values of ΔH were found to be 21 0, 16 5, and 21 0 kcal/mol for Cd, In, and Sn, respectively For Cd and In, these energies agree with the activation energies for self-diffusion, but the result for Sn differs from the self-diffusion value obtained by Fensham Australian J Sci Research 3 (1950) 91] It is suggested that the difference may be due to difficulties in determining the self-diffusion activation energy for Sn

(471) Frenkel , Ya I

On the Temperature Dependence of Plastic Deformation and Creep (In English)

J Phys (U S S R) 2 no. 1 (1940) 49-54

The Becker-Orowan theory of plastic slip (creep) velocity as a function of temperature is reviewed, and an alternative theory based on the assumption that the limit of elasticity of an ideal crystal lattice is zero, is advanced. A relaxation theory is given of creep, based on the assumption that the crystal lattice is distorted and accordingly hardened by previous slip and reintegrated by gradual return of the dislocated atoms to regular positions The dynamics of the intermittent creep under small stresses on the basis of an analogy between velocity dependence of the limit of elasticity and that of the friction coefficient of two solid surfaces are outlined

(472) Frenkel', Ya I

Viscous Flow of Crystalline Bodies Under the Action of Surface Tension (In English)

J. Phys (U.S.S.R.) 9 no. 5 (1945) 385-391

It is suggested that the viscous flow usually attributed to amorphous bodies, which occurs by the motion of a small number of holes or cavities, may also take place in crystalline substances. In the latter case, flow would proceed by the diffusion under stress of vacant sites of the crystal lattice This process is distinct from plastic deformation The conception is developed mathematically and applied to the rate of welding of crystalline powders at temperatures below their melting points into a crystalline body. The development of crystal faces on the surface of a spherically ground single crystal is also discussed from the same point of view, the common factor in each case being the reduction in surface energy caused by the change

(473) Frenkel', Ya. I.

Introduction to the Theory of Metals

State Publishing House of Technical-Theoretical Literature, Moscow (1950) 383 pp

This book considers the electron theory of metallic bodies, the zone theory, the molecular-kinetic theory of solid and liquid bodies and its application to metals, the kinetic theory of alloys, and the strength and plasticity of metals.

(474) Frenkel', Ya I

Theory of Reversible and Non-Reversible Cracks in Solids

Zhur. Tekh. Fiz. 22 (1952) 1857-1866

The Griffith theory of cracks in solids is reviewed and criticized New expressions for crack behavior are derived, taking into consideration the shape of the crack and the total energy of the system

(475) Frenkel', Ya. I , and Kontorova, T

Theory of Plastic Deformation and Twinning

J. Phys. (U S S.R.) 1 (1939) 137-149

The process of twinning and of plastic deformation in a crystal is assumed to be propagated along the corresponding direction in a wavelike manner This mechanism is applied to a one-dimensional model consisting of a chain of elastically bound atoms, which can slip over a chain of equidistant atoms, exerting upon them a sinusoidally distributed field of force. Two types of motion are possible: the propagation of small vibrations about equilibrium positions and the propagation of the slip wave. This slip wave has a critical initial value and is propagated with a velocity approaching that for sound as the energy is increased. If the atoms underlying the movable chain are allowed to vibrate about fixed equilibrium positions, the energy of the slip wave is gradually dissipated. This dissipation is inversely proportional to the energy of the wave. Owing to this dissipation, one-dimensional slip waves cannot account for self-diffusion phenomena in crystals. A generalization to the three-dimensional case is reached by considering the propagation, in a thin surface layer of a crystal, of a displacement similar to ordinary shear, which brings the atoms from their original position into an equivalent or symmetrical position Conclusion: Increasing plasticity of various simple substances corresponds to a decreasing critical energy for the possibility of slip propagation.

(476) Freudenthal, A M

Work-Hardening of Metals: A General Theory

J. Franklin Inst 248 (1949) 523-536

Reviews the mechanism of the structural changes which take place when a metal is work hardened by deformation and suggests that current theories lead to a relationship between "hardness" of the worked material and some function of the crystallite size. A general equation of this form is developed and discussed in terms of experimental observations

(477) Freudenthal, A. M.

The Inelastic Behavior of Engineering Materials and Structures

John Wiley and Sons, Inc , New York (1950) 587 pp

A fundamental approach to material research based on analysis of the underlying unifying principles Includes problems of research in mechanical properties and behavior of materials; problems of mechanical testing and evaluation of engineering materials; problems of design of structures and the theory of technological processes

(478) Freudenthal, A M.

Theories of Mechanical Behavior of Materials

Appl Mechanics Revs 4 (1951) 394-396

A literature survey of 103 references lists the articles with little or no discussion The following categories are considered: (1) research on atomic and molecular level, (2) research on microscopic level, and (3) phenomenological approach.

(479) Frey, D. N., Freeman, J W., and White, A E.

Fundamental Effects of Aging on Creep Properties of Solution-Treated Low-Carbon N-155 Alloy

NACA TR 1001 (1950)

Method for investigating fundamental mechanisms by which processing, heat treatment, and chemical composition control the properties of alloys at high temperatures. This method uses metallographic examination – both optical and electronic, studies of X-ray diffraction-line widths, intensities, and lattice parameters; and hardness surveys Mechanical properties at high temperatures are then measured and correlated with structural conditions.

(480) Fridman, Ya. B.

True Diagrams of the Deformation and Mechanical Properties of Metals (In Russian)

Zhur Tekh. Fiz. 11 (1941) 902-917

A full picture of the mechanical properties of metals could be obtained by studying a complete stress-strain diagram from the region of elastic deformation up to the breaking point. High values of deformation are best expressed in terms of the true strains of Ludwik If the true reduction of area is found, a number of relationships can be determined which are characteristic of the plastic state: the strength of single and polycrystalline materials can be compared and the true value of the statistical work of deformation can be determined. Graphs necessary for the calculations are given

(481) Fridman, Ya. B

On the Mechanism of the Fracture of Metals (In Russian)

Zhur Tekh Fiz. 11 (1941) 983-998

The views of N N. Davidenkov on the two types of fracture of metals-brittle and tough--are discussed and confirmed, and various cases of fracture under single loading are considered from a general point of view

(482) Fridman, Ya B.

A Unified Theory of the Strength of Materials and a Diagram of Mechanical State (In Russian)

Zhur Tekh. Fiz. 13 (1943) 502-519

Suggests a general theory of the strength of materials, based on the theories of maximum deformation and maximum shear stress The main feature of the former is its applicability to those cases where interatomic forces enter into the calculation of the equilibrium of the forces in the system; while by the use of the latter theory, it is possible to explain the behavior of materials during plastic deformation and fracture It is considered that at a certain temperature and rate of deformation a material fails either with a brittle fracture under tensional stress or with a ductile fracture under shear stress In view of the fact that the main mechanical properties, viz., tensile strength, shear strength, and elastic limit, do not depend upon the type of stress, it is possible to plot a graph (called the diagram of mechanical state) which gives the equivalent tension, compression and shear-stress components for any type of stress in the system.

(483) Fridman, Ya. B

Brittle Fracture of Ductile Metal (Letter)

Metal Progr 50 (1946) 1208-1209

The laws of fracture are considerably simpler than is generally supposed if, instead of a single cohesive strength one assumes the existence of two cohesive strengths, namely a tensile and a shearing cohesion, at any particular temperature and rate of loading This view is briefly supported by two or three examples

(484) Fridman, Ya B

Influence of Structure and Composition of Alloys on Their Mechanical Properties (In Russian)

Vestnik Inzhenerov i Tekh. no. 2 (1946) 44-50

Analyses of influence of such factors as grain size, distribution of solid solutions, intercrystalline brittleness and tempering temperatures on the mechanical properties of metals under varying conditions, including extreme low temperatures

(485) Fridman, Ya. B.

On the Development and Co-Ordination of Theories of the Strength of Materials (In Russian)

Zavodskaya Lab. 15 (1949) 221-231

It is impossible to evolve a theory of the strength of materials on a purely mathematical basis; the actual physical processes leading to loss of strength must be taken into consideration. Leaving aside complex destructive phenomena, e.g., wear and loss of stability, there are three basic kinds of loss of strength to consider: plastic flow, shear, and tensile fracture (usually brittle), and therefore three distinct safety factors are involved. It is proposed to characterize each material by its plastic flow limit, shear strength, tensile strength, and a generalized stress-strain function. Deformation laws established for a given material (steel or copper) cannot usually be applied without modification to other materials.

(486) Fridman, Ya. B., and Zilova, T. K.

The Fracture Process in Plastic Metals (In Russian)

Doklady Akad. Nauk S.S.S.R. 73 (1950) 697-700

Study of the fracture process from its initial stages to the point of failure using a macroscopic method. A mesh design impressed into specimen by a rolling process is used to follow the stages of deformation.

(487) Friedel, J.

Anomaly in the Rigidity Modulus of Copper Alloys for Small Concentrations

Phil. Mag. ser. 7 44 (1953) 444-448

Mott's theory of work hardening [Ibid., 43 (1952) 1151] is extended to solid solutions by assuming the dislocations to be "pinned down" by the solute atoms, and it is shown that the addition of solute atoms will always at first increase the shear modulus, though large concentrations may lead to a decrease. Such an anomaly has been observed by Bradfield and Pursey [Ibid., 44 (1953) 437] for small concentrations in Cu alloys and in Ag alloys [Smith, J. Inst. Metals 80 (1951-52) 477]. It disappears after long annealing, probably owing to the formation of loose Cottrell "clouds". A length of ~ 10^{-5} cm is derived for the network dislocations in the Cu alloys.

(488) Friedel, J.

On the Linear Work-Hardening Rate of Face-Centred Cubic Single Crystals

Phil. Mag. ser. 7 46 (1955) 1169-1186

At a sufficiently low temperature the stress/strain curves of fcc single crystals have a linear hardening range after the end of easy glide. The slope in this range is proportional to μ (the shear modulus) but does not vary with temperature or between metals. These facts can be explained if at the beginning of linear hardening Cottrell barriers form around every Frank-Read source of the active slip system and during linear hardening the number of dislocations blocked around each source increases. Calculations show that the rate of linear hardening can be predicted on this model, provided that the reduction in the back stress of piled-up groups due to the activation of neighboring sources on other slip systems is taken into account. The effect of different initial distributions of dislocations is also considered. The end of the linear hardening range is attributed to dislocations penetrating the Cottrell barriers under the combined action of applied stress and temperature. A mechanism for this penetration is proposed.

(489) Friedel, J.

The Mechanism of Work-Hardening and Slip-Band Formation

Proc. Roy. Soc. (London) 242A (1957) 147-159

A summary of current theories on the mechanism of work hardening of single crystals and polycrystalline materials. Discussion includes consideration of crystals of Si, Al, brass, and Cu. The different stages of crystal hardening are classified.

(490) Friedel, J.

Regarding Seeger's Paper on Work-Hardening

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 330-332

Seeger's treatment of the crossing of a forest of dislocations and of the variation of the beginning of the third stage of work-hardening with temperature are modified.

A 1 (491) Friedel, J.

Dislocation Interactions and Internal Strains

Paper from Symposium on Internal Strains and Fatigue in Metals, GM Research Lab., Detroit, Michigan (September 1958)

Stress-strain curves of pure solids are studied in relation to the internal stresses due to dislocations already present or developed by work hardening. Mono crystals and polycrystals are studied in turn. In well-annealed mono crystals, the elastic limit is related to the presence of the three-dimensional Frank net of dislocations. The role played by long range internal stresses and by jog formation is discussed in the light of recent observations. The onset of prismatic slip in hexagonal crystals is explained by a cross-slip mechanism. The influence of polygonization is discussed. The work hardening of mono crystals is then discussed. In the "easy glide" range observed in most crystals, at least at small strains, slip lines are few and long; strain hardening is observed only when many dislocations are introduced by bending or twisting the crystals. The large hardening rates observed by traction on fcc crystals start with a shortening of the slip lines; the dislocations pile up in a characteristic way in front of the internal Cottrell barriers. In both processes, the internal stresses can be partly relaxed and at the same time stabilized; in the easy-glide range, this occurs by polygonization, which develops fully only by atomic diffusion at high temperature; but in the short slip range in fcc crystals, it occurs immediately by plastic deformation around the tip of the slip lines, and also, at large enough strains, by thermally activated cross slipping. In polycrystals, the lack of clear elastic limit and the parabolic behavior of the stress-strain curve at small strains are related to the inhomogeneity of deformation; some grains deform before the others. At higher strains, the lack of easy glide and the high stress level are of course due to the grain boundaries. In conclusion, it is pointed out that the average internal stresses measured by plastic properties are somewhat different from those measured by other methods such as X-rays or electrical resistivity.

(492) Frye, J. H., Jr., Caum, J. W., and Treco, R. M.

Hardness and Lattice Stress in Solid Solutions

Trans. AIME 152 (1943) 83-93

The increase in the ultimate Meyer hardness produced by the solution of Zn, Ge, and As in Cu and of Cd, In, Sn, and Sb in Ag is discussed theoretically. These solutes produce an expansion of the respective solvent metals, but the ionic radius decreases with increasing valency and, consequently, the ionic overlap decreases with increasing valency of the solute. When the hardness of alloys containing equal atomic percentages of solutes is considered, it is found that a simple relation exists between the increase in hardness and increase in lattice stress when Zn dissolved in Cu is replaced by Ga, Ge, or As, or Cd dissolved in Ag is replaced by In, Sn, or Sb.

(493) Frye, J. H., Jr., and Hume-Rothery, W.

The Hardness of Primary Solid Solutions with Special Reference to Alloys of Silver

Proc. Roy. Soc. 181A (London) (1943) 1-14

Accurate Meyer analyses have been made on annealed bars of Ag and on binary alloys of Ag containing up to 5 at. % of Cd, In, Sn, Sb, Zn, Al, Mg, and Au. The results show that the ultimate Meyer hardness P_u increases as the grain size of the specimens diminishes. A comparison of the relative hardening effects of the different solutes was made. The results are discussed from the standpoint of lattice distortion, and it is shown that for a given atomic percentage of solute, the increase in P_u is proportional to the square of the lattice distortion for solutes in the same row of the periodic table. No simple relation exists for solutes from different rows of the periodic table and for a given solute the relation between P_u and the composition is not necessarily a simple one. The conclusions are tested by experiments on ternary alloys, and data for Cu alloys are discussed.

(494) Frye, J. H., Jr., Scott, J. L., and Woods, J. W.

Effect of Strain and Temperature on the Yielding of Copper and Nickel

Trans. AIME 209 (1957) 708

Yield point versus temperature (up to 500 C) curves for annealed and prestrained Ni and Cu are presented. Annealed Ni shows no measurable variation of yield point with temperature. Prestrained Cu and Ni show a linear yield point versus temperature relationship when the internal structure remains constant. This relationship would be expected if the shear moduli of the metals are linear functions of temperature, for according to Cottrell and Stokes [Proc. Roy. Soc. 233A (1955) 17] in all dislocation theories of strength the yield point appears to be proportional to the shear modulus of the material.

(495) Frye, J. H., Jr., and Sun, C. P.

Factors Affecting Rates of Work-Hardening in Primary Substitutional Solid Solutions

Trans. AIME 156 (1944) 111-116

One of the factors controlling the hardness of solid solutions is the rate at which the solution hardens under penetration of the hardness indenter. This factor is of extreme importance because hardness changes are partly, perhaps predominantly, the result of variations in rate of work hardening. The rate of work hardening depends on concentration of solute, period of the periodic table in which the solute occurs, plastic deformation, and lattice-parameter increment. When the first three of these variables are held constant, a linear relation is found between rate of work hardening and lattice expansion in Cu and Ag primary solid solution.

A 41 (496) Fujita, F.

Possible Mechanism for the Fracture of Metals

J. Phys. Soc. Japan 11 (1956) 1201

It is generally accepted that pre-existing large stress concentrators, such as the Griffith crack, are inconceivable in pure metal crystals because their dimensions would be too large. Since the fracture of metals is usually accompanied by plastic flow, the mechanism of failure might be to produce a long flat void of length equal to the number of annihilated pairs of dislocations multiplied by the Burgers vector of each dislocation. Such a mechanism gives the required large stress concentrator in plastically deformed crystals; the eventual size of the void is unsatisfactory as a cause of fracture because it collapses after a little further increase in its length. However, if it may be assumed that when some excess dislocations of either sign are squeezed into the void due to concentrated stress exerted by the rear dislocations in one side, the cross section of the void may be considered elliptical and the stresses around it computed. In this way, computations may be made of the number of excess dislocations contained in the void and liable to produce a crack.

(497) Fujita, F. E.

Dislocation Theory of Fracture of Crystals

Acta Met. 6 (1958) 543-551

A dislocation theory of fracture of crystalline materials is proposed. First, the stability of a thin flat void in a crystal is considered. The estimated critical length of the void is of the order of 10^{-6} to 10^{-5} cm provided that the thickness is of a few atomic spacings. From such a small crack we cannot expect a large stress concentration nor a high strain energy sufficient to produce a spreading crack. Piling up of edge dislocations might be a cause of fracture in some cases, but this mechanism is also inconceivable unless a strong obstacle to impede the release of piling up dislocations exists. On the other hand, we can consider a long flat void which is produced on the slip plane during plastic deformation of the crystal and contains a certain number of edge dislocations. This void has an effect to trap dislocations with the aid of piling up dislocations in the rear of it but without that of the obstacle. Stress distribution around the void is calculated, and it is shown that this kind of small void can produce a concentrated tensile stress so large as to make a crack spread from the tip of it. Strain-energy method is also applied, and it is found that this small void can grow to be a large crack, even if it is as small as of the order of 10^{-6} to 10^{-5} cm in length.

(498) Fujita, H., and Nishiyama, Z.

Subgrains in Cold-Worked Aluminum (In Japanese)

Nippon Kinzoku Gakkaishi 21 (1957) 607-611

Electron-microscope observation showed subgrains bounded by slip bands and deformation bands. The formation of small kink bands divided the subgrain into areas less than 1 μ across, and the final size of the subgrain was independent of the grain size before working.

(499) Fuks, M. Ia., Slonovskii, N. V., and Lupilov, L. I.

A Radiographic Study of Phenomena Accompanying Creep of Steel Over Extended Periods at Higher Temperatures (In Russian)

Fiz. Metal. i Metalloved. Akad. Nauk S.S.S.R. Ural' Filial 2 (1956) 328-338

A quantitative X-ray evaluation of the degree of diminution of cohesion domains and of the magnitude of microstresses in C and Cr-Ni-Mo steels plastically deformed by creep at various temperatures and rates.

(500) Fuks, M. Ia., Slonoskii, N. V., and Lupilov, L. I.

X-Ray Study of Phenomena Accompanying High-Temperature Creep of Steel (In Russian)

Izvest. Akad. Nauk S.S.S.R. Ser. Fiz. 20 (1956) 671-675

Relation of dimensions of mosaic blocks and microstresses to the character of the deformation, rate of deformation, and temperature.

(501) Fujita, H., and Nishiyama, Z.

Subgrains in Cold-Worked Aluminum (In Janpanese)

Mem. Inst. Sci. and Ind. Research, Osaka Univ. 14 (1957) 91-105

Mechanism of formation, size, and shape of subgrains and characteristics of slip bands in heavily worked specimens of Al.

(502) Fürth, R.

Relation Between Breaking and Melting

Nature 145 (1940) 741

Relation between low-temperature tensile strength, heat of melting/unit volume, and Poisson's constant for isotropic bodies is obtained, based on purely thermodynamic considerations.

(503) Fürth, R.

A Thermodynamical Theory of Tensile Strength of Isotropic Bodies

Proc. Roy. Soc. (London) 177A (1941) 217-227

According to the theory of Born, the tensile strength of a crystal is connected with the energy of melting rather than with that of sublimation. This conception is developed, and a model is put forward by means of which the process of fracture can be treated thermodynamically. The conclusions are compared with values for a number of metals, and a good agreement is obtained with the equation:

$$F = Q\rho \frac{1 - 2\mu}{3 - 5\mu},$$

where F is the tensile strength, μ is Poisson's ratio, Q is the melting energy/unit mass, and ρ is the density.

(504) Fürth, R.

Experimental Evidence on Recent Theories of the Equation of State and the Melting of Solids

Proc. Cambridge Phil. Soc. 37 no. 1 (1941) 34-54

A short survey of Born's theory of the thermodynamics and melting of crystals is given. It is shown that Lindemann's and Gruneisen's laws can be deduced from the theory; the theoretical relation $V_m = 1.15V_0$ where V_m + Vo are the volumes at the melting point and zero temperature respectively, is approximately correct for a large number of elements. A relation between the compressibility k, the specific volume V, and the coefficient of linear expansion β, $k = 3.4 \times 10^{-9} \beta V$, is also confirmed by experiment. Data are tabulated which confirm equations derived for the variation of the compressibility and of the elastic constants with temperature and pressure. The relation between breaking and melting is discussed; melting occurs when the lattice is expanded by thermal expansion to the same degree as that which would make it unstable if it were deformed by the action of a stress at zero temperature. The constancy of the ratio between tensile strength and Young's modulus, which holds for a number of metals, is deduced theoretically. Finally, an equation of the form $Q/S = -\Delta\rho/\rho$, where Q is the heat of melting, S the heat of sublimation, ρ the density, and $\Delta\rho$ the change of density on fusion, is deduced and compared with experiment.

(505) Fürth, R.

On the Theory of Finite Deformations of Elastic Crystals

Proc. Roy. Soc. 180A (1942) 285-304

The general theory of finite deformation of cubic crystals at zero temperature is developed to a second-order approximation, and the cases of (1) a uniform hydrostatic pressure, (2) a tension in the direction of one of the axes, (3) a shear along the (010) planes, and (4) a shear along the (011) planes of the lattice, are worked out in detail. A number of "second-order effects" (deviations from Hooke's law) are predicted.

(506) Fürth, R.

On the Equation of State for Solids

Proc. Roy. Soc. 183A (1944) 87-110

The problem of the equation of state of a solid is discussed. The most simple approximation is that the potential energy may be written in the form $\phi = ar^{-m} + br^{-n}$ $(m<n)$, which assumes that the interatomic force is a superposition of an attracting and a repelling force, both depending on the interatomic distance r by a simple inverse power function. Methods are developed which make it possible to calculate the exponents m and n for a given element from measurements of the sublimation energy, the compressibility, the thermal-expansion coefficient, and the dependence of these quantities on pressure and temperature. Tables are given showing the different quantities and various derivatives for a large number of elements, and in general the theory is satisfactorily confirmed. The problem of melting is discussed, and it is concluded that melting takes place in a region where the lattice should be stable to all disturbances caused by the thermal movement, so that melting cannot be regarded as the result of a simple mechanical breakdown of the lattice, although the two processes might be related. A relation is deduced which is closely related to the well-known melting-point equation of Lindemann.

(507) Fürth, R.

On the Theory of Strength of Quasi-Isotropic Solids

Phil. Mag. 40 ser. 7 (1949) 1227-1233

Shows that Bragg's theory of strength of metals, based on assumption of a block structure of crystallites, and Fürth's thermodynamic theory of strength, based on the idea of a connection between breaking and melting, can be related to each other if it is assumed that the block structure is an intrinsic feature of the crystal lattice. Fürth showed [Proc. Roy. Soc. A183 (1944) 87] that melting actually occurs with most elements at temperatures ~ 3.5 times lower than the "critical temperature" at which the breakdown of the perfect lattice due to thermal vibrations should take place.

(508) Fusfeld, H. I.

New Interpretation of the n-Power Law in Plastic Deformation

J. Appl. Phy. 20 (1949) 1052-1055

Shows that the n-power law describing a true stress-strain curve, normally written as $S = k\delta^n$, can be placed in the form $S = S_0 (e\delta/n)^n$ where S_0 is engineering tensile strength. Application to tensile curves. A plot of S/S_0 as a function of n, for a fixed value of logarithmic strain, provides a general description of the behavior of all materials in plastic deformation.

(509) Garofalo, F., Malenock, P. R., and Smith, G. V.

Hardness of Various Steels at Elevated Temperatures

Trans. ASM 45 (1953) 377-396

A hot-hardness tester of the static-loading type is described. A number of different steels were tested at temperatures ranging from room temperature to 1500 F. The results indicate a general relation between hot hardness and creep or creep-rupture strength, which, to a first approximation, is independent of structure or test temperature. A similar relation was observed between hot hardness and ultimate tensile strength in short-time hot tensile tests.

(510) Garofalo, F., Smith, G. V., and Royle, B. W.

Validity of Time-Compensated Temperature Parameters for Correlating Creep and Creep-Rupture Data

Trans. ASM 78 (1956) 1423-1429

Three proposed empirical relationships correlating time, temperature, and stress in creep rupture are discussed, and their validity is checked against experimental results for several ferritic and austenitic steels. The relationships, which are all expressed as single-valued functions of stress, are

$$T(C + \log t), \quad \frac{T - T_a}{\log t - \log t_a}, \quad \text{and } t \exp(-\Delta H/RT)$$

where T is the temperature, t the time to rupture, and ΔH the activation energy, R the gas constant, and C, T_a, and t_a material constants. It is shown that the parameters are not single-valued functions of the initial stress and that the existence of a master curve for the parameters is doubtful. The correlation of minimum creep rate, temperature, and stress by the function $T(C - \log r) = F(\sigma)$, where r is the minimum creep rate and σ the initial stress is also discussed. Although the strict validity of the parameters is disputed, they are a useful means for summarizing data for the purposes of comparison and when judiciously used, yield valuable predictions.

(511) Garrod, R. I., Suiter, J. W., and Wood, W. A.

An Electron-Microscope Study of the Effect of Temperature and Strain-Rate on the Mechanism of Deformation of Aluminium

Phil. Mag. 43 ser. 7 (1952) 677-685

Electron-microscope observations show that there are three basic stages in the mechanism of deformation of metals. These are the slip, cell, and boundary micro-flow processes. Interpretation of these experimental observations, in terms of structural changes, and their possible relationship to the dislocation theory of deformation are discussed briefly.

(512) Garstone, J., and Honeycombe, R. W. K.

Deformation of Alloy Single Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 391-405

With Al-3.5% Cu crystals, easy glide only occurs in the supersaturated solid solution when deformed at a low temperature, so that aging does not take place during the deformation. If the crystals are aged to peak hardness or overaged, before deformation, then the subsequent stress-strain curve shows normal parabolic hardening.

(513) Garstone, J., Honeycombe, R. W. K., and Greetham, G.

Easy Glide of Cubic Metal Crystals

Acta Met. 4 (1956) 485-494

The structural features associated with easy glide in high-purity Al crystals were studied, and the temperature dependence was examined on identically oriented crystals. The influence of specimen length was studied at room temperature. The orientation dependence of the stress-strain curves of Cu single crystals confirms the results of Rosi. It is shown that the length of the easy-glide range varies because of the existence of a size factor. The addition on the extent of easy glide, has been investigated. The view is advanced that easy glide ends as a result of secondary slip arising prematurely in the vicinity of dislocation pile ups. This model gives results that are in accord with the experimental data. The value of the critical resolved shear stress determines the extent of easy glide, and from this follows an explanation of the temperature dependence. Variation in the length of the slip path, and consequently of the number of pile ups, is put forward as an explanation of the orientation dependence of the phenomenon.

(514) Geguzin, Ya. E., and Bengus, V. Z.

Study of Diffusion Creep of Metals and Alloys. I. Diffusion Creep of Fine Metal Threads (In Russian)

Fiz. Metal. i Metalloved. Akad. Nauk S.S.S.R., Ural' Filial 1 (1955) 269-272

Deformation of crystalline bodies caused by diffusion displacement of atoms and produced by external loads below the yield point, known as diffusion creep, is a function of metal viscosity. Determined these viscosities for Sn and Pb single-crystal wires at 175 and 285 C, respectively, by measuring elongation versus time.

(515) Gemant, A.

Frictional Phenomena. XI — Solids. The Plastic Flow of Solids

J. Appl. Phys. 13 (1942) 688-696

The general features of plastic phenomena in solids are reviewed and illustrated by typical deformation-time curves. The Prandtl theory of plastic properties is described, and the later more physical theories of Becker, Orowan, and G. I. Taylor are dealt with in detail. Reference is made to experimental material representative of the chief plastic phenomena.

(516) Gemmel, G. D., and Grant, N. J.

Effects of Solid-Solution Alloying on the Creep Deformation of Aluminum

Trans. AIME 209 (1957) 417-423

The effects of solid-solution alloying on the creep-rupture properties, deformation characteristics, and fracture of pure Al were studied by means of creep-rupture tests on Al-Cu (0.21, 0.79, and 2.05%), Al-Zn (4.93, 9.89, and 19.75%), and Al-Mg (0.93, 1.97, and 5.10%) alloys at 500, 700, and 900 F. Both Cu and Mg are highly effective in improving the creep resistance and rupture life. Zn has little or no effect, and under certain conditions appears to have a weakening action. At 500 F and certain strain rates, the deformation mechanism changes from slip predominantly to the high-temperature processes of grain-boundary sliding and migration and fold formation, and this effect becomes more marked with increasing alloy content. When recovery processes are slowed down so that grain-boundary migration is highly restricted, and accommodation of strains across grain boundaries cannot be achieved, extensive intercrystalline cracking occurs with large loss of ductility. For longer times (lower strain rates) at 500 F grain-boundary sliding and migration and fold formation become more active and result in a resumption of transcrystalline failures, an effect which becomes more marked with increasing temperature. Thus, alloying addition to pure Al often reduces grain-boundary migration, while folds become shorter and broader, although slip-band spacing measured at fracture, remains inversely proportional to stress; there appears to be a wider spacing of slip bands for a given stress.

(517) Gensamer, M.

Strength and Ductility

Trans. ASM 36 (1946) 30-60

Strength is not sensitive to local variations in composition and structure but depends regularly on composition and on the mean spacing between particles but not on the shape of the particles. The effect of dissolved elements is insignificant in comparison to the strengthening effect of fine dispersion. Ductility, on the other hand, is much affected by local conditions. Local ductility, unless very low, may have little effect on energy absorption in a structure. The distribution of deformation may be of more consequence. Improvement in deformation distribution by modification of the plastic properties of substances should be more profitable when the intrinsic ductility is considerable. However, this should not be true at high strength levels, where intrinsic ductility is low enough to be a more important factor. The limiting, local deformation prior to fracture of high-strength materials, should be improved even though it be of less importance in our more ductile alloys.

(518) Gensamer, M.

General Survey of the Problem of Fatigue and Fracture

Paper from Fatigue and Fracture of Metals, MIT, Cambridge, Massachusetts (1952) 1-17

Reviews such important items as the nature of the fatigue process, grain-size effects, and the role of the relative temperature deficiencies of the processes of flow and fracture, in determining the transition temperature.

(519) Gensamer, M.

The Effect of Grain Boundaries on Mechanical Properties

Paper from Relation of Properties to Microstructure, Am. Soc. Metals, Cleveland, Ohio (1954) 16-29

Crystallographic translation predominates at low temperatures and high speeds of deformation, whereas grain-boundary shear predominates at elevated temperatures and slow speeds. Impurities play a large role in determining the effectiveness of grain boundaries in limiting ductility.

(520) Gensamer, M., Lowrie, R. E., and Larson, H. R.

A Theoretical Study of Materials for Extremely High Temperature Applications

Penn. State Coll. (September 3, 1947) Report to ONR

Literature survey to find theoretical reasons for strength at high temperatures in some metallic materials. No reasons were found. Proposes an experimental program to determine general relationships between high-temperature strength and ductility, and physical properties. Materials suggested were intermetallic compounds, metals hardened by internal oxidation, and cold-worked metals with high recrystallization temperatures.

(521) Gensamer, M., Pearsall, E. B., Pellini, W. S., and Low, J. R.

The Tensile Properties of Pearlite, Bainite, and Spheroidite

Trans. ASM 30 (1942) 983-1020

The tensile properties of four steels have been determined as a quantitative function of the measured dimensions of the aggregate structures pearlite and spheroidite, and of the austenite decomposition temperature for the structures pearlite and bainite. The strength indices (stress at corresponding strains, tensile strength, hardness) vary linearly with the reaction temperature and the logarithm of the dimensions of the aggregate. The spacing of pearlite is shown to be proportional to the C diffusion coefficient in austenite. A rule of strength for aggregates is proposed: The resistance to deformation of a metallic aggregate consisting of a hard phase dispersed in a softer one is proportional to the logarithm of the mean straight path through the continuous phase. A simple explanation of the semi-logarithmic character of the relationship is advanced.

(522) George, W.

Nucleation and Growth of Flow and Fracture Markings

Ind. Eng. Chem. 44 (1952) 1328-1331

Macroscopic observations of the temporal and spatial development of localized plastic flowing and fracturing in polymeric solids (and metals) are used to suggest "models" of the physical character of the microscopic processes of plastic flow.

(523) Gertsriken, S. D.

The Energy to Form a Vacancy in Metals and Alloys (In Russian)

Fiz. Metal. i Metalloved. Akad. Nauk S.S.S.R., Ural' Filial, 3 (1956) 238-241.

Describes a method of calculating the vacancy concentration and the energy to form a vacancy (E_g) from measured values of the thermal expansion at high temperatures. The method is an improvement of an earlier method given by Gertsriken [Doklady Akad. Nauk S.S.S.R. 98 (1954) 211]. Calculated values of E_g for Au, Cu, Ag, Pt-Al, Pt-Ir, Ni-Cr, and Ag-Au of various composition are tabulated. Agreement is good with values of E_g (where available) from electrical-resistivity and quenching measurements.

(524) Gervais, A. M., Norton, J. T., and Grant, N. J.

Subgrain Formation in High-Purity Aluminum During Creep at High Temperatures

Trans. AIME 197 (1953) 1166-1174

Creep deformation of coarse-grained Al at temperatures approaching the melting point permit the formulation of a theory of subgrain formation. Subgrain boundaries are found to be formed by two different processes: kinking and polygonization. The latter is considered to be the main factor in subgrain formation. The results are discussed in relation to those of other workers. They lead to a new theory of subgrain formation, which bridges the gap between the theory based on fragmentation and that based on polygonization. It is considered that subgrains are formed by two different processes: (1) kinking, which results in a small number of boundaries being formed, which are sharp from the very beginning of deformation; this is in agreement with Wood's argument that fragmentation is taking place, if fragmentation is synonymous with kinking; no significant sliding is observed along this type of boundary, however, but primarily rotation, and (2) polygonization of the smoothly bent regions delineated by kinking; this is the main factor in subgrain formation, and the size of the grains is a function of the extent of bending and of temperature. It is concluded that, since polygonization is mainly responsible for subgrain formation, the grains must form as a consequence of deformation and are not a main cause of deformation.

(525) Gervais, A. M., Norton, J. T. and Grant, N. J.

Kink-Band Formation in High-Purity Aluminum During Creep at High Temperatures

Trans. AIME 197 (1953) 1487-1492

Observations have been made by metallographic and back-reflection X-ray techniques, of the mode of formation of kink bands formed during creep testing of very large-grained Al, in the temperature range 425 to 620 C. The results show that: (1) the formation of kink bands needs a bending moment during deformation in tension of the specimen; (2) the kink bands form in regions which have been deformed by prior slip or where slip takes place simultaneously; (3) the plane of kinking bisects the angle between the slip planes on the two sides of the kink boundary; (4) for moderate deformations the kink bands keep the same width during the deformation process; and (5) in addition to the sharp bending about the kinking planes, a smooth bending occurs in the bands themselves and also in regions outside them. The observations are used to develop a theory of kink-band formation.

(526) Gibbs, R. E. and Ramlal, N.

Crystallite Orientation in a Polycrystalline Metal During Plastic Flow

Phil. Mag. 18 (1934) 949-956

In confirmation of results obtained by Andrade and Chalmers, X-ray measurements show that when a polycrystalline metal flows, the part of the flow which gradually diminishes with time is associated with rotation of the axes of the crystallites.

(527) Gibbs, I. W.

Tensile Properties of HK31XA-H24 Magnesium Alloy Sheet Under Rapid-Heating Conditions and Constant Elevated Temperatures

NACA TN 3742 (1956) 20 pp

This alloy was tested at room temperature and 600 F, both in conventional constant-temperature stress-strain tests, and at heating rates of 0.2 to 150 F/sec. Yield and rupture stresses and temperatures derived from the two tests were compared using the parameters $(T_y + 70)/(\log h + 8)$ and $(T_r + 1060)/(\log h - 7)$ where T_y and T_r (F) are the yield and rupture temperature and h (F/sec) is the heating rate. The correlation of data is very good for yield values, but relatively poor for rupture values. Yield and rupture stresses obtained under rapid-heating conditions can be either smaller or greater than corresponding constant-temperature values.

(528) Giessmann, E. J.

Inertia of Plastic Deformation of Steel (In Russian)

Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh. Nauk, no. 11 (1955) 50-57

Tensile testing at high rates reveals anomalies of elongation associated with inertia of propagation of plastic deformation. Amplitudes of waves of plastic deformation of steel with and without heat treatment are considered.

(529) Gifkins, R. C.

The Variation with Strain-Rate of the Mechanism of Deformation of a Lead-Thallium Alloy

J. Inst. Metals 79 (1951) 233-242

The deformation of high-purity Al takes place by three mechanisms which depend systematically on the temperature and rate of straining. The present paper describes similar changes in mechanism that occur when a single-phase Pb-Tl alloy of high purity is deformed at room temperature. At high rates of strain, deformation occurs almost entirely by slip within the grains, the shapes of which change in conformity with the extension of the aggregate. As the strain rate is decreased the slip lines become less regular and more widely spaced, and at this stage deformation takes place partly by the formation of these slip zones and by "micro-flow" within them, and partly by "boundary micro-flow". At still lower strain rates, deformation proceeds almost entirely by "boundary micro-flow", and consequently the grains remain comparatively undisturbed, except in the neighborhood of the boundaries. These stages of deformation found in the alloy are discussed and correlated with those which have been described for Al.

(530) Gifkins, R. C.

A Mechanism for the Formation of Intergranular Cracks When Boundary Sliding Occurs

Acta Met. 4 (1956) 98-99

A model is proposed for the formation of cracks as a result of slip across a sliding boundary resulting in the formation of a jog which develops into a cavity. The model is discussed in relation to observations of the behavior of various metals.

(531) Gifkins, R. C.

A Surface Effect of Boundary Sliding During Creep

Bull. Inst. Metals 3 (1957) 185-186.

A note explaining why grain translation appears to be inhibited at the surface of Al during creep, based on grain topography which arises during annealing. The observations of Rachinger and of Farmer are explained, as well as demonstrating that differences in results may be due to the annealing and polishing sequence used.

(532) Gifkins, R. C.

Slow Deformation of Metals, Particularly at Elevated Temperatures

J. Australian Inst. Metals 1 (1956) 134-147

Literature review gives empirical and formal expressions for creep curve; examines the functions of coarse slip, cell substructure, fine slip and boundary sliding in relation to theories of creep in pure metals and simple alloys.

(533) Gifkins, R. C.

Effect of Stress on the Recrystallization of Lead During Creep

J. Inst. Metals 86 (1957) 15-16

The strain necessary to initiate recrystallization during creep of high-purity Pb has been determined for stresses from 300 to 1500 psi. Results appear to be best fitted by an exponential law, recrystallization occurring at higher strains with higher stresses, and grain size after recrystallization becoming smaller with increased stress.

(534) Gifkins, R. C.

Effect of Prior Strain on the Creep of High-Purity Lead

J. Australian Inst. Metals 2 (1957) 66-71

Effect of small amounts of prior strain on creep at stresses of 400 psi on vacuum-cast and extruded high-purity Pb

Declassified in Part - Sanitized Copy Approved for Release @ 50-Yr 2014/01/27 : CIA-RDP81-01043R003200240005-1

(535) Gilman, J J

Deformation of Symmetric Zinc Bicrystals

Acta Met 1 (1953) 426-427

Stress-strain data for a symmetric Zn bicrystal with a longitudinal boundary Shows that the bicrystal deforms as if it were a monocrystal Observations in terms of dislocation theory

(536) Gilman, J J

Plastic Deformation of Rectangular Zinc Monocrystals

Trans AIME 197 (1953) 1217-1222

Thirty-five pairs of rectangular Zn single crystals were used, in which both members of the respective pairs had the same orientation with respect to the longitudinal axis, but each had different orientations with respect to their rectangular external shapes Data indicate that critical shear stress and strain-hardening rate depend on the orientation of the slip direction with respect to its external boundaries The interpretation of all the known size or shape effects is difficult because they may either be bulk effects, or surface effects which depend on some surface parameter, and as they are almost inversely proportional to one another, it is not yet possible to make an unambiguous distinction. It is suggested that surface-effect studies like those of Pfutzenreuter and Masing [Z Metallk (1951) 42 361] might help to resolve the dilemma

(537) Gilman, J J

The Role of Thin Surface Films in the Deformation of Metal Monocrystals

Paper from Symposium on Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures, Spec. Tech Publ No. 171, ASTM, Philadelphia (1955) 3-13

The literature on the strengthening effects of surface films on metal monocrystals (termed the "Roscoe effect") has been reviewed Available data show that the effect cannot be explained in terms of the strength of the film itself, rather, an interaction between the film and the crystal surface must be involved. New data confirming this viewpoint are presented. X-ray diffraction measurements of the distortions at the surface of Zn crystals were made The measurements showed that a Cu film caused a marked increase in the surface distortion that occurs when a crystal is pulled in tension It is concluded that the Roscoe effect is caused by the inhibiting effect that a surface film has on the exit of slip from a crystal The effect that a film might have on the generation of slip on the surface is not believed to be an important factor

(538) Gilman, J J

Cleavage Steps on Zinc Monocrystals Their Origin and Patterns

Trans AIME 203 (1955) 1252-1255

Characteristic cleavage step patterns are observed on the cleavage surfaces of undeformed, slipped, bent, twinned, compressed, and indented Zn crystals; the effect of temperature is discussed Dimples were seen to produce cleavage steps in a treelike pattern in otherwise undeformed crystals The steps seem to originate when cracks intersect screw dislocations

(539) Gilman, J J.

Study of a New Mode of Plastic Deformation in Zinc Crystals

Trans AIME 203 (1955) 206-214

Characteristics of "μ-bands" formed during compression of zinc single crystals. A dislocation model for this phenomenon Diagrams, graphs, photographs, micrographs Zn single crystals of various orientations were deformed in compression at temperatures of -200 to +200 C, after which their structure was examined. Compression nearly parallel to their basal planes (within 2 deg) produced a new mode of deformation, a characteristic of which is the formation of deformation markings designated "μ-bands" It is concluded that the μ-bands are not the result of nonbasal slip but are caused by a microbuckling mechanism A dislocation model that is consistent with some of the features of the μ-bands is described

(540) Gilman, J J

Etch Pits and Dislocations in Zinc Monocrystals

Trans AIME 206 (1956) 998-1004

A technique is described for producing etch pits at the sites of edge dislocations in zinc monocrystals A survey was made of the etch-pit patterns that appear in cast crystals as well as crystals that were deformed in various ways, including basal glide, twinning, kinking, pyramidal glide, and bending.

(541) Gilman, J J

Propagation of Cleavage Cracks in Crystals

J Appl Phy 27 (1956) 1262-1269

Data on crack propagation in elastic media are summarized, showing that this phenomenon is adequately understood at present For inelastic media, it is postulated that two critical velocity conditions must be satisfied or crack propagation cannot occur One critical velocity pertains to propagation through a crystal and the other to propagation through an aggregate

(542) Gilman, J J

Plastic Anisotropy of Zinc Single Crystals

Trans AIME 206 (1956) 1326-1336

A study is made of basal and prismatic glide, in tension and in bending, of single crystals of Zn with and without additions of 0 1% Cd, within the temperature range 250 to 400 C Basal glide is the primary glide element, with prismatic glide the dominant secondary element Prismatic glide obeys Schmid's law of the resolved shear stress to a high degree of accuracy, and and equation of state relating the glide strain rate $\dot{\gamma}$ and the shear stress τ, viz , for Zn, $\dot{\gamma}$ 700 τ^3 exp (38,000/RT), and for Zn + 0.1% Cd (which raises the stress exponent and the activation energy), $\dot{\gamma}$ 1400 $\tau^{3\ 6}$ exp (46,000/RT) Strain hardening is negligible at these temperatures and even multiple prismatic glide causes no hardening Experiments on polycrystalline Zn show that creep is controlled by the rate of prismatic glide and not by grain boundary relaxation or other diffusional processes Calculations emphasize the importance of interactions between dislocations and the crystal lattice of Zn

(543) Gilman, J J

Discussion to paper by Hibbard and Dunn on "Polygonization"

Creep and Recovery Am Soc Metals, Cleveland (1957) 79 83

The movement of dislocations in LiF crystals during recovery was studied, and four processes which accompany recovery and lead to polygonization were observed They are a reduction in the number of dislocations by annihilation within glide bands and by motion out of the crystal/surface dispersion of screw dislocations by glide, glide or edge dislocations under internal stress and climb of edge dislocations

(544) Gilman, J J

Fracture of Zinc-Monocrystals and Bicrystals

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Tests of Zn monocrystals have shown that the fracture stress of zinc is reduced by as much as 100X by small amounts of prior plastic glide Tests of Zn bicrystals have shown that the effect of a grain boundary on fracture depends markedly on the type of boundary Symmetric boundaries have no effect on either plasticity or fracture Antisymmetric boundaries raise the plastic resistance but do not reduce the fracture stress Asymmetric boundaries cause marked embrittlement It is shown that fracture begins along the glide plane of a group of blocked dislocations, not ahead of the group and not below it This is consistent with the behavior of bubble rafts A simple, approximate, theoretical treatment is given that is qualitatively and semi-quantitatively consistent with the experimental results

(545) Gilman, J J , and Johnston, W G

Observations of Dislocation Climb and Glide in Lithium Fluoride Crystals

J Appl Phy 27 (1956) 1018-1022

Pyramidal etch pits were produced on cleavage surfaces of LiF crystals by etching It was shown that the etch pits correspond to dislocations and not to impurities After heavy etching, pits due to edge and screw dislocation were distinguishable, the latter being asymmetrical. Dislocation glide during bending and climb during annealing were observed by etching before and after these operations

(546) Gilman, J J , and Johnston, W G

The Origin and Growth of Glide Bands in Lithium Fluoride Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 116-163

Evidence concerning the origin of glide dislocations in LiF crystals is given It is pointed out that dislocation loops can be nucleated at the tips of cracks in LiF crystals Then, three sets of experiments are described which indicate that dislocation nucleation occurs at stresses as low as about 1 kg/mm^2 In these experiments dislocation loops were nucleated (a) by lightly pressing balls into contact with LiF crystals, (b) by means of thermal stresses; (c) during plastic bending. The expansion and multiplication of dislocation half loops under applied stresses is described It is shown that a single half loop can multiply sufficiently to create a large glide band consisting of thousands of dislocations The multiplication process beings by the formation of new dislocation loops behind an expanding half loop. After large glide bands have been established they spawn other glide bands by new nucleation at stress concentrations and by the motion of (100) screw dislocations off (110) planes onto (100) planes It is demonstrated that dislocations in LiF crystals experience a large viscous lattice resistance to their motion This lattice resistance depends strongly on temperature

(547) Gilman, J J , and Johnston, W G

Viscous Dislocation Motion in LiF

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Direct observations of dislocation motion in LiF crystals show that there is a quasi-viscous resistance to dislocation motion in this material. This resistance does not involve dislocation interactions, but occurs for dislocations moving in dislocation-free regions of the lattice. The viscosity increases with impurity content, with neutron bombardment, and with decreasing temperature The velocity of a dislocation increases exponentially with stress for stresses greater than a critical stress

(548) Gilman, J J , and Read, T A

Surface Effects in the Slip and Twinning of Metal Monocrystals

Trans AIME 194 (1952) 875 883

Experiments described on (1) effect of crystal shape and (2) effect of metallic surface films, on plastic deformation Crystals of Zn Sn, and Pb were grown in various shapes and were tested in simple tension Macroscopic rotations about tension axis which are unpredicted by classical theory of slip were observed. The effects of evaporated and electrodeposited films of Cu, Ni, Au, and Zn on mechanical properties of the crystals were determined Films influenced both slip and twinning in creep and tensile tests

(549) Gilvarry, J J

Temperature-Dependent Equations of State of Solids

J Appl Phy 28 (1957) 1253 1261

Discusses an isothermal equation of state which reduces to Birch's, Murnaghan's, and to special equations of Bardeen, Grüneisen, Born, and Fürth The equation is generalized to arbitrary temperature whose functional form is determined by considerations of thermodynamic consistency The form of the equation of state at low temperature is given as an explicit function of volume and temperature for a solid whose heat capacity obeys the Debye law This equation shows good agreement with experimental pressure/volume data

(550) Glander, F

Determination of Rigidity and Resilience Properties of Soft Copper Wire (In German)

Metall 9 (1955) 972-978

Relation between resilience properties and rigidity, direct measurement of resilience, bending tests

(551) Glen, J

A New Approach to the Problem of Creep

J Iron Steel Inst 189 (1958) 333-343

A number of strain-age-hardening phenomena were observed in high-temperature tensile tests, each being associated with the presence of a particular alloying element. Related effects can be detected in the creep curves of various steels and other alloys. These take the form of a sudden deceleration of creep rate over an interval of time and have been called transitions in creep rate Several transitions usually occur in the creep curves of commercial alloys To show up these transitions in creep rate in their true perspective, the creep data were plotted in the form of log strain versus log creep-rate curves (strain-rate curves). A family of such curves either at constant stress or at constant temperature forms a regular pattern so that the strain-rate curves of tests at lower stress or temperature can be estimated By integration the ordinary strain-time creep curves are obtained. In this way accurate extrapolation of creep or rupture tests is claimed

(552) Glen, J W

The Creep of Cadmium Crystals at Liquid-Helium Temperatures

Phil Mag. ser 8 1 (1956) 400-408

Theories of creep assume that flow is due to thermal fluctuations assisting the applied stress to force dislocations past obstacles, and therefore creep might be expected to vanish as the temperature approaches 0 K However, one report exists of sizable transient creep at liquid-He temperature To investigate this, single crystals of Cd were tested in tension at 1 2 to 4 2 K Measurable transient creep was found, the amount of which did not vary rapidly with temperature Calculations show that this transient creep is 5 to 10 times faster than would be expected from the behavior at liquid-air temperature It is suggested that this creep is due to the quantum-mechanical tunnel effect, which allows dislocations to penetrate barriers to their motion that cannot be overcome by the action of stress alone Features of the creep curves agree qualitatively with this suggestion, though theoretical calculation of the quantitative effect expected is not attempted, owing to uncertainities about the exact nature of the barriers

(553) Gol'denbalt, I I

Some General Laws of the Process of Elastic-Plastic Deformation (In Russian)

Doklady Akad Nauk S.S S R

Theoretical investigation Proposes a new generalized formula, which is interpreted for different values of the variables

(554) Goldhoff, R M

Comparison of Parameter Methods for Extrapolating High-Temperature Data

GE Materials and Process Lab. Report (May 20, 1957)

It is shown that prediction of long-time working stresses using parameter techniques will generally give better results than can be obtained from long extrapolations on double logarithmic plots

(555) Goldhoff, R M , and Spretnak, J W

Distribution of Boron in Gamma Iron Grains

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The distribution of B in gamma Fe grains as a function of temperature is studied, employing three experimental techniques (a) grain growth in high purity Fe C and Fe C B alloys, (b) X-ray parameter measurements on Fe B alloys as a function of temperature, and (c) the metallographic test for the B constituent It is concluded that B undergoes positive adsorption to gamma Fe grain boundaries and that the temperature coefficient of adsorption is positive

(556) Gombás, P.

Theory of Metallic Bonding - Part I

Z Physik 99 (1936) 729 742

A mathematical theory of interatomic forces in metals, employing Hartree's eigen functions, is developed and applied to derive values of the physical constants of the K atom The following values of the respective constants are derived, for comparison the experimental values are given in parenthesis lattice constant, 5 37 (5 15) A, lattice energy, 111 1 (126 2) kcal/mol, heat of sublimation, 11 4 (26 5) kcal/mol, compressibility, 2 6 x 10 ^{11} (2 0 x 10 ^{11}) cm^2/dyne

Part II, ibid. 100 (1936) 599-614

Formulae deduced are applied to the calculation of the lattice constants, the lattice energies, and the heats of sublimation of K, Rb, and Cs The results are in satisfactory agreement with the experimental values

Part III, ibid 104 (1936) 81-92

It is shown that in the case of the alkali metals, a sufficiently close approximation of the lattice energy is obtained by taking into account only the interaction of metal electrons and ions The respective lattice energies are inversely proportional to the lattice constants δ, while the compressibilities are proportional to δ^4 These results are in agreement with experimental values The lattice constant and energy of sublimation of K calculated by means of the simplified theory are likewise in agreement with experimental values

Part IV, ibid 104 (1937) 592-603

The theory of metallic linkages is investigated by a simplified statistical method. The lattice energy, U, of the alkaline earth metals is found to be proportional to 1/R, and their compressibilities, K, proportional to R^4, R denoting the equilibrium value of the radius of the sphere containing each individual ion Satisfactory agreement is found between experimental and theoretical values of U and of K in the case of the alkaline earth metals. The theory requires modification before it can be applied to the discussion of the metals Cu, Ag, Au, Zn, Cd, and Hg. The significance of this is briefly discussed

(557) Gondi, P

A Study of the Deformation of Polycrystalline Zinc Twinning, Substructure, and Phenomena at the Crystal Boundaries (In Italian)

Met Ital 48 (1956) 15-31

Tests to evaluate the separate contributions of the tensile behavior of slip, twinning, and work hardening. Twinning is detected below 300 C by jumps in the tensile curve With these jumps subtracted, the tensile curve shows the effect of work hardening The temperature variation of this hardening is explained in terms of substructure Below 100 C there is little formation of substructure, and only at the crystal boundaries; above 100 C conditions are favorable Near 200 C, slip at the boundaries increases, and becomes predominant above 350 C, the substructure then serving to maintain cohesion

(558) Goranson, R W , Bancroft, D., Burton, B L., Blechar, T , Houston, E E , Gittings, E F , and Landeen, S. A.

Dynamic Determination of the Compressibility of Metals

J Appl Phy 26 (1955) 1472-1479

Theory is presented which allows comparison with data obtained by other experimenters, and which yields the relationship between pressure and compression either at constant entropy or constant temperature

(559) Gordon, R B , and Nowick, A S

The Pinning of Dislocations by X-Irradiation of Alkali Halide Crystals

Acta Met 4 (1956) 514-527

A study is made of the effect of X-irradiation on the room-temperature elastic modulus (s_{11}^{-1}) of NaCl crystals The modulus is observed to be unchanged by irradiation for well-annealed crystals, but may increase by as much as 7% when cold-worked crystals are irradiated. It is demonstrated that the modulus change on irradiation corresponds exactly to the elimination of the modulus decrease due to oscillating dislocation loops through the creation of pinning points along the dislocations This theory assumes that vacancies released within the volume of the crystal through the action of the radiation, migrate to dislocations and contribute to the formation of pinning points The theory appears to be in good agreement with experiment and makes possible a calculation of the density of dislocations and the mean length of the free dislocation loops prior to irradiation

(560) Gorsky, W S

Theory of Elastic After-Effect in Disordered Solid Solutions (Elastic After Effect of the Second Class) (In German)

Physik Z Sowjetunion 8 (1935) 443 456

Prevalent theories of the elastic aftereffect, which attribute the phenomenon to nonuniform plastic deformation, are considered to be unsatisfactory; a theory of the effect in solid solutions attributing it to an association of diffusion under conditions of nonuniform stresses is developed. The flexure of solid solutions in the presence of infiltrating solutions is examined in some detail mathematically and it is shown that the elastic aftereffect may amount to as much as 50% of the elastic deformation. In the case of bent single crystals an aftereffect is established extremely slowly when the thickness of the crystal exceeds 10^{-2} to 10^{-3} mm. An attempt to interpret the phenomenon in polycrystalline metals and alloys is presented

(561) Goss, N P.

Grain Displacement in Metal Stressed Below Elastic Limit

Metal Progr 61 (May, 1952) 87-91

A study by X-ray diffraction methods of movements within the mosaic substructure of coarse-grained metal under moderate stress. Materials were 3% Si steel and high purity annealed Fe

(562) Gouzou, J

The Structural Theory of Elastic and Plastic Phenomena in Metals (In French)

Publ 'assoc ingro. fac polytech. Mons 97 No. 2 (1949) 17-29

Born's theory of the elasticity and plasticity of single crystals, and Taylor's theory of the elasticity and plasticity of polycrystals have certain defects. Attempts are made to overcome these defects by extending to plasticity a simplified theory which has afforded the best results in elasticity of metals. Essentially, the theory proposed is based upon the hypothesis of Huber and Schmid [Hev. Phys Acta, 7 (1934) 620] that under tensile stress all the grains of an aggregate experience the same dilatation in all other directions. It is considered that this theory is applicable to a variety of mechanical processes, e g., rolling and stamping, and to the phenomena of mechanical hysteresis

(563) Graham, A.

Phenomenological Theories of Creep

Engineer 193 (1952) 198-201; 234-236

A formula with four adjustable constants relating permanent strain to stress, time, and temperature, is shown to represent successfully the decelerating stage of uniaxial creep in several dissimilar metals. Applications to tertiary creep, the tensile test, and stress relaxation are discussed together with its limitations as an equation of state. A closely allied formula is also put forward, for which the state of the metal is not characterized by the instantaneous rate of straining.

(564) Graham, A.

The Phenomenological Method in Rheology

Research 6 (1953) 92-97

Suggests a progressive method of building up a mathematical theory relating stress, strain, and flow. Starting with the Nutting equation, the superposition principle is applied, and effect of temperature is allowed for. The various modes of deformation of alloys are handled by assuming that each mechanism makes its contribution to the total strain.

(565) Graham, A., and Walles, K F A

Relationships Between Long- and Short-Time Creep and Tensile Properties of a Commercial Alloy

J Iron Steel Inst 179 (1955) 105-120; Discussion, ibid. 182 (1956) 185-194

Experimental results are given for short-time creep tests, two forms of tension test, and creep recovery tests, on Nimonic 80, and comparisons are made with long-time creep data. Satisfactory relationships are established among the various results and the long-time data. A theory of deformation is developed, based upon the Nutting equation and the Boltzmann memory principle, which meets a variety of requirements

(566) Granato, A., Hikata, A., and Lücke, K

Recovery of Damping and Modulus Changes Following Plastic Deformation

Acta Met 6 (1958) 470 480

A theory is developed which assumes that changes with time in the decrement and modulus of a crystalline material following plastic deformation are a result of dislocation pinning by deformation induced point defects. This time dependence is based upon the Cottrell Bilby $t^{2/3}$ law for strain aging. Comparison of the results of the theory with available data shows that the measured time law is that predicted by the theory for specimens which have been deformed between about 0 4 and 4 0 per cent. For smaller and larger deformations, deviations are obtained. Although measurements so far available permit only a qualitative check of the predictions of the theory with regard to the dependence of the recovery rate on purity and deformation, a check of the temperature dependence is afforded by recovery measurements of Young's modulus for Cu. From these an activation energy for the migration of vacancies in Cu is determined to be 1 0 ev. A number of experiments needed for checking the theory further are proposed

(567) Grant, N J

Creep and Fracture at Elevated Temperatures

Paper from Utilization of Heat Resistant Alloys, Am Soc Metals, Cleveland, Ohio (1954) 1 28

Reviews work on creep and fracture at elevated temperature, particularly that carried out since 1940 and concludes that not even three simple equations will fit all creep curves for pure metals over a range of temperatures and stresses. Commercial metals and alloys exhibit even greater complexity in their creep behavior. Post 1940 attempts to utilize creep data for purposes of extrapolation are discussed; these include the rate-process theory, the structural instability method, the Larson Miller method [Trans ASME 74 (1952) 765] and the work of Sherby, Orr, and Dorn [Trans AIME 200 (1954) 71]. While no method has proved completely successful, the means of evaluation and interpretation of data have been improved

(568) Grant, N J

Grain Boundary Participation in Creep Deformation and Fracture

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office London (1956) 317-310

Based on creep-rupture studies of a series of metals and alloys varying in composition from that of very high-purity Al to that of a complex age-hardenable gas turbine alloy, it is shown how alloying affects the behavior of grain-boundary deformation and fracture. See discussion by Recorder II [Metal Ind. (London) 84 (1954) 514] who points out that in high purity Al no evidence of intercrystalline cracking was found at any stress. However, extensive grain-boundary sliding and migration took place under these conditions

(569) Grant, N J, and Bucklin, A G

On the Extrapolation of Short-Time Stress Rupture Data

Trans ASM 42 (1950) 720 751

Extensive data for an age-hardenable alloy, S-590, a typical complex high-temperature gas-turbine alloy were examined over a range of seven cycles of time for stress-rupture data and eight cycles of creep rate for minimum rate graphs. Breaks in curves of stress versus rupture time may be due to change from typical low-temperature-type deformation to high-temperature-type deformation, oxidation and corrosion, overaging, agglomeration, and resolution of precipitate, other structural changes such as recrystallization, with or without grain growth, phase changes, formation of sigma-phase, etc

(570) Grant, N J, and Bucklin, A G

Creep-Rupture and Recrystallization of Monel from 700-1700° F

Trans ASM 45 (1953) 151-176

Extensive creep-rupture tests were made on wrought Monel at temperatures from 700 to 1700 F and for rupture times from about 0 001 to 2700 hours. Tests were made on annealed, 30 and 75% cold-worked structures. Recrystallization data were obtained for Monel cold worked from 4 to 70% and annealed from 0 5 to 500 hours at temperatures from 800 to 1700 F. Correlation of recrystallization data from static tests with hardness changes and equicohesion values from stress-rupture tests was attempted. Experimentally determined values of equicohesion are given for 30% cold-worked Monel

(571) Grant, N J, and Chaudhuri, A. R

Creep and Fracture

Paper from Creep and Recovery, Am Soc Metals, Cleveland, Ohio (1957) 284-343

Processes of deformation and structural changes during creep, types of fracture and effects of metallurgical variables and conditions of deformation on fracture. Very competent, extensive review of all aspects of creep process, with special emphasis on the work of Grant and students

(572) Grant, N J, and Gemmell, G D

Effects of Solid Solution Alloying on Creep Deformation of Aluminum

Trans AIME 209 (1957) 417 423

Effect of solid-solution alloying on creep rupture properties, deformation characteristics, ductility and fracture of pure Al. Study by means of creep-rupture tests of Al alloys containing copper, zinc or magnesium heated to 500, 700, and 900 F

(573) Grant, N J, and Preston, O

Dispersed Hard Particle Strengthening of Metals

Trans AIME 209 (1957) 349 357

Review of methods for strengthening metals and alloys at high temperature. Emphasis is on powder metallurgy products, such as SAP, Cu Al_2O_3 $Ni-Al_2O_3$, and Be Be_2C. The theoretical aspects of the hardening and strengthening mechanism are presented

(574) Grant, N J, Servi, I S, and Chaudhuri, A

Slip and Grain Boundary Sliding as Affected by Grain Size

Trans AIME 197 (1953) 217 218

2S Al was recrystallized to yield a mixed grain size, and specimens were tested in creep at 900 F at 880 psi to total elongation of 3 5 and 9%. Similarly, a high-purity Mg specimen was tested at 500 F and 670 psi. Photomicrographs show slip in coarse grains and grain-boundary sliding in fine-grained zones; medium grains exhibit both phenomena. The results support the previously reported evidence (Trans AIME 191 (1951) 917) that grain boundaries have a blocking effect on slip at high temperature, and at a given grain size for a given stress, will undergo sliding as a primary mechanism of deformation

(575) Green, A E.

Hypo-Elasticity and Plasticity

Proc Roy Soc (London) 234A (1956) 46-59

A general theory of work hardening incompressible plastic materials is developed as a special case of Truesdell's theory of hypo-elasticity.

(576) Green, A P

Some Aspects of Theoretical Plasticity

Metal Treatment 20 (1953) 534-540

Discusses the development and application of the theory of plasticity in metals. The discussion is confined to single bodies

(577) Green, L., Jr

Correlation of Creep Properties by a Diffusion Analogy

Trans ASME 74 (1952) 320-326 (in J. Appl Mechanics section)

Two empirical approximations for the strain versus time behavior of eight pure metals lead to a creep equation defining an activation energy as the only undetermined constant. The application of this equation to published creep data effects a correlation which shows that the apparent activation energies observed for creep and self-diffusion have a similar temperature dependence. The qualitative effects of impurities, grain size, cold working, and surface conditions upon creep as predicted by a diffusion analogy are found to agree with experimental results, but the analogy does not hold if the creep deformation is a result of slip.

(578) Green, R B

Intersection-Faulting Mechanism Theory of Flow and Fracture of Face-Centered Cubic Metals

Phys Rev 102 (1956) 376-380

The intersection of any dislocation avalanche with a stationary dislocation having a Burgers vector component perpendicular to the slip plane is shown to produce a close-packed partial plane of vacancies or interstitials in the slip plane, intrinsic or extrinsic faults in (111) slip planes. It is considered that, for most conditions, slip would occur on these planes at lower stress than it occurred on (100) or 110) planes. Metallographic slip observations are consistent with the hypothesis that etch indications occur at faults produced by this mechanism. Fracture is considered to result from the growth of "head-on" faults until transition to the Griffiths mechanism occurs. Fault correction by partial slip produces additional dislocations, some potentially active as Frank-Read sources in other slip planes. For Cu, intrinsic or extrinsic faults have energies of 40 ergs/cm^2 and maximum widths of 400 A

(579) Greenfield, P, and Bever, M B

Effect of Composition on the Stored Energy of Cold Work and the Deformation Behavior of Gold-Silver Alloys

Acta Met 5 (1957) 125 140

Energy stored in chips formed by drilling at room temperature and at -195 C was determined for five Au-Ag alloys. Energy varies with composition and temperature of deformation. Energy expended in deformation is larger at lower temperatures and increases with increasing concentration of solute

(580) Greenough, A P

The Deformation of Silver at High Temperatures

Phil Mag 43 ser 7 (1952) 1075 1082

A new explanation of development of kinking is advanced to account for experimental observations, and it is shown that surface energy effects can give rise to offsetting in a direction which causes wires to shorten

(581) Greenough, G B.

Residual Lattice Strains in Plastically Deformed Polycrystalline Metal Aggregates

Proc. Roy. Soc (London) 197A (1951) 556-567

Using X ray diffraction methods, determinations were made of the mean residual lattice strains in polycrystalline wires of Ni, Cu, and Al of commercial purity. The results show that the residual lattice strains vary both in magnitude and sign. This is in qualitative agreement with the facts that (1) a complex intergranular stress system exists in the deformed aggregate, arising from the variation of yield tension with the orientation of the grains, and (2) in the diffraction process only grains with certain orientations contribute to a given diffraction line, so that the lattice strain measured is not the mean strain of all the crystals, which should be zero, but the average of the strains in crystals with particular orientations, which may be positive or negative. It is concluded that this constitutes one of the reasons for the hitherto unexplained observations which have been made on residual lattice strains

(582) Greenough, G B., Bateman, C. M., and Smith, E M

X-Ray Diffraction Studies in Relation to Creep

J Inst Metals 80 (1952) 545-550

To investigate a hypothesis regarding the mechanism of creep put forward by Greenough and Smith, two Al-Ag alloys, one a solid solution and the other containing a precipitate, were examined. Experiments were also carried out on recovery of specimens quickly pulled at either 20 or 300 C

(583) Greenough, G B., and Smith, E. M.

The Mechanism of Creep as Revealed by X-Ray Methods

J Inst Metals 77 (1950) 435-443

A hypothesis is proposed to explain in terms of dislocation theory the recent observations of Wilms and Wood and of Wood and Rachinger in relation to the mechanism of deformation of metals. Some new X-ray observations on Al which support the hypothesis

(584) Greenspan, J

The Strengthening of Beryllium for High-Temperature Use by Means of Beryllium Oxide and Beryllium Carbide Dispersions

Paper from Metallurgical Information Meeting, Ames Laboratory (May 1956) U. S. AEC TID-7526 (Pt 1) 34-53

The high-temperature rupture life of beryllium is extended considerably when small percentages of either oxide or carbide particles are well dispersed throughout the metal. Correlations are shown between stress-rupture results and microstructure and particle content

(585) Greenwood, G W., and Quarrell, A G

The Cleavage Fracture of Pure Polycrystalline Zinc in Tension

J Inst. Metals 82 (1954) 551-560

A study has been made of some of the cleavage properties of Zn: the effects of grain size, temperature, strain rate, and plastic deformation on the type of fracture and the true fracture stress have been investigated. The true fracture stress has been shown to be inversely proportional to the square root of the mean grain diameter in tests at -196 C. This relationship was found to be valid at higher temperatures if a correction was made for the effect of deformation before fracture. The constant of proportionality increased with increasing temperature. An activation energy for elongation to fracture was determined from the related effects of temperature and strain rate. It is concluded that a dislocation theory can be developed to account for the build-up of large internal stresses from which cracks leading to cleavage are formed

(586) Greenwood, J N

The Creep Phenomenon in Metals

Australasian Engr. (December 1948) 78 83

Earlier work in this field is reviewed, and creep is discussed under the following headings characteristics of deformation below the creep field of temperature; the influence of temperature on cold worked metal; characteristics of deformation in the creep field of temperature, deformation within the crystals; movement at crystal boundaries inter crystalline cracking; Pb as an experimental material for the study of creep; and mechanism of creep.

(587) Greenwood, J N

Recrystallization of Metals Under Stress

Nature 163 (1949) 248-249

The creep rates employed are lower than those of Andrade, and this has a fundamental effect on the mechanism of creep. It is not believed that increased stress or recrystallization is the cause of the transition from constant to accelerating creep rates in uniform-load tests

(588) Greenwood, J N

Intercrystalline Cracking of Metals (Letter)

J Iron Steel Inst 171 (1952) 380

Suggests that cracks are caused by the aggregation of vacant lattice sites When a sufficient number of vacant sites have accumulated in any boundary, conditions for the breaking of the cohesive bonds will have occurred, i e., an intercrystalline crack will have started, which would then open out under the continued stress The conditions for intercrystalline cracking would then appear to be (1) increased temperature, and (2) decreased rate of strain

(589) Greenwood, J N

Intercrystalline Cracking of Metals

Bull Inst Metals 1 (1952) 104-105

Suggests that cracks in metals are initiated by the aggregation of vacant lattice sites The postulated process is illustrated by photographs of a "ball" model Points out that aggregation of the vacant sites in a crystal containing one vacant site in every 150,000 would separate by two atomic distances an area of boundary surface 0 1 mm square

(590) Greenwood, J N

Intercrystalline Cracking of Brass

Bull Inst Metals 1 (1952) 120-121

Observations were made of the distribution of cavitation and cracking in 70·30 brass strained at 400 C. It is suggested that the cracks are formed by vacant lattice sites (present or formed during deformation) which migrate to certain boundaries and aggregate to form cavities: these cavities eventually link up to form a crack which spreads as a result of stress concentration at the edges [See comments by Frey, D. N., Bull Inst Metals 1 (1952) 126] Frey says that Greenwood's model appears superior to theories involving growth of subcritical microcracks. Quotes Zener's theory [Fracturing of Metals, Am Soc Metals (1948) 3] of ductile fracture and suggests that not only solute atoms but also precipitate particles can act as barriers to the movement of vacancies and thus delay fracture

(591) Greenwood, J N , and Worner, H. K

Types of Creep Curve Obtained With Lead and Its Dilute Alloys

J Inst Metals 64 (1939) 135-167

Four types of creep curves are shown strain hardening, and after some elongation, recrystallization, strain hardening but no recrystallization, increasing creep rate; and normal strain hardening curve Creep is partly "viscous" movement and partly crystalline (slip) with the proportional limit being approximately the lower limit of slip. Impurities have a marked effect on the creep rate and critical stress and strain necessary for recrystallization Solute atoms may cause increased or decreased creep rate above the critical stress Vibration increases the creep rate and causes recrystallization to take place after smaller deformations Larger grain sizes retard recrystallization owing to stress

(592) Greiner, E. S., and Ellis, W C.

Dislocations and Plastic Flow in Germanium

Bell Labs Record 34 (1956) 403-406

Conductivity studies demonstrate the introduction of other imperfections in plastic flow, and provide means for identifying the types of these imperfections and estimates of their concentrations

(593) Griffith, A A

The Phenomena of Rupture and Flow in Solids

Phil Trans Roy Soc (London) 221A (1921) 163-198

Scratches increase locally the maximum stress and this produces local yielding at stresses far below that corresponding to the elastic limit of the unscratched material Thus, the ordinary hypothesis of rupture cannot safely be employed to predict the safe range of alternating stress for scratched metals Rupture will occur where as a result a diminution in the potential energy of the specimen is found. Rods and pieces of fused glass and quartz have been prepared which have a tenacity of 10^6 psi This high value decreases with time, probably as the result of the formation of cracks A theory is developed to explain these phenomena, based on the surface energy produced as a result of the cracks It should be possible to raise the yield point and tensile strength almost to the theoretical strength and correspondingly increase the fatigue range A thin film of liquid between solid boundaries which are wetted should act as a solid

(594) Griffith, J S

The Cohesive Energies of Transition Metals

J Inorg. & Nuclear Chem 3 (August 1956) 15-23

The cohesive energy is regarded as made up of just two parts, one arising from the breakdown of intra-atomic spin couplings and the other from the formation of interatomic ones The former is calculated in terms of atomic spectral parameters and the latter is assumed to vary smoothly along the series with a maximum in the middle

(595) Gross, B

On Creep and Relaxation

Phys Rev 71 (1947) 144

When the principle of superposition is valid, the range of creep and of relaxation is connected by Laplace transforms of distribution functions for creep and for relaxation There results a general relation, suitable for numerical computation, for the conversion of one distribution into another.

(596) Gross, B

On Creep and Relaxation

J Appl Phy 18 (1947) 212-221

The creep and the relaxation fuctions of linear systems, for which the principle of superposition is valid, are mutually connected in a simple way This makes it possible to calculate the distribution function of relaxation times of stress and the distribution function of retardation times of strain when the relaxation function or the creep function is given It also allows a transformation formula to be established for the conversion of one distribution function into another The results of the theory are applied to a detailed discussion of the relaxation process in a particular case

(597) Gross, B

On Creep and Relaxation II

J Appl Phy 19 (1948) 257-264

A phenomenological theory of the elastic aftereffect can be formulated with the aid of the principle of superposition In a previous paper the theory of the transient effects, caused by the sudden application of a constant load or a constant deformation, has been developed. In the present paper the theory of the steady-state behavior under alternating load and deformation is given Relations are established between the loss factor, the storage factor, the distribution functions, and the Laplace transforms of the creep and relaxation function.

(598) Gross, B

The Flow of Solids

Phys Today 5 (August 1952) 6-11

Fundamental behavior of solid materials under stress, principles of elasticity, viscosity, and complex viscoelastic behavior, problems of measuring creep, role of memory function in deformation of solids, parameters which affect deformation of loaded system.

(599) Gross, B

Rheological Distribution Functions (In German)

Kolloid-Z 131 (June 1953) 161-168

Creep and relaxation curves which describe viscoelastic processes are shown to be inadequately represented by the simple exponential equations of the elementary theory Viscoelastic phenomena are analyzed mathematically in terms of two functions, the relaxation and the retardation times The relaxation time is considered in terms of the relaxation function and the elasticity model, and the retardation time is in terms of the creep curve and the plasticity model Equations are given interrelating these functions

(600) Gross, B , and Pelzer, H

On Creep and Relaxation III

J Appl Phy. 22 (1951) 1035 1039

The general theory of reversible linear creep, developed by Gross [Ibid , 19 (1948) 257] is extended to cover creep with a plastic component It has to be assumed that the creep rate is linear and that, after a fixed period of creep, the strain is proportional to stress A distribution function of stress relaxation times is incorporated in the theory, and one type of distribution function is considered in detail

(601) Guard, R W

Metals at Elevated Temperatures

Prod. Eng. 27 (October 1956) 160-164

Hot and cold behavior of metals compared using homologous temperature scale, fatigue versus rupture stress as design criterion, predicting long-term properties from short term tests

(602) Guard, R W

The Relation of Microstructure and High Temperature Strength

Paper from High Temperature Materials, Their Strength Potentials and Limitations, Fourth Sagamore Ordnance Materials Research Conference (1957) 90-105

The application of metallurgical principles to the solution of the problem of increasing operating temperatures of Fe-Co-Ni base alloys are discussed The principles could be applied to alloys of any base if the necessary information is available One surprising fact in this investigation is that the effect of alloying additions persists to quite high homologous temperatures This observation is not easily explained by any existing theory of strengthening. The results are even more striking if they are examined on a relative basis The effect of a given alloy addition to increase the strength by a given percentage is much less dependent on temperature than is the actual strength It should be remembered that the results are for temperatures at or above the recrystallization temperature Another observation that does not fit existing concepts is the marked upper and lower yield point in the alloys above 1600 F This yielding behavior was at first thought to be caused by recrystallization Metallographic examination failed to show this to be the case Examination of the results indicates that the following structural principles are valid for dispersion strengthened alloys 1 The best strength is obtained for the alloys having the finest dispersion of compound 2. Large amounts of excess compound are detrimental to rupture ductility 3. A slight excess (5-10 per cent) of compound not in solution at the highest solution temperatures gives the best rupture strength 4 The matrix composition should be as high in alloy content as possible 5. Stability of particle size is important in promoting high rupture strength

(603) Guard, R W

Role of Polygonization in Creep

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Dislocation etch-pit patterns in a number of specimens of Ni subjected to creep deformation at elevated temperatures have been examined. Etch-pit patterns show two distinct morphologies as follows (1) broad bands of high density of pits showing some subboundaries within the bands and (2) single subboundaries (and some random pits) between the broad bands The direction of the boundaries is generally normal to the bands The changes in the over-all patterns of the specimens with time (and strain) during a creep test show that the broad bands form on initial loading (or early in the creep test) and the single boundaries increase in number (and density) during the creep straining. These effects have been examined as a function of stress and temperature for creep strains from 0 002 to 0 05 A model is proposed for creep deformation in which the rate of creep is dependent on the rate of generation and the mobility of dislocations in the dislocation structure The rates of generation and mobility are dependent on the magnitude of the long range stress fields of the dislocations (Taylor's model of strain hardening) The stress fields are lowered by annihilation and/or polygonization of the dislocations generated Taylor's model of strain hardening is used although its specific details are not necessary for the hypothesis The predictions of the model with respect to the effects of temperature, stress and prior dislocation structure are discussed and the observed morphologies of the dislocation structure rationalized

(604) Guard, R W , Hibbard, W R , Jr , and Hoffman, R E

A Review of Some Recent Russian Literature on the Theories of Strength and Its Temperature Dependence

G. E. Research Lab Memo M C-67 (1958) 15 pp

Manuscripts and rough translations of 82 recent (1956-1957) Russian papers listed in the bibliography were evaluated in relation to the status of American literature in a comparable period

(605) Guard, R W , Keeler, J H , and Reller, S F

Observations on Elevated Temperature Tensile Deformation

Trans AIME 200 (1954) 226 227

In tensile tests at elevated temperatures on fcc, hcp, and bcc materials (Ni, Zr, Fe, and their binary alloys) the load versus elongation curve reached a maximum load at relatively small amounts of strain, and a large amount of elongation occurs subsequently with a continuously decreasing load, until finally localized necking and fracture take place This early maximum load behavior occurs without localized necking or cracking The detailed characteristics are dependent on the prior strain (cold work), strain rate, test temperature, and crystal structure of the material, but the general features of the behavior are similar in all materials so far investigated

(606) Guard, R W , and Westbrook, J H

Alloying Behavior of Ni_3Al (γ' - Phase)

Paper presented at AIME Fall Meeting, Chicago (November 1957)

In many superior nickel-base high-temperature alloys the elevated temperature strength is attributable to the presence of a dispersion of Ni_3Al (γ') in solid solution matrix In order to improve our understanding of these materials the effects of alloying additions on the properties and equilibrium relationships of Ni_3Al have been considered Several tests were made to establish whether there is any transformation present in Ni_3Al at high temperatures as has been proposed by several workers No evidence was found in support of any crystallographic change between room temperature and 1000 C A survey of phase diagrams was made to determine the extent of the γ' -region for ternary systems of Ni-Al-X where X is Fe, Co, Cu, Mn, Ti, Cr, Si, Zr, and Mo Extensive solubility in Ni_3Al occurs for Fe, Co, Cu, Ti, Cr, and Si In several of these cases the effect of alloying on the lattice parameter and hardness at room and elevated temperatures was investigated. The effect of deviations from stoichiometry in the binary Ni_3Al phase was also examined. In general alloying additions and deviations from stoichiometry increase the hardness in a manner which is to be expected from the known rules of solid solution effects The changes in lattice parameter are dependent on the relative size of the alloying atom and its position in the periodic table The rules proposed for binary terminal solid solutions are obeyed satisfactorily. A discussion is presented of the stability of Ni_3Al with respect to neighboring phases and the extent of solubility

(607) Gubkin, S. I

Methods of Determination of Deformability (In Russian)

Izvest Akad Nauk S.S.S.R , Otdel Tekh. Nauk (September 1948) 1463-1482

Critically analyzes existing mathematical and physical theories of deformation of solid bodies Proposes a theory using dimensionless numbers for deformations between +1 and -1 On the basis of this assumption, equations are proposed and graphically interpreted

(608) Gubkin, S. I

Schematic Diagrams for the Mechanical State (In Russian)

Izvest Akad Nauk S S.S.R., Otdel Tekh Nauk (August 1950) 1165-1182

Two types of diagrams which form a firm basis for classification of mechanical states, mechanisms of plasticity, and basic methods of press working of metals Special features of each type of diagram Theoretical derivations are based on tensor analysis

(609) Gubkin, S I , and Bogdanov, Ye S

The Path of the Deformation Process as a Basic Characteristic of the Deformed State of a Plastic Body (In Russian)

Doklady Akad. Nauk S.S S R 88 (1953) 967-970 (NSF Translation 125)

It is suggested that, in order to define the state of a deformed body, not only the extent of the deformation, but also the path of the deformation process must be considered The elementary steps of the deformation can be described by a series of vectors, the origin of each one being the end of the preceding one, and the resultant vector closing the path is the geometric sum of the steps and represents the simple deformation which is equivalent to the compound one, the arithmetic sum of the lengths of the vectors represents the physical intensity of the deformation It is concluded that the physical intensity is proportional to the work done and to the change in physical state, and that the dependence of the state of stress on the physical intensity of the deformation is the sole characteristic of the plastic behavior of metal

(610) Gubkin, S I , and Rapoport, L A

Nature of Fracture During Plastic Deformation of Metals (In Russian)

Doklady Akad Nauk S S S R 94 no 4 (1954) 685-688

Formation of tensile stress, structural changes induced by recrystallization and formation of new phases

Declassified in Part - Sanitized Copy Approved for Release @ 50-Yr 2014/01/27 : CIA-RDP81-01043R003200240005-1

(611) Guillet, L.

Elastic Deformation of Single and Polycrystals (In French)

Metaux (Corrosion-Inds) 26 (1951) 153 158

Elastic constants of various metals, elastic anisotropy of grains and aggregates, modulus of elasticity of alloys, and evidence for allotropic transformations of alloys by thermoelastic methods

(612) Guinier, A.

Imperfections of Crystal Lattice as Investigated by the Study of X Ray Diffuse Scattering

Proc Phys Soc (London) 57 (1945) 310 324

The theory of the production of diffuse scattering of X rays by lattice imperfections is briefly described, and the methods of calculating actual structures from the observed distribution of anomalous scattering are indicated The arrangement of atoms in solid solutions is discussed, and it is concluded that the distribution is not completely random a small amount of short range order is present In the case of ordered solid solutions, the influence of geometrical lattice deformations must be taken into account Low-angle scattering by small particles, and the information which can be obtained with regard to age hardening, is also discussed.

(613) Guinier, A.

Substructures in Crystals

Chapter from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc , New York (1952) 402-436

Subboundaries divide crystalline grains into slightly disoriented subgrains which are revealed by the optical or electron microscope, by special etching agents, or by their property of favoring the formation of precipitates in supersaturated solid solution or the gathering of impurities; such a structure of disoriented subgrains has often been called mosaic structure, but the dimensions of coherent blocks of this mosaic structure are much smaller than those of subgrains Generally, subgrains are formed by annealing following slight deformation (polygonization), or during creep, when deformation and annealing are simultaneous. Along subboundaries, dislocations of the same sign are regularly spaced at rather great distances apart, and this accounts for the properties of subboundaries, viz , easy mobility and atomic disorder concentrated at special points A substructured crystal is characterized by imperfections occurring in special planes between rather perfect lattices The substructure is a metastable stage of energy intermediate between that of the cold-worked and the recrystallized metal At present, fragmentation of a metallic cold-worked crystal into perfect crystallites or into crystallites without too many defects, cannot be regarded as proved. Hence, a cold-worked metal cannot be regarded as an assembly of subgrains, small but little deformed; it is more likely that such metal comprises small domains having an average orientation rather badly defined owing to internal distortions and stresses

(614) Guinier, A.

Fundamental Experiments in the Fracture of Solids (In French)

Métaux (Corrosion-Inds) 27 (1952) 150-155

Reviews complex phenomena on the basis of the literature Calculation of cohesion in ionic crystals; measurement of surface tension of solids the role of defects, and the work of Griffith, Joffé, Smekal, and Orowan

(615) Gulyaev, B B.

Periodic Mechanical Properties of the Elements (In Russian)

Doklady Akad. Nauk S.S.S.R 70 (1950) 797 799

Graphs show relationships of mechanical properties of metallic elements (similarly heat treated) to each other, to location in the periodic system, and to atomic structure

(616) Gulyaev, B B

Influence of Position in the Periodic Table on the Effect of Elementary Additions on the Mechanical Properties of Copper, Silver, and Gold (In Russian)

Doklady Akad Nauk S S S R 74 (1950) 1089-1092

Attempts to develop rules for the strengthening influence of solute elements as an aid in predicting properties obtainable with different elements Relationships are shown to be periodic

(617) Gulyaev, B B

Periodicity of the Influence of Additions on the Mechanical Properties of Metals

Doklady Akad Nauk S S S R 75 (1950) 25 28 (Battelle Translation 51R3)

Periodic curves of strengthening presented for alloys based on (1) Mg Zn, Cd, (2) Pb, Sn Al, and (3) Fe, Ni, Pt, Pd Slopes of tensile strength (or hardness) curves versus composition, and % elongation at rupture plotted versus atomic number The periodic behavior of the properties is determined by the nature of the electronic shell of the atom

(618) Gulyaev, A. P , and Trusova, E F

Relationship in the Variations of the Properties of Solid Solutions

Zhur Tekh Fiz 20 (1950) 66 78

Brinell hardness H and lattice parameter A_0 were measured for solid solutions in Al, Cu, and Fe Alloying always increased H except for <1 at % Cr in Fe The greater the change in A_0, the more marked the hardening effect Elements producing a contraction of A_0 have a stronger hardening effect than elements causing an expansion of A_0. No clear parallelism was noted between hardening and the change in electron concentration on alloying.

(619) Gur ev, A V

The Origin of Elastic Imperfections in a Polycrystalline Alloy (In Russian)

Fiz Metal i Metalloved. 3 (1956) 349 359

Akad Nauk S.S.S R , Ural' Filial

An apparatus is described for the study of elastic hysteresis and other anelastic effects in polycrystalline solids The anelasticity is ascribed to local plastic deformation by slip in microscopic regions Hence, a new constant (K) of the material is derived and called the "coefficient of microplasticity" K is evaluated experimentally for several materials (steels) which have undergone a variety of heat treatments

(620) Gur'ev, A. V

Theory of Elastic Deformations of a Polycrystalline Alloy (In Russian)

Zhur Tekh Fiz 24 (1954) 1644-1659

A theory based on consideration of the fact that polycrystalline aggregates deform inhomogeneously, some grains deforming elastically, some plastically, under the applied stress If there are m_0 grains in a cross section of the specimen, of which, under applied stress σ_y, m_π deform plastically and the rest elastically, then a new quantity, the "modulus of plasticity", π, is introduced, defined by $\frac{m_\pi}{m_0} = \frac{\sigma_y}{\pi}$ π is shown to be a constant of the material and is the only new quantity which has to be determined experimentally. Experiments show, e g , that π increases linearly with increase of C content of a steel Using π, stress/strain curves for compression and tension can be calculated, as well as the hysteresis loop under alternating stress All calculations agree well with experiment Finally, it is pointed out that the true local stress in a polycrystalline aggregate may be very much higher than the mean applied stress The smaller the parameter π, the greater is the discrepancy

(621) Gurevich, G I

The Question of Strength Criteria (In Russian)

Doklady Akad Nauk S S S R 82 (1952) 245 248

A theoretical discussion of equations describing the relationships of stress and strain in a uniform isotropic body

(622) Gurevich, G I

On the Law of Deformation of Amorphous and Polycrystalline Bodies

Compt rend acad sci U R S.S 55 (1947) 493 496

A relationship is derived for the dependence of yield stress on rate of deformation and for dependence of rate of deformation on the load It was found to be valid experimentally for a wide range of rigidities for materials of diverse structures, such as different plastic film materials, aluminum, lead, and copper wire

(623) Gurney, C

Delayed Fracture in Glass

Proc Phys Soc (London) 59 (1947) 169-184

The phenomenon of delayed fracture in glass and the Griffith crack theory are discussed from the therodynamical viewpoint Various factors which may be responsible for the spreading of cracks are considered, and it is concluded that neither entropy changes due to stress nor evaporation of the reactive material at the base of a crack are likely to be responsible for crack spreading. Stress causes increased atomic mobility and a faster relaxation toward equilibrium at the base of a crack, while atmospheric attack is also most serious for the highly stressed material in this region Both these factors contribute toward delayed fracture in glass A change in the stable phase at room temperature under the action of stress is not likely to be important for glass, but phase changes under stress may have important effects on the behavior of other materials such as metals.

(624) Gurney, C.

The Effects of Rate of Loading on Fracture of Materials

Article from The Fracture of Metals, London (1950) 101-116

Effects over various times Experimental methods Effects of rate variations on yield strength, ultimate stress, and deformation at fracture. Some theoretical ideas given to dynamics and effects of stress and time on deformation and fracture Data for Al, Cu, their alloys, and for carbon and stainless steels

(625) Gurney, C.

The Effect of Surface Condition on the Strength of Brittle Materials

Properties of Metallic Surfaces, Inst Met , London (1953) 145

Strength of crystalline nonmetallic materials is very sensitive to surface defects, except plastics, and glass other than fine fibers.

(626) Haasen, P.

The Orientation-Dependence of the Hardening Curve of Face-Centered Cubic Metal Crystals (In German)

Z Physik 136 (1953) 26-39

The theory of Haasen and Leibfried [ibid., 131 (1951-1952) 538] is extended to crystals which are already hardened. The dislocations piled up in the main glide plane produce shear stresses in the other glide systems The specific interaction of dislocations on different glide planes is discussed, following the reaction suggested by Lomer [Phil Mag. 42 (1951) 1327]. The predictions are compared with experimental results, and good agreement is obtained.

(627) Haasen, P.

Plastic Deformation of Nickel Single Crystals at Low Temperatures

Phil Mag. 3 (1958) 384-418

Single crystals of Ni were deformed in tension at various temperatures between 4 2 and 300 K Shear stress-shear strain relations, and reversible change of flow stress with temperature The work-hardening parameters obtained are discussed in terms of dislocation theory developed mainly on the basis of data on Al and Cu. From the temperature dependence of the stress at the beginning of dynamical recovery the activation energy of cross slip is estimated to be slightly lower than that of Cu, implying a somewhat higher stacking fault energy.

(628) Haasen, P.

Interaction of Dislocations and Foreign Atoms

Paper from Symposium on Internal Strains and Fatigue in Metals, GM Research Lab , Detroit, Michigan (September 1958)

Several mechanisms of interaction between dislocations and foreign atoms are reviewed in relation to the phenomenon of the upper yield point in metals Some current problems in the theory of the yield point are connected with the thermal activation of dislocations from locked positions and the temperature dependence of the yield stress An investigation of the yield point in Zn single crystals (probably due to nitrogen) suggests that locking occurs by precipitates. The effect on the yield point of a tension or compression stress during aging is discussed

(629) Haasen, P., and Kelly, A.

A Yield Phenomenon in Face-Centered Cubic Single Crystals

Acta Met 5 (1957) 192-199

A small yield-point effect is observed when single crystals of Al and Ni are tested after prior deformation and aging. The yield points are most marked at low temperatures so that they are unlikely to be due to thermally activated migration of point defects to dislocations. An explanation based on dislocation interactions during unloading is proposed.

(630) Haasen, P., and Leibfried, G

Creep Curves of Aluminum Single Crystals in the Region of Small Plastic Deformation (In German)

Z Metallk. 43 (1952) 317-321

The extension of Al single crystals under tensile stress was studied up to a maximum extension of 2% The tensile load was applied in a series of steps, following a preliminary load. The normal course of the extension (or creep)/time curves is as follows: (1) the extension at first is proportional to t^{α}, where t is the time of application of the load, and α is a constant; (2) later the extension is proportional to log t The dependence of the constant in the creep law upon the preliminary load is discussed. The curves are, in general, smooth but show occasional waves and other peculiarities, e. g., an initial inflection.

(631) Haasen, P., and Siems, R

Growth of Slip Lines on Aluminum and Zinc Single Crystals (In German)

Z Metallk 48 (1957) 315-327

Electropolished pure Al single crystals of rectangular cross section, and single-crystal rods of pure Zn were incrementally loaded, and the rate of increase of depth of the slip lines, determined cinematographically, increases with applied stress, in Al it is about 10^4 times smaller than the theoretical value calculated on the assumption of resistance-free rotation of a dislocation spiral, the velocity of a dislocation is small relative to the velocity of sound. Slip lines develop on the top surfaces of the crystals almost twice as fast as on the sides; steady-state conditions are reached in 2-3 seconds after loading Al crystals, as compared with 20 seconds for Zn crystals. The resistance to the movement of a dislocation is calculated as 2.5×10^3 and 80 kg/mm^2 in Al and Zn, respectively

(632) Habraken, L., and Cuvelier, P.

Study of Grain Boundaries and Substructures in Steels (In French)

Métaux (Corrosion-Inds) 31 (1956) 105-125

Electron-microscope study of pure Fe, C, and alloy steels. Examination of growth during interrupted isothermal and anisothermal treatments. Influence of annealing and high-temperature creep tests

(633) K-Habraken, L., and Greday, T

Deformation Mechanics in Metals (In French)

Rev universelle mines 12 ser. 9 (1956) 38-55, 209-227

Present status of physical metallurgy in the field of metal deformation, based on various X-ray and microscopic studies Essential differences between the behavior of single crystals and polycrystalline aggregates Theoretical interpretation of deformation within the theory of dislocations

(634) Haessner, F., and Schreiber, D.

The Strain-Hardening of Single Crystals of Aluminum Containing Small Additions of Silver (In German)

Z Metallk. 48 (1957) 263-271

Single-crystal wires of various orientations of Al containing up to 0 5% Ag were annealed, air or furnace cooled, and tensile tested at room and liquid-air temperatures, and their strain-hardening characteristics determined. The strain hardening and slip of specimens containing about 0 125 at. % Ag are similar to those of pure Al, but upon further addition of Ag the room-temperature critical shear stress increases by a factor of 3 to 4 and there is a 300% increase in the region of easy glide; with furnace cooling the critical shear stress increases by a factor of about 10, and the orientation dependence of strain hardening disppears, as does the initial flat section of the strain-hardening curve which now rises steeply and discontinuously. At liquid-aid temperature 0.5% Ag decreases the strain-hardening characteristics; the region of easy glide is reduced to about 20% of normal, and strain hardening becomes more marked only in the later stages of stressing Differences in the strain-hardening behavior are discussed in terms of the creation of barriers to the movement of dislocations, due to the increasing precipitation of Ag from the supersaturated solution

(635) Hall, E. O.

The Brittle Fracture of Metals

J Mech and Phys Solids 1 (1953) 227-233

A study of the cleavage surfaces of Si ferrite single crystals, where plastic deformation arises during the initiation and spread of a crack. X-ray evidence shows that the amount of plastic deformation can vary greatly and is related to the microstructure of the cleavage surface A theoretical study shows how the plastic work influences the crack length derived from the Griffith formula, and a simple analysis in terms of plastic waves indicates that the surface work should decrease as the crack speeds up.

(636) Hanson, D.

The Creep of Metals (A Review)

Trans AIME 133 (1939) 15-57

The creep curve, metallographic study of creep, and types of flow and fracture are discussed Flow may occur by (1) normal slip, (2) slipless flow, (3) recrystallization, and (4) grain-boundary movements Fracture may occur by (1) transcrystalline, (2) intercrystalline, or (3) point fracture The effects of temperature and grain size are reviewed.

(637) Happ, M G , and Grant, N J

Role of Recovery and Recrystallization on the Creep Rupture Behavior of 2S Aluminum

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The influence of recovery processes on ductility and the nature of fracture during creep at elevated temperatures were investigated in annealed, commercially pure 2S Al. The normal transition to intercrystalline cracking and failure with increasing temperature, with attendant decrease in ductility, is shown to reverse itself with further increase in temperature or decrease in strain rate, as certain recovery processes become operative. With this reversal there is an increase in ductility. The inhibiting effect of intercrystalline cracking on recrystallization is demonstrated.

(638) Hardie, D., and Parkins, R N

Solid-Solution Hardening of Aluminum and Magnesium

J Inst Metals 85 (1956-1957) 449 455

A linear relation between concentration and extent of hardening was observed for various solutes dissolved in Al and Mg. A relationship also exists between hardening and the distortion introduced into the lattice by the solute, with certain exceptions, this relationship takes a linear form with Al and a quadratic form with Mg. The results are in reasonable agreement with the predictions of Mott and Nabarro'[Report of a Conference on Strength of Solids, Phys Soc. (London) (1948) 1], whose approach is considered likely to prove of greatest value to the metallurgist interested in alloy development

(639) Hargreaves, M E

Deformation of Polycrystalline Aggregates

J Australian Inst. Metals 1 (1956) 125-133

Includes theories that attempt to calculate plastic properties of a polycrystalline aggregate from properties of single crystals. Experimental evidence relevant to these calculations and to the general behavior and interactions between metal grains in the deformation of aggregates

(640) Harper, J., and Dorn, J E

Viscous Creep of Aluminum Near Its Melting Temperature

Acta Met 5 (1957) 654-665

Creep of pure polycrystalline Al was studied at low stresses and temperatures near the melting point. It was found that at stresses between 3 and 13 psi the secondary creep rate varied linearly with the stress, whereas at slightly higher stresses, the creep rate increased with the fourth power of the stress. The activation energy for creep was determined to be about 35,500 cal/mole over the entire stress range. The low stress creep results in the range of "viscous" creep were analysed from the viewpoint of the Nabarro-Herring model for stress directed self-diffusion of vacancies, and it was found that the experimental creep rates were about one-thousandfold greater than those predicted theoretically. This factor plus additional experimental observations on the displacements of markers at grain boundaries, and on creep recovery upon removal of the stress, led to the conclusion that the Nabarro-Herring model does not apply to the case of Al and that creep occurs by a dislocation climb mechanism at all stresses considered

(641) Harper, J G., Shepard, L. A., and Dorn, J E

Creep of Aluminum under Extremely Small Stresses

Acta Met 6 (1958) 509-518

At high temperatures Al exhibits two laws for creep, dependent of the stress. At stresses below 13 5 psi the creep rate increases linearly with the stress, and at intermediate stresses between 33.5 and 1000 psi the creep rate increases with a power of the stress. Creep in both regions is believed to take place by dislocation mechanisms. Over the low stress range the contribution of grain-boundary shearing to the total creep strain increases linearly with the stress. But over the intermediate range of stresses, the grain-boundary shearing contribution to creep rate decreases as the stress increases. The two distinctly different laws for grain-boundary shearing reflect the fact that high-temperature creep is controlled by two distinctly different crystallographic mechanisms, the relative proportions of each being dependent on the stress. A dislocation model involving motion of jogged screw dislocations appears to account well for the low stress creep behavior of Al. Intermediate stress creep behavior was found to agree with Weertman's dislocation climb creep hypothesis

(642) Harper, S.

A Note on the Brittle Intergranular Fracture of Beta-Brass

J Inst. Metals 85 (1956-1957) 415-416

Stress concentrations at grain boundaries, in conjunction with a rapid rate of straining, are shown to be essential factors in causing intercrystalline failure at high temperature in ordered beta-brass

(643) Harper, S., and Cottrell, A. H

Surface Effects and the Plasticity of Zinc Crystals

Proc Phys Soc (London) 63B (1950) 331-338

The effects of various surface treatments on the plastic properties of zinc crystals are examined. Rocoe's observation of the hardening effect of a surface film of oxide is confirmed; electrolytically polished specimens have critical shear stresses of about 33 gm/mm, whereas oxidized specimens have values up to 65 gm/mm. Similar effects are observed on the rate of creep under constant stress. The Rehbinder effect – softening crystals by immersing them in paraffin and oleic acid – can be produced on oxidized specimens but not on others. Oxidized specimens do not respond instantly to immersion and the time of response is proportional to the viscosity of the liquid. It is suggested that the liquid penetrates the oxide film and reduces its ability to harden the metal; the action of the oxide film itself is not yet clear.

(644) Hart, E. W

The Slip Process During Yield Point Deformation

Acta Met 2 (1954) 416-418

An extension of the theory due to Fisher, Hart, and Pry [Phys. Rev 87 (1952) 958] which assumes dynamic operation of Frank-Read sources. If the dislocation is anchored by solute atoms, it will not begin to move until a yield stress is attained. Assuming there is no energy dissipation by the moving dislocation, it is shown that the source may begin producing dislocation loops as soon as the applied stress reaches τ_y, even if $\tau_y < \tau_c$, the critical stress for operation of the source, as normally calculated. This effect is a result of the absence of loop expansion while τ increases from 0 to τ_y, on the assumptions of the theory, the condition for operation of the source is $\tau_y > 0.85\ \tau_c$. The number of loops emitted is very sensitive to the ratio τ_y/τ_c. Qualitative applications to experimental observations are given

(645) Hart, E W

Theories of Dispersion-Hardening

Paper from Relation of Properties to Microstructure, Am. Soc. Metals, Cleveland (1954) 95-107

Three modern theories of precipitation hardening due to Mott and Nabarro, to Orowan, and to Fisher, Hart, and Pry are critically reviewed. Using data for Al-Cu and Cu Cr alloys, it is concluded that Orowan's theory is most satisfactory, at least with regard to coherent precipitates

(646) Hart, E W

A Uniaxial Strain Model for a Luder's Band

Acta Met 3 (1955) 146-149

An investigation of the plastic properties of Luder's bands in tensile test specimens leads to a relatively simple description of those properties of the band which may be termed classical. It is shown that the mechanism which is responsible for the propagation of the band and which determines its velocity is independent of the classical plastic properties. A model is proposed to explain the load-elongation test behavior for a wide range of types of materials which exhibit yield point phenomena in one form or another.

(647) Hart, E W

Lattice Resistance to Dislocation Motion at High Velocity

Phys Rev 98 (1955) 1775-1776

The question as to whether or not the crystal lattice presents a large resistance to dislocation motion at high velocities is discussed theoretically, and it is shown that the lattice sites are too small to limit the dislocation velocity by collisions

(648) Hashimoto, H., and Uyeda, R

Detection of Dislocation by the Moire Pattern in Electron Micrographs

Acta Cryst 10 (1957) 144

Dislocations detected in Moire patterns on thin CuS crystals and are shown to be caused by edge dislocations nearly perpendicular to the crystal sheets

(649) Hasiguti, R R., and Owadano, T.

Formula for Creep Curves of Metals

Nature 168 (1951) 706

Extensive experiments on the creep of polycrystals and single crystals of high-purity and commercial-grade Al at elevated temperatures under constant stress have given the following equation $s = a - [1/(bt + c)] + kt$, where s is, for single crystals, the resolved shear strain at time t and for, polycrystalline materials the logarithm of the ratio of the length of the specimen at t to its initial length; a, b, c, and k are constants. Illustrative figures are given to show that the equation agrees with experimental results better than Andrade's equation does for large strains on single crystals, especially after long times. Andrade (ibid., 1007) points out that unfavorable values for the constants in the Andrade creep formula were used with the correct values. The three-constant formula of Andrade shows a better fit than the four-constant formula of the authors

(650) Hauser, F E., Landon, P R., and Dorn, J E

Fracture of Magnesium Alloys at Low Temperature

Trans AIME 206 (1956) 589-593

The flow and fracture strengths of polycrystalline aggregates of high purity Mg and a solid solution of Al in Mg were determined as functions of temperature and grain size. Mg obeyed two distinch fracture laws. Over the high-temperature range, the fracture stress decreased with increasing test temperatures in a manner parallel to the flow stress-temperature relationship. However, over the low-temperature range, the fracture stress was independent of the test temperature though highly dependent on grain size, following the trend that is typical for the low-temperature brittle fracturing of polycrystalline aggregates of bcc and cph metals. Even at 78 K, however, plastic strains of 1 to 7% were obtained preceding onset of brittle fracture. The fracture stress and the flow strength increased linearly with the reciprocal of the square root of the mean grain diameter

(651) Hauser, F E., Landon, P R., and Dorn, J E

Deformation and Fracture of Alpha Solid Solutions of Lithium in Magnesium

Trans ASM 50 (1958) 856-883

Whereas coarse polycrystalline Mg is brittle at 78 K, alpha solid solutions of Li in Mg are ductile. The improved ductility of the alloys is associated with prismatic slip in addition to basal slip. Evidently in the absence of prismatic slip, dislocation arrays pile up against the grain boundaries causing high localized tensile stresses that exceed the cohesive strength of the metal. But the introduction of prismatic slip permits deformation of the adjacent grains and reduces the tendency toward pile ups. The incidence of prismatic slip is unique for Mg Li alloys since Li is the only effective alloying element for reducing the axial ratio of Mg

(652) Hayes, A., Everling, W O., and Smith, E C., Editors

Plastic Deformation of Metals

Amer Iron & Steel Inst, New York, New York

Literature surveys on above subject. Contributions to the Metallurgy of Steel

No. 21	June (1948)	Covers the years	1940 1946
No. 38	November (1950)	Ditto	1946 1949
No. 42	December (1952)	"	1950-1951
No. 46	October (1954)	"	1952 1953

(653) Haslett, T H., and Hansen, R D

Influence of Substructure on the Shape of the Creep Curve

Trans ASM 47 (1955) 508-516

Tests on Ni and Ni alloys at 700 C show that substructure has a marked effect on creep behavior. The amount of initial strain was considered to be an index of the amount of substructure present in the specimen when the creep tests were started. Resultant creep curves were correlated to show the effect of the amount of substructure. The shape of the curves varied drastically with different amounts of substructure. Varying the alloy content has also been shown to affect the influence of substructure on the shape of the creep curve

(654) Haslett, T H., and Parker, E R

Effect of Some Solid Solution Alloying Elements on the Creep Parameters of Nickel

Trans ASM 46 (1954) 701-715

Constant stress creep data at 700 C were obtained on solid solution Ni alloys containing Fe, Ti, or W. The results fit the equation $\epsilon - \epsilon_0 = At^b$ (ϵ_0 = total true strain, ϵ_0 = instantaneous strain on loading, t = time, A and b constants). The parameters A, b, and ϵ_0 vary with at. % alloy addition as follows: A decreases exponentially, b increases directly, and ϵ_0 decreases directly.

(655) Haslett, T H., and Parker, E R.

Nature of the Creep Curve

Trans AIME 197 (1953) 318-323

A study of the effects of stress, temperature, alloying, and structure on the creep characteristics of high-purity Ni and solid-solution alloys with Ti. Structurally stable metals like Ni, tested under conditions of constant stress, exhibit a continuous decrease in creep rate up to the point of initiation of failure; there is no region of constant creep rate. The creep curve may be accurately represented by the empirical equation, (1) $\epsilon - \epsilon_0 = At^b$, at constant temperature, or (2) $\epsilon - \epsilon_0 = Bt^b \exp(-Q/RT)$, over a considerable temperature range, ϵ = total true strain, ϵ_0 = instantaneous strain at loading, t = time, A = a constant which varies in a regular manner with stress and alloy content, and exponentially with 1/T, B and b = constants, and Q = the "experimental activation energy". An analysis of the results of other workers on the creep of mild steel, Pt, and Cu, and of Pb and high-purity Al, confirms equations (1) and (2). Equation (2) is also substantiated by single crystals of Zn tested in shear, thus indicating that the continuously decreasing creep rate is not solely a grain-boundary phenomenon, although it does vary with grain size

(656) Haslett, T H., Robinson, A T., and Dorn, J E.

An Evaluation of a Theory for Plastic Flow in Anisotropic Sheet Metals

Trans ASM 42 (1950) 1326-1356

A mathematical theory for the correlation of plastic deformation in anisotropic work-hardenable metals under combined stresses is derived, the theory is based on the following assumptions (1) that the strain increments are linear functions of the stresses (2) that the work-hardening is a function of the plastic strain energy; and (3) that the kind and degree of anisotropy do not change materially over the range of deformations considered. To test the theory true stress/true strain curves were obtained from tensile specimens whose orientations, with respect to the direction of rolling of the sheet metal from which they were cut, varied between 0° and 90°. The curves thus obtained were compared with those predicted by the theory. Two materials were used in the investigation an Al alloy (61S-T6) and an Mg alloy (AZ31X). The results of the investigation showed that the sheets of both materials possessed a considerable degree of anisotropy. In the case of the 61S specimens, the experimental stress/strain curves agreed fairly well with those predicted, at all orientations. The degree of anisotropy of this material is little affected by the amount of deformation. However, the theory was not found to be applicable to the AZ31X sheet because the degree of anisotropy of this material decreases markedly with increase in the amount of deformation

(657) Head, A K

The Interaction of Dislocations and Boundaries

Phil Mag 41 ser 7 (1953) 92-94

A method analogous to that of electrical images used in electrostatics is applied to the discussion of screw dislocations due to grain boundaries, and to the case of a surface film on a free surface, viz, an oxide layer on Al. If the oxide layer has the same elastic constants as the bulk oxide the equilibrium position of a screw dislocation is at a depth approximately equal to the thickness of the surface layer. The behavior of an edge dislocation is about the same.

(658) Hearmon, R F S

The Elastic Constants of Anisotropic Materials

Rev Mod Phys 18 (1946) 409-440

Reviews the theoretical and experimental points of interest connected with the elastic constants of anisotropic materials (mainly crystals). Attention is confined exclusively to the "elastic" range, and such topics as ultimate strength and plastic slip and glide are excluded. Aim has been to make the account complete to the end of 1944. Includes material on both metallic and nonmetallic materials, as well as 125 references

(659) Hedgepeth, J M

Theoretical Distribution of Slip Angles in an Aggregate of Face-Centered Cubic Crystals

NACA TN 2777 (August 1952) 32 pp

Analysis of the relative frequency of occurrence of any given slip-line angle in a plastically deformed polycrystal composed of fcc crystals for the case of simple tension. Comparison is made with another theory and with experimental results for 25-0 Al alloy

(660) Hedgepeth, J M., Batdorf, S. B., and Sanders, J. L., Jr

On the Angular Distribution of Slip Lines in Polycrystalline Aluminum Alloy

NACA TN 2577 (December 1951) 18 pp

An attempt to assess quantitatively the adequancy of a model used by examining the statistical distribution of slip angles – those angles which express the orientation of slip lines. Theoretical distributions are derived on the basis of the model and are compared with an experimental distribution obtained from previous investigations

(661) Heidenreich, R D.

Structure of Slip Bands and Cold-Worked Metal

Paper from Cold Working of Metals, Am Soc Metals, Cleveland (1949) 57-64

Application of electron-microscope and electron-diffraction methods to the structure of deformed metals. Surfaces of Al single crystals after plastic deformation. Interprets transmission electron-microscope images of thin Al sections

(662) Heidenreich, R D., and Shockley, W

Electron Microscope and Electron Diffraction Study of Slip in Metal Crystals

J Appl Phy 18 (1947) 1029-1031

The slip bands observed in the light microscope are shown to be laminar regions, the laminae being about 200 A thick, by electron microscopy. Electron-diffraction experiments showed that the lattice distortion was confined almost entirely to the slip bands, very little occurring in the remainder of the crystal

(663) Heidenreich, R D., and Shockley, W

Study of Slip in Aluminum Crystals by Electron Microscope and Electron Diffraction Methods

Paper from Report of a Conference on Strength of Solids, Phys Soc (London) (1948) 57-75

Electron-microscope studies of slip bands in single crystals of Al indicate that bands which appear in an optical microscope as single steps are really laminated. Electron-diffraction studies show that as deformation increases, more and more Laue spots appear on the reflection patterns from an etched surface. It thus appears that rotation as well as slip occurs in a slip band. Also, Kikuchi lines, which are interpreted as an indication of the extent of perfection in the crystal, were not affected by loading at or just above the yield point for at least 20 min but rapping or vibrating for 10 to 20 sec extinguishes the lines, although no slip bands were detectable.

(664) Heimerl G J

Time-Temperature Parameters and an Application to Rupture and Creep of Aluminum Alloys

NACA TN 3195 (June 1954) 35 pp

Relationships among stress, strain, strain rate, and temperatures, based either on the rate-process theory or on empirical observation, have been suggested in the form of "time/temperature parameters" (a) the Larson Miller T(C + log t) or T(C - log r) (b) the MacGregor-Fisher: $T(1-k \log r/r_0)$, (c) the Sherby-Orr-Dorn t exp(-Q/RT); and (d) the

Manson-Haferd $(T - T_a)/(\log t - \log t_a)$ or $(T - T_a)/(\log r + \log r_a)$, where T is the temperature, r is the strain rate, t is the rupture time, and the other symbols are constants The parameter was applied (a) to published data for 17 Al alloys and found that the constant C is a function of the material Extrapolation of short-time data is feasible if C is known with sufficient accuracy

(665) Heimerl, G J , and McEvily, A J , Jr

Generalized Master Curves for Creep and Rupture

NACA TN 4112 (October 1957) 31 pp

Similarity of Larson Miller master curves for creep rate, rupture life, and creep strain is shown for various alloys The individual master curves are generalized into a single curve, the same as the master curve for rupture, by use of the approximate invariance of the product of minimum creep rate and rupture time

(666) Henderson, C H

The Application of Boltzmann s Superposition Theory to Materials Exhibiting Reversible ; -Flow

Proc Roy Soc (London) 206A (1951) 72-86

Boltzmann's theory of superposition is applied to the flow and recovery of a material in the so-called anelastic region, and formulae are developed which give the amount of creep recovery and stress relaxation at constant stress, after any duration of an applied stress, for any material which obeys the Andrade $t^{1/3}$ equation The formulae are compared with existing data on Pb wires and it is found that theory and experiment are in substantial agreement Deviations, such as the necessity for introducing a constant term to represent the recoverable flow, are to be expected, for the theory takes no account of such phenomenon It is concluded that the Andrade $t^{1/3}$ flow formula, which also applies for large strains of a nonreversible character, should in conjunction with the superposition theory give a phenomenological explanation of recoverable flow, thus indicating underlying uniformity between these two types of deformation, as yet unexplained.

(667) Hendrickson, J A., and Wood, D. S.

The Effect of Rate of Stress Application and Temperature on the Upper Yield Stress of Annealed Mild Steel

Trans ASM 50 (1958) 498-516

The upper yield stress of an annealed low-C steel was determined under various constant rates of stress application and temperatures These data are compared with two expressions derived in different ways from the dislocation theory of the distinct yield point The three undetermined constants appearing in each of the theoretical expressions are evaluated by means of previous data on the delay time for yielding under constant stress Both theoretical expressions are found to be in good agreement with the experimental results This indicates that the dislocation theory provides a means for accurate prediction of the upper yield stress and the time for yielding when the applied stress varies with time in any manner.

(668) Hendrickson, J A , Wood, D S , and Clark, D. S.

The Influence of Temperature of Pre-Yield Plastic and Anelastic Microstrain in Low Carbon Steel

Acta Met 4 (1956) 593-601

Rates of preyield microstrain when stress is first applied are compared with the theoretical rates for the thermally activated release of dislocations from atmospheres of interstitial solute atoms

(669) Hendrickson, J A., Wood, D S , and Clark, D. S.

The Initiation of Brittle Fracture in Mild Steel

Trans. ASM 50 (1958) 656-681

This paper presents the results of a study of the conditions underlying the initiation of brittle fracture in an annealed low-C steel Notched tensile specimens have been tested at temperatures of -23, 110, and -200 F at rates of application of nominal stress ranging from 10^2 to 10^7 psi/second. The magnitude of the maximum nominal stress (fracture stress) has been determined for those tests in which brittle fracture occurred. The distribution of stress on the cross section at the root of the notch at the instant of brittle fracture has been determined analytically The effect of local plastic deformation at the root of the notch has been taken into account by employing an elastic-plastic stress analysis The analysis makes use of values of the upper yield stress of the material determined in a previous investigation as a function of temperature and rate of stress and application

(670) Henry, W G , Jaswon, M A , and Raynor, G V

The Cohesion of Alloys I. Intermetallic Systems Formed by Copper, Silver, and Gold, and Deviations From Vegard's Law II Some General Metallurgical Implications

Henry, W G , and Raynor, G V

III Extension to High Solute Concentrations, and Application to the Alloys of Group IA Metals

Proc Phys Soc (London) 64B (1951) 177-206

A new treatment designed to extend the theory of the cohesion of metals to alloy structures Excess energy of the solid solution, as compared with that of a mixture of the pure components, is estimated by assuming that introduction of a solute atom causes a major disturbance extending only to its nearest neighbors and a less serious disturbance in the surrounding matrix Deviations from Vegard's law to be expected in the solid solutions formed by Cu, Ag, and Au taken in pairs are evaluated Application of the theory to problems of solid solution formation Part II certain phenomena of general theoretical interest Part III the theory is applied to estimation of extra energy associated with the solution of one metal in another to form an alloy. Calculations made for the binary alloys of the alkali metals give good results

(671) Hentz, A

Plastic Deformation of Metals (In Swedish)

Jern Ann 140 (1956) 575 602

Structural and crystallographic features of deformation, considering conditions in pure metals at room temperature and normal strain rates under simple stress situations Slip in single metal crystals and polycrystalline metals reorientation from slip, twinning

(672) Hérenguel, J

Influence of Structure on the Deformation of Metals (In French)

Métaux Corrosion Ind 27 (1952) 1 13

Numerous macrographs and micrographs illustrate the concepts discussed, as applied to a variety of ferrous and nonferrous metals and alloys Includes table showing the relationships of various fabrication processes to structural characteristics

(673) Hérenguel, J , and Lelong, P

Study of the Internal Disorientation in Aluminum Magnesium Alloy Single Crystals Subjected to Plastic Deformation (In French)

Rev mét 48 (1951) 875 878

Follow changes in crystal orientation by etch pit shapes, using Lacombe's etching reagent and anodic oxidation of thin films of an Al +3% Mg alloy

(674) Herman, M , and Brown, N

Influence of Order-Disorder on Creep of Beta Brass

Trans AIME 206 (1956) 604-606

Creep strength increased as the amount of long-range order increased Also the yield point, measured as a function of temperature, increased abruptly with order at the critical temperature Concluded that long-range order increases the mechanical strength of beta brass

(675) Herman, V L

On a Possible Explanation of the Bridgman Effect - The Increase in Strength Under Uniform Pressure on All Sides (In English)

Compt rend. Acad Sci U R S S 51 (1946) 671-674

A theoretical explanation of the Bridgman effect is suggested Calculated increases in strength are of the same order of magnitude as those obtained experimentally

(676) Herring, C

Diffusional Viscosity of a Polycrystalline Solid

J Appl Phy 21 (1950) 437-445

According to a suggestion of Nabarro, any crystal can change its shape by self-diffusion in such a way as to yield to an applied shearing stress, and this can cause the macroscopic behavior of a polycrystalline solid to be like that of a viscous fluid It is possible that this phenomenon is the predominant cause of creep at very high temperatures and very low stresses, though not under more usual conditions The theory underlying it is developed quantitatively, and calculations of rate of creep, or equivalently of effective viscosity, are given for aggregates of quasi-spherical grains and for wires composed of cylindrical grains Allowance is made for the effect of tangential stress relaxation at the grain boundaries It is suggested that mosaic boundaries and boundaries between grains of nearly the same orientation may be unable to serve as sources or sinks of the diffusion currents, in which case the creep rate will depend only on the configuration of grain boundaries having a sizable orientation difference Numerical comparison of the theory with experiments on the high-temperature creep of wires favors this view but is not entirely satisfactory

(677) Herring, C., and Galt, J K

Elastic and Plastic Properties of Very Small Metal Specimens

Phys Rev 85 ser 2 (1952) 1060-1061

Investigated by performing experiments on the thin whiskers which grow out from the surfaces of a number of low-melting-point metals Observations were made on some Sn whiskers grown from an Sn-plated surface

(678) Heslop, J , and Petch, N J

The Stress to Move a Free Dislocation in Alpha Iron

Phil Mag 1 ser 8 (1956) 866-873

The portion of this stress due to interaction with random carbon and nitrogen atoms is temperature independent. At low temperatures, a very temperature-dependent portion is dominant

(679) Heslop, J , and Petch, N J

Dislocation Locking and Fracture in X-Iron

Phil Mag 2 ser 8 (1957) 649-658

The inhibition of plastic deformation by dislocation locking promotes brittleness The influence of Mn in Fe is studied in detail, and it is concluded that the ductility conferred by the Mn is associated with weakened dislocation locking as well as with grain refinement The weakening of the locking appears to be due to interaction between N and Mn atoms

(680) Hess, J B , and Barrett, C S

Structure and Nature of Kink Bands in Zinc

Trans AIME 185 (1949) 599-606

The formation of kink bands during the compression of single crystal rods of Zn occurs by a progressive rotation of the lattice within the band as deformation proceeds rather than by a twin like abrupt shear to a final orientation The width of a simple kink band is fixed by the grooves that form initially on the surface

(681) Hibbard, W R , Jr

Plastic Deformation of Large Grained Copper Specimens

Trans AIME 180 (1949) 52-72

Introduction of even a single grain boundary into a metal crystal, in such a manner that areas deforming differently under stress are produced, causes marked deviations from theoretical single crystal behavior These deviations consist of macroscopically inhomogeneous deformations resulting in measurable differences in crystal orientation within a single grain

(682) Hibbard, W R , Jr

A Theory of Deformation Structures in Metals (In French)

Rev mét 48 (1951) 131-134

During severe cold working the orientation of most of the grains of a polycrystalline metal approach a common orientation with respect to the axis of stress, which defines the deformation texture This texture develops progressively, but, once it is established, the grains can be subjected to further cold working without much change of orientation A theory of deformation texture is offered, starting from considerations of the stable orientation of single crystals and of the slip and flow under stress particularly applied. This theory predicts the predominant textures found experimentally in fcc, bcc, and hcp metals, but, it takes no account of the deviations from the ideal orientations that are found in polar figures

(683) Hibbard, W R , Jr.

Solid Solution Hardening

Trans AIME 212 (1958) 1-5

Models of solution strengthening depending solely on lattice parameter changes are incomplete Direct evidence for Suzuki interaction obtained from alloys with constant lattice parameter, for which solution strengthening was approximately independent of temperature from 300 to 20 K

(684) Hibbard, W R , Jr., and Dunn, C G

A Study of (112) Edge Dislocations in Bent Silicon-Iron Single Crystals

Acta Met 4 (1956) 306-315

Cancellation of unlike dislocations was observed in detail during removal of a polygonization structure and also during removal of a cold-worked structure The change in distribution of edge dislocations after bending and annealing was investigated

(685) Hibbard, W R , Jr., and Dunn, C G

Polygonization

Paper from Creep and Recovery, Am Soc Metals, Cleveland (1957) 52-78

The recovery of bent and annealed single crystals of Fe-Si was studied by a metallographic method in which the sites of edge dislocations were revealed as etch pits after etching Recovery occurred by thermally induced glide in regions of high elastic strain and by a process of cancellation of dislocations of opposite sign, requiring both climb and glide of individual dislocation Polygonization then occurs in two stages first, by the formation of short, low-angle boundaries, containing 5 to 10 dislocations formed by glide and subsequent glide of individual dislocations These short-range boundaries then coalesce by Y-junctions into a long-range boundary, which then straightens itself The second stage involves combination of the longer boundaries, mainly by movement of the elastically strained free end until it combines or overlaps with an adjacent boundary This forms a Y-junction in which dislocation climb results in the formation of a higher angle boundary. Polygonization is distinguished from recrystallization in that nuclei of critical size for the development of grain-deviating orientations are unavailable

(686) Hill, R

A Note on Estimating Yield Point Loads in a Plastic-Rigid Body

Phil Mag 43 ser 7 (1952) 353-355

Limits are obtained for the error involved in use of an approximate theory of plasticity to estimate yield-point loads Illustrates these by using the Mises yield function and potential to approximate the Taylor-Quinney data for Cu and Al

(687) Hill, R

The Elastic Behavior of a Crystalline Aggregate

Proc Phys Soc (London) 65A (1952) 349-354

Connection between the elastic behavior of an aggregate and a single crystal with special reference to theories of Voigt, Reuss, Huber, and Schmid Elastic limit under various stress systems was also considered. Illustrated by data on Al, Cu, Au, and alpha-Fe

(688) Hill, R

The Mechanics of Quasi-Static Plastic Deformation in Metals

Paper from Surveys in Mechanics, Cambridge Univ Press V 7-31, Cambridge (1956)

Deformation of single crystals, plastic behavior of crystalline aggregates, continuum mechanics and the plastic rigid model

(689) Hilton, H H

Thermal Stresses in Bodies Exhibiting Temperature-Dependent Elastic Properties

Trans ASM 74 (1952) 350-354

An analysis of thermal stresses and strains, taking into account variations of elastic shear modulus and coefficient of thermal expansion with temperature

(690) Hino, J , Shewmon, P G , and Beck, P. A

Effect of Simultaneous Strain on Subgrain Growth

Trans AIME 194 (1952) 873-874

Recently, Wood and Scrutton found that rate of subgrain growth upon annealing increased very considerably if, simultaneously, a creep strain were applied at a low strain rate Experiments on high-purity Al strip were carried out in order to confirm their results by direct metallographic observation Also, information was sought as to minimum creep strain necessary to produce this effect

(691) Hiorns, F J

The Relation Between Brittle Behavior and the Strength and Structure of Materials

Bull Brit Coal Utilisation Research Assoc 19 (February 1955) 49-60

Factors affecting breakage of solids, particularly those in a brittle state Experimental and theoretical work on brittle fracture are reviewed. Discusses microcrack theories of brittle fracture including the action of flaws within a material, statistical treatments of fracture, and the propagation of cracks Also, treats relation of fracturing phenomena to melting, the effect of surface condition adsorption, size of specimen, time of loading, temperature and structural changes on fracture

(692) Hirsch, P B

Dislocations and Strength

Paper from Proceedings of the 1955 Sagamore Research Conference on Strength Limitations of Metals, OTS, U S. Dept Commerce, PB 131280 and PB 131281, (1955) 36-70

Current theories on plastic deformation Yield stress of a metal is determined by two factors, the elastic interactions between the dislocations which must be overcome before the dislocations move, and the "frictional force" on the dislocations on account of the presence of jogs or because of the difficulty of cutting through other dislocations

(693) Hirsch, P B

Mosaic Structure

Paper from Progress in Metal Physics 6, Edited by B Chalmers and R King, Pergamon Press, London & New York (1956) 236-338

Systematic summary of experimental and theoretical work on the "mosaic structure" of metals, including a historical survey Theoretical views of Dorwin, Buerger, Smekal, and Zwichy are covered, and experimental techniques described The distribution and densities of dislocations in annealed and deformed crystals are discussed

(694) Hirsch, P B

X-Ray Experiments on Tin Whiskers

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 545-547

X-ray pictures were taken to determine the twist of the lattice of the whiskers and none was found, within the experimental accuracy Hirsch suggests a possible mechanism for the formation of a kink in a whisker.

(695) Hirsch, P B.

Observation of Dislocations in Metals

Papers from Symposium on Internal Stresses and Fatigue in Metals GM Research Lab, Detroit, Michigan (September 1958)

The electron-microscope transmission technique has been applied to study the arrangement and movement of dislocations in a number of metals, including stainless steel, alpha-brass, Cu, Au, Ni, Al, Fe, Co and Mg. In fcc metals the type of arrangement of dislocations is related to the ability of the screw dislocations to cross-slip and this is determined by the stacking fault energy, gamma In metals of low gamma, such as stainless steel and alpha-brass, the dislocations are piled up against grain boundaries for very low deformations, but for larger strains networks are formed on the slip planes by interaction with dislocations on other systems No thermally activated cross-slip is observed in these metals In Cu, Au, and Ni, for which gamma has an intermediate value, the dislocations are arranged in poorly developed substructures after deformation at room temperature In Al, which has a high gamma, the dislocations are arranged in almost perfect subboundaries Cross-slip has been observed in Cu, Au, Ni, and Al The mechanism of formation of these dislocation arrangements was discussed. A study of the dislocation interactions suggests that the basic hardening mechanism in metals is due to the elastic interaction between the gliding dislocations and those of the "forest"

(696) Hirsch, P B , Horne, R W , and Whelan, M J

Direct Observations of the Arrangement and Motion of Dislocations in Aluminum

Phil Mag 1 ser 8 (1956) 677-684

Electron optical experiments on Al foils have revealed individual dislocations in the interior of the metal, and their arrangement and movement were observed.

(697) Hirsch, P. B., Horne, R W , and Whelan, M J.

Electron Microscope Observations of Dislocations in Metals

Acta Cryst 10 (1957) 823-4

Dislocations can be revealed directly in thin metal foils by transmission electron microscopy The arrangement and movement of dislocations have been studied in a number of metals Foils about 0 1 mm thick are thinned by electropolishing or etching to a thickness of 1000 A. The contrast at the dislocations is due to their strain field, which causes them generally to diffract more strongly than the surrounding crystal In slightly deformed polycrystalline austenitic stainless steel the dislocations are found to be piled-up against grain boundaries Many of the pile ups are intersected by dislocations on other planes forming networks The dislocations are pinned at the metal-oxide interface, and stresses of about mu/1000 (mu = shear modulus) are necessary to move the dislocations This and other results lead to an explanation of the reported high strength of thin metal foils The stresses can be estimated from the curvature of the dislocations lines, and are large enough to drive the partial dislocations apart, leaving wide stacking faults The stacking-fault energy is estimated to be about 15 to 20 ergs/cm^2 Dislocations are observed to cross-slip through twin boundaries, and these latter also appear to contain Frank-Read sources Certain observations suggest that twins or thin lamellae of hexagonal phase are produced by a cone source of partial dislocations Dislocations are observed to nucleate near thin edges of the foil at comparatively low stresses Some of these effects have been recorded on cine film

(698) Hirsch, P. B., Horne, R. W , and Whelan, M J

Direct Observations of the Arrangement and Motion of Dislocations in Aluminum

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 92-115

It has been possible to observe directly dislocations in Al by transmission electron microscopy using a high resolution electron microscope Most of the specimens examined so far were prepared by heating Al at room temperature, followed by etching in dilute HF

(699) Hirst, H

Deformation by Creep of a Specimen of Lead Consisting of Five Large Crystals

Proc Australasian Inst Mining & Met (N S) 121 (1941) 29-44

A Pb specimen consisting of five large crystals gives a creep curve of the same strain-hardening type as that given by a single-crystal specimen, the deformation of each crystal proceeding as though the specimen consisted of that crystal only The crystal lattice deforms most rapidly near the crystal boundary and it is here that recrystallization begins and from here that grain growth occurs All the new crystals that appear in different parts of the specimen are formed immediately preceding the fracture when continuous recrystallization and necking down are taking place in one of the five crystals

(700) Hoff, N J

On Primary Creep

J Mech and Phys Solids 5 (1957) 150 151

Discusses the presence of variations in the properties of the individual crystals of a polycrystalline aggregate Makes the assumption that only two mechanisms of deformation exist, namely one of linear elasticity and one of nonlinear steady (or secondary) creep These suffice to explain the existence of primary (or transient) creep

(701) Hogan, M B

Engineering Application of the Absolute Theory to the Creep of Lead

OTS, U S Dept Commerce, PB 121127 (May 1955) 83 pp

Data from three different published sources were analyzed through the absolute rate theory based on a four element mechanical model. Metallurgical complexity of Pb and the influence of alloying elements and other factors on its mechanical properties were also examined

(702) Hogan, M B

Engineering Application of the Absolute Rate Theory to the Creep of Some Aluminum Alloys

OTS, U S Dept Commerce, PB 131119 (June 1956) 61 pp

Creep data for seven cast and three wrought Al alloys analyzed in terms of a four-element mechanical model and the absolute rate theory Values of the modulus of elasticity are included

(703) Holden, A N , and Kunz, F W

Note on the Strain Aging of Iron Single Crystals

J Appl Phy 23 (1952) 799

Single crystals of high purity Fe in wire form were grown for use in internal-friction damping experiments Tensile tests indicated that these crystals had only very small initial yield points, but were very susceptible to strain aging and exhibited very marked yield-point effects after straining and aging short times at room temperature Several interesting results are pertinent to a theoretical understanding of the strain aging phenomena

(704) Holden, A N., and Kunz, F W

Dimension and Orientation Effects in the Yielding of Carburized Iron Sheet Crystals

Acta met 1 (1953) 495-502

Single crystals of Fe containing 0 01 to 0 02% C were grown by strain anneal methods with a wide range of orientations Specimens having the tensile axis within 10 degrees of a <111> direction gave sharp yield point accompanied by a drop in load, and deformation involved the formation of tensile kink bands This behavior was independent of specimen dimensions or C content it was also found in decarburized crystals The yield behavior of the remaining crystals was independent of orientation, but could be correlated with the maximum dimension in the direction of slip. Sharp yield point with drop in load was preponderant in crystals in which this dimension was >0 2 inch no yields were found when it was <0 1 inch, and flat yield point without load drop was favored in the intermediate range The results for the orientations >10 degrees from <111> are consistent with Cottrell's theory of the yield point and with Holden's theory [Trans AIME 194 (1952) 182] that for a given density of dislocations, the longer the slip path the greater is the probability of the collision interaction of a moving dislocation with anchored dislocations

(705) Hollomon, J H

The Effect of Heat Treatment and Carbon Content on the Work Hardening Characteristics of Several Steels

Trans ASM 32 (1944) 123 133

The true stress-strain curves for several C steels were determined Both C content and strength level serve to increase the rate of strain hardening for these steels, irrespective of their microstructure The strength and rate of work hardening specify completely the tensile plastic properties of metals The study of the effect of composition of steel on the plastic properties has been reduced to the study of the effect of alloying elements on these parameters

(706) Hollomon, J H

Tensile Deformation

Trans AIME 162 (1945) 268 290

Information concerning the relations between stress and strain during plastic deformation has been reviewed in recent papers This paper attempts to further coordinate and amplify the knowledge concerning the plastic deformation of metals in simple tension

(707) Hollomon, J H

The Problem of Fracture

Welding J 25 (1946) 534s 583s

An analysis which attempts to interpret the knowledge of fracture in terms of consistent theory Divergencies in knowledge are pointed out, and an attempt is made to indicate the direction of research to resolve inadequate theory.

(708) Hollomon, J H

The Mechanical Equation of State

Trans. AIME 171 (1947) 535 545

Suggests that the stress required for flow depends upon the instantaneous values of the strain, strain rate, and temperature, and not upon their past values These ideas are applied to creep, and other applications

(709) Hollomon, J H

Fracture and the Structure of Metals

Article from Fracturing of Metals, Am Soc Metals, Cleveland, Ohio (1948) 262-274

A consistent theory is being developed to coordinate the many diverse facts pertaining to fracture, such as the size effect, time effect, and surface effects crystal structure, equicohesive temperature, and temper brittleness phenomena Griffith made the initial step toward such a theory, but modifications have been necessary to account for the relations between the structure of the metal and their fracture characteristics The difficulty with the fracture problem is that plastic flow often precedes fracturing, modifying the material The amount of plastic flow is in turn determined by the continuously changing fracturing characteristics

(710) Hollomon, J H

Nucleation of Deformation

Article from Cold Working of Metals, Am Soc Metals, Cleveland, Ohio, (1949) 148-162

The theory of nucleation is applied to the formation of "slips" in crystalline solids Qualitative agreement is realized with observed deformation characteristics The conditions under which the stress at a given strain rate and temperature is independent of the prior deformation history are discussed

(711) Hollomon, J H , and Fisher, J C

A Statistical Theory of Fracture

Trans AIME 171 (1947) 546-561

The possibility of developing a quantitative theory of fracture is discussed The analysis is based only on the assumption that fracture is caused by randomly oriented defects having the properties of cracks, and that the number of defects of a given size is an exponential function of the size A further effort is made to rationalize by statistical analysis the size effect in solids, the scatter of fracture-stress values and dependence of fracture stress upon strain, and to make an approach to quantitative relations between structure and fracture stress

(712) Hollomon, J H , and Jaffe, L. D.

Time-Temperature Relations in Tempering Steel

Trans AIME 162 (1945) 223-249

Deals with the relations of time, temperature, and composition with the structure obtained on tempering. Hardness is used as a quantitative measure of the tempered structure It is assumed that the relation between time and temperature of tempering has the usual form of diffusion equations, the hardness being some form of the parameter $te^{-Q/RT}$ Investigates variation of C, the shape of the curve; gives expression when temperature varies during tempering.

(713) Hollomon, J H , and Lubahn, J D

Plastic Flow of Metals (Letter)

Phys Rev. 70 (1946) 775

An equation has been derived connecting the four variables, strain, strain rate, temperature, and stress, required for plastic flow At constant strain rate and temperature, the stress σ and ϵ are related by the equation $\sigma = K\epsilon^m$, where K and m are constants which may depend on the strain rate and temperature If α is the strain rate, the empirical relation $\sigma = K_1\alpha^n$ has been discovered, where K_1 and n may depend on the strain and temperature A relation giving all combinations of temperature and strain rate that correspond to a given stress at a fixed strain is of the form $Q/R = -T \ln \alpha/\alpha_1$, where α_1 may be a function of the strain and Q a function of stress and strain From these a general relation is deduced of the form $\sigma = C(\alpha/\alpha_o)^{DT}\epsilon^{(E - FT \ln \alpha/\alpha_o)}$exp, where α_o, C, D, E, and F are constants of the material The problem of determining the plastic behavior of a metal in the range in which there is no phase change becomes a question of evaluating the five constants of this equation [See correction made by Lubahn, Trans ASME 69 (1947) A-220]

(714) Hollomon J H , and Lubahn, J D.

The Flow of Metals at Elevated Temperatures, Part I

Gen Elec Rev 50 (February 1947) 28-32

The authors introduce a general relation stating the combined effects of strain, strain rate, and temperature on the stress required for plastic flow. A relation of the form assists in making possible a prediction of the flow characteristics of a metal under a wide range of conditions The deformation characteristics of materials are discussed, and mathematical expressions to explain this behavior are presented The authors then deal in turn with the relationships between strain and flow stress; strain, strain rate, and flow stress; and strain, strain rate, temperature, and flow stress. There is considerable evidence now available to show that there are two mechanisms of flow, one operating at low and the other at high temperature, the former occurring primarily by slip and the latter by grain-boundary rotation

(715) Hollomon, J H., and Lubahn, J D.

The Flow of Metals at Elevated Temperatures, Part II

Gen. Elec Rev. 50 (April 1947) 44-50

The general equation relating stress, strain, strain rate, and temperature was applied to cases in which temperature or strain rate is not constant during deformation. Results of experiments on effect of strain rate and temperature histories, and on the relationship between tensile and creep test data Certain unsolved problems for future research. The main equation derived in Part I applies only to the relation between stress, strain, strain rate, and temperature, when the last two variables are constant in arriving at the strain As these terms are not maintained constant during the deformation of metals, an investigation was made of the validity of the empirical relationships in these cases Evidence is presented in support of the concept that the general relation should be an equation of state in which the stress at a given strain should not depend on the past history of the temperature or the strain rate This is provided that no phase changes occur during that history Using tensile-test data alone, the derived relation is able to describe the plastic-flow characteristics of certain metals in the uniaxial tension over wide ranges of strain, strain rate, and temperature

(716) Hollomon, J H , and Zener, C.

High Speed-Testing of Mild Steel

Trans ASM 32 (1944) 111-122

One of the difficulties encountered in high speed-testing of materials is associated with the unavoidable inertia of the test material itself The intrinsic limitation which this puts upon high speed testing is discussed Data regarding the variation of the tensile properties of mild steel with rate of deformation are correlated so that the tensile properties may be extrapolated to high strain rates By such an extrapolation, it is predicted that in mild steel the yield strength becomes equal to the tensile strength in the range of strain rates between 1 and 10^4 sec^{-1}, depending upon grain size and carbon content. The dynamic implications of an equality of the yield and tensile strengths are pointed out

(717) Hollomon, J H., and Zener, C.

Conditions of Fracture of Steel

Trans. AIME 158 (1944) 283-297

The flow stress and fracture strength have been obtained over a wide range of temperature and of strain rate for both pearlitic and tempered martensitic steels The observations indicate that deformation has a negligible effect upon the fracture strength of the tempered martensitic steel. The anomalous effect of deformation upon the fracture strength of pearlitic structure may be interpreted as due to a reorientation of the carbide lamellae. In the yield-strength ranges of the steels examined, only the pearlitic steels were brittle at high strain rates and at low temperatures The phenomenon of fracture is rationalized in terms of the concept of a flow stress and a stress at fracture first introduced by Ludwik

(718) Hollomon, J H , and Zener, C.

Problems in Fracture of Metals

J Appl Phy. 17 (1946) 82-90

Effects of following variables on virtual fracture stress: (a) strain, (b) strain rate, (c) temperature, (d) stress distribution, (e) structure, and (f) mechanical history (i e , fatigue). Comparison of fracture characteristics of metallic crystals Hindrances of plastic deformation by short stress gradients. Introduction of stress concentration by: (a) nonmetallic inclusions, (b) precipitates, (c) slip bands, (d) twin bands, and (e) grain-boundary deformation Effect of reversal of stresses upon properties of slip bands

(719) Holmes, P. J

Dislocations in Diamond-Type Lattices

Report of a Meeting on Semi-Conductors, Phys Soc (London) (1957) 27-32

A summary is given on the experimental crystallographic evidence on the types of dislocation existing in materials of the diamond structure. A distinction is drawn between macroscopic growth defects and dislocations capable of analytic treatment by current theories Possible dislocation models of the latter type are described and their dissociations and interactions discussed The correlation of etch pits with dislocations is also discussed

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(720) Holth, T.

Creep of Metal Crystals (In English)

Paper from Proceedings International Symposium on the Reactivity of Solids, Gothenburg, Sweden (1952) 909-911

Creep appears to be a boundary process in regions of reduced crystal order involving dislocation or the movement of stressed atoms

(721) Homes, G. A., and Gouzou, J

Contribution to the Study of the Mechanism of the Fracture of Metals (IN French)

Rev. met 47 (1950) 678-692

It is of little significance to call a metal ductile or brittle unless the nature of the stress and of the structure is specified. An investigation of the mechanism of metallic rupture in Zn and mild steel showed that even in simple fracture by tension there are three mechanisms possible; (a) pure cleavage, (b) cleavage accompanied by shearing, and (c) slipping by translation followed by shearing Only the first two occur, and they always occur, in cold-fractured Zn; (c) occurs with mild steel and hot-drawn Zn. Premature cleavages are often observed in Zn, but these do not cause fracture, probably owing to the high plasticity of the contiguous crystals Twinning appears to play only a secondary part in the mechanism of fracture. In Zn, as in mild steel, a considerable heterogeneity during deformation and fracture is observed No tearing apart of crystals before fracture was observed with either Zn or mild steel, and none of the fracture was complete intercrystalline. In mild steel, where the possibilities of slipping by translation are much more numerous than in Zn, cold drawing alone causes slipping, which ends by a shear in the body of the grain after appreciable work hardening.

(722) Honeycombe, R. W. K.

Inhomogeneity of Deformation in Metal Single Crystals (Letter)

Proc. Phys. Soc. (London) 63 (1950) 672-673

Results of an investigation of local orientation changes in deformed Al crystals by means of a modification of the Berg method

(723) Hopkin, L. M. T

A Note on the Mathematical Analysis of Creep Curves

J. Inst. Metals 81 (1953) 443-448

The Andrade equation $L_t = L_0 (1 + \beta_t^{1/3}) \exp (Kt)$ and an equation containing a logarithmic term have been found to give good fits of creep curves on high-purity Pb and a Pb-1% Sn alloy. The Andrade equation was the better for longer times up to 5000 hr. An attempt to correlate the values of the constants in the Andrade equation with the effects of grain size and stress was not possible for Pb. For the Pb-1% Sn alloy, however, it was found that $\sqrt[3]{K}$ was linearly related to stress and relative grain-boundary areas, although no simple relationship existed between these variables and the β constant

(724) Hu, L. W.

Studies on Plastic Flow of Anisotropic Metals

J. Appl. Mechanics 23 (1956) 444-450

Based on Hill's theory of plasticity for anisotropic metals, the plastic stress-strain-increment relations are derived for materials with strain hardening. The influence of anisotropy on the plastic behavior of metals in a state of plane strain or plane stress is discussed

(725) Hu, L. W.

Determination of the Plastic Stress-Strain Relations in Tension of Nitanny No. 2 Brass Under Hydrostatic Pressure

ASTIA, Bulletin No. U-58-11 (August 1, 1958) 1543

A testing method to determine the plastic stress-strain relations of metal under high pressure with continuous loading was developed. Results showed that the strain-hardening coefficient of the material remains essentially a constant for various pressure, but the strength coefficient increases with the intensity of the pressure to which the material is exposed. The average true stress and the reduction in cross-section area at rupture were found to increase with pressure. Fracture surfaces changed from brittle to ductile as the hydrostatic pressure increased.

(726) Huang, H. I., Sherby, O. D., and Dorn, J. E.

Activation Energy for High-Temperature Creep of High-Purity Aluminum

Trans AIME 206 (1956) 1385-1388

The activation energy for the high-temperature creep of high-purity aluminum was evaluated by a new technique involving rapid changes in temperature, and was found to be 32,200 cal/mole insensitive to stress and strain Concludes that both Becker-Orowan and Absolute Reaction Rate theories are inconsistent with experiment, and that high-temperature creep arises from dislocation climb

(727) Hume-Rothery, W.

On the Bond Lengths and Interatomic Distances in Certain Molecules and Crystals

Proc Roy. Soc (London) 197A (1949) 17-27

Internuclear distances in crystals of some elements at absolute zero were calculated, and the values are compared with those in some molecules. Several whole-number relationships are found to exist between squares of bond lengths and atomic numbers.

(728) Hund, F

Theory of Binding in Non-Polar Crystal Lattices (In German)

Z. Elektrochem. 61 (1957) 891-895

A short, clear survey of cohesion in crystals of various lattice types, and the properties of the crystals

(729) Hundy, B B

Plane Plasticity

Metallurgia 49 (1954) 109-118

Fundamental ideas of theory of plasticity as basis for understanding more useful parts of theory

(730) Hundy, B B

The Strain-Age Hardening of Mild Steel

Metallurgia 53 (1956) 203-211

Effects of strain aging on mechanical properties; a modification of the dislocation theory of strain aging to cover the change in strength and ductility during aging

(731) Huntington, H B

Modification of the Peirls-Nabarro Model for Edge Dislocation Core

Proc Phys Soc (London) 68 (1955) 1054-1064

Critical review of various assumptions implicity in the Peirls-Nabarro treatment of the core of an edge dislocation.

(732) Hutchison, M. M , and Louat, N.

The Effect of Preloading on the Yield Point in Iron

Acta Met 6 (1958) 8-12

Measurements of the increase in yield stress in Fe caused by preloading below the yield point have been carried out with a view to distinguishing between current theories of the yield point in Cottrell locked systems The results obtained tend to favor a theory based on a model in which prior to yielding the dislocations move significantly carrying their atmospheres with them

(733) Il'ina, V A , and Kritskaya, V K.

X-Ray Determination of the Characteristic Temperature of Chromium, Nickel, and Molybdenum (In Russian)

Problems in Metallography and the Physics of Metals, no 4, Moscow (1955) 399-401

Characteristic temperature, theta, of annealed and deformed Mo at 650 C is the same (Same results obtained previously with Fe) Cr has highest theta Interatomic bonds of Ni and Fe are weaker than Cr and Mo. Agreement with these data and other characteristics, such as melting point, coefficients of diffusion, self-diffusion, etc , obtained--except for Cr.

(734) Il'ina, V A , and Kritskaya, V K.

Interatomic Bond Strength and Static Distortions in Crystals of Alloyed Ferrite (In Russian)

Doklady Akad Nauk S. S. S. R 100 (1955) 79-72 (Brutcher Translation No. 3511)

Investigation of effect of V, Mn, Co, Cb, and Mo upon bond strength and distortion of alpha-iron lattice, based on measurements (at room temperature) of the thermal factor of the intensity of X-ray diffraction lines. The strength of interatomic bonds in the crystals of the component phases is believed to be one of the main factors determining the temperature of softening of the alloy. Showed that all elements (Mn, Co, Cb, Mn), except V, increased the band strength in ferrite which agrees with effect of alloying on the temperature dependence of the shear modulus. No direct correlation was found between the static distortion of the solid solution and the differences in dimensions of the atoms of the solvent and the alloying elements.

(735) Il'ina, V. A., and Kritskaya, V. K., Kurdyumov, G. V., and Stelletskaya, T. I.

The Influence of Hot and Mechanical Working on the Thermal Scattering of X-Ray Beams with Solid Solution (In Russian)

Izvest Akad Nauk S. S. S. R , Ser. Fiz., 20 (1956) 723-728

Alloying found to influence strength of interatomic bond in alpha-Fe. In some solid solutions, strength may be changed only by thermal and mechanical working (no composition change).

(736) Il'yushin, A. A.

Theory of Elastic-Plastic Deformation and Its Applications (In Russian)

Izvest Akad. Nauk S. S. S. R , Ser. Fiz. (June 1948) 769-788

On the basis of theoretical analysis, a very general mathematical expression covering all known and several not yet fully investigated theories of solid bodies under deformation is proposed Practical application to various states of stress.

(737) Il'yushin, A A

Contemporary Problems of the Theory of Plasticity (In Russian)

Vestnik Moskov. Univ. Ser Fiz. Met. i Estratven Nauk (April-May, 1955) 101-113

Theories of small elasto-plastic deformation, plastic flow, creep of metals, strength of structural materials and concrete, etc

(738) Ivanova, V. S.

A Criterion of Ductility in Creep (In Russian)

Zavodskaya Lab. 21 (1955) 212-215

Suggests the use of a new material characteristic to estimate the properties of heat-resistant alloys, called the plasticity resource, $\epsilon_r = V_p t_{cr}$ where V_p is the creep rate and t_{cr} is the time to failure

(739) Ivanova, V. S.

Nature of Fracture of Metals During Creep (In Russian)

Metalloved i Obrabotka Metal (1955) 19-26 [See Metal Progress (March 1956) 158, 160, 162]

Theories suggested include that of the intensity of vacancy formation during creep. Discusses relation between stress and time up to fracture in steels with low-creep resistance and of the deformation resistance and cohesive strength to service life of a metal.

(740) Ivanova, V. S.

The Role of Dislocations in Creep Processes (In Russian)

Prochnost Metallov, Akad. Nauk S. S. S. R (1956) 16-26

The theory of dislocations explains (a) local plastic deformation ϵ and (b) the thermodynamic strengthening of metals The distribution of ϵ over the length of steel specimens was determined after deformation at 575 C With an over-all deformation of 0.06% the value of ϵ of 12 out of 18 sections was 0.1% and zero in the other 6 sections All sections retained residual deformation, and the differences of ϵ of the different sections decreased. Dislocations accounting for plastic deformation require different stresses to become mobile. This is a function of their configuration and of the atmosphere of dissolved atoms surrounding them Repeated cycles of stress at high temperature, and rest, with load removed, at room temperature, did not effect the creep curve But when the specimen at rest was maintained at the testing temperature the metal was strengthened. However, to gain this strengthening effect, the value of stress must exceed the critical deformation stress of a given metal at a given temperature During prolonged resting periods or repeated cycles sufficient blocking effects are accumulated to arrest the migration of dislocations when the stress is applied.

(741) Iveronova, V I

Distortion of Crystal Lattice in Solid Solution

Acta Cryst 10 (1957) 821

Mean square static displacement measured and compared with the degree of short-range order. The dependence of the Debye temperature for Ni-Fe alloys is deduced. For Cu_3Au and Ni_3Fe, the dependence of Debye temperature on long-range order theta for ordered solid solutions is less than for disordered.

(742) Iveronova, V I., and Katsel'son, A. A.

On the Mosaic Structure of Crystals in Polycrystalline Metals (In Russian)

Zhur Tekh. Fiz. 25 (1955) 696-699

X-ray extinction is shown to be a measure of the extent to which mosaic blocks in deformed polycrystalline aggregates have grown as a result of various temperatures and times of annealing. Specimens studied were an Fe-Pd alloy and Fe-Co alloys containing 15, 20, 30, or 50 at.% Co. It is shown that the temperature at which block growth begins is higher the less the concentration of impurity. In the Fe-50 at.% Co alloy, an anomalous apparent failure of the mosaic blocks to grow on prolonged annealing at 660 C is ascribed to processes of ordering of the alloy, which disturb the coherence of the individual parts of the crystalline lattice.

(743) Jackson, K. A., and Chalmers, B.

Influence of Striations on the Plastic Deformation of Single Crystals of Tin

Can. J. Phys. 31 (1953) 1017-1018

Effect of existing substructure on a substructure subsequently formed by deformation. Micrograph, macrograph, three references. Single crystals of tin contained striations running parallel to their axis. After deformation in tension a banded structure was observed on the top surfaces of the crystals, the bands being regions with orientations differing by rotations about the C-axis The boundaries of the bands coincide with striation boundaries wherever possible. Deformation bands in regions of striation-free crystal had quite irregular boundaries. The results are discussed in terms of the characteristics of deformation bands and of striations.

(744) Jaffe, L. D., Reed, E. L., and Mann, H. C.

Discontinous Crack Propagation

Trans AIME 185 (1949) 526

It has been generally believed that fracture originates at a point and, if the stress is sufficient, propagates across the material from this point Evidence to the contrary is illustrated for a low-alloy steel. An explanation is offered

(745) Jamison, R E , and Sherrill, F A

The Critical Shear Stress in α-Brass as a Function of Zinc Concentration and Temperature

Acta Met 4 (1956) 197-200

Single-crystal tensile specimens of α-brass of various compositions up to 30 at % Zn were pulled at temperatures below 297 K to measure the critical shear stress The ratios of the critical shear stress at each of the lower temperatures to that of 297 K show a sharp increase from unity for 0 % Zn (measured by previous workers) to a plateau at about 7% and then another rise starting at about 20% Zn A significant result is that for small percentages of Zn the critical shear stress at 4 2 K is actually lower than that at 78 K. An explanation of this anomaly is offered in terms of jog formation in the dislocations during their movement prior to yielding of the specimen.

(746) Jaoul, B

Contribution to the Study of Plastic Deformation (In French)

Publ sci. et tech ministère air (France) 290 (1954) 86

Analysis of stress-strain curves for Al and a number of its alloys shows that they may be resolved into three parts: (1) a range of proportionality, elastic or anelastic (for polycrystalline specimens); (2) a first region of plasticity, where the tensile stress, σ , is related to the elongation, ϵ, by the equation: $\sigma = \sigma_0 + A\epsilon^m$, where σ_0 is the limit of proportionality and M > 0·5; and (3) a second region of plasticity, where the curve can be represented by the equation: $\sigma = \sigma_0 + B\epsilon^n$, where σ_0 is negative, and n has a very small value, positive or negative There is a sharp change of slope on the stress/strain curve between the two plastic regions, and this "transition point" for a pure metal or a lightly alloyed metal, in the recrystallized state, is independent of the thermal treatment or conditions of testing. The transition point corresponds to: (a) the degree of cold working at which the metal begins to creep perceptibly; (b) the elongation at which the metal will recrystallize on annealing; and (c) the point at which crosslipappears

X-ray diffraction investigations show that below the transition point continuous asterism appears on the photographs, whereas beyond the transition point the spots become broken up into a series of distinct reflections. The transition elongation thus represents the deformation at which the number of dislocations piled up in the lattice is sufficient to cause a reorganization of the lattice accompanied by fragmentation of polygonization; this would explain the connection between the transition elongation, the critical amount of cold working, and Juretzek and Sauerwald's point [Z. Physik, 83 (1933) 483]

(747) Jaoul, B

Influence of Impurities on the Form of the Stress/Strain Curves of Aluminum Single Crystals (In French)

Compt. rend. 240 (1955) 2532-2534

Tests were carried out on binary alloys of Al containing Si, Cu, or Zn. The values of the shear to the elastic limit and up to the point of inflection were constant for the same metal. The influence of impurities on the strength of single crystals is comparable to that in polycrystalline materials. From these results, E. Schmid's law [Schmid and Boas Kristallplastizitat (1935, Berlin)] can be generalized as follows: The shear corresponding to comparable states of deformation is independent of the orientation. But, as has been observed with pure Al, specimens with an orientation near (111) are an exception; the divergence relative to the other orientations is still greater in impure metals. Micrographic observations show that the presence of impurities diminishes the importance of the second system of slip. For the same orientation, the slip at the point of inflection is greater in impure metals.

(748) Jaoul, B.

Variation in the Slope of Stress/Strain Curves of Metals (In French)

Compt. rend. 243 (1956) 16-19

The transition point of stress/strain curves marks a stage beyond which further deformation is due solely to intracrystalline effects. The reversible or "pseudoelastic" part of the curves has a flatter slope than the elastic part if the metal is well recrystallized, and the slope increases with progressive deformation. In the first or "elastic-plastic" part of the deformation, the slope decreases, and experiments with pure Al of various grain sizes show that, up to the transition point, the slope is always E/100. This is confirmed for other metals, such as Cu, Fe, Zn, and even Fe-Ni and Al-Mg alloys. In the completely plastic region beyond the transition point, the slope decreased more rapidly owing to stress relief due to the removal of the piled-up dislocations; but if this does not occur, the curve does not show the above transition point as in the case of single crystals at very low temperatures. An example of this is the case of 18:20 stainless steel.

(749) Jaoul, B.

Influence of Grain Boundaries on the Cold Work of Metals (In French)

Paper from Deformation and Flow of Solids, Edited by R. Grammel, Springer-Verlag, Berlin (1956) 13-24

The forms of the tensile curves for single crystals and polycrystals are described, and the two compared.

(750) Jaoul, B

Plastic Deformation of Aluminum Single Crystals at Low Temperatures

Compt. rend. 242 (1956) 3039-3042

Investigations of the characteristic changes with orientation at temperatures below 20 degrees. The curves show the usual characteristics: well-defined elastic limit, first part concave upwards and then parabolic Contrary to the observations at room temperature, the curves are only slightly affected by the crystal orientation, and at -195 C all the curves have the same general direction. The rate of hardening increases linearly up to the point where the curve inflects; the value of the slope at the origin suggests that there are a considerable number of barriers at the elastic limit and that these grow until a complete network is formed round each Frank-Read source, when the slope G/200 is attained, where G is the shear modulus.

(751) Jaoul, B.

A Study of the Form of Plastic-Deformation Curves (In French)

J Mech. and Phys. Solids 5 (1957) 95-114

The stress-strain curves in tension for single crystals and polycrystalline materials can be defined by a series of successive mechanisms The main body of the work is on Al, though additional information was obtained on Ni, Cu, Pb, Fe, Zn, and low-C steel. Four stages were identified: (i) an initial elastic range; (ii) plastic deformation accompanied by rapid strain hardening, this being associated with the mutual interference of dislocations; (iii) linear increase in strain hardening giving a value for the modulus of plasticity; (iv) rapid deformation with a decrease in strain hardening, considered to be due to the blocked dislocations freeing themselves. Fragmentation occurred in this final stage before fracture In polycrystalline materials, a strain-hardening component was identified with grain-boundary effects.

(752) Jaoul, B

Plastic Deformation Behavior of 18% Cr-11% Ni Stainless Steel Alloys

Unpublished Report of Research at Ecole Nationale Superieure des Mines, Paris (1958)

Below room temperature a direct correlation is observed between the applied stress and the amount of martensite formed, independent of the temperature or strain rate Shows the existence of a mechanical equation of state under these conditions.

(753) Jaoul, B., and Bricot, I

Plastic Deformation of Aluminum and Aluminum Alloy Single Crystals (In French)

Rev. met. 52 (1955) 629-642

The behavior of the single crystals of pure Al and of Al alloys was studied during plastic deformation, as a function of various factors: orientation, impurities, substructure, and rate of deformation. The results led to the following conclusions: (1) all the deformation curves, regardless of orientation, show a more or less marked inflection; (2) according to the orientation, the first sections of the curves are of two types: (a) those showing a break at the elastic limit, even in pure Al, and (b) those showing a rounded portion beyond the elastic limit; (3) the values of the shear up to the elastic limit and the point of inflection are independent of the orientation, which enables Schmid's law to be extended to the plastic region; (4) the slip at the point of inflection varies within large limits as the orientation; (5) micrographic observation during deformation leads to a rejection of the hypothesis of a second system of slip where the deformation bands appear only after a certain elongation; (6) the alloying elements increase the importance of the first region of deformation, and (7) the rate of deformation has an influence on the value of the elastic limit and on the shape of the curve near to it, but not on the general shape of the curve, particularly on the value of the shear at the point of inflection.

(754) Jaoul, B., Bricot, I., and Lacombe, P.

Deformation Bands and Kinks in Aluminum Single Crystals (In French)

Rev. met. 54 (1957) 756-768

A micrographic and X-ray study of the disorientation of a single crystal of pure Al subjected to tension, discloses six types of deformation bands These depend on the orientation, the possibility of secondary slip, and the degree of deformation. They can be classified as (1) bands in which secondary slip starts at the beginning of deformation, and (2) kinks corresponding to a simple bending of the lattice without secondary slip in the early stages.

(755) Jaoul, B., and Crussard, C.

Relationship Between Tensile and Creep Strains and Recrystallization (In French)

Met. ital 44 (May 1952) 175-179

During a study of the shape of tensile curves of several Al alloys, a sharp break in the curves was found to exist. The transition point between the two types of deformation corresponds to the beginning of fracture of the grains. Creep tests on the same alloys show that the stress corresponding to the beginning of fracture has approximately the same value as the creep limit. Concludes that creep cannot occur until grain fracture begins From exact analysis of the stress curves, approximate values of creep limit and critical recrystallization point may be determined.

(756) Jastram, G.

Plastic Behavior of Copper Wires at Various Rates of Extension (In German)

Arbeitstag Festkörperphysik II (1954) 82-93

The extension at various rates, up to fracture, of Cu wires was studied at room temperature and the results were interpreted by means of theories due to Kochendorfer, Nadai, Prandtl, and others, with a view to deciding whether it is possible to associate the effect of the rate of extension upon the elasticity with three regions of (1) perfectly complete, (2) imperfectly complete, and (3) perfectly incomplete disappearance of dislocations Evidence is derived for the transition (1)--->(2).

(757) Jaswon, M A.

Dislocations, A Review of Some Recent Books

Research 7 (1954) 457-464

Theory, strain energy, edge and screw dislocations and stress boundaries are discussed

(758) Jaswon, M. A

The Theory of Cohesion

Pergamon Science Series Metal Physics and Physical Metallurgy Vol 11 Interscience Publishers, Inc , New York (1954) 245 pp

Mathematical and physical arguments involved in the theory of cohesion in aggregates, particularly in metals, which help bridge the gap between elementary and advanced treatments

(759) Jaswon, M A., and Foreman, J E

The Non-Hookean Interaction of a Dislocation With a Lattice Inhomogeneity

Phil. Mag 43 ser 7 (1952) 201-220

The equilibrium position of an edge dislocation near certain types of lattice irregularities was investigated quantitatively, using the Peierls model of a dislocation The external shear stress required to maintain equilibrium was calculated and the result extended to an array of like dislocations piled up against a barrier The integral equation for the atomic displacements is linearized by a perturbation technique, the resulting equation being solved exactly

(760) Jellinek, H H G , and Brill, R

Viscoelastic Properties of Ice

J Appl Phy 27 (1956) 1198-1209

Deformation under tension of single and polycrystalline ice was measured as a function of time, stress, and temperature Recovery curves on removal of loads were investigated – plastic flow was found to be Newtonian. Total deformation can be represented satisfactorily by a large number of Voigt units representing a distribution of retardation times in series with a Maxwell unit Experimental results are discussed from dislocation theory standpoint and tentative mechanisms for deformation of ice are proposed

(761) Jenkins, C H.M

Observations on Third Stage Creep and Fracture

Paper from Creep and Fracture of Metals at High Temperature, Her Majesty's Stationery Office, London (1956) 287-298

Experiments are described concerning the mutual relationship of intercrystalline cracking, polygonization, recrystallization and transcrystalline rupture during the tertiary stage of creep in Fe, in plain C and Mo steel, and in a Cu-base alloy The tests were carried out in vacuo over the temperature range 15 to 950 C Although the mode of deformation varies considerably, according to observed structural changes, intercrystalline cracking appears to increase at low stress Minor variations in composition, melting, and hot-working practice, etc , may alter the behavior of a material in creep testing by their influence on recrystallization

(762) Jenkins, C H M , and Jenkinson, E. A

Investigation of the Behavior of Metals Under Deformation at High Temperatures Part III The Deformation, Microstructure, and Form of Carbides in a 0 15% C, 0.5% Mo Steel in Creep Tests

J Iron Steel Inst 185 (1957) 23-46

Vacuum tests at 450 to 850 C from a few minutes to 13,470 hours were made to trace extent of transcrystalline and intercrystalline cracking Relationship of cavities to further deformation and cracking is discussed Carbides identified by X-ray method

(763) Jenkins, C H M , and Mellor, G A , and Jenkinson, E A

Investigation of the Behavior of Metals Under Deformation at High Temperatures

J Iron Steel Inst 145 (1942) 51P-86P

The behavior to rupture of C steels with up to 1 14% C was studied after short-time (tensile) and long-time creep tests in high vacuum over the temperature range of 15 to 950 C. The effect of C content was most noticeable in tensile tests, but as the temperature of test was increased this effect was reduced In creep tests at a temperature of 450 C, there was a marked difference in the life of the specimens of certain materials, those of high C content showing the greatest strength. At 550 C, and above, the effect of C on the life in creep tests was not very noticeable The alpha-gamma structural change in Fe and low-C steels between 700 and 900 C caused a marked increase in the strength of the materials as measured by short-time (tensile) tests, but in high-C steels there was little change The work shows the general weakening of the material with increase of temperature and describes the nature of the structural changes set up.

(764) Jenkins, W D

Creep of High-Purity Aluminum

J Research Natl Bur Standards 46 (1951) 310-317

A study was made of cold-drawn Al at 105 F, to determine effects of variations of creep rate on mechanism of deformation Extension on loading and extension at the beginning of the third stage both increased with increase in stress Cyclic temperature changes appeared to increase the ductility. Discontinuous flow was evidenced in constant-load creep tests and in tensile tests at 80 F Conformance to Andrade's law of transient flow was found within a limited range of strain rates A mechanism of flow based on observed structural changes is proposed

(765) Jenkins, W D., and Digges, T G

Influence of Strain Rate and Temperature on the Creep of Cold-Drawn Ingot Iron

J Research Natl Bur Standards 43 (1949) 117-131

Results of a similar study for Monel and OFHC Cu were previously reported Since Monel and copper are fcc metals, the program was extended to include a study of the behavior of bcc Fe as affected by variations in strain rate and in temperature

(766) Jenkins, W D., and Digges, T G

Creep of Annealed High-Purity Copper

J Research Natl. Bur Standards 45 (1950)

Effects on creep behavior of stress, temperature, mechanical and thermal history, rate of loading, and sudden changes in both stress and temperature Tests were made at 110, 250, and 300 F Metallographic examination, hardness measurements, and tension tests were conducted at room temperature

(767) Jenkins, W D , and Digges, T G

Creep of Annealed and Cold-Drawn High-Purity Copper

J Research Natl Bur Standards 47 (1951) 272-287

A study was made of the effect of temperature and stress on the creep behavior at 110, 250, and 300 F of high-purity, OFHC Cu initially as annealed and as cold drawn to 40% reduction of area Correlations are made of changes in structure with time, stress, temperature, and discontinuous flow

(768) Jenkins, W D., Digges, T G., and Hohnson, C R

Creep of High-Purity Nickel

J Research Natl Bur Standards 58 (1954) 329-352

Influence of stress, temperature, and prior-strain history on creep behavior of annealed Ni; evaluation of prestraining effect in creep on hardness and tensile properties at room temperature

(769) Johnson, A E., Jr , and Batdorf, S B

A Study of Slip Formation in Polycrystalline Aluminum

NACA TN 2576 (December 1951) 18 pp

Experimental results shed light on the assumptions that have been made in several attempts to bridge the gap between physical and mathematical theories of plasticity The results are compatible with, but do not necessarily verify, the conception that plastic deformation in strain-hardening materials is primarily due to slip.

(770) Johnson, A. E., and Frost, N. E.

Rheology of Metals at Elevated Temperatures

J. Mech. and Phys. Solids 1 (1952) 37-52

The general stress, time, and temperature dependence of creep, plastic strain, and relaxation properties of several metals and alloys are discussed. Tests involve simple tensile, torsion, and combined stress-creep tests, and similar varieties of short-period plastic strain tests and relaxation tests. The period to fracture (P) is related to the maximum principal stress σ_1 by the relation: $\log P = A - B\sigma_1$, where A and B are constants. The creep rates are compared with current theoretical formulae. In general, curve fitting was possible only over a limited temperature range, and empirical formulae are suggested. At low-strain rates for an Al alloy, creep and relaxation are directly related. Finally, an investigation was made of the stress/strain curve for a Mg alloy at various temperatures. At all temperatures this material obeyed the von Mises criterion of yielding

(771) Johnson, A. E., and Frost, N. E.

The Temperature Dependence of Transient and Secondary Creep of an Aluminium Alloy to British Standard 2142 at Temperatures Between 20° and 250°C and at Constant Stress

J. Inst. Metals 81 (1952-1953) 93-107

The effects of temperature on the various phases (transient and steady-state creep) of forward to creep and on creep recovery have been investigated by means of creep tests in pure torsion on thin-walled tubular specimens at a constant stress of 2 tsi, and at 50 C intervals over the range of 20 to 250 C. The tests were of moderately long duration. It is concluded that for this alloy no current fundamental theory adequately describes the transient creep between 20 and 250 C although up to 200 C the secondary creep rates agree quite well with theories based on the Eyring rate process conception. Superposition theories do not represent the recoverable creep measured. The total forward creep is well represented at all temperatures by an equation

$$\alpha = K_1 t^{1/m_1} + K_2 t^{1/m_2},$$

where K_1 and $1/m_1$ refer to the nonrecoverable portion of the forward creep strain, and K_2 and $1/m_2$ refer to the recoverable portion of the creep. K_1, K_2, and $1/m_1$ vary with temperature; $1/m_2$ is effectively constant

(773) Jones, G. O.

Viscosity and Related Properties in Glass

Repts. Progr. in Phys. 12 (1948-1949) 133-162

The formation of glasses by a freezing-in of the liquid configuration is described with particular emphasis on the importance of flow properties for this process. A review of observations on viscosity, delayed elasticity, and transformation is followed by their representation in terms of models whose molecular interpretation is discussed. The ideas surveyed have practical applications to annealing problems and thermometer creep. Diagrams show typical flow and transformation phenomena

(774) Jones, H.

Electron Theory of Alloy Formation and Elastic Properties

Paper from Science of Engineering Materials, John Wiley and Sons, Inc., New York (1957) 128-141

Fermi energy and other wave mechanic concepts relate phase formation in alloys to the atomic properties of the constituents. Brief theoretical explanation of elastic properties of metals and alloys.

(775) Jones, H.

Structural and Elastic Properties of Metals

Physica 15 (1949) 13-22

Properties at low temperatures depend only on the energy of the structure and the way it changes as the crystal is subjected to homogeneous strains. In the theory of Bloch, Wigner, and Seitz, the energy is regarded as a sum of terms which, to a useful approximation, can be calculated separately. Effect of these various contributions in determining the structural type, and particularly the values of the elastic constants of the metals and alloys for which measurements are available

(776) Jones H.

The Change of the Elastic Constants of β-Brass With Composition

J. Appl. Phy. 23 (1952) 697

Effects of ion-ion interactions on shear constants and bulk modulus and Fermi-energy phenomena

(777) Jung-Koenig, E., Schmid, E., and Graf v. Schweinitz, H. D.

Adaptation of Hardness-Time Curves for the Evaluation of Creep Relationships

Metallwirtschaft 19 (1940) 492-494

A procedure is described, which allows a quantitative comparison of the creep resistance of different materials in the recrystallization region. Data are presented in graphical form for pure Zn and two Zn alloys containing about 10% Al. Brinell hardness is plotted against time of loading at loads from 12.7 to 1.6 kg/mm^2. An exact quantitative evaluation of the curves has not been carried out, but a rough numerical index of creep resistance may be used, based on the mean speed or penetration during a total time of loading of 20 minutes

(778) Kachanov, L. M.

On the Stress-Strain Relations in the Theory of Plasticity (In English)

Compt. rend. acad. sci. U.R.S.S. 54 (1946) 309-310

An analysis of Hencky's generalized theory of plasticity

(779) Kaderavek, Z.

Examples of Intergranular Fracture of Steel (In Czech)

Hutnické listy 9 (1954) 578-593

Theory of grain-boundary conditions and fracture of carbon and alloy steels

(780) Kambe, K.

Cohesive Energy of Noble Metals

Phys. Rev. 99 ser. 2 (1955) 419-422

Calculations include the effects of the deviation of the effective ion-core potential from pure hydrogenic form in the vicinity of the surface of the s-sphere. Formula derived for calculating logarithmic derivative of the wave function at the surface of the s-sphere

(781) Kanter, J. J.

The Problem of the Temperature Coefficient of Tensile Creep Rate

Trans. AIME 131 (1938) 385-418

The problem of creep is discussed, with special reference to an explanation of the constant rate of flow of secondary creep. Expressions are deduced for the energy change involved in secondary creep, and this is of the order of the free energy change of vaporization of metals. Taylor's dislocation theory provides a satisfactory explanation of the rapid primary flow, but an additional hypothesis is necessary to explain the continuance of deformation at the uniform creep rate associated with metals above their recrystallization temperatures. Microstructures of Pb alloys suggest that the uniform flow corresponds with viscous flow in the layers surrounding each grain, leaving the grains themselves comparatively unaltered. A self-diffusion theory of secondary creep is developed, based on the principles of the Dushman-Langmuir [J. Inst. Metals 31 (1924) 403] theory of solid diffusion, and an equation for the rate of tensile creep is given. Much previous work, both theoretical and practical, is discussed

(782) Kanter, J. J.

Discussion to Article by Miller and Guarnieri, Trans. ASM 41 (1949) 188-193

Using the authors' data for short-time high-temperature tensile tests, proposes his own relation between strain rate, stress, and temperature. On a log-log plot, tensile strengths converge to a point for different temperatures at a high strain rate

(783) Kanzaki, H.

The Plastic Deformation of Copper Single Crystals. I — Two Stages in the Progress of Deformation. II — Recovery Process and Mean Length of Dislocations (In English)

J. Phys. Soc. Japan 6 (1951) 451-459

(I) The stress/strain curves for Cu single crystals at 20 C show that the stress increases rapidly at 20% strain, so that deformation progresses in two stages. The corresponding change of work hardening is attributed to the two types of strains occurring in work-hardened metals discussed previously. If this view is correct, then the number of stopped dislocations will show a rapid increase in the second stage of dislocation. (II) The anomalous specific heat of Cu, due to recovery from strain hardening, has been measured at 0-200 C for single crystals of Cu deformed at -180, -80 C, and room temperature. The maximum value of energy stored during deformation at room

temperature is 0.1 cal/g. The calculated separation distance of dislocations is 200 A, which agrees extremely well with the value found by means of the electron microscope

(784) Kanzaki, H.

Pure Gliding of Metal Crystals (Letter)

J. Appl. Phy. 24 (1953) 811

Röhm and Kochendörfer's method of deforming a long crystal in so-called pure shear was improved by using cantilever loading, which allows the Cu specimen to stretch. Strain was derived by precision measurements on surface markings. It was shown that much of the deformation was due to bending. When the true shear component (along the intended glide system) was separated, a roughly parabolic stress/strain curve resulted. If the whole deformation was attributed to pure shear, a linear relation of gentle slope resulted. It is concluded that Röhm and Kochendörfer's low and linear rate of work hardening is the result of faulty interpretation

(785) Karnop, R., and Sachs, G.

The Behavior of Aluminum Crystals Under Tension. II (In German)

Z. Physik 41 (1927) 116-139

Details relating to the fracture of Al single crystals under tension, applied at various inclinations to the crystallographic axes, are given. The tenacity is related to the crystallographic orientation in much the same way as the tension necessary to produce a constant thrust in the initial state of the crystal. Calculated and observed values of the change of cross-sectional area of the crystals are in fair agreement

(786) Kauffman, J. W., and Meshil, M.

Quench Hardening in Pure Gold

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The effect of rapid quenching from temperatures in the range of 500 to 1040 C on the mechanical properties of 99.999 per cent gold wires was studied. The specimens were deformed in tension at various temperatures from liquid nitrogen to 200 C. Upon aging at temperatures from 25 to 100 C subsequent to quenching, the yield stress was found to increase markedly, the magnitude depending on the quenching temperatures and for slower quenches on the rate of quenching. Increases in the rate of work hardening in the early stages of deformation were also observed with aging. The activation energy corresponding to the rates of increase in yield stress is 0.7 ev. This is interpreted in terms of the energy of motion of quenched-in defects. Changing the testing temperature over the range -196 to 100 C had no effect on the increase in yield stress resulting from quenching and aging within the experimental sensitivity. Therefore, hardening by a Cottrell atmosphere or pining of dislocations by point defects is not considered to be the primary mechanism involved here. Rates of resoftening subsequent to quench hardening were determined in the range 500 to 800 C. Preliminary data give an activation energy in agreement with that for self diffusion. The effect of quenching temperature can be divided into three temperature ranges. Range I lies from about 930 C to the melting temperature, Range II from 930 to 740 C, and Range III below 740 C. Little temperature dependence is found much above 930 C, indicating the quench is not sufficiently rapid, some of the disorder recovering during the quench. In Range II the increase in yield stress is approximately proportional to the amount of quenched-in defects. Range III exhibits a very rapid fall off with decreasing temperature to no quench hardening effect. A mechanism involving disorder produced as a result of coagulation of vacancies is proposed

(787) Kauzmann, W.

Flow Creep of Solid Metals From the Standpoint of the Chemical-Rate Theory

Trans. AIME 143 (1941) 57-83

Eyring's statistical mechanical theory of shear rates [J. Chem. Phys. 4 (1946) 293] is described in detail, and applied to data on the creep of metals. The numerical values of the constants obtained from the equations suggest that creep occurs by the shear of rather large blocks of material, and not by the movement of single atoms past one another as in diffusion. This agrees with existing theories involving the passage of dislocations. Values for the heat and entropy of activation for the shear process are deduced for several metals. A large amount of previous theory is discussed and criticized, and numerous references are given

(788) Kawada, T.

The Plastic Deformation of a Zinc Bicrystal. II (In English)

J. Phys. Soc. Japan 6 (1951) 485-488

The stress/strain curves and change of appearance of Zn bicrystals with longitudinal grain boundaries were studied, taking into account the mutual interaction of the neighboring crystals and disregarding mechanical properties of the grain boundary. On this basis a satisfactory explanation of the stress/strain curve, the change of shape of the cross section, and twisting of the bicrystals was derived. The experimental results, combined with those of Miller [Trans. AIME 111 (1934) 135], enable the stress/strain diagrams for polycrystalline metals to be discussed in terms of those for single crystals

(789) Kawaka, I.

The Discontinuous Elongation of Aluminum Crystals — IV (In English)

J. Phys. Soc. Japan 7 (1952) 240-241

The discontinuous elongations (of the order a few microns) of comm... coarse-grained Al polycrystals, and Al single crystals under tension, were studied at 20 to 350 C. Discontinuous elongation occurred only when the slip lines terminated at a grain boundary and did not occur when the slip lines crossed a grain boundary. No discontinuity was observed in the elongation of an Al single crystal. A mechanism of the discontinuities is discussed.

(790) Kawasaki, M., and Ichiyama, T.

Some Observations on the Inter-Relation of Cleavage, Twinning, and Kinking in Polycrystalline Zinc (In Japanese)

Nippon Kinzoku Gakkaishi 21 (1957) 414-418

Strain markings were observed after successive thermal cycles between room temperature and -196 C. The initiation of twins at the tip of a cleavage crack, and their subsequent development, was studied. Some cracks were arrested by boundaries but propagated across them after further cycles. Microkinks were frequently seen along cleavage cracks

(791) Kê, T.-S.

Experimental Evidence of the Viscous Behavior of Grain Boundaries in Metals

Phys. Rev. 71 (1947) 533-546

A simple torsional apparatus is described which permits measurement of of these effects at very low stress levels (a) internal friction at low frequencies, (b) variation of dynamic rigidity with temperature, (c) creep under constant stress, and (d) stress relaxation at constant strain. These effects were studied with pure polycrystalline, and single-crystal Al wires. The internal friction of single-crystal Al is very small up to 450 C, while that of polycrystalline wire increases to a marked maximum in the region of 285 C. Differences between the behavior of single crystals and polycrystalline specimens were found for all four of the properties (a), (b), (c), and (d). The four anelastic effects are practically absent in single crystals; in polycrystalline specimens they are completely recoverable, and are linear with respect to the applied stress and prior strain. The results support the view that the grain-boundary material behaves in a viscous manner. The maximum amount of shear-stress relaxation in polycrystalline Al is about 33%, in agreement with the value of 36% expected for viscous material. The heat of activation associated with slip along the grain boundaries is 34,500 cal/mole, and the coefficient of viscosity of the grain boundaries is consistent with that which molten Al would possess at the same temperature. Results with Mg are referred to briefly

(792) Kê, T.-S.

Viscous Slip Along Grain Boundaries and Diffusion of Zinc in Alpha Brass

J. Appl. Phy. 19 (1948) 285-290

The viscous behavior of the grain boundaries in 70-30 alpha brass has been demonstrated by anelastic measurements. The grain boundaries cannot sustain permanently a shear stress and have a coefficient of viscosity decreasing with an increase of temperature. Using the same specimen, activation energy associated with stress-induced preferential orientation of pairs of Zn atoms in alpha brass was determined and found to be identical, within experimental error, to activation energy associated with grain-boundary slip in alpha brass. This indicates that grain-boundary slip is a diffusion process and that the diffusion mechanism is similar to volume diffusion

(793) Kê, T.-S.

On the Structure of Grain Boundaries in Metals

Phys. Rev. 73 (1948) 267-268

The activation energies calculated from volume diffusion, creep, and grain-boundary slip are in reasonable agreement for alpha-brass, alpha-Fe, and Al. This suggests that grain-boundary slip can be considered as a microscopic creep.

(794) Kê, T.-S.

A Grain Boundary Model and the Mechanism of Viscous Intercrystalline Slip

J. Appl. Phy. 20 (1949) 274-280

Study of activation energy associated with viscous intercrystalline slip shows that conventional theories are untenable. A grain-boundary model is described in which the transition region is considered to consist of numerous disordered groups of atoms of diffused holes. Intercrystalline slip occurs through atomic rearrangement by thermal agitation within each "disordered group" by a s... r process involving as units of flow only a few atoms. A unified viewpoint as to the mechanism of viscous intercrystalline slip, volume diffusion metals, and constant-rate creep of metal crystals under small stress. Experiments on the influence of previous deformation and impurities on grain-boundary viscosity

(795) Keeler, J. H.

Tensile Characteristics of Particle-Strengthened Alloys of Zirconium With Iron

Trans. AIME 206 (1956) 486-491

Declassified in Part - Sanitized Copy Approved for Release @ 50-Yr 2014/01/27 : CIA-RDP81-01043R003200240005-1

The tensile characteristics of Zr-Fe binary alloys containing up to 5 at % Fe are reported for the temperature range -195 to 500 C. A linear relation between stress at constant strain and volume fraction $ZrFe_2$ was found. The coincidence of data from the unalloyed Zr with zero volume fracture $ZrFe_2$ indicated little or no solid solution in α-Zr. The absolute increase in strength due to particle strengthening, although decreasing with increasing temperatures, was a greater percentage at high temperature

(796) Kelly, A

The Mechanism of Work Softening in Aluminum

Phil. Mag 1 ser 8 (1956) 835-845

Crystals strained at one temperature and subsequently deformed at a higher temperature show a yield point (work softening), this is accompanied by an increase in the amount of cross slip and in the intensity of cross-slip traces.

(797) Kelly, A.

Strength of Age-Hardened Alloys

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The crystallographic structures produced during the aging of a supersaturated solid solution are, in general, varied and complex. For this reason a variety of processes may contribute to the strength of an age-hardened alloy, and it is unlikely that a single theory will account for the strength at all stages of aging. The present review considers in detail the Al-Cu and Al-Ag systems, since these have been most thoroughly studied using X-ray methods. The appearance of the various structures correlates very well with the various hardening stages. Stress-strain curves of single crystals of Al-Cu, aged by various amounts, are presented and the appearance of the slip lines discussed. A broad correlation is found between the slip lines appearance and the type of stress-strain curve.

(798) Kelly, A , and Fine, M. E.

The Strength of an Alloy Containing Zones

Acta Met 5 (1957) 365-367

Rough estimates are made of the stress necessary to force a dislocation through a Guinier-Preston zone in alloys of Al with 2 at % Cu and 13 at % Ag. The values found are significantly less than those calculated using a model for the strength of a precipitation-hardened alloy proposed by Orowan. It is suggested that the process of shearing the zones determines the initial flow-stress in these age-hardening alloys

(799) Kennedy, A. J.

The Effect of Instantaneous Pre-Strain on the Character of Creep in Lead Polycrystals

Proc. Phys Soc. (London) 62B (1949) 501-508

Shows how extension versus time curves of Pb wires subjected to rapid strain just before the experiment may be expressed by the Andrade creep equation, using the same constants as those which satisfy the creep of the metal under the same constant stress, but with the t value associated with β replaced by $(t + t_0)$, where t_0 is a constant for a given experiment, its value increasing with increasing prestrain

(800) Kennedy, A J.

The Creep of Metals Under Interrupted Stressing

Proc Roy Soc (London) 213A (1952) 492-506

The creep behavior of polycrystalline Pb subjected to interrupted stress, or stress pulses, was examined with an apparatus which enables the creep curve to be recorded as a magnified photographic trace. When the metal is reloaded after an interruption, a new creep transient is exhibited which can be adequately expressed by assuming a fraction n of the material to have recovered its original Andrade β-flow properties, while the remaining fraction continues to deform as if unloading had not occurred. It is shown that this analysis is valid whether the material exhibits a finite Andrade K-flow or not. Variation of n with the time of creep previous to interruption, for a constant recovery time R, and variation of n with R for a constant time were each investigated.

(801) Kennedy, A J

On the Generality of the Cubic Creep Function

J. Mech and Phys Solids 1 (1953) 172-181

Discusses the application of the Andrade $t^{1/3}$ creep law to the creep curves of metals, as well as nonmetals. In most cases this law, or one with an exponent close to 1/3, satisfies the results as well as some of the more complex formula which have been proposed. An attempt is also made to find a physical basis for this value. A simple mechanical model is shown to give a creep curve of this type, and it is suggested that a statistical approach will lead to a solution.

(802) Kennedy, A J

Creep and Recovery in Metals

Brit. J Appl Phys 4 (1953) 225-234

Experimental evidence relating to the nature of the creep and recovery mechanisms in single-crystal and polycrystalline metals is reviewed. The character of creep when periods of recovery under reduced stress are interposed is discussed, and it is shown that such conditions have an important effect on the behavior of structures and machines, particularly at high stresses and temperatures. Subjects discussed include the progress of creep and recovery studies and the relation between creep and recovery. Experiment has revealed the very great effect of boundary conditions and the close relation that exists between recovery properties and grain-boundary mobility

(803) Kennedy, A J

Creep of Copper Under Stress Pulses

Nature 171 (1953) 927-928

Annealed Cu wires were tested at 258 C, under 730 kg/cm^2 applied intermittently. Accurate cubic creep parabolas were obtained (as with Pb) with an instantaneous strain recovery on unloading, followed by a negligible creep recovery. A formula is given [following the previous treatment, Proc Roy Soc (London) 213A (1952) 492] for the ratio of the creep strain under a regular intermittent stress system to that under an equal continuous stress. Variation of the wave-form and frequency produces effects in agreement with this formula, suggesting that the basic assumptions are correct

(804) Kennedy, A J

A General Creep and Recovery Property of Metals

Nature 175 (1955) 674-676

If a metal, under particular isothermal conditions, exhibits a transient-creep function of the form, $\epsilon = \beta t^p$, where β is a constant, p a fraction, ε the strain, and t the time of creep then, if the stress is interrupted after a time for a certain period and then reapplied, a small new transient appears. The new curve is interpreted as due to complete recovery of a fraction of the metal. For Mg, Fe, Pb, Zn, Cu, Cd, and Sn, p ≈ 0 33. The results show that the same relation between intermittent and continuous transient creep holds for all materials

(805) Kennedy, A J

A Reconciliation of Certain Recovery Properties in Metals

J Mech and Phys Solids 4 (1956) 162-166

A variety of time and temperature functions proposed to express the mechanical and electrical properties of metals can be reconciled with the behavior of a particular kind of physical model built up from relaxation-type elements

(806) Khotkevich, V I, Chaikovsky, E F, and Zashkvara, V V

Latent Energy of Deformation of Metals (Cadmium, Lead, and Copper) at Low Temperatures (In Russian)

Doklady Akad Nauk S S S R 96 (1954) 483-486

The latent energy of deformation of Cd and Pb at -196 C and of Cu at room temperature was measured. The latent energy of deformation was released during annealing, causing an increase in temperature of the deformed specimen. The method was capable of measuring quantities of heat of the order of 10^{-3} cal, with an error of 7%. The absolute magnitude of the latent heat of deformation increased with the degree of deformation, and for 6% 85% deformation amounted to 1 13 cal/g for Cd, 0 53 for Pb, and 0 77 for Cu. The ratio of the latent heat of deformation to the total energy expended in effecting deformation was ~1 for small deformations and decreased rapidly with increase in the degree of deformation. This indicated that the initial stage of plastic deformation occurs with the formation of imperfections in the crystalline metal lattice, stable at the temperature of deformation, and that the work of deformation is stored in the form of the potential energy of imperfections. At a later stage, macroscopic displacements accompanied by the evolution of heat decrease the ratio of the latent energy to the work of deformation

(807) Kiessling, R

Bonding in Metals

Metals Rev 2 (1957) 77-107

Discussion of physicists' and crystallographers' viewpoint of bonding; Several theories represent bonding in metals as similar to covalent bonds. Need for further research on study of localized covalency of bonding. "Expanded" metallic structures may be means of studying metallic bonding

(808) King, R , Chan, R W , and Chalmers, B

Mechanical Behavior of Crystal Boundaries in Metals

Nature 161 (1948) 682

Results of some preliminary experiments on specimens of Sn subjected to tensile loading so arranged as to provide a component of shear stress acting on the boundary. When such a stress was applied at a temperature a few degrees below the melting point, progressive relative shear displacement of the two crystals took place

(809) Kishkin, S. T

Mechanism of Weakening and Rupture of Crystalline Bodies as a Function of Time at High Temperature (In Russian)

Doklady Akad Nauk S S S R 95 (1953) 789-791

Differences in behavior of various metals and alloys subjected to constant stress at high temperatures are discussed. All cases of breaking can be represented by a similar curve of the strain/time diagrams, but static failure under load at high temperature occurs as a result of the development and propagation of intergranular cracks, in contrast with brittle failure at room temperature and fatigue failure at all temperatures where the cracks appear inside the grains. The real difference between these types of failure lies in the fact that in the first case the cracks appear after only 10-20% and in the second case after 80-85% of the total time required for fracture. In this connection the problem of increasing the strength of the grain boundaries of high-temperature resistant alloys is of great importance

(810) Kistler, W

Investigations Into the Rapid Deformation of Aluminum (In German)

Schweiz Arch angew. Wiss u Tech 12 (1946) 169-176

X-ray examination of Al tubes produced by impact extrusion failed to provide evidence that the type of deformation taking place as the result of a sudden blow is in any way different in kind from that obtained in slow methods of working. The deformation is by slip along the same planes and in the same directions in both cases. A large part of the paper is devoted to a mathematical consideration of the process of deformation in impact extrusion, based mainly on Kochendörfer's theories of plasticity. This showed that any difference in the plastic behavior of Al in slow and in rapid deformation can be adequately explained by the temperature increase which occurs in the latter case

(811) Klinkenberg, W , Lücke, K , and Masing, G

Acceleration of the Plastic Flow of Metals in Paraffin by Polar Additives (In German)

Z. Metallk 44 (1953) 362-369

A study of the effect of polar additives on the creep of various single- and polycrystalline metal specimens in paraffin. The metals studied were Zn, Cd, Sn, and Cu; the nonpolar solution was purified paraffin; the polar additions = surface-active media = were: valeric acid, (ii) acetyl alcohol, and (iii) oleic acid. All specimens exhibited the Rehbinder effect, i e , an increase in the rate of flow in the presence of polar addition. The results are discussed, and are considered to support the interpretation of Pfützenreuter and Masing [ibid , 42 (1951) 361] based on electrochemical polarization and consequent reduction of the surface tension between the metal surface and its surroundings rather than any theory that the surface-active substances disintegrate an oxide film on the surface of the metal, thereby removing its strengthening effect

(812) Klyachko, Yu. A

Crystallite Theory of Strength of Metals (In Russian)

Zhur Priklad Khim 23 (1950) 448

Claims that the ideas put forward by Wood and Rachinger [J Inst Metals 75 (1948-1949) 571] were contained in the theory first published by him in 1936-1936 [Kolloid-Beih 44 (1936) 387] and later developed in a series of papers [Zhur Priklad Khim. 22 (1949) 455]

(813) Kochanova, A , and Yampol'skii, B Ya

Influence of Oxide Coating on Deformation of Aluminum in Inactive and Active Mediums (In Russian)

Doklady Akad Nauk S S S R 94 (1953) 119-122

Tests were made on polycrystalline pure Al wire

(814) Kochendörfer, A

Dynamics of Plastic Deformation (In German)

Krist 97 (1937) 263-299

An examination is made of the behavior of single crystals of naphthalene subjected to various stresses. The crystals are cylindrical and the method of preparing them is described. The results obtained hold qualitatively for all plastic materials

(815) Kochendörfer, A

Theory of Crystal Plasticity (In German)

Z Physik 108 (1938) 244-264

A theory of plasticity is outlined, which is based on conceptions previously put forward by the author and by Taylor, Orowan, and W G and J M Burgers. The results obtained experimentally for the variation of strength with temperature and with velocity of slip agree well with those predicted by the theory

(816) Kochendörfer, A

Atomistic Bases of Crystal Plasticity (In German)

Z Metallk 30 (1938) 174

Experiments on the plastic deformation of naphthalene crystals, in which the creep rate at strain, ε, after preliminary rapid straining, is much less than the rate at ε attained by slow straining along

(817) Kochendörfer, A

Plastic Properties of Crystals and Metallic Materials (In German)

Julius Springer, Berlin (1941) 312 pp

Treats uniaxial homogeneous and heterogeneous deformation of single- and polycrystals, as well as the case of alternating stress. The theory of homogeneous deformation, applied to single crystals, deals with temperature and strain-rate effects on critical shear stress; the origin of strengthening, etc., from atomic, or dislocation, standpoint. For polycrystals, the true creep limit and the practical creep strength are discussed from a theoretical point of view.

(818) Kochendörfer, A

The Relationship Between Strengthening and Lattice Distortion (In German)

Naturwiss 29 (1941) 456

It has been assumed that lattice distortions of metals, as evidenced by asterism, are the result of slip and cause strengthening of the metal (Burger, et al). With naphthalene crystals it was shown that no asterism appears after slip caused only by forces parallel to the slip face. Asterism is caused only by forces parallel to the slip face. Asterism is caused by other incidental forces such as those that give nonhomogeneous distortion. However, even with simple slip strengthening is effected

(819) Kochendörfer, A

Calculation of the Tensile Strength of Metals and Its Dependence on the Rate of Loading and Temperature (In German)

Metallforschung 2 (1947) 173-186

Using as a basis the ideal stress-strain curve for a single crystal of an fcc metal, equations are derived which enable the stress-strain relationships and tensile strength of similar polycrystalline metals to be ascertained. Formulas are also developed which enable the effects of rate of loading and temperature to be ascertained. There is close agreement between the theoretical and experimental results obtained with Al and Cu, for which adequate single-crystal and polycrystalline data are available. It is shown how, with the exception of metals having a hexagonal crystal structure, the results can be applied to other metals for which no single-crystal data are available

(820) Kochendörfer, A

On the Size of Crystallites and the Distances Between Glide Planes in Plastically Deformed Crystals (In German)

Z Metallk 39 (1948) 359-360

From a review of the literature it is concluded that in plastically deformed crystals electron-microscope determinations of the distances between glide planes given, within the limits of experimental error, values corresponding to those obtained for the diameter of crystallites or mosaic structures as determined by X-ray diffraction techniques

(821) Kochendörfer, A

Concerning Particle Sizes and Slip-Plane Interval in Plastically Deformed Crystals (In German)

Z Metallk. 39 (1948) 359-360

Points out that electron optically measured slip-plane intervals agree with particle sizes determined by X-rays, agreeing with the assumption that the lattice distortions in the slip planes interrupt the X-ray optical coherence. The light microscope reveals the slip lines only as individual lines at an interval of 1μ.

(822) Kochendörfer, A

Theory of Glide-Hardening (With a Description of a Hardening Model) (In German)

Z. Physik 126 (1949) 548-568

A theory of work hardening is developed in terms of the assumption that new dislocations can be formed by thermal agitation. The formation of a dislocation is accompanied by a distortion of the lattice in the immediate neighborhood of the dislocation The interaction between this distortion and bound dislocations already present in the lattice is responsible for the hardening, since the interaction raises the height and steepness of the energy barrier for a new dislocation. A mechanical model is described which illustrates this process The theory is compared with that of Mott and Nabarro

(823) Kochendörfer, A

Plastic Deformation and Recrystallization *

Chapter in The American Flat Review of German Science, General Metallurgy, 31 (1950) 166-194

* A review of recent German researches on plastic deformation, recrystallization, and related topics Contributions to the study of homogeneous and inhomogeneous deformation of single crystals are commented on, and brief discussions of the deformation of polycrystalline aggregates and the nature of the cold-worked state are included Recent experiments on creep and fatigue, mainly from the technological point of view, are summarized. The nature and effects of recrystallization are discussed, and mention made of recent results on several alloy systems.

(824) Kochendörfer, A

Creep Limit and Its Relationship to Other Mechanical Properties From the Point of View of Physics

Arch Eisenhüttenw 23 (1952) 183-191

The plastic behavior of single crystals is discussed, as are slip, rate of work hardening, and the significance of glide Proposes application of the same laws to polycrystals Possibility of influencing the creep curve, and thus the creep resistance

(825) Kochendörfer, A.

The Slip Process and Work Hardening of Metallic Substances (In German)

Z. Ver deut Ingr 94 (1952) 267-273

Literature review. Discusses the slip process in both single and polycrystals. Application of the results to technical problems

(826) Kochendörfer, A

The Quantitative Explanation of Crystal Structures in Terms of Dislocations (In German)

Z. Elektrochem. 56 (1952) 283-294

Edge and screw dislocations in slip planes and latent dislocations are explained and used to account quantitatively for crystal defects. Thus, mosaic structures and grain boundaries are discussed in terms of regular dislocations or in terms of definite collections of defects, while latent and mobile dislocations are considered as sources of crystal defects of high concentration, together with other phenomena requiring such high concentration of defects.

(827) Kochendörfer, A

On the Theory of the Fracture Process (In German)

Naturwiss 40 (1953) 432-433

A vacancy-dislocation mechanism is proposed whereby a stable crack of atomic dimensions is formed and grows to microscopic dimensions Thereupon the fracture process can proceed spontaneously, as described by Griffith

(828) Kochendörfer, A

Relation Between the Lattice-Vacancy Energy, the Surface-Energy Constants, and the Elastic Constants of Crystals (In German)

Naturwiss 41 (1954) 36

The energies of lattice vacancies determined for a number of fcc metals by means of Peierls' relationship have been shown to be in close agreement with those determined on the basis of quantum mechanics. Consideration of relationships between the elastic constants, the activation energy for self-diffusion, and the surface-energy constants, has shown that these functions can be determined one from the other providing certain apparent crystal constants are known

(829) Kochendörfer, A

A Dislocation Mechanism for the Initiation and Propagation of Brittle and Deformation Fracture I Stability Limits Between Dislocation Arrays and Vacancies II Effect of Temperature, Strain Rate, and Stress Distribution on Crack Formation and Fracture (In German)

Arch Eisenhüttenw 25 (1954) 351-372

I The stress fields around single dislocations and the associated elastic and potential energies are calculated, the calculation is extended to dislocation arrays, and it is shown that certain aggregates of dislocations are unstable and lead to the formation of groups of vacancies in the lattice Equilibrium between the two states is reached when the energy of the lattice aggregate equals the surface energy of the vacancy group, i e , the elastic energy liberated by the disappearance of the dislocation aggregate equals the energy required for the creation of the new surface An increase in the number of dislocations in the aggregate leads to a very rapid increase in the length of the stable pore The relations between the elastic properties, surface energies, and vacancy energies of various types of lattice are discussed The discontinuities formed in this way can be regarded as incipient cracks, the propagation of which, by the further accumulation of dislocations, will lead to fracture. II The repulsion between dislocations is so high that an aggregate can form only if the moving dislocations have a high kinetic energy; calculations show that the velocity required is 90% of the speed of sound. Once the stable vacancy group or incipient crack is formed, the elastic stress field is relaxed, and dislocations are no longer repelled; their further accumulation leads to the growth of the crack until it is large enough to propagate under stress alone (Griffith crack) If conditions are not favorable to the formation of suitable dislocation aggregates, slip occurs by the movement of dislocations, vacancies are formed in the wake of the moving dislocations as shown by Seitz, and these condense or are precipitated in the form of small pores which link up into chains of the same length as the dislocations and wide enough to form a stress-free incipient crack which propagates in the same way as in the case of brittle fracture.

(830) Kochendörfer, A

A theory of Brittle and Ductile Fracture With Application to Creep Fracture, Based on the Dynamic Behavior of Dislocations and Condensation of Vacancies (In German)

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 263-280

The static and dynamic properties of dislocations are used in an analysis of the processes leading to brittle or ductile fracture. By suitable arrangement of dislocations, the lattice may be broken up if its energy is greater than the surface energy of the "holes" produced, and a crack is formed, which can grow to microscopic dimensions to initiate fracture according to the Griffith mechanism It is assumed that at normal stresses the motion of dislocations is undamped and the dislocations are accelerated by external shear stresses to about 90% of the velocity of sound If the acceleration is not obtained, plastic flow followed by ductile fracture occurs In this case a crack of atomic dimensions is formed by condensation of vacancies produced by dislocations and grows by addition of dislocations until it reaches the Griffith size An equation is derived for the stability limit between dislocation arrangements and holes which contain a constant having the same values for Cu, Ag, and Au The theory is applied to the conditions for tertiary creep and creep fracture.

(831) Kochendörfer, A , and Seeger, A

The Theory of Displacements in One-Dimensional Atomic Lattices I Displacements in a Periodic Potential (In German)

Z Physik 127 (1950) 533-550

A model is suggested for studying the plastic deformation of a crystal Atoms of a one-dimensional lattice are subject to a periodic potential with the period of the lattice, a, and may be displaced through distances α, (α ± a) The motion of an initially specified displacement through the lattice is calculated under the assumption that the variation of the displacement along the lattice is not great The equations of motion are nonlinear, and are solved in terms of elliptic integrals

(832) Kocks, U F

Polyslip in Polycrystals

Acta Met 6 (1958) 85-94

The idea that polyslip, i.e , simultaneous glide of dislocations in many slip systems of each grain, is responsible for the plastic deformation of cubic polycrystals at low enough temperature, is discussed in the light of new evidence Taylor's formula for the calculation of the polycrystalline stress-strain curve from the shear hardening curve of a free single crystal is derived in a general way, partly following Bishop and Hill, but with emphasis on the physical implications of the assumptions involved Homogeneous deformation need not be assumed, and none of the necessary hypotheses seems physically unreasonable A new experimental check on the Taylor formula is presented for high purity Al A proposal to compare the polycrystalline behavior with that of symmetrically oriented single crystals which show poly slip, in particular with the <111> and <100 tensile curves, yields a good agreement between theory and experiment. The different stages of deformation of an fcc single crystal, except easy-glide, can be retraced in the polycrystal thus permitting the ideas about the mechanisms of single-crystal plasticity in the various stages to be applied to the polycrystal

(833) Koda, S , and Takeyama, T

Interaction Between Slip Bands and Particles of Precipitate in an Aluminum Alloy (In English)

J Phys Soc Japan 10 (1955) 822-823

The effect of particles of precipitate upon slip bands in a polycrystalline Al-4% Cu alloy sheet was studied by electron diffraction The alloy was age hardened at 250 C for 2.5 hours after quenching from 530 C, extended 1%, and a replica was prepared by the anodic-oxidation process. It is shown that the slip bands have a fine structure of the Heidenreich-Shockley type; each slip band is short, being broken into about 2-3μ lengths, the plate-like particles of precipitate are bent by slip bands. Data relating to the total slip distance and slip interval of a band, and the number of elementary slip lines are calculated from the results and are tabulated.

(834) Koehler, J. S

On the Dislocation Theory of Plastic Deformation

Phys Rev 60 (1941) 397-410

The dislocation theory of plastic deformation is discussed critically and is further developed assuming a type of dislocation different from that of Taylor In general, it requires about twice as much energy to produce a pair of dislocations inside the metal as to produce a dislocation near the surface. This, however, does not necessarily mean that most of the dislocations are formed at the surface, since there is a much larger volume inside The energy stored during work hardening is calculated, and a good agreement with fact is obtained. The process of annealing is also considered

(835) Koehler, J S.

The Energy Stored During Work Hardening

Phys Rev 59 (1941) 943-A

A calculation of the energy which is stored in a solid when it undergoes work hardening has been made using the theory of dislocations Following Taylor, a work-hardened material is assumed to contain many dislocations arranged in a regular two-dimensional lattice. The energy required to produce a dislocation pair in such a lattice is the energy required to form an isolated dislocation pair minus the binding energy of a dislocation pair in the lattice The energy required to produce an isolated dislocation pair is found to be about 3.16 ev per atomic plane in Cu. Taking the density of dislocations to be 10^{12} per cm^3, the binding energy of a dislocation in a lattice is found to be 0 43 ev per atomic plane in Cu The energy stored in the process of work hardening in Cu thus becomes 0 42 cal/g. The experimental value is 0 5 cal/g.

(836) Koehler, J S.

On Dislocation Theory and the Physical Changes Produced by Plastic Deformation

Am J Phys. 10 (1942) 275-285

A general account is given of the application of the theory of dislocations to explain work hardening and changes in the internal energy, magnetic properties, density, elasticity, and electrical resistivity of a metal when it is severely deformed at temperatures low enough to prevent recrystallization.

(837) Koehler, J. S.

A Calculation of the Changes in the Conductivity of Metals Produced by Cold Work

Phys Rev 75 ser. 2 (1949) 106-117

The increase in the electrical resistance of severely cold-worked metals was calculated by assuming that the important change which occurs during cold work is the introduction of large number of Taylor dislocations The calculated increase for polycrystalline Cu was in good agreement with the measured value For single crystals, there is a decided dependence of the dislocation resistance on the orientation of the electric field relative to the crystallographic axes

(838) Koehler, J S

The Production of Large Tensile Stresses by Dislocations

Phys Rev 85 ser 2 (1952) 480-481

Presents a mathematical analysis to show that an edge-type dislocation has large tensile stresses associated with it Maximum tensile stress is calculated to be $n\sigma$ where n is number of piled-up dislocations and σ is the applied stress The fact that large tensile stresses arise in a stressed material containing locked dislocations can be of importance for ductile fracture and fatigue

(839) Koehler, J S.

The Nature of Work-Hardening

Phys. Rev 86 ser 2 (1952) 52-59

To explain the initial stages in the work hardening of metal crystals, the present theory adopts the suggestion that sources of easy glide of the Frank-Read type can produce only a finite number of dislocation loops A reasonable assumption about the distribution of Frank-Read sources and the way in which they will be used up, to give "source-hardening", leads to agreement of the predicted low-temperature low-strain stress/strain curve with experiment. At higher temperatures, the effects of thermal fluctuations are introduced into the theory, and also the observation that sources produce more glide before exhaustion at high temperature than at low temperature. The theory correctly predicts the importance of the past history of the specimen to its glide properties Under higher stresses it is postulated that both source hardnening and hardening by the interaction of crossed dislocations with one another occur Suggestions are put forward about important experimental work needed Speculations are made about the reason for sources giving more glide at high temperatures and how the interlocking of Frank-Read sources can occur.

(840) Koehler, J S.

Theory of Initial Stress-Strain Curves in Face-Centered Metals

Acta Met 1 (1953) 377

Recent data obtained by Blewitt on Cu and Brown on Al are examined in terms of Koehler's theory of source hardening. Brown's results, which show that the number of lamellae in a slip band of Al deformed at 450 C depends on the rate of strain, are consistent with the theory The theory implies that the initial slope of the stress/strain curve is also dependent on strain rate.

(841) Koehler, J S.

Work Hardening in Face-Centered Substitutional Alloys

Acta Met 1 (1953) 508-512

Previous experimental work on the mechanical properties of single crystals of fcc alloys is reviewed Koehler interprets the data to suggest that in alloys source hardening and impurity hardening are important, but (unlike pure metals) interaction hardening is not During deformation, some process, presumably associated with the formation of vacancies and interstitial atoms, reduces impurity stresses in the neighborhood of the active slip bands and facilitates further deformation of this material For this reason, glide continues on the original system of slip planes even when the orientation has changes so as to give a greater resolved shear stress on a second system of slip planes. The distribution of the free lengths of Frank-Read sources seems to be nearly independent of composition and to vary little from one metal to another

(842) Koehler, J S., and Blewitt, T. H

Evidence for a Change in the Nature of Work Hardening at Small Strains

Phys Rev 75 ser. 2 (1949) 1952-1953

Discusses Taylor's theory of work hardening and raises certain questions.

1 Does stress-strain curve remain relatively flat as long as the slip bands consist of a single step?

2 Does slip continue to occur at a slip band throughout entire course of deformation?

3. Do new slip bands appear throughout the course of deformation?

4 At large strains is all of the strain accounted for by the relative shearing displacements of neighboring laminae or should one suppose that a portion of the strain is associated with a Taylor dislocation lattice?

5 For deformations at low temperatures does the maximum shearing displacement at a step depend on the size of the specimen?

(843) Koehler, J. S., Henderson, J W , and Bredt, J H

Thermal Annealing of Imperfections in the Noble Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 587-602

The annealing of irradiated, quenched, cold-worked, and evaporated noble metals is examined. Six stages of annealing are described; the associated activation energies range from 0 1 to about 2.1 ev At attempt is made to assign each stage of annealing to a particular atomic process The magnitude of the resistance introduced by dislocations is considered

(844) Koehler, J S., and Seitz, F.

Proposed Experiments for Further Study of the Mechanism of Plastic Deformation

J. Applied Mechanics 14 (1947) A-217 - A-221

Discuss theoretical considerations and propose certain new experiments to be carried out, using single crystals, in an attempt to simplify interpretation. It is suggested that the internal friction, the electrical resistance, and the creep rate be all measured on the same spectroscopically pure metal single crystal, these three measurements being made at various temperatures and being successively caried out on crystals of various crystallographic orientations. It is also suggested that stress-strain curves be obtained on fine single-crystal wires, and that the electrical resistance and internal friction of an ordered alloy be measured while the single crystal specimen is subjected to a very small plastic deformation

(845) Koehler, J S., and Seitz, F

The Nature of Dislocations in Ideal Single Crystals

Article from Dislocations in Metals, Edited by M Cohen, Am Inst Mining Met Engrs, New York (1954) 1-36

Article deals with basic ideas of dislocations A physical description of dislocations is given with emphasis on geometry, type, movement, and generation Also included is a discussion of energies and interactions of dislocations

(846) Kolesnikov, G. N., Pavlov, V A., Yakovleva, E S., and Yakutovich, M V.

Plastic Deformation and Fracture of Polycrystalline Metals Under Tensile Stress II. Form of Stress Diagrams of Pure Metals (In Russian)

Zhur. Tekh. Fiz. 19 (1949) 62-75

Eight pure metals (beta-Sn, Cd, Zn, Mg, Pb, Al, Cu, and alpha-Fe) were tested at different temperatures below the melting point or temperature of phase transformation. Stress diagrams of pure metals may be divided into two basic types: "high temperature" and "low temperature"

(847) Kolesnikov, G N, Yakovleva, E S., and Yakutovich, M V.

Mechanical Properties of a Silver-Copper Alloy Under Tensile Stress (In Russian)

Zhur. Tekh Fiz. 19 (1949) 347-354

Tensile-strength diagrams from 20 to 100 C were obtained in the hardened and aged conditions and the existence of "low-temperature" and high-temperature" types was shown Tensile-strength diagrams for the hardened condition have "saw-tooth" shapes at temperatures of 150 C and above. The dependence of resistance to deformation, yield strength, and elongation on temperature are indicated.

(848) Konobeevskii, S. T

Physical Bases of the Strength of Materials (In Russian)

Vestnik Akad. Nauk S S.S.R. 25 (1955) 15-22

Theoretical background and present concepts; dislocations in single metallic crystals; elastic and plastic deformation of different orders; diffusion mechanism of plasticity.

(849) Kontorova, T A

The Conditions of Intercrystalline Fracture (In Russian)

Zhur Tekh. Fiz. 10 (1940) 1101-1106

On the basis of the fracture of polycrystalline substances, two critical temperatures are considered: (1) T_{eq}, "equicohesive temperature", determining the fracture of the intercrystalline layer, and (2) T_c, "critical temperature of brittleness", characterizing the transformation of crystal grains from the brittle to the plastic state The character of fracture is determined mainly by the speed of deformation and by the temperature. For given speeds of deformation there are: (1) at $T < T_c$ brittle fracture along the crystal grain, (2) at $T_c < T < T_{eq}$ fracture along grains with prior plastic deformation, and (3) at $T > T_{eq}$, intercrystalline fracture. For a given temperature there are: (1) at high speed of deformation brittle fracture in the region of crystal grains; (2) at certain mean speeds plastic flow with subsequent fracture along the grains; and (3) at slow deformation fracture in the intercrystalline layer

(850) Kontorova, T. A.

On the Relation of the Strength of Materials to the Stressing Time (In English)

Compt. rend. acad sci U.R.S.S. 54 (1946) 23-26

The problem of deformation and failure of materials subjected to tensile stress is treated mathematically, and a function is developed relating the value of the strength of material to the time of duration of stress

(851) Korber, F., and Eichinger, A

The Principles of Plastic Deformation (In German)

Stahl u Eisen 60 (1940) 829-832, 851-862, 882-887

The mechanics of deformation are thoroughly investigated mathematically. As a starting point, Newton's expression for the internal friction of viscous substances is taken, then the effects of straining single crystals, and homo- and heterogeneous crystal aggregates are considered Expressions are obtained for the effort necessary to deform small cubical elements of solid bodies when strained in various ways, e g, tension, compression, and shear, up to and past the elastic limit. The various deformations are shown pictorially, and use is made of Mohr's diagrams. Viscous substances are shown to correspond to plastically deformed solids as regards force necessary for deformation The expressions obtained in the theoretical analysis are considered in connection with practical applications

(852) Kornilov, I I

Classification of the Solubility of Elements in Iron (In Russian)

Izvest.Akad Nauk S.S S R, Otdel Khim Nauk, no. 2 (1945) 104-112

Reviews previous work on the relationship of the above solubilities to position in the periodic table, atomic sizes and structure, etc This is followed by a thorough discussion of the solubility of the various elements classified according to groups and subgroups in the periodic table A definite relationship is shown between solubility in iron and atomic diameter, which permits prediction of approximate values for individual elements

(853) Kornilov, I I

Solid Solutions (In Russian)

Izvest Akad Nauk S.S S R, Otdel Khim Nauk 2 (1945) 104

Solubilities of elements in Fe in the solid state from the point of view of Hume-Rothery's size-factor theory. The size factor alone is adequate to account for the experimental results except in the case of Ce and certain elements of the B subgroups of the fourth and fifth periods of the periodic system.

(854) Kornilov, I I

Theory of the High-Temperature Strength of Metallic Solid Solutions (In Russian)

Doklady Akad. Nauk S.S.S.R. 67 (1949) 1037-1040

A suggested measure of high-temperature strength is the time required for a specimen to creep or bend a predetermined amount in a centrifugal testing machine By this means data were obtained for alloys of several binary systems The high-temperature strength of a solid solution is higher than that of a pure metal and increases with increasing solute content. The high-temperature strength decreases when a second phase is produced by further addition of the solute The concept "chemical hardening" by a solute atom is suggested in analogy with work hardening

(855) Kornilov, I I

Continuous Solid Solutions of Metals of the Transition Group of Mendeleev's Periodic System of the Elements

Doklady Akad Nauk S.S.S.R 73 (1950) 495-497

Discusses possibility of predicting solid solubility ranges of binary combinations of various elements of the eighth group of the periodic table, on basis of known values for the binary solutions with Fe and values for atomic diameters of different elements

(856) Kornilov, I. I

Creep of Solid Solutions and Compounds in Metallic Systems

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 215-219

Short survey of centrifugal creep test results on solid solutions and compounds in metallic systems and conclusions drawn as a result of this work

(857) Kornilov, I I.

Hardening of Solid Solutions of Nickel at High Temperatures (In Russian)

Izvest Akad Nauk S.S S R 1 (1956) 119-125

Relation to yield strength of Ni and its alloys and the hardening multiple to temperature Effect of chemical composition and number of components Hardening in relation to distortion of crystal lattice of solvent metal Hardened state preservation at high temperatures is dependent on the degree of of the solid solution

(858) Kornilov, I I

The Strengthening of Solid Solutions of Nickel at High Temperatures (In Russian)

Izvest Akad Nauk S S.S R, Otdel. Tekh Nauk 1 (1956) 119-125

Shows the exceptionally strong influence of chemical composition of solid solutions on the strength of the solvent Illustrates important role of chemical bonds between different atoms in a solid solution of complicated structure in maintaining the strengthened condition at high temperatures

(859) Kornilov, I I, and Kosmodem'yansky V V

Relationships Between Composition Temperature, and High-Temperature Strength. II Alloys of the Ternary System Nickel Chromium-Titanium (In Russian)

Izvest Akad Nauk S S S R Otdel Tekh Nauk 2 (1955) 90-97

Results on alloys of Ni containing 20% Cr and 0-10 wt % Ti are summed up as follows (1) All isotherms of composition/yield point between 500 and 1250 C show a maximum (2) Composition required to give maximum high temperature strength varies with the temperature of test This is related to the mechanism of hardening by foreign atoms in solution and to the degree of supersaturation (3) At sufficiently low temperatures (500 to 700 C), the strength of alloys containing finely divided precipitates exceeds the strength of homogeneous solid solutions Highest strength occurs in supersaturated alloys with compositions close to the solubility limit (4) At temperatures above 1100 C, alloys of maximum strength have compositions corresponding to unsaturated solid solutions Alloys with homogeneous solid solutions are stronger than alloys with compositions near to the solubility limit and with consequently greater heterogeneity (5) At 1200 to 1250 C, changes in the composition corresponding to maximum strength are very rapid (6) The results give a sensitive test of Kornilov's theory of high-temperature strength of solid solutions [Doklady Akad Nauk S S S R 67 (1949) 1037]

(860) Korotkov V I

Effect of Plastic Deformation on the Modulus of Elasticity of Low-Carbon Steel (In Russian)

Fiz Metal i Metalloved Akad Nauk S S S R Ural' Filial 2 no. 1 (1956) 160-167

Effect of cold plastic deformation and of heat treatment on Young's modulus and shear modulus of plastically deformed steel

(861) Kossel W

The Strength of Metals as an Atomic-Physical Phenomenon (In German)

Z Ver deut Ingr 97 (1955) 516-518

Effect of crystal growth and lattice structure on the mechanical properties of metals

(862) Köster, W

Analysis of the Modulus of Elasticity of Metals and Alloys (In German)

Z Metallk 39 (1948) 145-158

Relation of the modulus of elasticity to the atomic number, the shear and compression moduli, and to the atomic volume and melting temperature The temperature dependence of the moduli is examined, as well as the influence of polymorphic transformations, impurities, ferromagnetic state, and ordered atomic arrangements The variation of the moduli is shown for solid solutions and for intermetallic phases

(863) Köster, W

On the Influence of Elements on the Polymorphic Transformations of Cobalt (In German)

Z Metallk 43 (1952) 297-303

Classifies the influence of alloy additions on the γ-ε transformation of cobalt There is a periodic change of the type of effect with the atomic number of the element A comparison is made with the systematization of iron and its alloys

(864) Köster, W, and Rauscher, W

Relations Between the Modulus of Elasticity of Binary Alloys and Their Structure (In German)

Z. Metallk. 39 (1948) 111-120 (Translation by NACA TN 1321)

A comprehensive survey of the elastic modulus of binary alloys as a function of the concentration is presented Alloys that form continuous solid solutions, limited solid solutions eutectic alloys, and alloys with intermediate phases are investigated Systems having the most important structures have been examined to obtain criteria for the relation between lattice structure, type of binding, and elastic behavior

(865) Kostron, H.

The Mathematics of the Tensile Test

Arch. Eisenhüttenw 22 (1951) 317-324

The true stress/strain curve for polycrystal metals is taken to follow the equation $\sigma = a\ \delta^n$, where σ is the stress, δ the elongation, a is a measure of the resistance to deformation, while n indicates the work-hardening capacity With the aid of this equation the values of any agreed proof stress, of the ultimate tensile strength, and of the true stress under maximum loading, can be stated in terms of a and n the ratios of various proof stresses and if present, of the yield point to the ultimate tensile strength, as well as the strain corresponding to the ultimate tensile strength, i e, the strain at which work hardening and reduction of cross section are in balance, can be expressed in terms of n alone Thus, the mutual interrelations between these various functions can be expressed in terms which have general validity

(866) Koyfman M I

New Conception of the Term "Hardness" (In English)

Compt rend acad sci U R S S 30 (1941) 830-831

The suggestion is made that "hardness" be redefined as resistance of the outer layers of a body to local injury (breakage or deformation) under the influence of mechanical strains concentrated within a limited area of the body It differs from "strength" in that the latter is the resistance of the whole body to complete destruction (shearing, breakage, crushing)

(867) Kramer I R and Maddin, R

Delay Time for the Initiation of Slip in Metal Single Crystals

Trans AIME 194 (1952) 197-203

Single crystals of alpha-brass, Al and beta-brass were studied A delay time for slip was found in beta-brass when the specimens were tested below room temperature however one was not found for alpha-brass or Al A general theory of the existence of the brittle transition temperature is proposed

(868) Krasnikov, A I, Sotnikova, I I and Orlov, I G

Dislocation of the Deep Energy Layers of Iron Atoms During Cold Deformation of the Metal (In Russian)

Doklady Akad Nauk S S S R 102 (1955) 943-945

Loads of 45,000 and 80,000 kg/cm^2 were used, effect of alloying elements relation between levels and valence duplet distances calculated

(869) Krisch, A, and Wepner, W

Conversion of Rupture-Times to Other Temperatures (In German)

Arch Eisenhüttenw 28 (1956) 339-344

Creep curves were obtained experimentally from 19 ferritic and 19 austenitic steels for at least two temperatures Experimental rupture times were compared with results obtained from the Larson-Miller procedure The correlation was unsatisfactory and no master curves could be established There was ±10% accuracy of estimates for 10,000 hr obtained from creep curves of 100 hr and 1000 hr at a 50 C higher temperature However, errors up to 40% occurred in some materials

(870) Krishnan, A A, and Greenwood, J

Intercrystalline Cracking of Metals (Two letters)

J Iron Steel Inst 176 (1954) 267-269

Krishnan suggests that the phenomena of crack formation and propagation may be explained by combining Greenwood's hypothesis [ibid, 171 (1952) 380] that cracks are formed by the aggregation of vacant lattice sites, with the ideas of Smith concerning interfacial tensions in two-phase alloys Greenwood is in general agreement but thinks that the application of the Smith concept of the dihedral angle to a cluster of lattice sites appears unnecessary. Although the dihedral-angle concept is not considered applicable to the formation of intercrystalline cracks from vacancy cavities there is strong evidence to suggest its importance when failure occurs under stress in contact with liquid metals

(871) Kritskaya V K, Kurdyumov, G V, and Tikhonov, L. V

The Effects of Working on the Bond Strength of Crystals of α-Solid Solution of Iron-Nickel Alloys (In Russian)

Doklady Akad Nauk S S S R 102 (1955) 271-274

A 1% Ni alloy was annealed and examined by X-ray techniques Forging, deformation, and quenching after annealing all changed bond strength

(872) Kronberg, M I

Plastic Deformation of Single Crystals of Sapphire Basal Slip and Twinning

Acta Met 5 (1957) 507-524

A model is presented based on a framework of oxide ions in hexagonal closest packing with Al ions in octahedral interstices Dislocation concepts are used for interpreting the significance of the crystallographic elements of slip and comparisons are made with the structurally related hexagonal metals The Burgers vector of a total dislocation is discussed in terms of the structure of the crystal, and reasons are given for questioning whether slip occurs by a total dislocation mechanism The concept of partial slips involving synchronized shears of both kinds of ions is used extensively and should be useful in understanding plastic flow in ionic crystals in general

(873) Kroner E

Fundamental Relationship Between Dislocation Density and Stress Functions (In German)

Z Physik 142 (1955) 463-475

Mathematical analysis of fundamental equations of nonsymmetrical dislocations In an elastic body containing a distribution of dislocations specified by a tensor density α, the stresses are characterized by a symmetrical tensor but the strains, ε contain an antisymmetrical component The compatibility equation of elasticity theory is replaced by a relation between α and the antisymmetric part of ε The formal relations between these quantities and the tensor stress functions are derived.

(874) Kröner, E., and Rieder, G.

Continuum Theory of Dislocations (In German)

Z. Physik 145 (1956) 424-429

A short review of the basic ideas of this new approach to dislocation theory, which was developed independently by Kroner and by Bilby [Report of a Conference on Defects in Crystalline Solids, Phys Soc (London) (1955) 124]. A dislocation distribution can be described macroscopically by means of a second-order tensor in the continuum theory the further step from the discrete to the (imaginary) continuous distribution is taken. It is hoped that this approach will help to bridge the gap between macroscopic and atomistic plasticity theory

(875) Krupkowski, A., and Balicki, M.

The Physical and Mechanical Properties of Cold-Worked Copper

Ann. acad sci tech. Varsovie 3 (1936) 90-122

Experiments on Cu wires of uniform diameter subjected to varied amounts of cold working. It was shown that there is a close analogy between the variation of the physical and the mechanical properties of copper with the degree of cold working. Recrystallization temperature and the thermoelectric power were determined as a function of the degree of cold working. From a comparison between the variations with the degree of cold working, of thermoelectric power and the constants of elasticity, it was concluded that the thermoelectric power is a measure of the internal stress in the rolled metal. It is shown that the phenomena of recrystallization may be explained by a theory of activation

(876) Kubaschewski, O

The Change of Entropy, Volume, and Binding State of the Elements on Melting

Trans. Faraday Soc 45 (1949) 931-940

Molar heat capacity at the melting point (C_p), absolute temperature of fusion (T_m), cubic coefficient of expansion at the melting point (α) involves a measure of the bonding mechanism $\left(\frac{C_p}{T_m \alpha}\right)$ and is nearly constant for true metals and meta-metals, as is $\left(\frac{\Delta S_m}{\Delta V_m}\right)$

(877) Kuhlmann, D.

On the Theory of Plastic Deformation

Proc Phys Soc (London) 64A (1951) 140-155

A model for plastic deformation in soft metals is based on the assumption that in real crystals there is always a number of regions present which, by an unknown process, act as sources of dislocations. It is also assumed that in soft metals dislocations are very mobile except in a limited number of regions which act as obstacles. The model is applied to explain a number of facts connected with plastic deformation

(878) Kuhlmann, D., and Masing, G.

Investigations on the Plastic Deformation of Copper Wires (In German)

Z. Metallk. 39 (1948) 361-375

A study was made of the deformation of loaded spirals of annealed and of hard-drawn pure Cu wires, under shear stresses up to 3.15 kg/mm^2 between 15 and 41 C. The results are described in detail, and an equation is derived which shows the relationship between the deformation, the load, and the temperature

(879) Kuhlmann, D., Masing, G., and Raffelsieper, J

The Theory of Recovery (In German)

Z Metallk 40 (1949) 241-246

Plastic deformation is considered as movement of dislocations, only a few of which are dissipated during the course of the deformation, the remainder accumulating on the glide planes. When the stress is removed, recovery from strain occurs as a result of the dissipation of the dislocations. It is shown that the relationship between the recovery (x), temperature, and time (t) can be expressed by an equation of the type $x = B - A$ $(t + t_0)$, where A and B are constants which are proportional to the absolute temperature. Experimental results on the recovery of Al single crystals are considered to be in satisfactory agreement with those derived from the theory

(880) Kuhlmann-Wilsdorf, D.

Elementary Structure and Slip Band Formation in Aluminum

Phil. Mag. 43 ser 7 (1952) 632-644

From electron micrographs of deformed high-purity Al, numerical estimates for spacing, length, and amount of glide of the individual elementary lines were obtained. Experimental evidence relating to the problem of whether or not slip starts at the crystal surfaces

(881) Kuhlmann-Wilsdorf, D., and Wilsdorf, H.

The Surface Structures of Deformed Aluminum, Copper, Silver, and Alpha-Brass, and Their Theoretical Interpretation

Acta Met 1 (1953) 394-413

The surfaces of deformed Al, Cu, Ag, and alpha-brass are investigated by electron microscopy. The three pure metals examined show similar surface structures after deformation, namely, an elementary structure and slip bands. On deformed alpha-brass, neither an elementary structure nor slip bands are visible, but, instead, single slip lines apparently arranged at random

1. The simultaneous occurrence of slip bands and elementary structure on the three pure metals and the absence of both on alpha-brass strongly supports the idea, put forward in a previous paper, that slip bands develop out of an elementary structure

2. The two types of surface structure indicate two different mechanisms of plastic deformation. These two mechanisms of plastic deformation are discussed, and the conclusions drawn are compared with experimental evidence

(882) Kuhlmann-Wilsdorf, D., and Van der Merwe, J. H

Elementary Structure and Slip Band Formation in Aluminum

Phil Mag 43 (1952) 632-644

From electron micrographs of deformed high-purity Al numerical estimates for the spacing, length, and amount of glide of the individual elementary lines have been obtained. It is found that the latter two quantities are compatible with the conception that each line is formed by dislocations emitted from one freely acting source of dislocations. The existing experimental evidence relating to the problem whether or not slip starts at the crystal surfaces is discussed. The evidence suggests that the sources of dislocation might well lie at the surfaces, and, therefore, it is considered possible that the elementary structure is confined to the surface layer. The observed spacing of the steps, in the elementary structure as well as in the slip bands, is comparable with the theoretical critical distance below which rows of dislocations cannot pass each other. This indicates that there are many more possible sources than become active. A mechanism for the development of slip bands out of the elementary structure is proposed. This mechanism entails the annihilation of all dislocations in the immediate neighborhood of an expanding slip line

(883) Kuleshov, P. I.

Onset of Yield in the Torsion of Metal Crystals (In Russian)

Doklady Akad. Nauk S S S.R. 97 (1954) 1015-1018

The torsion of crystals with fcc, bcc, and hcp lattices is considered. The axial and crystallographic yield points of each slip system are related by derived expressions. Curves showing the dependence of yield point on orientation for torsion of single crystals of the cubic system have been plotted from calculated data and are compared with experimental values for Al-5% Cu alloy obtained by Karnop and Sachs [Z. Physik 53 (1929) 605]. In general, there is agreement

(884) Kunin, N F

The Change of Thermal Electromotive Force of Metals Due to Plastic Deformation (In Russian)

Fiz. Metal. i Metalloved Akad Nauk S.S.S.R., Ural' Filial, 2 (1956) 237-243

Relation between the plastic-deformation characteristics and the induced thermoelectromotive force. Induction of thermoelectromotive force in various kinds of plastic deformation. Induced thermoelectromotive force versus absorbed energy

(885) Kunin, N F, and Melamed, L. Z.

Variations in Thermo-Electromotive Force of Metals in the Copper Subgroup Subjected to Plastic Deformation at Various Temperatures (In Russian)

Fiz. Metal i Metalloved Akad Nauk S S S.R , Ural' Filial, 2 (1956) 423-427

An attempt to verify the applicability of the relationship known between the change in thermoelectromotive force and the relative deformation in Cu to other metals of the same subgroup of the periodic table The force-deformation function proves to be additive

(886) Kunst, E D

Remarks on the Temperature-Dependence of Hardness (In Dutch)

Metalen 9 (1954) 23-24

Shows that within the range from -183 to +500 C the graph of log Brinell hardness as a function of temperature shows a more or less sudden change of direction at about halfway from the absolute melting point This "kink" in the graph may be due to creep, which above a certain temperature ceases to have any influence

(887) Kuntze, W

Conditions for Brittle Failure in Metals and Steel (In German)

Stahlbau-Tech. 21 (1952) 159-164

Suggests that the transition from the elastic to the plastic range requires a certain amount of time (relaxation time), which is characteristic of the metal. If the rate of deformation is greater than the rate of stress relaxation, then the metal is brittle. If the rate of deformation is less than the rate of stress relaxation, the metal is ductile. Brittle failure in steel, cast Fe, and light metals is discussed in terms of this hypothesis

(888) Kurbatov, V

Nature of Crystals I Interatomic Cohesion of Metallic Crystals (In Russian)

Zhur Obshchei Khim 20 (1950) 945-957

On the basis of theoretical considerations, a formula is derived for calculation of energy of interatomic cohesion in metallic crystals. Relation between this energy and hardness, electroconductivity, and position of the particular metal in the periodic system is indicated. Shows that interatomic cohesion is a value characterizing the true mechanical properties of metal

(889) Kurdyumov, G V, Il'ina V A, Kritzkaya V K, and Lysak L I

X-Ray Investigation of the Deformation and Bond Strength in the Crystal Lattice of Metals and Alloys

Izvest Akad Nauk S S S R Ser. Fiz 17 (1953) 297 312

Measurements of X-ray diffraction line widths and intensities yield fundamental data related to the fine structure of metals and alloys These are sizes of coherent scattering domains for X-rays, magnitude of elastic deformation in crystallites amplitudes of atomic thermal vibrations and static disordered displacements of atoms in the lattice Based on these methods are studies of phenomena of hardening and softening of metals and alloys

(890) Kurdyumov, G. V, Kaminskii, E Z, and Rozenberg, V M

Effect of the Internal Structure of Austenite Grains on the Solid-Solution Strength at High Temperature (In Russian)

Doklady Akad. Nauk S S S R 109 (1956) 85-87

Relation between strength, temperature of heat treatment, and stress magnitude of a solid solution of Fe with 29% Ni and Ti

(891) Kurdyumov, G. V, and Travina, N T

X-Ray Investigation of Interatomic Interaction in Solid Solutions Based on Nickel (In Russian)

Doklady Akad Nauk S S.S R 99 (1954) 77-80

The states at which metals and alloys possess a high strength are metastable and can exist for a long time only when the mobility of the atoms is small The latter is determined (in crystalline lattice) by strength of interatomic bands - and increased bonding strength, a decreased mobility of atoms The quantitative evaluation of properties characterizing the interatomic bonds is obtained by studying heat of sublimation, energy of action of self-diffusion, characteristic temperature, elastic moduli, coefficients of expansion, etc Here, bond strength was measured through thermal scattering of X-rays, then calculated characteristic temperature from mean quadratic displacement of atoms from lattice equilibrium positions during thermal variations

(892) Kurnosov, D G., Tronina, N M, and Yakutovich, M V

Distribution of Deformation in Metallic Crystals During Deformation of Slip (In Russian)

Zhur Tekh. Fiz. 18 (1948) 197-206

The distribution of plastic deformation by slip was experimentally determined in Zn crystals by studying the topography of the surface of a microsection of deformed single- and polycrystalline samples For a single crystal specimen, plastic deformation is localized only to an insignificant extent in the slip planes, most of it is distributed through the crystal with low deformations The volume of the crystal is involved in deformation from the beginning, and this accounts for the hardening of all the crystal without assuming the presence of a sharply defined structure irregularity of the formation of separate crystalline layers

(893) Kurtz, A. D., and Kulin, S A.

The Interaction of Impurity Atoms with Dislocations in Germanium

Acta Met 2 (1954) 352-354

Existence of dislocations in Ge gives rise to certain specific distributions of solute atoms Approximate calculation and model is suggested

(894) Kuznetzov, V D

Works on the Physics of Solids in the U S.S R (In English)

J Phys (U.S S R) 5 (1941) 299-317

A general review of recent work carried out in the U S.S R The plasticity and strength of ionic crystals and the influence of twinning is discussed Plastic deformation of polycrystalline metals from the point of view of rate of deformation, the physics of compression, and the interrelation of various forms of deformation in the light of recent work are discussed briefly, and the dependence of the cold brittleness of steel on temperature and impact velocity is dealt with. Recent work on the mechanical properties of single crystals and polycrystalline metals is described, and the importance of twinning again stressed

(895) Lacombe P, Beaujard, L, and Yannaquis, N

'Sub-Boundary' and Boundary Structures in High Purity Aluminium A 'Sub-Boundary Structure B Boundary Structure

Paper from Report of a Conference on Strength of Solids, Phys Soc, London (1948) 91-94

"Macromosaic structure" has much greater dimensions than "micromosaic" and occurs when large single-metal crystals are prepared either by solidification from the melt or by annealing after critical deformation Study shows veining or line structure representing boundaries between blocks of slightly differing orientation The behavior of the grain boundaries of high-purity Al on attack by HCl supports the hypothesis of transition structure

(896) Lacy, C E, and Gensamer, M

The Tensile Properties of Alloyed Ferrites

Trans ASM 32 (1944) 88-110

The results of a systematic study of the effects of alloying elements in solid solution on the strength and rate of strain hardening of ferrites of substantially constant grain size, as revealed by true stress-strain curves The strengthening effect of an alloying element as a function of concentration may be represented by a single coefficient, and the strengthening effects of several elements in solution together are simply additive

(897) Laks, H, Wiseman, C D., Sherby, O. D, and Dorn, J E

Effect of Stress on Creep at High Temperatures

J Appl Mechanics 24 (1957) 207-213

Experimental investigation on pure Al and its dilute alloys revealed that the high-temperature creep rate is related to the stress According to a preliminary dislocation-climb model for high-temperature creep, the activation energy for creep is that for self-diffusion and the effects of stress on the creep rate depend on the number of active Frank-Reed sources, and the rate of climb depends on the structure as determined by the pattern of climbing dislocations. A creep rate equation is developed for constant structure.

(898) Lambot, H J

Sub-Structure Formation in Slightly Bent Aluminum Single Crystals

J Inst Metals 84 (1955-56) 473-474

A high-resolution X-ray method was used in the study of bent single crystals of high-purity Al having the cube orientation. The recovery process observed appears to consist of three stages (1) below 500 C, the polygonization mechanism described by Cahn transforms locally curved regions into new, perfect subgrains; (2) above 500 C, growth of some individual sub-grains is the main phenomenon, (3) within 10-30 C of the melting point, a decrease in the perfection of the remaining sub-grains is detected, which may be correlated with Crussard's "recrystallization in situ"

(899) Landauer, R

A Theory of Conductivity of Cold-Worked Copper

NACA TN 2439 (September, 1951) 23 pp

The increase in the resistivity of Cu under cold working is calculated The increase is assumed to be caused by dislocations surrounded by a long-range electrostatic field that scatters the conduction electrons From the calculated increment in resistance and the known increase of resistivity of heavily cold-worked copper, the number of dislocations was found to be in agreement with the number estimated on the basis of stored-energy measurements

(900) Landon, P R., Lytton, J L., Shepard, L. A, and Dorn, J E.

The Activation Energies for Creep of Polycrystalline Copper and Nickel

Trans ASM (Preprint) 51 (1957) 20 pp

The effect of an abrupt change in temperature on creep rate was used to determine the activation energy for creep which increased with increasing temperature from 3 to 5 kcal/mole at 78 K to that for self-diffusion at the highest temperature The results are discussed in terms of dislocation intersection, cross slip, solute atom locking, and climb mechanisms for creep.

(901) Lange, H., and Lücke, K.

Slip Disturbances in Aluminum Single Crystals II Microscopical Observations of Slip-Band Formation and Discussion of the Mechanism of Deformation (In German)

Z Metallk 44 (1953) 514-527

Single crystal wires of super-purity Al were elongated up to 20 8% at 20 C, and slip traces were observed Crystal orientation is the factor principally determining the slip pattern, i e, the occurrence of kink bands, secondary slip slip clusters, and duplex and cross slip With increasing deformation the slip bands increase in number, further slip occurs within each band, and new systems of slip are involved, kink bands are observed The results indicate that the strain-hardening of fcc metals results primarily from slip in systems other than the principal system, and, probably to a slight extent also, from kink-band formation

(902) Larson, F. R , and Kula, E. B

The Room Temperature Strain Rate Sensitivity of Annealed Titanium and Titanium Alloys

Watertown Arsenal Lab. TR 401/295 (April, 1958) 13 pp

The strain rate sensitivity of 6 heats of commercially pure Ti and 6 heats of alpha-beta Ti alloys in wire form has been determined at room temperature over a range of strain rates from 0.002 to 1 0/min An analysis of the results shows that the strain rate sensitivity varies with the logarithm of the strain, and the strain hardening exponent with the logarithm of the strain rate Moreover, the strain rate sensitivity and strain hardening exponent are shown to vary linearly with the stress on log-log coordinates The importance of stress level in controlling these variables is supported by other results from published literature

(903) Larson, F R , and Miller, J

A Time-Temperature Relationship for Rupture and Creep Stresses

Trans ASME 74 (1952) 765-774

Published creep data for a wide range of alloys have been examined, and it has been found that those combinations of time and temperature that give the same values of the parameter T(C + log t), where T is the absolute temperature C a material constant, and t the time, give equal stresses The results for each alloy when plotted against the parameter give a master curve on which lie all the points within the limits of experimental error. Similar master curves are obtained for the creep results with the parameter T(20 - log r), where r is the creep rate Although the constant C has been taken as 20 for each material, it may vary from alloy to alloy. A theoretical calculation for C gives a value of 21 5 The significance of the relationships that have been established is that the master curves may be obtained from short-time tests at different temperatures and can then be used to predict the results of long-time tests

(904) Larson, H., and Klier, E P

Strain Hardening of Mild Steel in the Torsion Test as a Function of Temperature

Trans ASM 43 (1951) 1033-1051

Steels tested in torsion showed extensive ductility at temperatures as low as -188 C. Torsion data were treated, using the generalized plastic-flow concept, to convert experimental torque-twist results to effective stresses and effective strains An equation for expressing results shows that values of the strength coefficient and strain-hardening exponent compare favorably with results from tension tests

(905) Lashko, N F

The Correspondence Principle in the Theory of Plastic Deformation (In Russian)

Zhur Tekh. Fiz. 20 (1950) 880-883

A theory of plastic deformation of solids is based on investigations of anisotropic single crystals and isotropic (or quasi-isotropic) bodies For each of these two fields of investigation relationships of plastic deformation have been established For single crystals these were formulated in terms of the elementary deformation phenomena taking the form of crystallographic displacements and twinning. For the quasi-isotropic body the relationships concern distributions of stresses and deformations, not considering the character of the plastic deformations in individual crystal grains The plastic deformation in the individual crystals of the quasi-isotropic body proceeds by the same elementary processes of displacement and twinning as in isolated single crystals

(906) Laszlo, F

Tessellated Stresses - Part I.

J Iron Steel Inst. 147 (1943) 173P-199P

Anisotropy of the single crystals of most materials and the differences between the bulk physical properties of the components of compound solids readily cause internal self-compensated stress systems to develop around such centers as crystals or components of the compound structure, respectively These self-compensated stress systems are called "tesselated stresses" It is shown how to determine the order of magnitude of stresses due to crystal anisotropy Those caused by differences in bulk properties are investigated by the statistical application of the theory of elasticity. A discussion is given of their influence on iron and steel, and some problems connected with other solids are mentioned

(907) Laszlo, F

Tessellated Stresses - Part II

J Iron Steel Inst. 148 (1943) 137P-159P

Results of recent investigations of structural tessellated stresses in materials consisting of components with different elastic constants are discussed, with special reference to cast and malleable iron The question of strain energy due to tessellated stresses is studied, with particular regard to phase transformation Tessellated stresses in the free surface are analyzed, and their possible role in connection with damping and surface deficiency in fatigue is pointed out.

(908) Laszlo, F

Tessellated Stresses - Part III.

J Iron Steel Inst. 150 (1944) 183P-209P

The characteristic component system of tessellated stresses due to crystal anisotropy is analyzed for metals with cubic, hexagonal, or tetragonal lattices The effect of tessellated stresses on thermal constants is studied Irreversibility and hysteresis may be involved The question of modification, i e , reduction, of tessellated stresses and their influence on density is discussed

(909) Laszlo, F

Tessellated Stresses

J Iron Steel Inst 152 (1945) 207-228

Further aspects of the mathematical treatment of tessellated stresses are discussed The criterion for units of structural tessellation to be self-compensated is that the shear elastic moduli of the components shall be equal in magnitude Among the matters considered are tessellated yield for lamellar and spherical structures, the influence of tessellated stresses and yield on the changes in shape of components on annealing, and the application of the theory of tessellated stresses to the problems of precipitation hardening, magnetization, and internal friction

(910) Laurent, P

Flow Deformation of Metals (In French)

Compt rend 212 (1941) 665-667

The so called flow deformation of metals is explained by the inhomogeneous tension of the surfaces compared with the interior of the crystals and by the anisotropy of the polycrystalline substances

(911) Laurent, P.

Contribution to the Theory of the Plasticity of Metals and Alloys (In French)

Rev. met 42 (1945) 79-92

Curves of tensile strength depend on crystal orientation; if, however, the variation of shear operating in the direction of movement in the crystal lattice is plotted as a function of the value of the shear, a "curve of consolidation" - which may be rectilinear, but is more usually parabolic - is obtained, and this is a physical characteristic of the metal concerned. Discusses the mechanism of crystal plasticity and critically summarizes the various theories already put forward to account for the phenomenon, particularly those of Burgers and of Kochendorfer Starting from these last two theories, he propounds a new theory, based on a consideration of the "consolidation of tensions", and works out the theory mathematically. In the course of developing this theory, he discusses critical consolidation; atomic consolidation, deformation at constant speed (based on Kochendorfer's equation and introducing the coefficient of consolidation); flow at constant load; reversion to normal at constant temperature; dynamic consolidation and consolidation in alloys; rupture of single crystals by slipping, polycrystalline deformation, the determination of consolidation, its application, and its relation to relaxation, and sub-permanent (slow return to equilibrium) deformation

(912) Laurent, P

State of Strain in the Neighborhood of the Kinks Characterizing the Theory of the Plasticity of Metals (In French)

J Phys radium 9 (1948) 207-211

Plastic deformation of single crystals may be effected by one or more of three processes, viz , (1) translation, (2) mechanical twinning, and (3) the formation of "kinks" or "knee bends" Of these three processes, the first is very general and by far the most important, the second occurs only in certain types of crystals, while the third process appears to be exceptional Three theories have been advanced to account for the low experimental values of the resistance of crystals to plastic deformation compared with the calculated values due to Born, viz , (1) Smekal's theory which postulates the existence of microfissures in crystals, (2) Taylor's theory which postulates the existence of dislocations, i e , atoms abnormally related to their neighbors, and (3) Becker's theory which depends upon a heterogeneity in atomic vibratory energies Laurent develops mathematically a theory of the production, propagation, and disappearance of kinks or defects of the crystal lattice, which agrees fairly well with experimental results Formulae for the strains in the neighborhood of such kinks are deduced, and it is shown that the kink hypothesis conforms to the conditions of elastic equilibrium

(913) Laurent, P.

Synthesis of Modern Theories on the Plasticity of Metals (In French)

Rev. universelle mines 4 (1948) 221-230

In addition to recent well known theories, the author's own theory is described, which depends on a special kind of fault (dislocation) called "accrochage" formed at Smekal fissures; these faults accumulate at Smekal fissures during glide and produce internal stresses which oppose the applied stress and reduce the rate of formation of new faults This theory is applied to curves of the mechanical properties of single and polycrystalline metals

(914) Laurent, P

Theoretical Study of the Plasticity of Crystals (In French)

Métaux (Corrosion-Inds) 26 (1951) 292-305

Classical theories of dislocations are reviewed, and a new theory ("theorie des accrochages") is compared with classical theories in relation to experimental data on effect of temperature on critical shear, strain-hardening curves, creep of single crystals, and plastic properties of solid solutions Concludes that while the new theory readily explains the plastic properties of crystals, the physical nature of the lattice defect postulated is not clearly defined; whereas, the more coherent dislocation theory is less closely related to experimental evidence

(915) Laurent, P

Theories of Deformation of Polycrystals (In French)

Métaux (Corrosion-Inds) 26 (1951) 111-141

Various theories concerning stress relief, work hardening, homogeneous triaxial strains, influence of rate of deformation and temperature, creep, and relaxation. As opposed to the deformation of single crystals, the effects of interaction between crystals and of grain boundaries play a part. Data of various investigations on a wide variety of ferrous and nonferrous metals are reviewed

(916) Laurent, P

Theories of the Fracture of Metals (In French)

Métaux (Corrosion-Inds) 27 (1952) 180-200

Reviews critically current theories of cleavage, shear, and ductile fracture, and supporting experimental evidence obtained with single crystals and polycrystalline test pieces. The effects of test piece size and temperature and the transition from brittle to ductile fracture are dealt with and finally theories of fatigue failure are discussed

(917) Laurent, P

Physical Principles of Creep (In French)

Métaux (Corrosion-Inds) 27 (1952) 265-271

Critically discusses literature on deformation by creep, behavior of metal during creep, and rupture by creep and their principles. Data from the literature are reviewed. Methods of testing intended to permit extrapolation of results to long times are discussed

(918) Laurent, P , and Eudier, M

Creep and Relaxation (In French)

Rev met 45 (1948) 415-418

In creep a constant force is applied to the specimen and the variation of the deformation with time is observed; in relaxation, a constant deformation is imposed on the specimen and the variation of the force exerted is observed From a number of determinations of these properties with an Al-9% Cu alloy, a mathematical analysis of the relation between them was made The superposition of the theoretical and experimental curves was found to be satisfactory only at low temperatures and it is proposed to describe a more satisfactory method in a later contribution

(919) Laurent, P , and Eudier, M

Comparison of Creep and Relaxation (In French)

Compt rend 227 (1948) 259-261

A new experimental method, applied at room temperature, for the creep of an Al alloy containing 9 7 per cent Cu. Comparison of results with theoretical ones based on the Boltzmann principle showed satisfactory agreement

(920) Laurent, P , and Eudier, M.

Theories and Experimental Data on Creep and Relaxation of Polycrystals (In French)

Rev. met 47 (1950) 39-52

Creep and relaxation were studied in a Mg and an Al alloy and the experimental results interpreted by theories of plasticity, partly Taylor's theory and partly the theory of the "consolidation of interaction"

(921) Laurent, P., and Eudier, M

Crystalline Interaction and the Brittleness of Metals (In French)

Rev. met 47 (1950) 582-588

Method of calculation of crystalline interaction and modulus of elasticity of pseudoisotropic polycrystals discussed in the light of the theory of pseudoisotropic media Results, particularly in their application to study of brittleness of metals

(922) Laurent, P , and Laurent-Lamothe, R

Plastic Deformation and Fracture of Metals (In French)

Rev met 45 (1948) 515-520

The plastic deformation of single crystals, twinned crystals, and polycrystals Factors involved in fracture after plastic deformation are analyzed for single and polycrystals The role of plastic phenomena, particularly in fatigue and stress corrosion are discussed Of the various hypotheses of plastic deformation put forward, that of the "consolidation of interaction" appears to be the most profitable The force necessary to produce a given deformation consists of (1) the force necessary to deform the polycrystals, supposing these to be independent of one another, and (2) the force due to the interaction of the different crystals this is called the "consolidation of interaction"

(923) Laurent, P , and Valeur, J

Theory of Plastic Deformation of Single Crystals (In French)

Compt rend 214 (1942) 808-811

Expressions are derived for the propagation of a dislocation through a single crystal under the influence of a shearing stress

(924) Laurent, P , Valeur, J , and Boroff, S

The Basis of Mechanical Strength in Metals and Alloys (In French)

Dunod, Paris (1947) 288 pp

Treats the general aspects of the subject, such as metal crystals, elasticity, and thermal agitation in crystals, then plasticity of single crystals and of industrial alloys The chapter on theories of crystalline plasticity discusses the contributions of Smekal, Zwicky, Taylor, Becker, and Orowan, among others

(925) Lauriente, M , and Pond, R B

Effect of Growth Imperfections on the Strength of Aluminum Single Crystals

J Appl Phys 27 (1956) 950-954

Stress/strain characteristics of Al single crystals were measured very accurately and observations of the elastic modulus made Crystals containing growth imperfections and others grown by the strain-anneal process were compared Observations of crystal perfection, by etch pit methods, were correlated with critical resolved shear stress, which was inversely proportional to the growth imperfections

(926) Lazan, B J

Mechanical Dynamic Properties at High Temperatures

Paper from High Temperature Properties of Materials, Dept Engr. Mech Pennsylvania State Univ (1954) 21-60

Reviews properties under the action of simple external forces which normally result in a simple stress system, and factors governing the flow and failure of metals during their service life

(927) Leaderman, H

Elastic and Creep Properties of Filamentous Materials and Other High Polymers

The Textile Foundation, Inc , Washington, D. C (1944) 278 pp

Theoretical discussion of primary creep and the superposition principle of Boltzmann, as well as experimental tests of the superposition principle, is followed by a review of the mechanical models applicable to primary creep

(928) Lee, H T , and Brick, R M

Slip and Twinning in Single Crystals of Beryllium

J Metals 4 (1952) 147-148

The critical resolved shear stress for basal slip in Be single crystals under compression was measured at different temperatures in the range from room temperature to 500 C In these studies, the basal plane was 20-70° from the stress axis

(929) Leeuwerik, J

The Kinematic Representation of the Fracture Phenomenon (In Dutch)

Metalen 11 (1956) 424-429

The fracture phenomenon in various materials studied through stages called first and second breaking fronts Fracture mechanism was depicted through diagrams and macrophotographs

(930) Leeuwerik, J

A Kinematic Picture of Fracture (In Dutch)

Metalen 11 (1956) 446-450

Mechanism of fracture with ultrasonic shock waves, while traces were formed by transverse waves in polymethylmethacrylates, glass, and quartz

(931) Legat, A

Contribution to the Problem of the Toughness of Metallic Materials (In German)

Berg- u Hüttenmann. Monatsh. montan. Hochschule Leoben 93 (1948) 92-99

The characteristics of metallic materials in relation to their mechanical strength, deformability, toughness, and brittleness, at temperatures between -250 and +600 C Mechanical strength is characterized by resistance to slip and molecular cohesion, but exact determinations of the values of these basic properties, whose relationship to one another affords a measure of the deformability, are prevented by structural alterations and other influences.

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results obtained from tensile tests do not adequately represent their true values One of the most important factors which affect the toughness is natural notches in the material, and alterations in changes, i.e., athermally, at high temperatures the process of fracture and, therefore, mechanical strength is dependent to a great extent on alterations, caused by thermal stress, in the conditions at the notches

(932) Lehr, P.

The Occurrence of Plastic Deformation of Iron in the Course of α ⇄ γ Transformation (In French)

Compt rend. 244 (1957) 77-80

The occurrence of deformation was confirmed photomicrographically The characteristics are those of high-temperature creep

(933) Leibfried, G.

The Force Acting on a Dislocation (In German)

Z Physik 126 (1949) 781-789

The negative gradient of the potential energy of a dislocation may be defined as a force acting on the dislocation For externally applied stresses, the magnitude of the force is completely determined by the stress at the center of the dislocation and the Burgers vector of the dislocation Only dislocations lying in a single glide plane are considered The more complex problem of internal stresses is briefly examined with respect to the forces between two dislocations and between an edge dislocation and a foreign atom.

(934) Leibfried, G

The Effect of Thermally Induced Sonic Waves on Plastic Deformation (In German)

Z Physik 127 (1950) 344-356

Theoretical, mathematical analysis develops relationship between average shear stress produced by sonic waves and melting points of metals Values for Al, Pd, Cu, Ag, Au, and Pb are tabulated. Estimates of the energy dissipated by a typical moving dislocation indicate that its terminal velocity is less than 1/10 the velocity of sound

(935) Leibfried, G

Distributions of Dislocations in Static Equilibrium (In German)

Z. Physik 130 (1951) 214-226

The distribution of dislocations in a glide plane under an external shear stress is considered. If the number of dislocations is large, all problems reduce to a type of integral equation for which the general solution is known. Dislocations of like sign confined to a fixed region of the glide plane (anchored at both ends of the distribution), and to a semi-infinite region (anchored at one end only) are first considered, and solution given for the problems previously treated. Solutions are also obtained for distributions of positive and negative dislocations in two separated regions and for a periodic arrangement of positive and negative dislocations.

(936) Leibfried, G

The Lattice Theory of the Mechanical and Thermal Properties of Crystals (In German)

Handbuch der Physik, Vol 7, Part 1, Kristallphysik I, Springer-Verlag, Berlin (1955) 104-324

Theoretical treatment, includes a section on the connection between lattice theory and elasticity theory.

(937) Leibfried, G

Dislocations and Lattice Theory (In German)

Paper from Deformation and Flow of Solids, Edited by R Grammel, Springer-Verlag, Berlin (1956) 25-32

For many problems in which dislocations play a role, the lattice structure and thereby the lattice theory enter in different ways Some simple examples of these kinds of connections are qualitatively discussed.

(938) Leibfried, G

Thermal Motion of Dislocation Lines

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 495-500

A mathematical treatment, based on statistical mechanics, is given of the thermal behavior of dislocations Considers in detail the thermal forces on anchoring points and the thermal amplitudes in a region where the dislocation is held by an internal shear stress

(939) Leibfried, G , and Dietze, H -D

The Theory of the Screw Dislocation (In German)

Z Physik 126 (1949) 790 808

The strain field of screw dislocation in an infinite solid and in a plate is calculated by (a) elastic theory and (b) the Peierls-Nabarro method. The structure of such a dislocation in the center of a thin plate is almost identical with that of a dislocation in an infinite solid. The dynamic properties of screw dislocations are examined, and a "relativistic" formula is derived It is concluded that in the absence of damping effects, dislocations will accelerate under the action of external forces, almost to the sound of speed See however L. ibid , 127 (1950) 344

(940) Leibfried, G , and Dietze, H -D

Dislocation Structures in Face-Centered Cubic Crystals (In German)

Z Physik 131 (1951-52) 113 129

The Peierls method is extended and applied to fcc lattices a/2 <110> dislocations lying in (001) and (111) planes, and a/6 <112> half-dislocations lying in (111) planes are considered Expressions for the displacements and the dislocation "widths" are given for edge and screw dislocations in (001) planes, for half-dislocations at 0 and 120 to the Burgers vector in (111) planes, and for perfect dislocations at 90 and 30 to the Burgers vector in (111) planes

(941) Leibfried, G , and Haasen, P

Mechanism of Plastic Deformation (In German)

Z Physik 137 (1954) 67-68

Plastic deformation is discussed in terms of dislocation theory, emphasize being laid on the interrelation of various stages. The dislocation distribution in undeformed crystals, homogeneous slip at low stresses, the formation of slip bands by large amounts of slip on a single plane, irreversible processes which stabilize the glide and prevent continuous deformation under constant stress, the formation of further slip bands and their interaction for large deformations and the hardening curve and the influence of temperature The probable effects are described for both fcc and hcp metals "Dynamic" Frank-Read sources, as proposed by Mott (Phil Mag 43 (1952) 1151) are thus not required, and all dislocations are believed to move much slower than the speed of sound. It is concluded that in fcc structures, hardened planes are characterized by an array of edge dislocations, and, in hcp structures, by an array of screw dislocations

(942) Leibfried, G , and Lücke, K

The Strain Field of a Dislocation (In German)

Z Physik 126 (1949) 450-464

The components of the strain tensor of an edge dislocation lying along the z axis are obtained (1) by treating the material as an elastic continuum and (2) by the Peierls-Nabarro method. The results are in agreement with each other and with the solution given by Koehler [Phys Rev 60 (1941) 397] The reasons for the different solution given by Taylor are discussed, and the Taylor dislocation is compared with the more recent (Burgers) concept of an edge dislocation.

(943) Leibovic, K N

Properties of Materials at High Rates of Strain

Metallurgia 56 (1957) 239-241

Propagation of stress waves, elastic and plastic strains, and the effect of high strain rate on yield and fracture are discussed. The greater the loading rate, the greater the ratio of dynamic to static yield strength The greater the static yield, the less the strength is enhanced by rapid loading. Stress greater than static yield strength, suddenly applied and held constant, will give enhanced strength and a delay time before rapid yielding sets in. The delay time depends on the material as well as the load

(944) Lenhart, R E

Relationship of Hardness Measurements to the Tensile and Compression Flow Curves

U S OTS, U S Dept Commerce, PB 121144, G E Research Lab to WADC (June, 1955) pp 14

Correlation of hardness and tensile tests and conversion of one measurement to the other was found workable Results with Al, Cu, and steel showed that the approximation of a uniaxial tensile stress flow curve from hardness measurements is possible by utilizing empirical conversion constants Mg was an exception because of twinning at low stress levels

(945) Lennard-Jones, J E

Some Theoretical Problems Concerning the Solid State

Proc Phys Soc (London) 52 (1940) 38-53

The discrepancy between the properties observed in actual crystals and those calculated for ideal crystals can be attributed to the presence of imperfections in the lattice; reasons are given for ascribing such imperfections to the conditions of growth from the melt. It is pointed out that the Taylor dislocation theory of slip involves certain difficulties and that a study of the conditions prevailing at the boundaries between crystallites may throw further light on the mechanism of deformation The boundary between two crystallites with slightly different orientations will have a steplike structure, with a maximum cohesion only at "points of contact" The energies necessary for complete rupture and for shear along such a surface of misfit

are calculated. Local melting may occur in crystals owing to slip and be a factor in producing strain hardening A method is given of evaluating the relation between stress and strain outside the usual elastic limits and at temperatures approaching the melting temperature

(946) Lepin, G F

A Statistical Theory of Creep and Relaxation (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk, no. 9 (1957) 134 136

An attempt is made using statistical laws on the dislocation theory to find a general equation of deformation and a particular equation of creep and relaxation Conclusions are based on assumptions by Read, Mott, and Orowan

(947) Lequear, H A , and Lubahn, J D

Some Transient Effects During Creep and Tensile Tests of an Aluminum Alloy

Trans AIME 206 (1956) 497 501

A specially devised test shows that the nature of the previous steady state conditions, which a sudden change in strain rate disturbs, is one of the factors affecting transient behavior

(948) Lequear, H A , and Lubahn, J D

Certain Departures from Plastic Ideality at Small Strains

Trans ASME 79 (1957) 97-110

Room temperature creep and transient loading tests were carried out on OFHC Cu to determine whether at low strains the plastic-deformation behavior depends only on current conditions and not on the prior history They conclude that there are four kinds of departures from plastic ideality (1) the Bauschinger effect, (2) the change in rate due to a change in a load depends on the sign of the load change; (3) changes due to strain aging; and (4) the effect found by Dorn [Trans ASM 41 (1949) 163] where the stress at a particular strain and rate depends on the rate at which the prior strain was introduced.

(949) Le Rolland, P

Mechanical Properties of Solids as a Function of Temperature (Plasticity, Viscosity, and Internal Friction) (In French)

Métaux (Corrosion-Inds.) 27 (1952) 216-232

Discussed on the basis of the literature Treats in particular the perfect crystal at absolute zero, thermal agitation, the imperfect crystal, the migration of atoms, hardening, and the role of internal stresses

(950) Leschen, J G , Carreker, R P , and Hollomon, J H

Nucleation of Slip Bands

Trans AIME 180 (1949) 131-138

It is suggested that the properties of slip bands may be considered in terms of a disk shaped region of slip which first appears in a limited region of a crystal, changes its size at finite rates, and which must be nucleated in order to attain any appreciable size The critical size of nucleus is considered, and the concept is developed mathematically sufficiently to allow certain qualitative conclusions to be made Since the rate of nucleation at the surface of a specimen is proportional to the surface area, and the interior rate proportional to the volume, the total rate of nucleation may be derived, and shows a dependence on specimen size similar to that experimentally observed The theory also allows an interpretation of the incubation period before appreciable slip takes place at low stresses; the incubation period is necessary for the few small nuclei in an unstressed specimen to grow to a size characteristic of the stable nucleus for a given stress The effects of sudden changes of stress and of temperature are considered, and it is shown that the theory indicates the existence of transient phenomena The strain rate characteristic of a given stress would not be expected to change sharply on increasing the stress, to the new strain rate, since, on change of stress, the nuclei must adjust themselves to the new equilibrium The phenomena to be expected under various conditions of changing stress and temperature are described

(951) Lewis, F G

Strain Ageing A Survey of the Literature

Australia, Commonwealth Dept Supply, Aeronaut Research Consultat Comm , Rept SM-187 (January, 1952) pp 56

Critical review of all aspects of the strain aging of steel including effect on mechanical and physical properties, influence of composition, relationship between strain aging and quench aging, yield point and blue brittleness, and current theories

(952) L'Hermite, R

The Deformation of Lead (In French)

Inst Tech Batiment Trav Publ , Circ Ser. G, no 4 (1942) pp 18

The extension and tensile strength of rods of pure Pb were measured for various extension rates at temperatures between -20 and 100 C Creep under constant load was measured as a function of time and was in part discontinuous The effects of strain rate and temperature on strain, on the compressional and torsional strengths, and on the creep of Pb specimens treated in various ways are discussed with reference to crystal structure and particle size, and an extended theory of the deformation of lead is given

(953) L'Hermite, R

The Variation of the Resistance to Tension of Solids with the Rate of Elongation Imposed (In French)

Compt rend 216 (1943) 871-872

The stress at fracture F_r, when plotted against the log of the rate of elongation v, increased linearly according to the equation $F_r = \alpha \log v + \beta$. If this law is applicable to metals at high temperatures, it should be possible to replace creep tests by tensile tests

(954) Li, C H , Edwards, E H , Washburn, J , and Parker, E R

Stress Induced Movement of Crystal Boundaries

Acta Met 1 (1953) 223 229

The stress induced movement of small angle boundaries in Zn crystals was investigated in the temperature range of 25 to 400 C The dynamic behavior of the boundaries seemed to require that they consist of an array of edge dislocations of like sign distributed more or less uniformly over the plane of the boundary The activation energy for the movement of the boundaries in the temperature range of 300 to 400 C was determined to be about 21,500 cal/mol Attention was drawn in the close agreement between this value and those of the activation energies for self-diffusion, creep, and recovery in Zn crystals. A mechanism was suggested for the formation of a substructure in crystals plastically deformed at low temperatures which depended only on the stress-induced movement of small angle boundaries

(955) Li, C H , Washburn, J , and Parker, E R

Variation of Plastic Properties With Annealing Procedure in Zinc Single Crystals

Trans AIME 197 (1953) 1223-1225

Yield stress in Zn single crystals is dependent on prior annealing temperature and rate of cooling after annealing. Tentative mechanism for the effect is suggested

(956) Lifsic, M

Some Problems of the Dynamic Theory of Non-Ideal Crystal Lattices (In English)

Nuovo cimento (Suppl) 3 (1956) 716-734

Influence of a local irregularity on the oscillations of lattice atoms and on the crystal free energy. Other applications of the method

(957) Likhtman, V I

Laws of the Creep of Metals (In Russian)

Doklady Akad. Nauk S.S S R 72 (1950) 1079-1082

Creep was theoretically investigated over a range of temperatures and applied loads Formulas are proposed which describe the constancy of internal cohesion of metal during creep. An equation for determination of the minimum rate of creep is derived and interpreted for different values of the variables

(958) Likhtman, V I

Physico-Chemical Phenomena in the Deformation of Metals (In Russian)

Uspekhi Fiz Nauk 54 (1954) 587-618

Creep of single crystals, electrocapillary effect; influence of surrounding medium on mechanical properties of semicrystalline metals

(959) Linde, J O., and Edwardson, S

Investigation of the Critical Shear Stress for Single Crystals of Metallic Solid Solutions II

Arkiv Fysik (1954) 511 519

Critical shear stress increases linearly with solute concentration for dilute solid solutions of eight Cu-base alloys, and the increase, per cent of solute, varies as the square of corresponding change in lattice parameter

(960) Lippmann, H

Contributions to a Theory of Plastic Strain of Wires (In German)

Acta Met 4 298-305

Different functions have been proposed to represent the probability of production of slip steps in a metal on application of stress This probability, however, varies in different parts of the lattice A theory based on the fundamental conceptions that the extension of wires is proportional to the number of newly formed dislocations, and that the probability of the occurrence of a slip step can be represented by a continuous function of the stress, is developed Essential features of the theory are the derivation of equations representing the spontaneous elongation and the creep behavior. The results are compared with those obtained by means of Taylor's theory of work hardening [Z Krist 89 (1934) 375]

(961) Lipson, H , and Stokes, A R

Strength of Metals

Nature 163 (1949) 871

Referring to experimental results of Wood and Rachinger in which an estimate of the yield stresses when values of Wood's "limiting crystal lite size" are substituted in an expression derived by Bragg, agrees strikingly for a number of metals Lipson and Stokes show that this agreement results also from the theory that the broadening of X ray reflections is due to inhomogeneous internal stress, and suggest that quantitative results, such as they quote, are necessary to distinguish between the two equations concerned.

(962) Liu, T S , Kramer, I R , and Steinberg, M S.

The Delay-Time Phenomenon in Metal Single Crystals

Acta Met 4 (1956) 364-370

The effects of strain duration on the critical resolved shear stress of Cu, Zn, and β-brass single crystals were studied by impact tests which produce short-duration compressions These tests were carried out at 25 C, and -190 C It was found that Zn and beta-brass crystals exhibit a definite increase of critical resolved shear stress at temperatures below room temperature, when the stress duration is less than 10^{-3} sec This phenomenon was not observed on fcc Cu single crystals It was shown that the delay time for the initiation of slip was not affected by the orientation of the stress axis with respect to the slip plane Activation energies for slip of Zn and β-brass single crystals were derived from the data obtained.

(963) Livingston, J D., and Chalmers, B

Multiple Slip in Bicrystal Deformation

Acta Met 5 (1957) 322-327

Experimental observation of slip lines on Al bicrystals deformed in tension Emphasis was on the multiple slip associated with the interaction between two crystals at the boundary Model employing pile up of dislocations at grain boundary led to a method of predicting which additional slip systems will operate in a given bicrystal

(964) Livshits, I M , and Rozentsveig, L. N.

On the Theory of the Elastic Properties of Polycrystalline Aggregates (In Russian)

Zhur. Eksp. i Teoret. Fiz. 16 (1946) 967-980

It is shown that in certain limited cases a connection between the elastic properties of a polycrystalline aggregate, regarded as a whole, and the properties of the crystallites constituting it, may be established in a general way.

(965) Logie, H J

The Yield Strength of Partly Ordered F C C Structures

Acta Met 5 (1957) 106-109

Partly ordered fcc alloys show a dependence of yield strength on the size of the ordered domains By considering the increase in disorder as slip progresses, a value for the yield strength is obtained in terms of the domain size which is in good agreement with experimental values

(966) Lŏhberg, K

The Creep Behavior of Some Nonferrous Metals and Their Alloys (In German)

Metall 6 (1952) 446-450

A general discussion of the dependence of creep behavior of metals on melting temperature, crystal structure, grain size, alloying additions, etc Results of experiments on Pb, Cu, Al, Mg, Zn, and their alloys are charted

(967) Lŏhberg, K , and Wolbank, F.

Hardness-Creep Experiments on Zinc Alloys (In German)

Z Metallk 32 (1940) 419-424

The penetration of a 2.5-mm ball under a constant load of 31 25 kg was measured as a function of the time in minutes over a period of 20 minutes The composition of the Zn alloys used varied from 0-1 7 per cent Al and 0-2.5 per cent Cu In general, the depth of penetration decreased to a minimum corresponding to the maximum solid solubility A definite interrelation existed between the phase diagram and the creep behavior

(968) Lohff, J

Emission of Electrons in a Plastic Deformation of Zinc Single Crystals (In German)

Z Physik 145 (1956) 501 507

Effect of mechanical finishing of sheet metal on the emission of electrons

(969) Lomer, W M

A Dynamical Model of a Crystal Structure III

Proc Roy Soc (London) 196A (1949) 182-194

Using the bubble raft previously described, experiments and calculations were made on the maximum shear stress under which a two-dimensional close-packed lattice is stable in terms of the forces between the lattice components The analogy with metals is discussed It is concluded that although the bubble raft shows structures which are supposed to exist in metals and simulates metallic effects, since the lattice components have no mass and no thermal components, dislocations have no kinetic energy, and energy dissipation against viscous forces replaces radiation of elastic waves

(970) Lomer, W M

The Yield Phenomenon in Polycrystalline Mild Steel

J Mech and Phys Solids 1 (1952) 64-73

Considers the variables involved in studies of Lüders bands in mild steel The grain-size effect is reviewed, as well as the temperature of testing. The geometry of the deformation is considered, and it is shown that the size of the specimen has a large influence on the form taken by the Lüders bands It is concluded that the boundary of the band is characterized by a pure shear deformation, and that the strong dependence of yield stress on grain-size is evidence for the grain boundaries acting as barriers to the deformation, rather than evidence for the dislocation-locking mechanism of Cottrell and Bilby, which is more applicable to single crystals

(971) Louat, N

The Effect of Temperature on Cottrell Atmospheres

Australia, Commonwealth Dept Supply, Aeronaut Research Consultat Comm , Rept SM 222 (1955) pp 13

The variation with temperature of solute-atom density close to an edge dislocation is discussed thermodynamically Expressions are derived for solute density in terms of the lowest energy level and temperature and for the effect of temperature on a predetermined Cottrell atmosphere The atmosphere density has a particular equilibrium value determined by the density of the solute and the ambient temperature At temperatures at which solute atoms diffuse slowly, this equilibrium will not be reached Hence, mechanical properties dependent on atmosphere density will also depend in part on the temperature history of the material Effect of temperature on the yield point is predictable, good agreement being obtained with three apparently dissimilar experimental results

(972) Low, J R., Jr

The Relation of Microstructure to Brittle Fracture

Paper from Relation of Properties to Microstructure, Am Soc Metals, Cleveland (1954) 163-179

Modes of brittle fracture, origin of flaws, crack propagation, and intercrystalline cleavage fracture

(973) Low, J R , Jr

Dislocations and Brittle Fracture in Metals

Paper from Deformation and Flow of Solids, Edited by R Grammel, Springer-Verlag, Berlin (1956) 60-72

A review of the knowledge of brittle fracture and crack formation in terms of dislocations Several dislocation models for crack initiation are discussed and compared with experimental facts The role of dislocations in influencing the propagation of cracks once they have been formed is also treated

(974) Low, J R , Jr , and Feustel, R G

Inter-Crystalline Fracture and Twinning of Iron at Low Temperatures

Acta Met 1 (1953) 185-192

It has been found that small amounts of C may strongly influence the ductility and the mode of fracture of Fe at low temperatures Fe containing 0.03 to 0 05% C normally exhibits considerable ductility and fracture by transcrystalline cleavage when tested in tension at -195 C After decarburization in moist H the same materials are completely brittle at -195 C and fracture occurs by intercrystalline cleavage; recarburization restores the original properties and mode of fracture In explanation of these results it is suggested that the grain boundaries in polycrystalline Fe are surfaces of low cleavage strength, and that the resistance to cleavage of these surfaces may be greatly increased by the addition of small amounts of C

(975) Lowrie, R

Mechanical Properties of Intermetallic Compounds at Elevated Temperatures

Trans AIME 194 (1952) 1093 1100

Nine intermetallic compounds were tested in tension at elevated temperatures and seven exhibited extensive plastic deformation Correlations of tensile strength and elongation were attempted with melting (or decomposition) temperature, valence electron configurations of the component elements, heat of formation, crystal structure density and volume decrease accompanying compound formation without success

(976) Lozinskii, M G , and Fedotov S G

On the Correlation Between Indentation Hardness and Modulus of Normal Elasticity of Pure Metals at High Temperatures (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk (March 1956) 59 67

Experimental data on hot hardness of 13 pure metals are construed to prove that the main part of the resistance to plastic deformation at higher temperatures is played by the strength of interatomic bonds, best characterized by the modulus of elasticity rather than melting point

(977) Lubahn J D

Derivation of Stress, Strain, Temperature, Strain Rate Relation for Plastic Deformation

Trans ASME 69 (1947) A229 A230

This paper carries out the derivation and correction of an equation previously presented [Holloman and Lubahn, Phys Rev 70 (1946) 775], relating to stress for plastic flow σ, plastic strain ε, strain rate Ė, and temperature T The corrected equation is $\sigma = CG^{T}(\epsilon/\epsilon_0)^{DT}\exp(E\ FT\ \ln \epsilon/\epsilon_0)$, where C, D E, F, G, and ϵ_0 are material constants

(978) Lubahn, J D

Simultaneous Aging and Deformation in Metals

Trans AIME 185 (1949) 702 708

If a metal is aging while it is being plastically deformed, various anomalies may appear, these include discontinuous yielding in a tensile test, periodic sudden extensions in constant load creep, complete absence of gradual extension under constant load, the appearance of disturbances in the stress-strain curves ("transients") following a rapid change of strain rate, and an effect in which an increase in flow stress is required to maintain a given strain rate

(979) Lubahn, J D

Creep of Metals

Paper in Cold Working of Metals Am Soc Metals, Cleveland (1949) 223-247

The possible mechanism of creep is discussed It is first emphasized that the view that the creep rate during the secondary stage of creep is constant is, fundamentally, not justified Reference is made to the conception of a "mechanical equation of state" The two explanations of strain hardening - that it is due to interference by previous deformation or to the "using up" of the sites of easiest slip - are reviewed It is suggested that under constant stress the over all deformation is the sum of anelastic and plastic components and that the slope of a strain/stress curve should continuously decrease, as a result only after the initial stages, of strain hardening At low temperature the stress required for continuing flow is primarily a function of strain, but at high temperature it depends markedly on the rate and much less on the strain

(980) Lubahn, J D.

Creep-Tension Relations at Low Temperatures of Metals

Proc ASTM 52 (1952) 905-933

The best previous notion of how to determine creep behavior from the results of tension tests was to cross plot tension curves determined at various constant rates This procedure will not yield the creep curves for metals like Cu or 61A I Al tested at room temperature because the stress-strain curves at different rates differ by less than the variations in deformation resistance among the specimens A new procedure is suggested, based upon a logarithmic relationship resulting from the hypothesis that mechanical behavior is independent of past history

(981) Lubahn J D

The Role of Anelasticity in Creep, Tension, and Relaxation Behavior

Trans ASM 45 (1953) 787-838

Experiments using Cr-Mo-V steel which show that creep recovery exhibits same behavior characteristics as anelastic deformation

(982) Lubahn, J D

The Role of Rate History Effects in the Calculation of Creep Behavior

GE Research Lab Rept No RL-876 (May, 1953) 19 pp

According to the "Mechanical Equation of State" idea, or the concept that deformation history has no effect on current deformation behavior, it should be possible to calculate tensile behavior from creep tests, and vice versa A recent investigation by Dorn indicates that there is a small rate-history effect, and therefore that the Mechanical Equation of State concept is invalid Calculations show that the rate history effect found by Dorn corresponds to a very small error in calculating creep behavior from tensile and transient results The error is smaller than the scattering of experimental results

(983) Lubahn, J D

Effect of Section Size on Fracturing

Paper from Proceedings of the 1955 Sagamore Research Conference on Strength Limitations of Metals, OTS, U S Dept Commerce, PB 131280 and PB 131281, (1955) 143-161

Size effect in mild steel has to do with the mode of crack propagation In large specimens, sudden cleavage fracture sets in after a smaller amount of gradual tearing than in smaller specimens There is a size effect on strength and ductility, in addition to the effect on mode of crack propagation, in certain heat treated steels and high-strength Al alloys The size effect is more pronounced for sharper notches or for harder metal

(984) Lubahn, J D

Effect of Temperature on the Fracturing Behavior of Mild Steel

Welding J 35 (1956) 557s-568s

Strength, energy-absorbing capacity, ductility and amount of gradual tearing preceding brittle crack propagation by cleavage are among the fracture properties observed at various temperatures

(985) Lucas, G , and Lücke, K.

The Theory of the Hardening of Metals During Creep (In German)

Z angew Phys 6 (1954) 64-70

The creep of metals is discussed from the standpoint of the formal "exhaustion" theory, and it is shown mathematically that an exponential distribution of the activation energy, a subject that is discussed, leads to the frequently observed parabolic law of creep, in the form $y = Ct^{\alpha}$, y denoting the creep extension at time t, first put forward by Andrade The effects of temperature and stress are discussed Good agreement is found between experimental and theoretical results relating to creep Physical causes of creep are discussed

(986) Lucas, G and Masing, G

Creep of Aluminum Wire Coil Springs (In German)

Z Metallk 43 (1953) 341-349

Results affirm the parabolic law for hard-drawn specimens Proposes new logarithmic flow for soft annealed and for hard-drawn specimens at liquid-air temperature The energy of activation, E, shows a considerable increase, much greater than would be anticipated from considerations based on work-hardening Even at relatively small deformations E is doubled In contrast, the small decrease of flow velocity with elongation indicates a very slow increase in the number of active centers E is found to be proportional to the log of the elongation This new effect is attributed to the presence of activation centers with various E's before deformation begins, such that centers of lower values of E are more quickly exhausted since they can more readily give rise to a slip band

(987) Ludwig, G

Effect of Type of Bonds on Mechanical Properties of Crystalline Substances (In German)

Z Metallk 41 (1950) 286-293

The behavior of heteropolar, homopolar, and metallic bonds toward lattice translation was investigated Lattice translation is explained as a composite process of dislocations of atoms, and movement of those dislocations followed by their dissolution Effects on lattice structures

(988) Lyons, W J

Statistical Theory of the Elementary Process of Plastic Deformation

Phys Rev 73 (1948) 413-414

A brief exposition of a mathematical framework, developed along statistical lines, into which more descriptive theories of the elementary processes of creep and other deformation phenomena may be built The basic assumptions in the method are discussed

(989) MacGregor, C W , and Fisher, J C

Tension Tests at Constant True Strain Rates

J Appl Mechanics 12 (1945) A-217 - A-227

True stress-strain tests, with constant true strain rate, were made at temperatures ranging from -183 C to 665 C The influence of temperature and strain velocity on the true stress-strain properties is described A single variable called the velocity-modified temperature is used to represent the combined influences of true strain rate and testing temperature

(990) MacGregor, C W , and Fisher, J C

A Velocity-Modified Temperature for Plastic Flow of Metals

J Appl Mechanics 13 (1946) A-11 - A-16

Based on the work of Eyring and others relating to the creep problem, a velocity-modified temperature is developed for representing by means of a single variable the combined effects of strain rate and temperature on the stress reaction in a tension specimen Available data are analyzed, indicating that the velocity-modified temperature is equally applicable to the tension tests conducted at both slow and rapid rates and to the creep test The data also indicate that the stress reaction, corresponding to tests at very slow and very rapid rates of deformation, may be found from tension tests at moderate strain rates and appropriately raised or lowered temperatures In the discussion by Zener and Hollomon [ibid 14 (1947) A-70 - A-71] the limitations of the relationship are further clarified.

(991) MacGregor, C W , and Welch, L. F

True Stress-Strain Relations at High Temperatures by the Two-Load Method

Trans AIME 154 (1943) 423-437

Depends on the areas of successive portions of a tapered tensile specimen and can be used in the short-time high-temperature test provided appreciable creep does not occur during the test. The true stress-strain curves are linear from the maximum load point to incipient fracture.

(992) MacKenzie, J K.

The Stresses and Energies Associated with Inter-Crystalline Boundaries

Proc Phys Soc. (London) 63A (1950) 1370

The interaction energy between two square lattice planes is calculated and the results are given.

(993) McAdam, D. J , Jr

Technical Cohesive Strength and Yield Strength of Metals

Trans. AIME 150 (1942) 311-357

The technical cohesive strength of a metal cannot be represented by a single stress value, but comprises an infinite number of stress values (cohesion limits) corresponding to the infinite number of possible combinations of the principal stresses Plastic deformation increases the technical cohesive strength continuously up to the point of fracture The influence of a plastic deformation on the cohesive strength cannot be represented by a single curve, but may be represented by a series of curves, each corresponding to a single value of S_3/S_1 Both the flow stress and the cohesion limit increase continuously with plastic deformation, but the flow stress increases more rapidly than the corresponding cohesion limit. Rupture occurs when the two curves intersect

(994) McAdam, D. J , Jr

Influence of Temperature on the Stress-Strain Energy Relationship for Copper and Nickel-Copper Alloy

Trans AIME 185 (1949) 727-740

Flow stress curves obtained with annealed materials at various temperatures are compared with curves obtained with the same materials after cold drawing or rolling Concludes that the mechanical state of a metal or alloy of this kind, which is free from structural changes other than those induced solely by plastic deformation, depends not only on the total strain, but also on the temperature during the straining

(995) McAdam, D J , Jr

The Stress-Strain Energy Relationship for Metals

Trans ASM 43 (1951) 970-992

Influence of temperature on flow stress and influence of plastic strain on latent energy, and on the ratios of latent energy to total strain energy and work-hardening energy How these energies vary with temperature

(996) McAdam, D J , Jr , and Geil, G W

The Variation of the Strength, Resistance to Oxidation, and Electrical Conductivity of Metals with Temperature

Trans ASM 33 (1944) 514-534

Additional evidence is presented that the strength of metals varies linearly with absolute temperature Previous data show that the logarithm of the oxidation time is linearly related to temperature and that the logarithm of the electrical conductivity increases nearly linearly with decrease of temperature This evidence considered in connection with the theory of interatomic forces suggests that the strength of metals continues to increase with decrease of temperature

(997) McAdam, D. J , Jr , Geil, G W , and Woodard, D. H

Influence of Strain Rate and Temperature on the Mechanical Properties of Monel Metal and Copper

Proc ASTM 46 (1946) 902-950

A study was made of the influence of temperature and strain rate on second-stage flow stress, ultimate stress, technical cohesive strength, and ductility It has been shown that the technical cohesion limit and the flow stress are similarly affected by either the stress system, amount of plastic deformation, or temperature In this paper, it is shown that these two strength indices are similarly affected by the strain rate

(998) McCance, A.

Creep of Metals (Discussion)

Engineering 161 (March 15, 1946) 258-259

New theory of creep proposed Metals subjected to plastic flow possess two characteristics - they increase in hardness and they increase in volume It is probable that these are correlated phenomena and that the internal stress produced by volume changes which are connected with compressibility of the material, account for changes in hardness Applications to experimental data from tensile tests, cold-drawn bars, creep tests, and fatigue are demonstrated

(999) McCance, A.

The Plastic Behavior of Solids

J Iron Steel Inst 163 (1949) 241-249

Discusses the theory of plastic extension, indicating disagreement with the van Mises-Hencky view that the plastic stage is merely a degenerated elastic stage whose behavior can be formulated by an extension of elasticity theory Equations derived from the author's theory were tested by work on steel, Cu, Al, Pb, and nonmetallics Includes variations in plastic behavior, brittleness and plasticity; behavior of rubber, and creep under constant load

(1000) McHenry, D.

A New Aspect of Creep in Concrete and Its Application to Design

Proc ASTM 43 (1943) 1069-1084

The nature of creep and recovery are discussed, and a principle is stated which governs the superposition of creep when the load varies with time An equation is developed which defines creep as a function of stress, age at loading, and elapsed time after loading This creep equation, combined with the superposition principle, provides a means for expressing the strain history when the stress history is known. The treatment indicates that problems of concrete design may be solved by the methods of conventional elasticity, provided the true loads of displacements are replaced by certain fictitious loads of displacements

(1001) McKinnon, N A

Characteristics of Plastic Deformation on the Surface and in the Interior of a Polycrystalline Aluminium-Silver Alloy

Australia, Commonwealth Dept. Supply, Aeronaut. Research Consultat Comm , Met Note, No 2 (1955) pp 16

By deforming immediately after solution treatment and quenching, and aging, Ag will diffuse to the deformed zones, without appreciable recovery (annihilation of lattice defects by diffusion) These zones etch differentially on electropolishing, thereby acting as markers for lattice imperfections It is concluded that where the stress system is complex, the distribution of slip bands seen at the surface is close to that in the interior For grains which slip appreciably on a single system, the interior differs somewhat from the surface

(1002) McKinnon, N A

Slip in the Interior of Aluminum-Silver Single Crystals

Phil Mag 46 (1955) 1150-1152

The mechanism of deformation in the interior of metals has been difficult to study experimentally In these experiments a solute element (3 8% Ag) was dissolved in Al, and after solution treatment and quenching the deformation was carried out quickly so that the precipitates form on any dislocations remaining in the interior Some crystals show only one system of slip bands on the surface, but the interior shows slip bands on the conjugate system This is probably due to the stresses around dislocations causing small amounts of slip on other, initially less favored, slip systems The stress-strain curves of crystals in this stage (though not those examined microscopically) gave linear hardening These observations provide experimental justification for Haasen and Leibfried's model to explain the orientation dependence of strain hardening

(1003) McLean, D

Creep Processes in Coarse-Grained Aluminum

J Inst Metals 80 (1952) 507-519

A specimen of super-pure Al was extended under a constant load of 1/2 tsi at 200 C to fracture, which occurred at 65% extension in 850 hr Observations were made of slip-band and grain-boundary movements, on a previously polished surface The movements were measured, mainly by means of an interference microscope, and their respective contributions to the creep extension calculated They accounted for only about one-half of the total extension, and it was necessary therefore to seek the cause of the "missing" creep It was believed that fine slip, difficult to detect, or viscous flow might be responsible Evidence was found that fine slip occurred throughout the extension, and polygonization in the second stage, the latter involving viscous flow by the diffusion of dislocations there was also some evidence that the known breakdown of the original crystals into subcrystals operated in this case by the specific mechanism of polygonization. It was possible to measure the orientation tilts between adjacent subcrystals, and the creep extension attributable to fine slip was thus calculated to be of the same order of magnitude as the missing creep It is concluded that, under the conditions of the experiment, creep occurred by coarse slip, fine slip, and grain-boundary displacement

(1004) McLean, D

Crystal Slip in Aluminum During Creep

J Inst Metals 81 (1952) 133-144

A study was made of types of slip bands formed in pure polycrystalline Al undergoing creep at 200 C Two types of slip bands were observed prominent slip bands of about 3/4μ displacement spaced about 30μ apart, and fine slip lines of about 50-500 A displacement and spaced less that 1μ apart which filled interspaces between the former Results are discussed in terms of dislocation theory

(1005) McLean, D

Crystal Fragmentation in Aluminium During Creep

J Inst Metals 81 (1953) 287-292

Seven specimens of super-pure Al having grain-sizes of 1 to 9-1/4 grains/mm, were crept at 200 C under loads up to 3/4 tsi; the extensions produced ranged up to 50 per cent Observations and measurements were made relating to the subcrystals formed These are consistent with a polygonization model for secondary creep and permit a quantitative check of this model to be made Certain of the observations appear to be inconsistent with the theory of subcrystal formation advanced by Wilms and Wood [ibid 75 (1948-1949) 693, 79 (1951) 159]

(1006) McLean, D

Grain Boundary Slip During Creep of Aluminium

J Inst Metals 81 (1953) 293-300

Grain-boundary displacements during creep at 200 C have been measured in seven superpure Al specimens. The tests covered a range of grain sizes from 1 to 9-1/4 grains/mm and of stress up to 3/4 tsi The curves of grain-boundary displacement plotted against time resemble the corresponding extension/time curves The fraction of the total extension due to the grain-boundary displacements was calculated At a constant load of 1/2 tsi this increased with decrease in grain size from about one-fiftieth for 1 grain/mm to about one-sixth for a grain size of 9-1/4 grains/mm At constant grain size (4-1/2 grains/mm) it increased with decrease in load, from about one-fiftieth for a load of tsi to about one-fifth for a load of 1/4 tsi A plot of grain-boundary displacement against extension due to crystal deformation is linear for all specimens, suggesting a linear interaction between these two quantities A model for this interaction is proposed, and calculation shows it to agree with experiment within 2 1

(1007) McLean, D

Interaction Between Crystal Slip and Grain Boundary Movement

Nature 172 (1953) 300-301

The amount of movement of grain boundaries in a direction perpendicular to themselves has been measured as a function of the applied stress at 250, 300, 350, and 400 C, for about 100 hours It is suggested that a pressure of n σ b is exerted on the boundary by the stopping of n dislocations/cm, where σ is the applied stress and b the Burgers vector An increase of increases n, causing the migration to be very sensitive to changes in The migration of the boundary should be hindered by solute atoms if their rate of diffusion is low

(1008) McLean, D

The Behaviour of Specimens in Tensile Creep Tests and in the Ordinary Tensile Test

Bull Inst Metals 2 (1955) 227-228

Compares the alterations in shape of specimens when subjected to tensile creep tests and ordinary tensile tests An explanation to account for the fact that necking is more localized in tensile tests is advanced, which depends on the difference in stress sensitivity of the rate of flow in the two tests A consideration of dislocation movements explains the occurrence of accelerated creep without necking, in contrast to the tensile test, when the strain corresponding to the ultimate tensile strength is reached By introducing a time factor, it is shown that there is a probability that more than one neck may form during the creep test, whereas only one forms in the tensile test

(1009) McLean, D

Interaction Between Crystal Slip and Grain Boundary Sliding During Creep

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 73-87

Rotation of sub crystals in Al during creep is shown to be proportional to elongation, from which it is decided that practically all the crystal deformation occurs by a normal glide process, the amount of grain-boundary sliding occurring in Al and Cu during creep is shown to be proportional to elongation, suggesting that a linear interaction exists between crystal slip and grain-boundary sliding

(1010) McLean, D

Grain Boundaries III Influence of Grain Boundaries on Plastic Deformation

Metal Treatment and Drop Forging 23 (1956) 91-96

Considers the influence of boundaries on strain hardening. The barrier and the complexity effect are discussed, as well as the strain hardening in different polycrystalline metals The significance of grain size is referred to.

(1011) McLean, D.

Migration of Grain Boundaries During Creep. Mechanism of Migration (In French)

Rev met 53 (1956) 139

Rates of sliding and migration vary differently with change in temperature Migration of grain boundaries involves diffusion along the grains

(1012) McLean, D

A Note on the Metallography of Cracking During Creep

J Inst Metals 85 (1957) 468-472

Commercial creep-resistant metals, broken in creep tests at various stresses and temperatures were examined At low stress, fractures began by formation of isolated cavities lying mainly in transverse grain boundaries, at high stress, fracture started with cracks which appeared to be produced by relatively large stress concentrations

(1013) McLean, D

Point Defects and the Mechanical Properties of Metals and Alloys at High Temperatures

Paper from Vacancies and Other Point Defects in Metals and Alloys, Inst Metals, London (1957) 159-198

Creep at high temperature seems to be governed in most metals by the rate of climb away from obstacles In single-phase metals, the obstacles are presumably the stress field of other dislocations, and in most commercial creep-resistant alloys they take the form of small particles of a second phase The experimental evidence agrees with the climb model in indicating that the strong effect of stress on creep rate is due to the influence of the stress on the number of active dislocations and their mean free path This applies to creep at high temperatures At low temperatures, the stress also alters the activation energy significantly

(1014) McLean, D

Grain Boundaries in Metals, Micrographs on the Physics and Chemistry of Materials

Oxford University Press, Oxford (1957) 346 pp

Starts with the structure and energy of grain boundaries, which is followed by a chapter on the microstructure of polycrystals The solubility at, and the thermodynamics of, grain boundaries are treated as well as the effect of grain and subgrain boundaries on yield stress, strain hardening, creep and fracture of metals Diffusion, sliding, and migration of boundaries are considered Both the experimental and theoretical sides of the various topics are competently handled

(1015) McLean, D., and Farmer, M H

Grain-Boundary Movement, Slip and Fragmentation During Creep of Aluminium-Copper, Aluminium-Magnesium, and Aluminium-Zinc Alloys

J Inst Metals 83 (1954) 1-10

Three polycrystalline Al alloys have been tested in creep, and observations have been made of the movements at grain boundaries, of slip, and of the fragmentation of the original crystals into subcrystals It is concluded that slip and grain-boundary displacement take place concurrently and bear a constant ratio to one another during a given test The magnitude of this ratio depends on the conditions of the test

(1016) McLean, D , and Farmer, M H.

The Relation During Creep Between Grain-Boundary Sliding, Sub-Crystal Size, and Extension

J Inst Metals 85 (1956) 41-50

Creep tests have been carried out on Al, Cu, Fe, Cd, Zn, Sn, and Al alloy and a Cu-Be alloy The object was to test two relations previously found with super-pure Al at 200 C, namely: (1) that the ratio (grain-boundary sliding)/(elongation), which has the dimensions of length, remains virtually constant throughout any one creep test, and (2) that is it related to the size of the subcrystals which form during creep. The former relation, but not the latter, was found to hold in all the present tests These and other recent results suggest a new mechanism for grain-boundary sliding, which is outlined.

(1017) McLean, D., and Tate, A. E. L.

Influence of Polygonization on Certain Properties of Aluminum (In French)

Rev met. 48 (1951) 765-777

Influence of polygonization on tensile strength at room temperature and on creep resistance

(1018) McReynolds, A. W

Anomalous Plastic Deformation in Brass and Aluminum

Phys Rev. 73 (1948) 1262

The stress-strain curve for solids is usually smooth, with slope constant in the elastic range and uniformly decreasing in the plastic range Such deformation is explained as the sum of a large number of small independent slips Measurements on 70:30 Cu-Zn and 2S Al, made at room temperature, and slow constant loading rate, show that deformation proceeds in steps of rapid flow followed by only elastic strain. Height and length of steps are approximately uniform in Al and are independent of rate of loading over a wide range The phenomenon is dependent on temperature and has been found not to occur in 2S Al below -50 C, nor in tests on Cu, Cl, or pure Al at 20 C. Further tests indicate that the horizontal portions of the steps occur as the propagation of a wave of deformation through the stressed regions, and thus represent a cooperative effect between grains rather than the sum of independent slips Consequent hardening of the entire lattice prevents plastic flow until arrival of another wave, and results in the vertical portions

(1019) McReynolds, A. W

Plastic Deformation Waves in Aluminium

Trans AIME 185 (1949) 32-45

Plastic deformation of 2S Al and Al-Cu alloys was found to proceed according to a stair-step stress-strain curve The same effect was observed in 70-30 α-brass The discontinuities were found to result from propagation of waves of plastic deformation along all or part of the specimen length The effect was found to depend on presence of an alloying element It does not occur in 99 99 per cent Al

(1020) McVetty P G

Interpretation of Creep Test Data

Proc ASTM 43 (1943) 707-733

This paper bases the interpretation of creep test data upon the establishment of relations among the four variables - temperature, stress, deformation, and time Various factors affecting these relations are considered, particularly the effects of stress and temperature upon the deformation-time (creep) curve Methods are suggested determining the necessary duration of a test and for extrapolation from short to long times and from high to low stresses Simple, practical interpolation and extrapolation methods are developed for the presentation of creep results in the form of tabulated data or charts covering any desired ranges of stress and temperature and using relatively few creep tests These methods are adapted particularly to the correlation of data from various sources and the correction of preliminary estimates when more data become available

(1021) McVetty, P G.

Creep of Metals at Elevated Temperatures - The Hyperbolic-Sine Relation Between Stress and Creep Rate

Trans ASME 65 (1943) 761-769

This paper recommends further use of the hyperbolic sine to express the relation between stress and creep rate at constant temperature. Evidence is submitted to show that the commonly used straight-line relation in the log-log plot becomes unreliable when extrapolated over a considerable range into the field of low stresses Reference is made to theoretical considerations in favor of the hyperbolic sine and to tests on a wide variety of materials which appear to support its use A chart is given to facilitate determination of the required constants from creep tests at two or more stresses at the same temperature

(1022) Machlin, E. S

An Application of Dislocation Theory to Fracturing by Fatigue

Paper from Fracturing of Metals, Am Soc Metals, Cleveland (1948) 282-289

A theory is developed for an idealized material containing no effective barriers to the motion of dislocations Data obtained with pure elements were used to check the predictions of the theory, and agreement is found within the experimental error

(1023) Machlin, E S.

Some Applications of the Thermodynamic Theory of Irreversible Processes to Physical Metallurgy

Trans AIME 197 (1953) 437-445

A brief résumé is given of the thermodynamic theory of irreversible processes, and the theory is extended to growth phenomena which are characterized by the motion of an interface separating two regions having different values of free energy The following applications of the theory are discussed (1) Grain-boundary migration- (a) the growth of a recrystallized grain in a strained matrix, and the origin of the grains of secondary recrystallization, (b) continuous grain-boundary migration, (c) the effects of diffusion across the boundary on grain-boundary-migration rate, and (d) the effect of temperature gradient, on grain-boundary migration (2) The rate of growth of a stable phase developing in a supercooled or superheated matrix. (3) The rate of growth of a stable phase developing in a supersaturated matrix, including (a) the growth of noncoherent precipitates and (b) the growth of pearlite (4) Plastic deformation, including (a) the growth of a dislocation ring (b) the phenomenon of "slipless flow", and (c) recovery A major advantage of the thermodynamic theory, as compared to the statistical-mechanical treatment, is that the former is independent of any assumption about model Within its realm of applicability this theory gives an accurate phenomenological description of nature, quite analogous to the description ordinary thermodynamics gives of the state of equilibrium

(1024) Machlin, E. S.

Creep-Rupture by Vacancy Condensation

Trans AIME 206 (1956) 106-111

Application of standard nucleation theory to the problem of void nucleation under creep-rupture conditions leads to the conclusion that nucleation of voids by vacancy condensation is highly improbable, however, growth, by vacancy condensation, of pre-existent submicroscopic voids to visible size is probable The theory leads to the following predictions which have been verified by published data (1) an increase in the density of dislocations and the number of void nuclei/unit volume should decrease the uniform elongation at rupture in the region of transcrystalline rupture - confirmed by data on Monel, (2) the total elongation values for intercrystalline rupture should be less than those obtained during transcrystalline rupture - confirmed by data on annealed Monel, in addition, other things being equal (a) an increase in grain size should decrease the measured elongation (less regions of high elongation contribute to the total value), and (b) the lower the creep rate or stress, the less the contribution of the matrix elongation to the total elongation until some stress or creep rate is reached below which the total elongation will be due only to that at the boundaries; it should then remain approximately constant in this range providing that the grain size, dislocation density, and void nucleation density remain constant confirmed by data on Monel and Cu, and (3) the product of rupture life and steady state creep rate for preannealed metals and single-phase alloys is an approximate invariant quantity, independent of stress, temperature and atomic number for a given type of structure; this relation applied, however, only to the cases where the measured creep rate and the creep rate producing vacancies for the voids are the same, the effect of cold work is to reduce the magnitude of this product - confirmed by data on Be and Monel some of the critical experiments that should be conducted to aid in the evaluation of the basic assumptions of the theory are discussed

(1025) Machlin, E S

Thermal Etching of Dislocations in Silver

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 161-171

Dislocations in Ag may be revealed by a thermal etch technique It is believed pits are formed at the points of emergence of dislocations as a result of the equilibration of the dislocation line tension and the surface tension In this technique, electropolished Ag is immersed in a dynamic flow of A containing O at 600 C for 5 to 10 minutes and then cooled to room temperature in purified A

(1026) Machlin, E S , and Nowick, A S

Stress Rupture of Heat Resisting Alloys as a Rate Process

Trans AIME 172 (1947) 386-412

In a stress-rupture test, a tensile specimen is held under a constant load at a constant temperature, and the time required for fracture is noted The process may be treated as a rate process, i e , a process resulting from a number of unit processes requiring a certain activation energy According to this theory, a plot of the logarithm of the time for fracture t_r, against the stress σ, will yield a straight line at high stresses Previous workers have shown that a straight-line relation often exists between log t_r and log σ, but the experimental error is too great to permit a conclusion to be drawn as to which relation is the more exact

(1027) Mack, C

Plastic Flow, Creep, and Stress Relaxation

J Appl Phy 17 (1946) 1086-1107

In Part I, it is shown that the product of strain rate and viscosity is equal to the sum of the differences between applied stress and yield values This relationship is applied to plastic flow Equations are given for coefficient of viscosity of such systems and for relaxation of stress at constant deformation as a function of time In Part II, the general equation in Part I is applied to creep Equations are derived which give stress as a function of strain rate and strain, and as a function of strain rate, strain, and time In Part III equations given in connection with plastic flow, creep due to work-hardening, thixotropy, and creep in combination with elastic aftereffect are applied to literature data. These equations describe the deformation and relaxation mechanisms of a wide variety of materials

(1028) Mack, D J

Young's Modulus - Its Metallurgical Aspects

Trans. AIME 166 (1946) 68-85

Attempts to relate the values of Young's modulus for different elements with the atomic volumes and melting points are reviewed In single crystals the modulus may vary with the direction relative to the crystal axes This implies that in some metals the modulus is almost independent of grain-size, while in others pronounced directional effects may be shown with coarse grains The rate of cooling may greatly affect the modulus if a eutectoid is involved, as in the Cu-Sn and Cu-Al systems There is general agreement that the modulus decreases as the temperature increases, but the data are incomplete

(1029) Mackenzie, J D , and Sondheimer E. H.

The Theory of the Change in the Conductivity of Metals Produced by Cold Work

Phys Rev 77 ser 2 (1950) 264-270

Attempts to calculate increase in residual electrical resistance of cold-worked metals by attributing the effect to an elastic distortion similar to that produced by the presence of edge-type dislocations Mean density of dislocations in a highly cold-worked polycrystalline specimen of Cu is estimated from observed resistance change and is found to be in reasonable agreement with the value derived from energy stored during work hardening

(1030) Maddin, R.

Extent of Strain of Primary Glide Planes in Extended Single Crystalline Alpha Brass

Trans AIME 194 (1952) 270

Shows that strain distribution originates in the incongruent nature of the slip process Use of a two-stage rotation process seems valid in attempting to explain the relation between the orientation of recrystallized grains and the matrix from which they have grown

(1031) Maddin, R , and Chen, N K

Geometrical Aspects of the Plastic Deformation of Metal Single Crystals

Paper from Progress in Metal Physics, V Interscience Publishers, Inc , New York (1954) 53-95

The plastic deformation of metal single crystals under stress is reviewed the following subjects being discussed glide in fcc and bcc metals, the effects of orientation, temperature, and rate of strain on the formation and appearance of slip lines, Laue asterisms the determination of glide elements, glide in hcp metals, and kink bands The metals Zn, Cd, Ti Be, Mg, Hg, U Si, Ge, and Sn are discussed separately

(1032) Maddin, R , Harrison, E. G and Gelinas, R W

Shear Along Glide Planes in Aluminum

Acta Met 1 (1953) 460-464

Ingerferometric methods were used to measure the shear on microscopically resolved slip zones of an Al tricrystal The true shear was measured as a function of distance along the zone from a grain boundary values from 5000 to 150 Å were observed, and in some slip zones there was a gradient of shear from 4000 to almost 100 Å. One zone was observed in which the amount of shear was greatest near to the grain boundary

(1033) Maddin, R , Mathewson, C. H., and Hibbard, W R , Jr

The Active Slip Systems in the Simple Axial Extension of Single-Crystalline Alpha Brass

Trans AIME 185 (1949) 527-534

The micrographic appearance of specimens in which cross slip had been induced was investigated, together with the Laue back-reflection X-ray analysis and stress-strain data during the later stages of the deformation process Specimen micrographs after varying amounts of deformation, and the cross-slip appearances, are discussed in detail The general indications are that plastic deformation in single crystals of 70:30 alpha-brass begins gliding on octahedral planes possessing cross-slip folds This stage is accompanied by no measurable strain-hardening. Further slip along planes segmented into form requires a greater stress than along other planes, so that slip is diverted to undisturbed areas When all available unslipped areas are eliminated, greater stress is required to cause further glide in previously slipped areas At this stage shear strengthening begins, with further glide on cross-slip and primary slip planes Fragmentation also occurs Thus, shear strengthening is caused by the necessity of forcing glide along planes segmented into folds

(1034) Maier, C G.

Theory of Metallic Crystal Aggregates

Trans AIME 122 (1936) 121-175

It appears logically necessary to describe lattice distortion as the result rather than the cause of changes taking place in the deformation of metallic crystals If lattice distortion is the result of the changes taking place in cold working, X-ray and density measurements can be explained only by the existence of a certain portion of material of density higher than normal presumably located in the zones of intercrystalline boundaries and having the nature in part of an adsorbed film

(1035) Makin M J

Unloading Effects in the Plastic Properties of Copper Single Crystals

Phil Mag 3 (1958) 287-301

Yield-point phenomena occur on retesting Cu single crystals during interrupted tensile deformation. The effect is observed only during the linear and parabolic regions of the stress-strain curve and the size of the yield drop is directly proportional to the reduction in the stress on unloading

(1036) Makin M J

The Temperature Dependence of Flow Stress in Copper Single Crystals

Phil Mag 3 (1958) 309-311

Crystals were tested in a hard beam tensile machine at a strain rate of 6×10^{-5} per sec Measurements were made between -195 and +196 C Results confirm that the ratio of flow stresses at two temperatures settles down after about 10% elongation to a constant value

(1037) Maksimov, S K.

Plasticity of Red Copper (In Russian)

Prochnost Metallov, Akad Nauk S S S.R (1956) 139-143

Long-term creep tests showed that the percentage of relative elongation, ε, up to rupture was an essential characteristic of Cu The plots of ε vs t (t = time to rupture) indicated that the plasticity of Cu began to decrease at 250° and might reach a brittle condition at higher temperature To obtain a correct evaluation of the properties of Cu, the additional criteria of long-term strength, ∂, and plasticity resource, ε_r, are suggested The former is the stress at rupture at a given temperature and t and the latter is the magnitude of plasticity accumulated during the first and second stage of creep, i e the beginning of rupture

(1038) Mallon, H D

Plastic Flow of Metals

Metallurgia 21 (1940) 151-152

The problems to be solved in connection with the breakdown of metals under tensile stress are described and the mechanism of failure of pure metal in the tensile test at room temperature is considered

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(1039) Manjoine, M J

Effect of Rate of Strain on the Flow Stress of Gas Turbine Alloys at 1200 and 1500 F

Proc ASTM 50 (1950) 931-950

The factors which influence the flow stress of a metal are discussed and a generalized flow-stress curve is proposed The short-time methods of comparing alloys and the limitations of these methods are reviewed

(1040) Manjoine, M J.

Mechanical Properties of Metals at High Temperatures Non-Periodic Loading

Paper from High Temperature Properties of Materials, Dept Engr Mech. Penn State Univ (1954) 9-20

Factors affecting elasticity, plasticity, and failure of metals during their service life

(1041) Manjoine, M. J

Influence of Rate of Strain and Temperature on Yield Stresses of Mild Steel

J Appl Mechanics 11 (1944) A-211 - A-218

This paper describes the influence of rate of strain and temperature on the yield stresses of mild steel Tensile tests are reported for room temperature, 200, 400 and 600 C, at reats of strain which vary from 10^6 to 10^3 per sec The results of the tensile tests are plotted to show the effects of strain-aging on the yield stress and ultimate stress The comparison of the yield stress at various strain rates permits an analysis of the influence of strain. The conditions necessary for discontinuous yielding are described and compared with test experience

(1042) Mann, E. H

An Elastic Theory of Dislocations

Proc Roy Soc (London) 199A (1949) 376-394

Theory for the internal stresses caused by slip in crystalline materials is based on the concept of dislocations as they occur in the mathematical theory of elasticity, and on the work of Volterra. General formulas are derived for calculating stresses corresponding to given dislocations. Four examples involving plane and screw dislocations are solved, and relations given between mathematical dislocations and some simple types of slip in crystals

(1043) Manson, S S., and Haferd, A. M

A Linear Time-Temperature Relation for Extrapolation of Creep and Stress-Rupture Data

NACA TN 2890 (March, 1953) 49 pp

Suggest a new parameter called the "linear time/temperature parameter" $S = \frac{T - T_a}{\log t - \log t_a}$, where T is the temperature in °F, t is the rupture time in hr, T_a and t_a are constants of the material determined from the data. A plot of S/stress for a given material results in a single curve Good agreement between extrapolated data (up to 10,000 hr) and experimental data was observed for 40 materials The method can be applied to extrapolation of creep data using a parameter $\frac{T - T_a}{\log r - \log r_a}$, where r is the minimum creep rate, T_a and r_a are constants of the material

(1044) Manson, S S, and Succop, G.

Stress-Rupture Properties of Inconel 700 and Correlation on the Basis of Several Time-Temperature Parameters

Paper from Symposium on Metallic Materials for Service at Temperatures Above 1600° F, Philadelphia (1955) 40-46

Creep data for stress of 5000-130,000 psi temperatures of 1100-2000 F; and times of 1-1000 hr The alloy may be suitable for use above 1600 F The results are analyzed on the basis of several time-temperature parameters

(1045) March, N H.

Cohesion of the Alkali Metals in the Thomas-Fermi-Dirac Theory

Phil Mag. 45 7th ser (1954) 325-328

Thomas-Fermi-Dirac method affords some explanation of metallic binding Results predicted by theory

(1046) Marshall, E. R, and Shaw, M C

The Determination of Flow Stress from a Tensile Specimen

Trans ASM 44 (1952) 705-725

An experimental study was made of the influence of the neck profile radium on the true stress - true strain tensile test. An increase in this radius lowered the true stress corresponding to a given strain The results obtained are in good quantitative agreement with those predicted by an equation derived by Bridgman However, the results of this investigation do not support the empirical relationship that Bridgman has proposed between the flow stress correction factor and the true strain The effect of neck profile radius is also examined with regard to fracture stress, and the results discussed in terms of several strength theories

(1047) Martin, J A, Herman, M, and Brown, N

Grain-Boundary Displacement Vs Grain Deformation as the Rate-Determining Factor in Creep

Trans AIME 209 (1957) 78 81

The height of the vertical grain boundary displacements was measured on creep specimens of beta-brass The displacements followed a normal distribution whose standard deviation was a function of strain and was independent of temperature from 150 to 501 C The strength of the grain, not the shear resistance of the boundary, was found to be the rate-controlling factor in the creep of beta brass

(1048) Martorell, J I.

Contribution to the Study of Hardness and Strength of Metals (In Spanish)

Technica met 7 (1951) 109 123

Application of Meyer's law for the relationship between hardness and strength properties of metals was studied theoretically Results are correlated with data collected from the literature for copper, alpha-brass, Al, and steel

(1049) Masing, G

Influence of Surrounding Medium on Plastic Deformation of Metals (In Italian)

Metal ital 43 (1951) 467-470

Conclusions of Rehbinder and co-workers are confirmed, except for effect on electrical resistance Theoretical analysis of the observations

(1050) Masing, G., and Schröder, K.

Microscopic Observation of the Elongation of Zinc Single Crystals (In German)

Z. Metallk 46 (1955) 860-866

Photomicrographs show the progress of basal slip during the elongation of cylindrical single crystals of pure Zn When two slip systems operate, various slip processes take place. The cross section of the specimen changes from cylindrical to elliptical or, often, "banana-shaped", with intermittent loading, so that necking occurs; simple bend-planes and then "wedge-shaped" kink bands develop for which mechanisms are discussed, further bend-planes are then generated The kink bands retard subsequent elongation and develop so that large knots form in the crystal

(1051) Mathewson, C. H.

Structural Premises of Strain Hardening and Recrystallization

Trans ASM 32 (1944) 38-87

An account of investigations which sought to clarify the macroscopic aspects of plastic deformation but failed to reveal in the slip mechanisms postulated a generally acceptable cause for strain hardening The inadequacy of slip interference between differently oriented crystallites to meet the requirement of strain hardening, as argued by G. I Taylor on a mathematical-geometrical basis, does not take into account the possibility of unique configurations of strain at inner surfaces of fragments or crystallites It is suggested that the slipping process is far more complicated than hitherto assumed, and that an observed slip direction is merely the resultant of movements in which the atoms find paths of lower potential than the direct route over barriers set up by their own volume requirements

(1052) Matsuura, K., Hamaguchi, Y, and Koda, S

On the Formation of Small Guinier-Preston I Zones During the Plastic Deformation of an Aluminium-Copper Alloy

J Phys Soc Japan 12 (1957) 1424

The increase in volume resistivity of polycrystalline wires of Al-4% Cu alloy with increasing plastic deformation was measured at room temperature and -196 C and related to the creation of point defects

(1053) Matthaes, K.

Observations on the Theory of the Strength of Materials, I, II (In German)

Z Metallk 43 (1952) 11-19, 90-95

Reviews and discusses relationships which exist among the various physical properties of metals and alloys and their mechanical properties during elastic and plastic deformation in tensile, impact, creep, fatigue, stress corrosion testing, and during hardening

(1054) Matthaes, K.

Theories of Strength of Materials, I (In German)

Metall 11 (1957) 99-104

The mathematical (or isotropic), physical (or atomistic), and chemical (or molecular) theories of the strength of material are reviewed Elastic properties are discussed in relationship to heat content, sonic velocity, resistance to volume change and its alteration during the liquid to solid transformation, and multiaxial stressing

(1055) Matthaes, K

Theories of Strength of Materials, II (In German)

Metall 11 (1957) 393-401

Concludes with a discussion of the flow behavior and the fracture state of materials. The results are summarized by two principles, bearing in mind the necessary reservations that result from the combination of shape- and volume-elasticity: (1) the energy of elastic change of shape is equivalent to the heat energy (heat of melting and transformation), and (2) the crystal behaves as a solid body such that under an external stress the elementary cell angle tends to change by only the least amount

(1056) Megaw, H. D, and Stokes, A R

Breadths of X-Ray Diffraction Lines and Mechanical Properties of Some Cold-Worked Metals

J Inst Metals 71 (1945) 279-289

The breadths of X-ray diffraction lines from cold-worked Fe, Ni, Cu, Ag, Al, and Pb have been measured, and are shown to be in satisfactory agreement with those calculated from the mechanical properties of the metals on the assumption that the crystals are stressed up to the ultimate tensile limit Observations have been made on the self-recovery of filings at room temperature

(1057) Meixner, J

Thermodynamic Extension of the Theory of After-Effects (In German)

Z. Physik 139 (1954) 30-43

Generalized matrix theory of elastic after-effect for bodies subjected to a generalized stress system Theory takes account of temperature changes associated with the aftereffect Analogies to the properties of electrical networks are pointed out No application to observation is attempted

(1058) Melchior, P

Modulus of Elasticity and Yield Point of Copper and Copper Alloy Spring Sheet (In German)

Metall 8 (1954) 850-852

Correlation between tensile strength, modulus of elasticity and yield point.

(1059) Merckx, K. R.

Developments Necessary for General Theories of Creep Useful in Stress Analysis

Paper presented at Pacific N W Metals and Minerals Conf. AIME (1954) Portland, Oregon, 14 pp

Two theories of creep are derived from the theory of plastic deformation and theory of plastic flow. The modifications given show the need of an integral criterion for the effect of stress, time, and temperature on strain. This criterion or a similar invariant is also needed to distinguish between the processes of loading and unloading. Experimental and theoretical work is also necessary to clarify the process of unloading during creep.

(1060) Metcalfe, A G.

Factors Affecting the Strength of Metals at High Temperatures

Metal Treatment and Drop Forging 16 (1949-1950) 235-246

A scheme for classification. By adopting a simplified picture of the mechanism, three groups of methods are obtained first, those which raise the softening temperature, second, those by which resistance to slip may be raised, third, those which decrease the chance of failure in a grain boundary Attempts to assess the relative importance of each factor

(1061) Meyer, M A

The Hardness of Primary Substitional Nickel Alloys

Bull Inst. Metals 1 (1952) 121-123

The hardness of Ni at -183 C, room temperature, and 300 C increases linearly with addition (up to 5%) of Co, Cu, Fe, Cr, Al, Mn, Mo and W, and in a nonlinear manner with Si, Sb, and Sn, with which supersaturation effects occur The hardness increase due to alloying is independent of temperature and the increase per at. % varies approximately linearly with the lattice strain An expression is given for the stress/strain curves of Ni alloys

(1062) Michaud, R.

Contribution to the Study of Mutual Reactions of Crystals in the Deformation of Polycrystalline Metals (In French)

Publ Scient et Techn. du Ministere de l'Air, Paris (1950) pp 98

An investigation of the plastic deformation of polycrystalline metals Experiments were performed on specimens of Al consisting of single crystals, bicrystals, and coarse polycrystals, and modes of deformation within the crystals and near the crystal boundaries were studied by means of X-rays, using both the Laue method and a divergent-beam method developed by Guinier. The main conclusion is that the boundary between adjoining crystals does not exert a direct influence of its own upon mode of deformation, it is regarded instead as a frontier across which the crystals interfere with each other.

(1063) Miller, J

Aid for the High-Temperature Designer

Gen Elec Rev 55 (November, 1952) 51-53

The rupture characteristics of a metal can be graphically represented in a single curve, for both long and short times and at different temperatures by use of the parameter T(C + log t) The constant C depends upon the material, but is close to 20 for many iron-base alloys

(1064) Miller, J, and Guarnieri, G

Short-Time High Temperature Deformation Characteristics of Several Sheet Alloys

Trans. ASM 41 (1949) 167-193

From short-time constant-rate tensile tests at elevated temperatures, true stress-strain characteristics were determined for five different types of alloys over a range of temperatures and strain rates The alloys included SAE 1020 steel as a reference material, regular Inconel to represent a comparatively stable annealed material, Inconel X, a fully aged alloy, and S-816, both annealed and cold rolled, to represent an alloy susceptible to age hardening in both conditions The variation of activation energy with temperature is shown, and a simplified mechanism of deformation, relating the flow process to metallic diffusion, is pointed out

(1065) Mirkin, I. L.

Contemporary Ideas About the Structure of Alloys in Connection with the Problem of Strength (In Russian)

Metalloved i Obrabotka Metal. (July, 1955) 11-18

Atomic structure and properties of metals, imperfections in crystals and peculiarities of the basic lattice; types of heat treatment and alloying elements in steels, Al, and other metals.

(1066) Mirkin, I L., and Livshits, D E.

Hardness Testing at High Temperatures (In Russian)

Zavodskaya Lab. 15 (1949) 1080-1087 (Brutcher No. 3197)

Correlation between hot-hardness and stress-rupture strength is demonstrated on a number of alloys The change in hardness with time of indentation gives quick information on rupture strength and other characteristics

(1067) Mirkin, I. L., and Trunin, I I.

Investigation of Creep and Failure of Steel in Areas of Stress Concentration (In Russian)

Paper in Strength of Metals, Izd-vo Akad. Nauk S S S R., Moscow (1956) 117-132

Deals with the analysis of stresses, deformation, and failure of metals under creep in the areas of stress concentration. The article concludes that the maximum stresses occur in the area of stress raisers and that the failure of metal under creep is characterized by formation and propagation of a crack within the crystalline structure of metal

(1068) Mirkin, I. L., and Trunin, I I

Study of Zones of Failure in Creep (In Russian)

Metalloved i Obrabotka Metal no. 6 (1957) 2-7 (Brutcher Transl 3979)

Microhardness was reduced near the fissure developed by creeping. This may be explained by fine cracks in the material which have grown out of an accumulation of voids in the crystal lattice along the line of failure

(1069) Mirkin, I L., and Trunin, I. I.

A Statistical Method of Studying the Rupture Zones of Metals by Measuring Microhardness (In Russian)

Zavodskaya Lab. 23 (1957) 229-235

Gives following steps in mechanism of rupture (1) development of cracks results from concentration of stresses in microregions (e g, at a triple point); (2) later, in a heterogeneous field of stresses under action of diffusion processes, vacancies accumulate at parts of metal

(1070) Mitchell, J W

Dislocations in Crystals of Silver Halides

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc, New York (1957) 69-90

Methods for preparing pure Ag halide crystals and for making the dislocations visible are described. Structures were produced by annealing between 250 and 410 C Dislocations in plastically deformed crystals were observed, and the conditions under which dislocation lines may be made visible in crystals of Ag halides are considered

(1071) Monkman, F C, and Grant, N J

An Empirical Relationship Between Rupture Life and Minimum Creep Rate in Creep-Rupture Tests

Proc ASTM 56 (1956) 593-605

Such variables as stress, temperature, composition, and total ductility were investigated for their effects on the empirical relationship determined for a wide range of alloys based on Al, Fe, Ni, T, Co, and Cu A straight line was generally obtained when the log time to rupture was plotted against the log minimum creep rate

(1072) Moore, H

The Fracture of Solids II The Fracture of Glass

Metallurgia 39 (1949) 179-181

From a consideration of the structure of glass its properties may be deduced and are outlined. Molecularly, the structure is irregular, but on a larger scale, isotropic, resulting in a conchoidal type of fracture Thin fibres, for a short time, are much stronger than massive glass, but exposure to moist air for even a few seconds reduces the strength considerably Glass shows no evidence of fatigue and when subjected to successive reversals of stress, although it twists like a metal, shows no evidence of weakening.

(1073) Morrison, J. L. M , and Shepherd, W. M.

An Experimental Investigation of Plastic Stress-Strain Relations

Proc Inst Mech. Eng. 163 (1950) 1-17

Tests on a low-alloy steel and on an Al alloy made in order to discriminate between and evaluate the merits of the "incremental" and "total" plastic-strain theories in the region where elastic and plastic strains are of comparable magnitude The tests appear to establish that for these two materials the "total" type of theory is incorrect and, in some instances, may lead to large errors The experimental results give strong support to the "incremental" theory

(1074) Mott, N F

Atomic Physics and the Strength of Metals

J Inst. Metals 72 (1946) 367-380

An account is given of the main contributions of the quantum mechanics to the physics of metals The methods of theoretical physics are illustrated by some remarks about the dislocation theory of slip, in particular, a hypothesis as to the cause of the high ductility of metals, and some remarks on the theory of precipitation hardening It is suggested on theoretical grounds that for precipitation hardening to have its maximum effect, the distance between the precipitates must not be too small. It is also shown that the relation of yield stress to temperature at low temperatures ought to depend on this distance

(1075) Mott, N F

Mechanical Properties of Metals

Nature 160 (1947) 696-698

A summary report of a conference held at the University of Bristol Among the topics discussed were oxidation hardening, the ordered state in alloys, mechanical properties at low temperatures, the creep of metals, slip planes in Ag halides, crystal boundaries, recovery and recrystallization, diffusion studied by thermoelectric methods, precipitation, elastic after-effects in Fe, internal friction, and the properties of sintered compacts.

(1076) Mott, N F

Fracture of Metals: Some Theoretical Considerations

Engineering 165 (Jan. 2, 1948) 16-18

Outline of present state of theory for brittle substances and application to ductile materials such as metals A methematical analysis is made of the stresses at the base of a crack, showing how a crack of atomic sharpness, moving with the velocity of sound, can be propagated in a single crystal Analysis is extended to polycrystalline metals

(1077) Mott, N F

Slip at Grain Boundaries and Grain Growth in Metals

Proc Phys Soc. (London) 60 (1948) 391-394

A theory of the slip process is advanced, based on some experimental results by Ke First, treats the case of one close-packed surface sliding over another and notes that the activation energy is of the order of the heat of fusion A theory of intercrystalline slip is then based on the postulate that the elementary act which allows slip to occur is the disordering of atoms around each island where the fit is good. The rate of recrystallization of a cold-worked material is derived next, based on the idea that the crystal grows by disordering or melting of the cold-worked metal, which then takes up the structure of the growing crystal.

(1078) Mott, N. F

Mechanical Properties of Metals

Physica 15 (1949) 119-134

A short account of the dislocation theory of the properties of metals Slip, work hardening, impurities, recrystallization, and recovery and grain-boundary effects are considered

(1079) Mott, N F

Theories of the Mechanical Properties of Metals

Research (London) 2 (1949) 162-169

Describes mechanisms by which deformation can take place in terms of dislocations Treats diffusion concept of dislocations, yield point and resistance to flow, early dislocations and the origin of age hardening; theories of work hardening and of transient creep and slip along the grain boundary, crystal growth and viscous creep

(1080) Mott, N F

Some Considerations of the Effect of Imperfections of Structure on the Physical Properties of Metals

Rev Universelle mines 6 (1950) 291-296

Discusses the effects of impurities on the deformation of metals in cases (a) where the grain structure is deformed, (b) where there is movement or slip along the grain boundaries, and (c) where the movement of the grain boundaries is in a direction perpendicular to the boundary, as in grain growth The deformations of grain structure are explained by the presence of dislocations which are found in all metals A mathematical treatment is presented for determining the temperature at which slip along the grain boundaries will occur, and it is shown that this will occur with Fe only at elevated temperatures It is also shown that where the deformation (creep) is due solely to internal deformation of the grain structure, mathematical relationships are deduced which give good agreement with experimental results

(1081) Mott, N F

The Mechanical Properties of Metals

Proc Phys Soc (London) 64B (1951) 729-742

A review of recent theoretical work, some of it unpublished, on the dislocation theory of cross slip, deformation bands, recovery, steady-stage creep, and the generation and motion of vacancies (particularly as a consequence of the interaction of two screw dislocations)

(1082) Mott, N F

Mechanical Strength and Creep in Metals

Paper from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, New York (1952) 173-196

Effects responsible for mechanical strength in metals include dissolved impurities, which may lock dislocations without diffusing to them, as well as impurities after a process of diffusion, as envisaged by Cottrell Frank's ideas on the strength of pure metals, which depend on the distance between the two locking points of a Frank-Read source, are reviewed Finally, a theory of exhaustion creep is compared with experiments of Davis and Thompson.

(1083) Mott, N F

Diffusion, Work-Hardening, Recovery, and Creep

Paper from L'Etat Solide, Rept 9th Solvay Conf , Edited by R Stoops, Brussels (1952) 515-534

The possibility of dislocations acting as sources or sinks for vacancies is considered, and on the basis of data on the Kirkendall effect in diffusion and on the viscous creep of polycrystals, it is tentatively concluded that grain boundaries are more important in this respect Evidence is quoted from the temperature dependence of work hardening that dislocations are impeded in motion at highly localized sites; interactions of dislocations on different slip planes are believed to be the cause, especially where cross slip is involved The diffusion process whereby a dislocation climbs out of its slip plane is held to be of central importance in recovery and especially in steady-state creep. The discussion includes an account of deformation bands and other substructures encountered in the creep of polycrystalline Al

(1084) Mott, N F

Mechanism of Work-Hardening of Metals

Engineer 194 (November 21, 1952) 694-697

Recent investigations suggest that, when formed a low temperatures, each slip line is the result of a displacement of the material along a single lattice plane through a distance of about a thousand atomic diameters Moreover, there is much evidence that the steps on the surface, which appear as slip bands, attain their full height in a small fraction of a second, though their length may thereafter increase slowly At higher temperatures and at slow rates of strain, the slip bands appear as clusters of lines about a hundred atomic diameters apart The origin of slip lines, the reason for this clustering and the cause of work-hardening are discussed. The two conceptions used in the discussion are the dislocation line and the vacant lattice site

(1085) Mott, N F

A Theory of Work-Hardening of Metal Crystals I

Phil Mag ser 7 43 (1952) 1151-1178

A theory of the work hardening of metal crystals, based on the properties of dislocations, is developed There are two types of hardening, viz , (1) the normal rapid hardening of cubic metal crystals, and (2) the slower hardening of hexagonal and cubic crystals under conditions of easy glide Rapid hardening does not occur unless dislocations are retained in the slip planes The retained dislocations are supposed to occur in groups of about 1000 at the ends of slip bands, and the strains round these groups are responsible for hardening, as in Taylor's theory The obstacles which stop slip are sessile dislocations, and the formation of these stabilizes the dislocation groups On the assumption that the formation of slip lines must be a dynamic process, a parabolic stress/strain curve is deduced It is shown that the formation of vacancies by moving dislocations can account for the clustering of slip lines The theory agrees qualitatively with observations of retained energy in cold-worked metal

(1086) Mott, N. F.

A Theory of Work-Hardening of Metal Crystals II Flow Without Slip Lines, Recovery, and Creep

Phil Mag ser 7 44 (1953) 742-765

Mott's theory of work hardening [ibid 43 (1952) 1151] is extended to account for fine slip Fine and coarse slip are both considered to originate in Frank-Read sources, fine slip occurring when the dislocations move slowly, when the stress to obtain dislocations from a source is less than that required to drive them through obstacles in the lattice without the aid of thermal activation The initial stages of deformation are normally by fine slip, and the hardening occurring in this region is much slower than for coarse slip. In creep, the deformation is normally fine slip. Logarithmic creep, represented by the formula $\varepsilon = \alpha \{\log(\gamma t + 1)\}$ is considered to occur when dislocations are hung up by obstacles from which thermal vibrations can release them. If the obstacles are strain islands around incipient precipitates in age-hardened alloys, then $\alpha \propto 2/3$; if they are other dislocations that have to be cut, then, as suggested by Cottrell, $\alpha \propto 1$ A theory of logarithmic creep, which attributes the slowing down of creep to increasing difficulty of movement experienced by the dislocations from obstacles as the material work hardens is developed and agrees better with experiments than do previous exhaustion theories A new theory of Andrade beta-creep which relates it to steady-state creep is developed The first stage of recovery is ascribed to dissolution of piled-up groups of dislocations by climb The formation of vacancies during creep is discussed

(1087) Mott, N. F

Dislocations and the Theory of Solids

Nature 171 (1953) 234-237

Outlines the evidence for the presence of dislocations in crystals and the application of dislocation theory to plastic deformation, work hardening, crystal growth, and recovery

(1088) Mott, N F

Dislocations, Plastic Flow, and Creep

Proc Roy Soc (London) 220A (1953) 1-14

A review of (1) the experimental evidence that in crystalline materials dislocations are formed during crystal growth, that they can move when the material is stressed, that networks of dislocations can be formed, and that piled-up groups of dislocations of high strength can be stable; (2) the Frank-Read hypothesis, and recent modifications therein, of the dislocation mechanism of both coarse and fine slip -- in which the major unresolved problem concerns the speed at which dislocations move, (3) the concept of "climb" of dislocations and its role in elucidating the processes of recovery and creep, and Mott's own tentative explanation of Andrade's law for transient creep. An outline is given of a theory of ductile fracture This depends on the production of piled-up groups of several hundred dislocations, from each of several active sources, at the ends of slip lines; there will thus be a high concentration of stress at the end of a slip line, similar to that of a Griffith crack. this may well approach the theoretical fracture stress of the material. Thus, after a certain stress is reached, small microcracks may be expected to appear, perhaps [illegible] when these weaken the material sufficiently, a visible crack, the beginning of ductile fracture should appear

(1089) Mott, N F

Difficulties in the Theory of Dislocations (In English)

Paper from Proc Intern Conf. Theoret Phys Kyoto and Tokyo, Japan, 1953, (1954) 565-569

Several difficulties pointed out, such as (1) how many dislocations are generated by a source, (2) what is the true step-height of a slip line, (3) the effect of temperature, and (4) the frequency of occurrence of slip clusters Considers three mechanisms that explain why a source should generate a fairly large number of dislocations Concludes the new mechanism presented by him is the most probable.

(1090) Mott, N F

Dislocations, Fatigue, and Fracture

Proc Roy Inst G Brit 35 (1954) 666-668

A review of recent results of the application of the concept of dislocations to the theory of fatigue The start of fracture in metals is considered to be associated with the existence of high tensile stresses at the extremities of slip planes In experiments on the fatigue of polycrystalline Cu, removal of surface slip lines by electropolishing has revealed that some of the lines conceal cracks running parallel to the slip direction Repeated fatiguing and polishing shows that such a crack can spread across a grain and from it, starting at about 15°, spread out jagged tears which ultimately prove fatal While the factors controlling the method and rate of speed of such a crack can be explained, it is more difficult to understand how it is first formed parallel to a slip line It is tentatively suggested, on the basis of recent experimental evidence of the complexity of slip lines, that small cracks form at the ends of each of the elementary lines of which the slip line is composed These so weaken the material along the line that eventually visible cracks form This hypothesis agrees with the observed fact that frequent annealing during fatigue testing, which might be expected to remove strain but not cracks, does not increase fatigue life

(1091) Mott, N F

A Theory of Fracture and Fatigue (In English)

J Phys Soc Japan 10 (1955) 650-656

It is suggested that a sufficiently large stress can induce fracture at a piled-up group of dislocations, and a large number of small cracks, so produced, can unite to produce a ductile or fatigue fracture It is assumed that there is present some mechanism which sometimes allows a source to produce a large number of dislocations, all at once, up to 1000 or so; but the discussion does not involve the nature of this mechanism

(1092) Mott, N F.

Dislocation, Work-Hardening, and Creep

Nature 175 (1955) 365-367

The presence of a dislocation network in an annealed metal explains the low yield stress and the localization of slip on a few planes The electron microscope show fine slip lines about 200 A apart in the space between the visible lines; this fine slip determines the stress/strain curve If there were no fine slip, there would be very little hardening. Coarse slip may be due to some instability in the mechanism of fine slip. One reason for believing that piled-up groups of dislocations are formed is the broad slip-lines observed in fatigue in polycrystalline Cu Work-hardening proceeds more rapidly in single crystals when slip occurs on more than one plane; this is due to locking between dislocations in different glide planes Polygonization can be explained by this model The annihilation by climb of a pair of dislocations may be the rate-determining process in creep.

(1093) Mott, N F

Dislocations in Crystalline Solids

Paper from Surveys in Mechanics, University Press, Cambridge (1956) 32-63

Attempts a broad, general survey of what has been achieved by the study of dislocations Treats origin of slip lines, barriers, energies of dislocations and mosaic boundaries, and stress required to move a dislocation. The strength of materials is discussed in terms of latest theoretical findings

(1094) Mott, N F

Discussion of Some Models of the Rate-Determining Process in Creep

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 21-24

Attempts to account for some of the facts of creep in terms of the movement of dislocations Maintains that there are great difficulties in accepting the hypothesis of "climb" of dislocations, and that cell formation (polygonization) may occur through slip alone In this case, the rate-determining process must be slip, and it is suggested that the barriers of greatest importance are jogs in screw dislocations A stress-dependent activation energy for creep, which approaches that for self-diffusion at low stresses, results from this model

(1095) Mott, N F

Fracture in Metals

J Iron Steel Inst 183 (1956) 233-243

Discusses three types of fracture in metals, ductile, brittle, and fatigue, from the standpoint of the dislocation theory

(1096) Mott, N F

Theories of Fracture in Metals

Paper from Deformation and Flow of Solids, Edited by R Grammel, Springer-Verlag, Berlin (1956) 53-54

A brief discussion of fracture theories based on dislocations A review of ductile and brittle fracture is included and a new theory of fatigue is presented. The formation of cracks is proposed to be due to the backward and forward movement of dislocations in a coarse slip line

(1097) Mott, N F

Effect of Impurities on Dislocation Climb

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 350-352

A mechanism by which impurities can impede climb is proposed, based on the assumption that many impurities will be strongly bound to jogs, more strongly than they are bound to the rest of the dislocation

(1098) Mott, N F

Behavior of Metals Under Reversed Stresses

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 458 178

Current theory of work hardening of metals especially with reference to their behavior under cyclic stress A model is proposed which insures that the Frank-Read sources responsible for slip lines should not generate dislocations of the opposite sign with consequent work softening when the stress is reversed. Model also gives explanation of the existence of fine and coarse slip. Friedel's model of work hardening is extended to explain the formation of multiple slip bands A theory for the formation of a fatigue crack is proposed

(1099) Mott, N F

A Theory of the Origin of Fatigue Cracks

Acta Met 6 (1958) 195-197

A model based on the concept of a cross slip is given to explain how a slip band can develop into a crack if dislocations in the band are free to move backwards and forwards

(1100) Mott, N. F., and Nabarro, F. R N

An Attempt to Estimate the Degree of Precipitation-Hardening, With a Simple Model

Proc Phys Soc. (London) 52 (1940) 86-89

The internal strain resulting from the precipitation of spherical particles in an isotropic matrix is estimated If the process of diffusion is assumed to result in a direct interchange of atoms, the strain depends only on the change in atomic volume and on the elastic properties of particle and matrix. The total strain energy and critical shear stress are found to be independent of the particle size and directly proportional to the precipitated volume.

(1101) Mott, N F , and Nabarro, F R N

Dislocation Theory and Transient Creep

Paper from Report of a Conference on Strength of Solids, Phys Soc , London (1948) 1-19

An explanation of yield and creep phenomena is developed in terms of the stress required to set in motion a small number of dislocations which are assumed to be present in a metal It is shown that if the dislocation line is constrained to move by not more than one atomic distance, it forms a smooth curve rather than a zig-zag. In developing the theory of creep, the new assumption is made that the early parts of the hardening curve are determined by the exhaustion of dislocations The resulting curves are of the form observed primarily at low temperatures and low stresses, as with Pb at -180 and -78 C Slip in solid solutions is also briefly considered

(1102) Muir, H , Averbach, B L., and Cohen, M

The Elastic Limit and Yield Behavior of Hardened Steels

Trans ASM 47 (1955) 380-399

A method of high strain sensitivity was used in investigating the elastic limit and initial yielding of heat-treated steels It is possible to define the elastic limit as a significant property of the material by this method Considerable plastic deformation was observed to precede the yield point in steels which displayed sharp yield points Except when brittle fracture occurs, the yield, tensile, and fracture strengths generally decrease with decreasing hardness as the tempering temperature is raised

(1103) Müller, G

The Stress-Dependence of the Spontaneous Initial Deformation of Face-Centered Cubic Metals (In German)

Ann Physik 17 (1956) 141-145

The instantaneous deformation accompanying the application of load at the beginning of a creep test was studied as a function of applied stress for Ag and Au Wires were formed into helical springs and the maximum shear stress computed from the applied load The curve of spontaneous strain/ultimate tensile strength for Ag and Au was superposable if the scale was suitably adjusted for each The corresponding data for Cu and single-crystal Al [see Kuhlmann and Masing, Z Metallk. 39 (1948) 361] and of Kornfield [Physik. Z. Sowjetunion 10 (1936) 605] were closely superposable on the master curve for Ag and Au, again with adjustment of scales Some data on creep rates of Ag and Au were also obtained

(1104) Müller, G , and Engelhardt, W

The Character of Spontaneous Initial Deformation (In German)

Ann phys 9 ser 6 (1951) 357-362

Study of plastic deformation of Cu wire in the range of low shear stresses Duration of spontaneous elongation is assumed to be functionally related to temperature

(1105) Musgrave, M J P

Fundamental Concepts of Matter in the Solid State

Paper from Chemical Engineering Practice, II Academic Press, New York (1956) 1-67

Shows how the variations of the mechanical properties of solids, both in degree and kind, are closely related to the fundamental crystal structure

(1106) Nabarro, F R N

Strains Produced by Precipitation in Alloys

Proc Roy. Soc (London) 175A (1940) 519-538

The process of precipitation in alloys is discussed with special reference to the strains produced. The strain energy is large, and if the lattice of the precipitate remains continuous with that of the matrix, the energy can only be reduced by a factor of the order of 5 by changes in the shape of the precipitated particles If the lattice of the precipitate breaks away from that of the matrix, so that the stress in the inclusion is a simple hydrostatic pressure, the strain energy tends to zero if the precipitate takes the form of thin sheets. The dynamics of the precipitation, and the surface energy of the precipitate encourage the formation of spherical particles, and by considering these effects a formula is deduced which represents the shape of the particles at any stage in their growth.

(1107) Nabarro, F R N

The Mechanical Properties of Metallic Solid Solutions

Proc Phys Soc. (London) 58 (1946) 669-676

The theoretical relation between lattice strains produced by precipitation in a metal and the corresponding increase in hardness is extended to lattice strain in metallic solid solutions The elastic limit of a single crystal of a solid solution is calculated on the assumption that the crystal will slip when the applied external stress is equal to the mean value of the internal stress Similar considerations are applied to the hardness of poly-crystalline solid solutions The theory is extended to cases in which the increase of hardness produced by alloying is not large in comparison with the hardness of the pure solvent

(1108) Nabarro, F R N

Dislocations in a Simple Cubic Lattice

Proc Phys Soc (London) 59 (1947) 256-272

Using a method of approximation due to Peierls, the properties of dislocations in a simple cubic lattice are calculated. The width of a dislocation is found to be small, and the shear stress required to move a dislocation in an otherwise perfect lattice (Peierls-Nabarro force) is about a thousandth of the theoretical shear strength Further properties, such as the energy of a dislocation, are also considered, and the results discussed in detail, particularly with reference to the relationship between the idealized model and the real crystal

(1109) Nabarro, F R N

Deformation of Crystals by the Motion of Single Ions

Paper from Report of a Conference on Strength of Solids, Phys Soc , London (1948) 75-90

A homogeneous stress exerts no force on a vacant lattice site or interstitial ion, and previous estimates of the rate of deformation of a solid due to the migration of lattice defects under stress must be rejected Surface forces alter the concentrations of defects, and their diffusion from one part of the surface to another leads to a rate of creep dependent on the size of the specimen The assumption of a mosaic structure removes many of the difficulties, but microcreep in tin cannot be thus explained Mechanisms of creep under nonuniform stress and their order of magnitude Creep phenomena to be expected under neutron bombardment

(1110) Nabarro, F R N

Mechanical Effects of Carbon in Iron

Paper from Report of a Conference on Strength of Solids, Phys Soc , London (1948) 38-45

By combining the theories of Snoek and Cottrell with the usual theory of age hardening it is possible to explain several mechanical effects as consequences of the presence of carbon in iron Three mechanisms of diffusion, precipitation hardening, the release of hydrostatic stresses around dislocations by local variation of C concentration, and the release of shear stresses by an ordering of C atoms interstitially around dislocations, are each linked respectively with the phenomena of quench aging, strain aging and delayed yield Deductions agree with experiment The need for further experiment is emphasized

(1111) Nabarro, F R N

The Dislocation Theory of Slip Recent Developments in Britain

Metallurgia 40 (1949) 199-205

Movement of dislocations, transient creep, multiplication of dislocations, solid solutions and precipitation hardening, the bubble model, and interaction of dislocations and dissolved atoms

(1112) Nabarro, F.R N

Influence of Grain Boundaries on the Plastic Properties of Metals

Article from Some Recent Developments in Rheology, United Trade Press, Ltd., London (1950) 38-52

Discusses theory of slip in single crystals, then, the grain boundary as an obstacle to slip. The previous work relating strength of single and polycrystals is reviewed, and an attempt is made to estimate the contribution of the grain boundaries.

(1113) Nabarro, F R N

The Mathematical Theory of Stationary Dislocations

Advances in Physics 1 (1952) 269 394

The various possible types of dislocations are defined and theorems proved about their properties, including their interaction and behavior in motion. The importance of the mechanism for the generation of large numbers of dislocation loops proposed by Frank and Read in the theory of slip-band formation is pointed out The various dislocation models of a grain boundary are included in the discussion of the properties of arrays of dislocations The dependence of the thermal activation energy necessary for creep to occur, upon the applied stress, is considered for various types of dislocation models of the creep process The theory of the properties of elastic dislocations is compared with that of dislocations in crystal lattices, and important differences are pointed out Also discussed is the compression-wave theory of slip proposed by Frenkel and Kontrova [Physik Z Sowjetunion 13 (1938)] and its extensions Finally, those aspects of dislocation behavior which depend upon the particular crystal lattice are reviewed, including those phenomena which have been explained on the basis of dislocation reactions

(1114) Nabarro, F R N.

Deformation of Sodium Chloride Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 235-237

The crystals were strained by compression and by the Bausch-type apparatus to see if the rate of shear hardening could be reduced by enforcing slip on a single system. In order of increasing rate of shear hardening the deformation mechanisms were Bausch deformation and kinking, single slip, double slip, and quadruple slip

(1115) Nabarro, F.R N

Theory of Whisker Dekinking

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 521-536

Several different mechanisms for the straightening on annealing of a single-crystal whisker which has been plastically kinked Analysis shows that the only mechanism of straightening which will explain the high and roughly uniform rate of the process is that of dislocation climb by migration of vacancies or interstitial ions The rate of evolution of vacant lattice sites from jogs in dislocations is only sufficient to maintain this rate of climb if the edges of the dislocations are densely packed with jogs Dislocation glide may account for the rapid initial recovery

(1116) Nádai, A

The Influence of Time Upon Creep – The Hyperbolic Sine Creep Law

Paper from Contributions to the Mechanics of Solids (S Timoshenko, 60th Anniversary Volume) The Macmillan Company, New York (1938) 155-170

Discusses the mechanical theory of plastic deformation at low temperatures and the creep of metals at elevated temperatures. Gives examples of "equations of state" or work-hardening equations The hyperbolic sine creep law is examined and agreement with experiment is shown.

(1117) Nádai, A

The Flow of Metals Under Various Stress Conditions

Proc Inst Mech. Engrs (London) 157 (1947) 121-160

A mathematical treatment of the phenomena associated with the permanent deformations of metals Engineering methods for dealing with finite strains are reviewed and certain new types of strains that offer possibilities for expressing the stress-strain relations required for this work are introduced. the creep of metals at elevated temperature is mentioned. Experimental work carried out on the flow of Cu is described

(1118) Nádai, A

Theory of Flow Fracture of Solids, Ud. 1, 2nd Ed

McGraw-Hill Book Co , New York (1950) 572 pp

New chapters discuss the theories of simple and composite substances based on the types of strains – elastic, permanent, or a combination of both – and on the types of laws of deformation postulated Treatment includes metals

(1119) Nádai, A

Strain-Hardening and Softening with Time in Reference to Creep and Relaxation in Metals

Trans ASME 74 (1952) 403-413

An analysis is given of the influence of strain hardening, the time rate of change of flow resistance, and the recovery strain on the creep and relaxation of a metal under uniaxial stress. The treatment does not consider the structural changes occurring in the metal during creep, but examines the relationships between stress, elastic strain, permanent strain, the rate of permanent strain, and the time at a given temperature A series of analytical equations are derived for both a complete and a simplified equation of state.

(1120) Nadai, A , and McVetty, P G

Hyperbolic Sine Chart for Estimating Working Stresses of Alloys at Elevated Temperatures

Proc ASTM 43 (1943) 735-745

To reduce the time required for creep testing and for determining the creep properties of alloys, tests are conducted at stresses higher than those used in service In this paper, a method of plotting results of creep tests in a new manner is suggested which departs from the usual double logarithmic plots of stress and minimum creep rate The method is based on the hyperbolic sine function for expressing the dependence of the rate of flow on the stress The new chart and its construction from one single curve is described Examples illustrate its application to a variety of materials to obtain estimates of stress for specified low creep rates

(1121) Nathans, M W , and Parker, E. R

The Significance of 'Activation Energy' as Applied to Creep

Progress Report, U S AEC Publ (COO-18) (1950) 22 pp

Summarizes the activation energy relationships for several different phenomena and points out the significance of a linear relationship between ln (rate) and (1/T) The application of these concepts to the creep of metals is then presented, the discrepancies and objections being considered. It is concluded that it is possible to postulate a meaningful "activation energy" which coincides with the expression $\frac{RT^2 d \ln (\text{rate})}{dT} = -\frac{R d \ln (\text{rate})}{d(1/T)}$ for chemical reactions, viscous flow of simple liquids, etc In the case of plastic deformation of metals, it is not yet possible to give such a simple and unambiguous definition of activation energy which ties in, in a simple way, with experiment

(1122) Nathans, M W , Parker, E. R , and Hazlett, T H

Some Considerations Concerning the Strain-Hardened State of Metals

U S AEC Publ (COO-11) (1950) 20 pp

The theories relating the plastic flow are discussed, and it is postulated that the expression for the temperature coefficient of plastic deformation may contain an important term which is related to the strain-hardened state of the material, the magnitude of which cannot be evaluated easily. Predictions are made as to the effect of stress and temperature which are in disagreement with the nucleation theory of slip bands due to Leschen, Carreker, and Hollomon [Trans AIME, 180 (1940) 131] but in agreement with the results of Carreker, Leschen, and Lubahn (ibid., p139)

(1123) Němec, J

The Strength of Materials (In Czech)

Hutnické listy 11 (1956) 583-592

Theoretical and practical aspects of ductile, brittle, and fatigue fractures are discussed. Heterogeneous stress distributions, surface, and size effects are also considered

(1124) Němec, J.

Plastic Deformation of Steel (In Czech)

Hutnické listy 12 (1957) 315-324

Fundamental questions concerning the possibility of calculating plastic deformation in inhomogeneous materia; examines static strength of ductile steels from fundamental physical deformation values of ferrite; discusses the mathematical bases as well as conclusions of the theory of instantaneous states in plastic deformation, and the theory of plastic deformation velocity; the results indicate the range of validity and applicability of the theory of instantaneous deformation states in plastic steels

(1125) Neurath, P W , and Koehler, J S

The Plastic Deformation of Pure Single Crystals of Lead and Copper

J Appl Phy 22 (1951) 621-626

Single crystals of pure Pb and Cu were grown by the Bridgman method. A tensile-creep apparatus is used Measurements on Cu at 23 and -190 C show that for resolved shearing stresses below 0 6 kg/mm², steady-state creep is negligible Measurements were also made of the steady-state creep of Pb at 25 and 110 C Results produced by annealing were investigated

(1126) Nichols, R. W

The Hardness of Some Carbon and Low-Alloy Steels at Low Temperatures

J. Iron Steel Inst 182 (1956) 348-354

In order to determine the effects of low temperature on various proposed relationships between hardness and tensile properties, tests were made at +18, -70, and -196 C The CPH number was approximately proportional to the tensile stress at 8% strain throughout these tests At all temperatures, stress/strain curves calculated from the ball hardness results showed good agreement over the range 4 to 8% strain with comparable curves obtained directly in tension tests.

(1127) Nield, B. J , and Quarrell, A G.

Intercrystalline Cracking in Creep of Some Aluminum Alloys

J. Inst Metals 85 (1957) 480-488

Two high-purity Al alloys containing 1 28 and 5 15% Mn were studied Constant-strain-rate method of deformation was employed. General theory of intercrystalline cracking is proposed

(1128) Nikitina, L. P

Determination of Creep Limit Accounting for the Plastic Properties of Materials (In Russian)

Tsentral. Nauch. Issledovatel Inst. Tekhnol. i Mashinostroen 79 (1957) 189-197

Structurally acceptable deformation is based on introducing into calculations the characteristics of the first two periods of creep. The method permits a better utilization of materials and prevents failures caused by the exhaustion of their plasticity

(1129) Nikitina, L. P.

Relation Between Deformation and Time During the Second Period of Creep (In Russian)

Tsentral Nauch. Issledovatel Inst Tekhnol i Mashinostroen. 79 (1957) 175-188

Analysis of the properties of the 2nd period of creep for different materials gave the relation in the first approximation as $\theta_2 = (v_o/v_{min})\,\phi$, where θ_2 is time of the 2nd period, v_{min} is the creep rate, and $\phi = 1/tg\,\alpha$ (α being the angle of inclination of the curve of this period to the horizontal) The ϕ characterizes the stability of the plastic state The relation permits the determination of the amount of available plasticity and the permissible useful life at a given creep rate.

(1130) Nikolaeva, S M., and Umanskii, Ia S.

Determination of Characteristic Temperatures and Distortions of the Lattice in Several High-Melting Metallic Compounds and Their Solid Solutions (In Russian)

Izvest Akad Nauk S.S.S.R. Ser. Fiz. 20 (1956) 631-635

Strength of interatomic bond in crystal lattice of TiC. Relation of crystal-lattice distortions, diffusion and microhardness to composition of Co-Al and Ni-Al

(1131) Nishihara, T., Taira, S , and Tanaka, K.

Creep of Mild Steel

Tech. Rept. No. 32, Engr Research Inst , Kyoto Univ. 6 (August 1956) 99-125

Creep behavior was studied under constant tensile stress By the rheological analysis of the creep strain, a formula which represents stress-strain-time relation is introduced By using the formula, tension test results, bending creep test results and creep test results under combined stress are interrelated with the data of tension creep test. In the case of creep under constant stress, the experimental results obtained concerning the relation of strain ϵ, to stress σ, and time t, are well represented by the empirical formula $\epsilon = \alpha\sigma^k + \beta\sigma^m t^n$, where α, β, k, m, and n are constants

(1132) Nishihara, T , Taira, S., Tanaka, K , and Koterasawa, R

Investigation on the Dynamic Creep Rupture of Materials (In English)

Proc Sixth Japan. Natl Congr Appl. Mech. (1957) 221-224

Analysis of stress-range diagram of dynamic creep rupture on basis of results concerned with fracture of low-C steel at elevated temperature under alternating stress

(1133) Nishihara, T , Taira, S , Tanaka, K , and Onami, M.

Primary Creep of Mold Steel (In Japanese)

Trans. Japan Soc Mech Engrs 23 (1957) 154-159

An empirical formula is introduced concerning the relation between transient creep rate, stress, and temperature

(1134) Nishimura, H , and Takamura, J -I

Role of Deformation Bands in the Plastic Deformation of Metallic Single Crystals (In English)

Tech Rep. Engr Res Inst Kyoto Univ 2 (1952) 139-169

The tensile deformation of single crystals of Al and Cu was studied experimentally, and the results are used to discuss: (1) the part played by crystallographic orientation in the development of deformation bands, (2) the origin of X-ray asterism, (3) the precise determination of inhomogeneous crystal rotation within a deformed single crystal, (4) the correlation between the development of deformation bands and crystal twisting during plastic extension, and (5) the stress/strain curves of extended single crystals in various stages of deformation.

(1135) Noggle, T S , and Koehler, J. S

Electron Microscopy of Aluminum Crystals Deformed at Various Temperatures

J Appl Phy 28 (1957) 53-62

Al single crystals grown from the melt, and by strain and anneal, were deformed in tension at 4 2, 78, and 295 K Deformation at 4.2 K, observed by electron microscopy, produced fine slip and gave rise to a linear stress/strain curve At 78 K, deformation resulted in a very slow development of a slip-band structure, but the majority of the strain was produced by fine slip, and gave rise to a slightly curved parabolic stress/strain curve At 295 K, deformation produced a prominent slip-band structure, and a uniformly distributed fine-slip structure, and gave rise to a parabolic stress/strain curve. The stress/strain curves were orientation dependent at all temperatures.

(1136) Noggle, T S., and Koehler, J S

Observations on Slip in Aluminum

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 208-214

Deformation of pure Al was performed at 4, 78, and 295 K. At 4 K, the curve above 0 1 shear strain is approximately straight; at 78 K, the curve begins to show stage III; at 295 K, the entire region seems to be in stage III of work hardening

(1137) Nowick, A S , and Machlin, E. S

Quantitative Treatment of the Creep of Metals by Dislocation and Rate-Process Theories

NACA Rept No. 845 (1946) 10 pp

An equation for the steady-state rate of creep is derived by applying the theory of rate processes and dislocations to the creep of pure metals The form of this equation is in agreement with empirical equations describing creep rates. The theory was also used to predict the dependence of steady-state rate of creep on the physical constants Good agreement with data in the literature for pure annealed metals was obtained.

(1138) Nowick, A S , and Machlin, E. S.

Dislocation Theory as Applied by NACA to the Creep of Metals

J Appl Phy 18 (1947) 79-87

An equation for steady-state creep rate in terms of a specific dislocation mechanism in which the generation of dislocations is assumed to be a rate process The theory considers a specific process for the formation of a dislocation one atom long under shear stresses An equation is developed for the shear rate u' in terms of Rg, the rate of generation of dislocations for a single generating source, which is assumed to be a single mosaic block The tensile creep rate u is taken as approximately equal to u' and the rate of generation of positive and negative dislocations (Rg^+ and Rg^-) is calculated in terms of the formation process, regarding this as a typical "rate process" in which an activated complex, produced by thermal fluctuations, surmounts an energy barrier to produce the dislocation. Subject to several assumptions, an equation for the steady creep rate is calculated, and compared with the experimental results available

(1139) Nowotny, H , and Reichel, H

Contribution to the Problem of Bonding in Solids

Powder Met Bull 7 (1956) 130-133

Effect of chemical bonding on X-ray spectra was used to determine the bonding character in different alloys X-ray emission as well as absorption spectra can serve for this purpose

(1140) Nutting, P G

A Study of Elastic Viscous Deformation

Proc ASTM 21 (1921) 1162-1171

A new relation between strain, s, stress, F, and time, t, is obtained: $s = at^nF^m$, where a, n, and m are constants This is of such generality as to include as special cases the relations ordinarily assumed to hold for elastic solids (n = 0 and m = 1) and for viscous fluids (n = 1 and m = 1)

(1141) Nutting, P G

Deformation in relation to Time, Pressure, and Temperature

J Franklin Inst 242 (1946) 449-458

Linear logarithmic relations between deformation, temperature and pressure have been directly derived from the defining equations for compressibility and thermal expansion Gibb's thermodynamic potential is shown to lead directly to simple exact expressions for the energy of change of phase and of deformation within any one phase including both elastic and viscous behavior The derived deformation and energy functions are applied to some experimental data on steel, one which include thermal and relaxation observations

(1142) Nygren, E

The Creep of Metals (In Swedish)

Jern Ann 139 (1955) 182-201

Literature survey regarding the creep of metals

(1143) Oding, I A

Interpretation of the Coefficient of Strength of Metals (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk (December 1947) 1713-1719

Coefficient is derived from Nadai's equation for plastic deformation It is assumed to be a composite value composed of modulus of elasticity and coefficient of relaxation

(1144) Oding I A

The Role of "Dislocation" in the Process of Creep (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk (December 1948) 1795-1802

Analyses all possible mechanisms for strengthening and weakening of metals during creep on the basis of the theory of dislocation Application of this theory is said to resolve certain controversies concerning the mechanism of the creep process Describes an additional mechanism of weakening caused by "dislocation" of the strength of metals

(1145) Oding, I A

Relaxation and Creep of Metals Considering Non-uniform Distribution of Stress (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk (October 1948) 1461-1575

Investigation assumed that plastic deformation proceeds by means of diffusion plasticity in the initial sections of the curves of creep and relaxation On the basis of the diffusion equation, formulas are proposed for initial sections of relaxation and creep curves, corresponding well with experimental data

(1146) Oding, I. A

Contemporary Views on the Mechanisms of Plastic Deformation and Fracture During the Creep of Metals (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk (1958) 110 118 (Battelle translation no. 55R22)

Survey of the current theories of creep and stress relaxation in metals Concludes that no generally acceptable theory exists

(1147) Oding, I A.

Dislocation Theory of Metal Fatigue (In Russian)

Doklady Akad Nauk S S S R 105 (1955) 1238-1240

Decisive factor for fatigue phenomenon is intensity of formation of vacancies Higher concentration of vacancies aggravates processes of coagulation and void growth

(1148) Oding, I A

An Interpretation of the General Equation for the Creep of Metals (In Russian)

Doklady Akad Nauk S S S R 116 (1947) 66-69

Derivations of fundamental equations of creep curves experimentally established for creep with constant, diminishing, or increasing rates

(1149) Oding, I A

The Structural Theory of Metallic Creep (In French)

Rev mét 55 (1958) 448-452

Starting from the dislocation concept, a structural theory of metallic creep is developed according to which the creep rate depends on the number of dislocations ready to begin movement A general equation for the creep curve, in agreement with experimental data, is derived from this

(1150) Oding, I A , and Burdukskii, V V

The Process of Deterioration in Metals During Creep (In German)

Paper from Deformation and Flow of Solids, Edited by R Grammel, Springer-Verlag, Berlin (1956) 298-303

The concept of defects in the crystal lattice and the role of dislocations are treated in problems of hot strength Expression is derived, based on coagulation of vacancies into micropores that agrees with experimental results

(1151) Oding, I A , and Burdukskii, V V

The Third Period of Stress Relaxation Curve

Zavodskaya Lab 23 (1957) 843-845

General discussion of existence of a third period of stress relaxation similar to a well-established third period of creep.

(1152) Oding, I A , and Ivanova, V S

Investigation of Local Plastic Deformation Under Active Tension (In Russian)

Izvest Akad Nauk S S S R , Otdel Tekh Nauk no 1 (1953) 96-105

Distribution of plastic deformation along a tensile specimen was investigated by X-rays Local deformation decreased with an increase of total deformation

(1153) Oding, I A , and Ivanova, V S

Some Characteristics of Diffusion Plasticity in the Relaxation of Stresses in Metals (In Russian)

Izvest Akad Nauk S S S.R , Otdel Tekh Nauk no 5 (1954) 81-90

The relaxation of stresses in metals takes place as a result of diffusion processes (occurring chiefly across grain boundaries within the first few hundred hr from the moment of application of stresses) and mechanical processes (slipping and turning of blocks) which contribute to the relaxation of stresses for a very long time from the moment of their application The experimentally determined relation between the coefficient of intergrain stability and temperature for various steels is in agreement with the equation derived by assuming the diffusional character of plastic deformation in the first stage of relaxation This relation can easily be obscured by phase changes, e g , aging of metals

(1154) Oding, I A , and Ivanova, V S.

Analysis and Application of Certain Creep Criteria (In Russian)

Bull Machine Constr no. 5 (1955) 62-66

Starting from the known approximate relationships (1) $\nu_p = P\sigma^p$ and $t_{life} = D\sigma_{en}^{-d}$ in which ν_p = creep rate, σ = stress, t_{life} = rupture time; σ_{en} = endurance limit Authors represent the characteristic of heat resistance $\epsilon_r = \nu_p t_{life}$, called the plasticity resourse, in the form (2) $\epsilon_r = PDp/d\, t_{life}(1-p/d)$ Values of the coefficients P, p, , d are calculated according to creep limits, and the endurance for steels between 470 - 700 C are given The value of these coefficients for various types of steels varies within very wide limits The plasticity resource according to Equation (2) characterizes both the capacity of the metal to resist deformation and the duration of its life Therefore, it is expedient to choose the amount of strength for machine parts under creep conditions according to the value ϵ_r For steel, authors consider the best combination of characteristics of creep and endurance one in which the value of ϵ_r exceeds the value of the permissible deformation 2 or 3 times.

(1155) Oding, I A , and Ivanova, V S

Interdependence of the Heat Resistance Criteria (In Russian)

Teploenergetika no. 1 (1955) 24 27

Basic criteria are creep limit, rupture strength, and plasticity resource Discuss Larson-Miller parameter and offer a new equation for extrapolation of stress-time dependence in long-time creep tests The main task of the heat resistance theory is to establish a relationship between the above criteria and to determine the interdependence of these criteria

(1156) Oding, I A , and Ivanova, V S.

Process of Metal Destruction During Creep (In Russian)

Doklady Akad Nauk S S S R 103 no 1 (1955) 77-80 [see Metal Progr (March 1956) 158, 160, 162]

A new interpretation of the process which begins from diffusion of vacancies into "colonies" of micropores, transformation of micropores into microfissures and continuous growth of microfissures resulting in cracks

(1157) Oding, I A , and Ivanova, V S

Generalized Diagram of Creep Criteria Plotted in the Light of the New Relations Among Stresses, Creep Rate, and Life of the Metal (In Russian)

Iss po Zhar Splav Akad Nauk S S S R (1956) 52-59

Long-time creep behavior is better expressed by the equation $t = Be^{-\beta\sigma}$, where t is the life, B and β are constants, and σ is applied stress With its use, a 2000-3000-hr test can be accurately extrapolated to 100,000 hr This is illustrated by actual tests Deviations from its results are possible when the failure of a sample is associated with a high plasticity Available plasticity, ϵ, is given as $\log \epsilon = (1 - \alpha/\beta) \log t$ + constant, where α is a constant A clear picture of creep characteristics is given by placing side by side semilog diagram for stress versus creep rate, stress versus life, and in a log diagram available plasticity versus life

(1158) Oding, I A , Sorokin, O. V , and Sazanova, N D.

Relation Between Creep and Relaxation of Stresses in Metals (In Russian)

Doklady Akad Nauk S S S R 92 no 3 (1953) 565-568 (NSF Translation 152)

If one dimension of a sample is maintained constant, then relaxation can be described as the conditions $\epsilon_o = \epsilon_{elastic} + \epsilon_{plastic}$ and the stress at time t $\sigma(t) = E\,[\epsilon_o - \epsilon_{plastic}(t)]$, and thus relaxation is creep occurring under a stress decreasing with plastic deformation If the processes of creep curve from relaxation data (and vice versa) The examination of creep and relaxation curves for an austenitic Cr-Ni steel in three states of heat treatment gave a qualitative agreement, thus confirming the similarity of the processes It is suggested that previous ideas, that certain steels behave well in creep but not in relaxation, are due to incorrect choice of criteria for comparison.

(1159) Oding, I A , Sorokin, O. V , and Savonova, N D.

Relation Between Phenomena of Creep and Stress Relaxation in Metals (In Russian)

Doklady Akad. Nauk S S.S R. 92 (1953) 565-568

Tests for creep and relaxation of austenitic chrome-nickel steel after three separate heat treatments

(1160) Odquist, F.K G

Recent Advances in Theories of Creep of Engineering Materials

Appl. Mechanics Revs 7 (1954) 517-519

Refinements in theoretical treatment of primary creep in terms of engineering mechanics Analytical expressions for describing the creep curve Examples are given of equations by F H Norton, dε/dt = kσ n R W Bailey, dε/dt = KσP, -q, and by the author, ε = ε(o) + kσ n t where ε = strain, t = time, σ = stress, and the other terms are constants

(1161) Odquist, F K G

Engineering Theories of Metallic Creep

Paper in Symposium su la Plasticita nella Scienza delle Construzioni Varenna (September 1956) 12 pp

Defends the need for phenomenological research until such time as theories of creep, probably based on the dislocation concept, can give more than an order of magnitude answer Discusses equations for stable and non-stable materials, constant and variable temperature and stress conditions, and an alternate theory Considers "equations of state" and their limits of application

(1162) Ohara, H

Creep of Oxygen-Free High-Conductivity Copper I Experimental Results and Metallurgical Aspect II Mechanical Metallurgy of Creep (In English)

Nippon Kinzoku Gakkaishi 20 (1956) 100-108

(I.) Creep properties of OFHC Cu and six dilute Cu-Ag alloys were studied in a N atmosphere at constant tensile stress in the temperature range 193-767 C Nonrecrystallized specimens showed a higher creep rate than annealed specimens; recrystallized specimens had a higher initial extension and a lower creep rate; after secondary recrystallization, a specimen showed a high creep rate The presence of Ag increases the resistance of Cu to creep. Cold-worked and coarse-grained samples had higher creep-rates than annealed samples Microstructures of the specimens used are shown (II) The data obtained are analyzed by using the relation $\epsilon - \epsilon_0 = Ct^n$, ϵ being the elongation in time t, and ϵ_0, n, and C are constants C is shown to be temperature and stress-dependent, and Q = 39 4 kcal/mol

(1163) Okada, M., and Fujita, H

On the Fracture of Aluminum Polycrystals (In English)

Osaka Univ Tech. Rept 6 (1956) 329-344

Nature of fracture studied in terms of the stress rate (loading speed) With an increase in loading speed the spacing of slip bands and the number of fine structures in each slip band are decreased, but the elastic limit, the rate of strain hardening, the heterogeneity of deformation in short range, the interaction of adjacent grains, the rate of fragmentation, the necking stress and the homogeneity of deformation all over the specimen are increased

(1164) Oldroyd, J G

On the Formulation of Rheological Equations of State

Proc Roy Soc (London) 200A (1950) 523-541

The invariant forms of rheological equations of state for a homogeneous continuum, suitable for application to all conditions of motion and stress, are discussed The right invariance properties can most readily be recognized if the frame of reference is a co-ordinate system convected with the material, but it is necessary to transform to a fixed frame of reference in order to solve the equations of state simultaneously with the equations of continuity and of motion An illustration is given of the process of formulating equations of state suitable for universal application, based on non-invariant equations obtained from a simple experiment or structural theory Anisotropic materials, and materials whose properties depend on previous rheological history, are included within the scope of the paper

(1165) Olds, G C E

Creep Curve for a Precipitation-Hardened Alloy

Nature 172 (1953) 999

Creep at various temperatures in a polycrystalline precipitation hardened Cu-3% Ag alloy heat-treated to give a Widmanstätten structure of maximum hardness and stability Three mechanisms of creep are distinguished, depending on the test temperature

(1166) Olds, G C E

Mechanisms of Creep in a Precipitation Hardened Alloy

Proc Phys Soc (London) 67B (1954) 832-842

The transient creep of a Cu-3% Ag alloy was measured over the temperature range 100-300 C, under constant stresses of 1-6 kg/mm^2 The alloy was solution-treated and then slowly cooled to give a Widmanstätten structure, which possessed a high hardness value At 100 and 150 C, the creep strain ϵ, obeyed the law $\epsilon = \alpha \log t + \delta$, but at higher temperatures (200 and 250 C), a new component appears, giving $\epsilon = \alpha \log t + \beta t^{1/3} + \gamma t + \delta$, at still higher temperatures, the γ term is dominant and the α term negligible The values of the transient-creep constants α and β, and the quasi-viscous term γ are determined The results are compared with those of Wyatt (ibid 66B (1953) 459), and the α, β, and γ terms related to possible deformation processes

(1167) O'Neill, H

The Hardness of Metals in Relation to Atomic Structure

Metallurgia 29 (1944) 243-247

The characteristics which determine hardness properties of metallic materials is given, special reference being made to the metallic atom, to the elastic compressibility of metallic crystals, and to indentation hardness and atomic spacing The mechanism of metallic cohesion, atomic sturcture, electron concentration, and reciprocal compressibility ("elastic hardness") of metallic alloys particularly solid solutions, are considered in relation to the hardness

(1168) Ookawa, A

Mechanism of Deformation Twins in Face-Centered Cubic Crystals

J Phys Soc Japan 12 (1957) 825

A mechanism is suggested to explain the apparent twin with (111) as twinning plane, observed in Cu at low temperatures This is referred to as the Cottrell-Lomer barrier

(1169) Opinsky, A J

A Crystallographic Analysis of the Ductile-Brittle Transition in Body-Centered Cubic Single Crystals

Trans. AIME 197 (1953) 1650-1651

The laws of critical normal stress for cleavage and critical shear stress for slip is applied to explain the orientation and temperature dependence of the ductile-brittle transition in bcc metals It was found that within a certain temperature range, single crystals tested in tension will cleave or slip, depending on their orientation Some data recently appearing in the literature are analyzed from this standpoint

(1170) Opinsky, A , and Smoluchowski, R

Clustering Phenomena in Solid Solution

Phys Rev 74 (1948) 343

The fundamental principles of the phenomena, especially as applied to metallic solid solutions, and particularly to Ag-Cu alloys Observed structures are explained on a theoretical basis; and it is stated that other metallic solid-solution phenomena can be explained similarly, for instance, the influence of Si on the mechanism of deformation of alpha-Fe, and the precipitation of Fe_4N from alpha-Fe

(1171) Opinsky, A J , and Smoluchowski, R.

The Crystallographic Aspect of Slip in Body-Centered Cubic Single Crystals I Theoretical Considerations

J Appl. Phy 22 (1951) 1380-1384

The mechanism of slip in bcc lattices is considered in terms of the relation between the orientation of the tensile axis and the active slip system. An expression is derived for the resolved shear stress for a crystal with a tensile axis at a particular point in the unit stereographic triangle This is applied to the observed systems of bcc metals The results of varying the ratios of critical resolved shear stresses on the three planes are discussed, and it is shown how these ratios may be simply derived by testing in tension a series of crystals with orientations at different points along the [001] – [011] zone and finding where the change-over from one slip plane to another occurs

(1172) Opinsky, A J , and Smoluchowski, R

The Crystallographic Aspect of Slip in Body-Centered Cubic Single Crystals II Interpretation of Experiments

J Appl Phy 22 (1951) 1488-1492

A new method for determining the ratios of critical shear stresses was applied to data taken from the literature and to original results Measurements of yield strength were found to be not too satisfactory for the investigation of the slip behavior of bcc materials On the other hand, any method which determined the slip plane and the orientation of the tensile axis gave useful results

(1173) Orowan, E

On Crystal Plasticity I Low-Temperature Plasticity and Becker's Formula (In German)

Z Physik 89 (1934) 605-613

The formula by R Becker for the flow rate of single crystals yields a temperature-dependence of the yield point, which is in quantitative agreement with measurements on Zn and Cd crystals down to the lowest temperatures The theory of Griffith for the low technical shear strength due to the effect of small material defects, and Becker's thermal conception of plastic flow, mutually supplement each other Crystal plasticity arises essentially through the cooperation of material defects and thermal stress fluctuations

(1174) Orowan, E.

On Crystal Plasticity. II. The Dynamic Conception of Crystal Plasticity (In German)

Z. Physik 89 (1934) 614-633

The usual "static" conception of crystal plasticity which – proceeding from the technical tension curve – regards the shear stress as a definite function of the shear, is unable to describe without contradiction the flow phenomena and other time effects of plastic deformation In order to explain flow as "recovery flow", recovery rates, e g., were necessary which exceeded the usual by orders of magnitude. On the other hand, the "dynamic" conception, which views the glide rate as a definite function of the shear stress, and which belongs also to Becker's theory, allows a satisfactory description of the available facts Also, it shows without further assumptions, that the steep rise of the initial portion of the stress-strain curve can be an apparent strengthening, just as the observable lowering of the yield point after a short-time interruption of the test can be an apparent recovery, which are simulated through the kind of test method employed

(1175) Orowan, E.

On Crystal Plasticity III About the Mechanism of the Glide Process (In German)

Z Physik 89 (1934) 634-659

Through suitable preparations of Zn crystals, their tension curve can be converted to one of irregular jumps, thereby it often occurs that a tension curve obtained after a fixed amount of recovery – contrary to the previous ideas on strengthening and recovery – begins at higher stress or also proceeds throughout a higher stress than the highest stress of the previous tensile test This phenomenon, like the irregular elongation in general, depends on the difficulty of formation of the first "local glide"; it resembles the difficulty of nucleus formation in phase transitions, since the introduction of the slightest glide produces an avalanche-type accelerated glide In one case the crystal could be loaded for several minutes 30 per cent over its (otherwise well reproduced) yield point, without the traces of observable elongation remaining From these and previously investigated material, conclusions were drawn on the formation and propagation of the glide process as well as on the relation of the macroscopic glide to the physically uniform "elementary" glide processes Finally, a summary of the new conception to crystal plasticity is given

(1176) Orowan, E.

Discussion on Plastic Flow in Metals

Proc Roy. Soc. (London) 168 (1938) 307

Discusses the rate of plastic flow as a function of temperature and of the energy barrier He concludes that on applying a load, gliding starts at places with a high local stress (primary creep), it becomes increasingly checked by the mutual hindrance of the crystal grains, by the interference of different sets of active glide planes, and to a smaller extent by the deterioration of the lattice in the glide zone Finally, plastic deformation can only proceed according to the rate at which these obstacles are removed by atomic rearrangement activated by thermal agitation (secondary creep)

(1177) Orowan, E.

Discussion to paper by J J Kanter

The Problem of the Temperature Coefficient of Tensile Creep Rate

Trans AIME 131 (1938) 411-413

Explains the reasons for the discrepancy noted by Kanter when applying secondary creep data to the Becker-Orowan equation for plastic glide Ideal secondary creep cannot depend on the rate of gliding, which would be exhibited in a freely gliding crystal, but only on the rate at which the obstacles to gliding are removed by thermal agitation.

(1178) Orowan, E

Problems of Plastic Gliding

Proc Phys Soc (London) 52 (1940) 8-22

It has been shown that true flow can occur in metal crystals in the absence of thermal softening; extensometers for the investigation of plastic gliding must therefore be designed to allow the load to be kept constant and uninfluenced by extension of the specimen or by inertia effects The experimental evidence for the dislocation theory of flow is presented (e g , thermal hardening in Zn, strain softening in Fe) and the origin, rate of production, and rate of movement of dislocations are treated

(1179) Orowan, E

Origin and Spacing of Slip Bands

Nature 147 (1941) 452-453

A simple explanation of the uniform spacing (0 5-10 microns) of the slip bands on plastically deformed crystals is advanced. It is shown that a patch of slip inhibits further slip in a zone on each side of it by annihilating the stress there, and that the minimum spacing d of the bands is given by the approximate relation σd = 1/2 Ga, where σ is the shear stress producing the elastic strain σ/G (G is the modulus of shear), and a is the atomic distance The relative constancy of G/σ for various materials explains the observed uniformity of slip spacing It is also pointed out that the spacing of the slip planes is the spacing of the parallel lattice planes enlarged in the ratio of the molecular shear strength to the actual shear stress

(1180) Orowan, E.

A Type of Plastic Deformation New in Metals

Nature 149 (1942) 643-644

Single-crystal wires of Zn and Cd in which the glide plane (0001) is parallel to the wire axis collapse on axial compression with the formation of kinks with sharp ridges and regular curvatures. Examination shows that this does not represent ordinary glide or twinning, but a combination of flexural glide (continuously bent glide lamellae) with sharp bending of glide lamellae. The distinction between ordinary glide and the observed kinking is discussed, and an equation, which may be checked by X-ray experiments, is deduced for the spacing of the glide lamellae in the plane of kinking. In some cases, it is easy to confuse kink bands, produced by short bending of lamellae, with genuine glide bands, and it is possible that glide may begin in many or in all cases with kinking Once a kink band has been formed, further deformation may take the form of a broadening of the band rather than glide across the band. such band-broadening has been observed with Cd crystals

(1181) Orowan, E.

Notch Brittleness and the Strength of Metals

Trans Inst Engrs Shipbuilders Scot 89 (1946) 165-204 205-215

Metals fail in four ways brittle fracture, ductile fracture (fibrous), ductile fracture (shear), and treacle-type rupture. The first two are those upon which most work has been done. Simple derivations are given of the relations that (1) the theoretical strength of the materials is $\approx\sqrt{(E\alpha/a)}$ (2) on the Griffith's crack theory the actual strength is $\approx\sqrt{(E\alpha/c)}$, where E is Young's modulus, α is the surface energy, a is the interatomic distance, and c is the length of the most dangerous crack These relations give an adequate picture of brittle fracture, and of the increase in strength when tension in the surface layers is avoided. Ductile materials yield by plastic deformation before the brittle strength is reached, and at least two conditions have to be satisfied: the shear strain energy must exceed a critical value, and a crack must start

(1182) Orowan, E

The Creep of Metals

J West Scot. Iron Steel Inst 54 (1946-1947) 45-96

The creep strain/time curve is described and its various stages are analyzed. The acceleration is a result of the rise in stress due to a decrease of cross-sectional area which may be brought about by either the contraction of the specimen or the formation of intercrystalline cracks Hence, the results of tensile creep tests cannot be applied to creep in compression, bending, or torsion When the test is carried out under a constant stress, there is a transient and a quasi-viscous component of creep, and at high temperature and prolonged straining the creep is mainly of the latter type. Kinds of disorder that are important sources of quasi-viscous creep are lattice misfits at grain boundaries, lattice distortions due to plastic deformations, etc , and viscous flow proceeds by thermal agitation. After considering the theories associated with creep, the deceleration of transient creep is explained, finally reference is made to the rapid transient creep of Cd and Zn crystals at 1 2 K "Microcreep", as observed in Sn crystals at very low stresses, is also described

(1183) Orowan, E.

Classification and Nomenclature of Internal Stresses

Paper from Symposium on Internal Stresses in Metals and Alloys, Inst Metals, London (1948) 47-59

The main types of internal stress are reviewed; they fall into two groups: (1) body stresses, arising from (usually macroscopic) nonuniformities of external (mechanical, thermal, or chemical) influences acting upon the body: and (2) textural stresses, due to textural (usually microscopic) inhomogeneities which may either be present in the material initially, or produced by plastic deformation or structural changes. Attention is directed to the possibility of investigating textural stresses in transparent single crystals or polycrystalline materials by means of polarized light

(1184) Orowan, E.

Fracture and Strength of Solids

Paper from Reports on Progress in Physics, 12 (1949) 185-232

The main types of fracture and the corresponding fracture mechanism Ultimate stress and necking, brittle fracture, ductile fractures and notch brittleness, fatigue, intercrystalline fracture, and fracture by molecular sliding

(1185) Orowan, E.

The Dynamics of Slip (In English)

Paper from L'Etat Solide, Rept 9th Solvay Conf Edited by R Stoops Brussels (1952)

The basic theoretical problems posed by the existence of crystal plasticity are reviewed, and the dislocation concept is chosen as the theoretical key by a process of elimination. The Frank-Read "dislocation source" is regarded as being typically anchored by a cross-slip segment in a dislocation line Effective multiplication of dislocations, producing slip on parallel slip planes, not far apart, is proposed as being due to the deviation of part of a rapidly moving dislocation line into an inclined slip plane (not necessarily a cross-slip plane) and back into a plane parallel to the original one Slip can then spread in this new plane Theoretical reasons for expecting such deviations of rapid dislocations are advanced, as are analogies from fractographic data The existence of a defined yield stress and strain hardening are interpreted with special reference to this model

(1186) Orowan, E.

Creep in Metallic and Non-Metallic Materials

Paper from Proceedings of the First U.S. National Congress of Applied Mechanics (1952) 453-472

Survey of creep phenomena. Viscous, elastic, and plastic creep are covered as well as the calculation of stress and strain fields in bodies under creep conditions. Disproves the validity of the mechanical equation of state and points out the flaw in the exhaustion theory of transient creep.

(1187) Orowan, E.

Fundamentals of Brittle Behavior in Metals

Paper from Fatigue and Fracture of Metals, Mass. Inst Technol., Cambridge, Massachusetts (1952) 139-167

After review of the classical theory of notch brittleness, it is suggested that brittle fracture with spontaneous crack propagation can be derived from the Griffith fracture condition by replacing surface energy by the plastic work/unit area of fracture-surface localized in a thin surface layer The critical crack arises during the test as a fibrous crack at the notch tip. Brittle fracture can occur at a much lower stress, if the test-piece contains a longer sharp crack; if the crack is many times longer, the brittle fracture may need no plastic constraint, and so can occur without substantial plastic deformation. The transition temperature of a structure may be lower than that of a Charpy specimen or higher than that of a wide-plate specimen, according to the notches and cracks present

(1188) Orowan, E.

Discussion to "Mechanical Strength and Creep in Metals" by N F Mott

Paper from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc., New York (1952) 191-196

Refutes Mott's "exhaustion theory" of creep. Quotes the experimental results of Davis and Thompson [Proc Phys Soc 63B (1950) 847] which show a deviation of 10^{-8} to 10^{-9} times the theoretical results using "exhaustion" model of creep. Presents a model of transient creep that conforms to experiment.

(1189) Orowan, E.

Dislocations and Mechanical Properties

Paper from Dislocations in Metals, Edited by M. Cohen, Am. Inst. Mining Met Engrs , New York (1954) 69-195

The historical development of dislocation theory is presented, including attempts to relate mechanical properties to other than dislocation theories Discussed in detail are (1) the mechanisms of dislocation movement, (2) energy of dislocations, (3) multiplication processes, and (4) mechanical properties of metals which can be treated by dislocation theory

(1190) Orowan, E.

Energy Criteria of Fracture

Welding J., Welding Research Suppl. 34 (1955) 157-s – 160-s

It is shown that, for fully brittle materials, the Griffith equation represents a neccessary and sufficient condition of tensile fracture. The author's modification of the Griffith equation is a necessary and sufficient condition of fast crack propagation in low-C steels In order to initiate and accelerate a cleavage crack under static load, however, an additional condition (e.g , one demanding a certain initial plastic deformation) must be fulfilled The Griffith energy principle from which the Griffith equation is derived cannot be applied to ductile fracture, except when the plastic deformation is confined to a thin layer of material at the surface of fracture

(1191) Orowan, E.

Strength and Failure of Materials

Chapter I, of Design of Piping Systems, 2nd Edition, M. W. Kellogg Company, John Wiley and Sons, Inc , New York (1956) 1-29

A thorough review and analysis of stable and unstable deformations Plastic deformation, creep, fracture, and fatigue are treated

(1192) Orowan, E.

Origin of Internal Stresses

Paper from Symposium on Internal Strains and Fatigue in Metals, GM Research Lab., Detroit (September 1958)

Internal stresses are present in a body if some part of it is constrained by its surroundings into a space differing in size or shape from what it would occupy if it were separated from the rest of the body Internal stresses arise (1) by a nonuniform expansion, contraction, or shear distortion of mechanical, chemical, or thermal origin; or (2) by "welding" into a gap or cavity an insert that is too large or small for it, or by displacing the walls of the gap or

cavity tangentially before welding them to the insert or to each other ("dislocation") It is usual to distinguish body stresses from microstresses. The former would arise even in a body of perfectly homogeneous material by a given mechanical, thermal, or chemical treatment; the latter result from microstructural inhomogeneities (grain structure of metals, inclusions, inhomogeneity or slip, etc) Some typical mechanisms by which internal stresses may arise were discussed

(1193) Orowan, E., and Parker, E R.

Extract from Research Outline, Report of Sub-Panel on Basic Research, August 27, 1952, Inst for Study of Metals, Chicago

III Mechanical Properties

The principles underlying the deformability, strength, and fracture of metals at elevated temperatures do not basically differ at high temperatures from those at low temperatures Diffusion processes become relatively more important as temperatures near the melting point of a given material are approached. Despite the enormous amount of work that has been done on creep, no basic laws can be enunciated. Work is badly needed on all of the following topics, carried out on a wide range of simple materials selected with the only point of view that they should be most likely to reveal the basic factors

A Strength

1 Brittle fracture, including notch brittleness. Stresses and fracture due to thermal shock and transformation.
2. Ductile fracture, including fibrous, ductile cleavage, and intergranular creep fracture
3. Fatigue (static and cyclic; with and without chemical action) At high temperatures does genuine cyclic fatigue exist (i e , fracture dependent on number of cycles only) or is static fatigue dominant (i e., depends on duration of load independent of intermissions)?

B Deformation

1 Elastic deformation and inelastic pnenomena, not based on plastic or viscous deformation.
2. Viscous deformation and creep. Studies of creep rate on pure materials and simple solid solutions, particularly aimed at showing relative significance and interrelation of yield stress, strain hardening, and strain-dependent recovery rate in affecting viscous creep rates The role of second phases and concentration gradients in various distribution, including precipitation hardening Determine, for pure metals and for alloys, the temperature limit, if any, above which the polycrystalline metal creeps faster than the single crystal of average orientation Interaction of grain body and age-boundary deformation Relationship between the viscous creep rate and the time to creep fracture.
3 Plastic deformation (mainly slip) mechanism of initial yield strain creep, solution and precipitation hardening, influence of grain structure and surface surroundings and size Crystallography of slip and twinning on deformation of high-melting materials, both metallic and nonmetallic

(1194) Orr, R L., Sherby, O. D., and Dorn, J. E.

Correlation of Rupture Data for Metals at Elevated Temperatures

Trans ASM 46 (1954) 113-128

A correlation between time to rupture, applied stress, and testing temperature in terms of the fundamental properties of a number of metals The equation: $t_r \exp(-\Delta H_r/RT) = f(\sigma)$, where σ is the applied stress, T is the absolute temperature, t_r is the time to rupture, and ΔH_r the activation energy for rupture, is found to apply to data for Al, Be, Ti, Ni, Mo, and several commercial high-strength alloys ΔH_r is constant for a given metal and independent of stress, temperature, grain size, subgrain structures, minor alloying additions, and dispersions of intermediate phases For relatively pure metals, ΔH_r is believed to equal the activation energy for creep and self-diffusion.

(1195) Osipov, K A.

Basic Principles for Development of Heat-Resistant Alloys (In Russian)

Doklady Akad. Nauk S.S.S R 60 (1948) 1535-1538 (Battelle Translation No. 48R58)

Describes a new method for prediction of heat resistance of alloys Data obtained from curves of density of electronic states and characteristic of each component give clues for such predictions The explanation of properties of solid solution based on alpha- and gamma-Fe is attempted in terms of the N(E) curves

(1196) Osipov, K A.

The Relation Between the Melting Temperature and the High-Temperature Strength of Alloys (In Russian)

Doklady Akad Nauk S.S.S.R 61 no 1 (1948) 71-74 (Battelle Translation No. 49R17)

Series of specimens were made up from Fe-Cr, Fe-Ni, Co-Ni, and Mn-Ni alloys and were centrifugal creep tested at 1100 C. The amount of creep (or deflection of the specimen) showed an increased creep strength in alloys with the higher melting point, except for a sharp break in the curve near FeCr It is held that the same binding forces are responsible for both the mechanical strength and for the resistance of the alloys to melting

(1197) Osipov, K A

Factors in the High-Temperature Strength of Heterogeneous Metallic Alloys (In Russian)

Doklady Akad Nauk S S S R 62 no 1 (1948) 491-494 (Battelle Translation No. 51R52)

The high-temperature strength of heterogeneous alloys is sometimes less, or sometimes more, than that of the single-phase alloys Considers those factors which promote viscous flow of the transition zone at the grain boundary and tend to increase the plasticity of alloys. At temperatures of marked diffusion (~0.4 - 0.6 T_{mp}), the heterogeneities of alloys in a eutectic system should reduce the high-temperature strength; in a system with a peritectic, heterogeneous alloys should have greater high-temperature strength than the phase with lower melting point and less than the phase with higher melting point

(1198) Osipov, K. A.

Mechanism of Plasticity of Homogeneous Metallic Alloys at High Temperatures (In Russian)

Izvest Akad Nauk S S S R (September 1949) 1372-1377

From theoretical considerations and experimental results, concludes that the increase of inhomogeneity of distribution of alloying elements in solid solution of metals is one of the most significant factors in plastic deformation This inhomogeneity is produced by the diffusion of dissolved atoms into preferred planes and in the direction of the applied stress In the extreme case a new phase may result It is to be expected that those alloys in which the solubility of the alloying element changes little with rise of temperature will be the most resistant to plastic deformation The resistance to plastic deformation is proportional to the specific energy required for the formation of a new phase which can exist at a given temperature according to the phase diagram

(1199) Osipov, K A

An Analytical Expression Relating the Melting Point of Alloys to Their High-Temperature Strength (In Russian)

Doklady Akad Nauk S S S R 68 (1949) 81-82

Experiment has verified that equations analogous to that developed by Mott [Proc Phys Soc (London) 60 (1948) 391] for the velocity of slip at grain boundaries of pure metals can be applied to solid solutions An equation is developed, assuming that the activity coefficients of the solute are the same in the liquid and solid phases It is deduced that high-temperature strength will increase with solidus temperature and width of solidus temperature and width of solidification range, but other factors must be considered

(1200) Osipov, K. A.

Grain Boundary Sliding in Metals at High Temperatures (In Russian)

Issledovaniya Zhar Splav Akad Nauk S.S.S R. (1956) 48-51

Coefficient of sliding determined by the Mott equation differs widely from the experimentally obtained results By making different assumptions as to the potential-energy barrier which a group of n atoms overcomes in its approach to the liquid state at absolute zero and at the melting point, the Mott equation can be modified so that better results are obtained

(1201) Osipov, K A

Activation Heat of Self-Diffusion in Solid Metals (In Russian)

Paper from Research on Heat Resistant Alloys I, Moscow (1956) 151-158

Activation energy of self-diffusion must have a direct connection with values which characterize strength of the interatomic bond, and must be greater, the greater the energy and force of that bond Compares experimental values of Q (volume self-diffusion) with the heat of evaporation, Young's Modulus; the constant of the quasi-elastic bond; and the heat content of the molten metal at its melting point Straight-line relationships are obtained

(1202) Osipov, K A

Mechanism of Plastic Deformation and Failure of Metals (In Russian)

Paper from Strength of Metals, Izd-vo Akad Nauk S S.S.R , Moscow (1956) 55-57

The mechanism of plastic deformation and failure of metals is one of the major problems in the study of metal resistance to heat Various theories of plastic deformation and failure of metals are discussed

(1203) Osipov, K A , and Fedotov, S.G

Heat Capacity and the Mechanical Properties of Metals

Izvest Akad Nauk S S S R , (1955) no 2 Otdel Tekh Nauk, 98-104

Many mechanical properties of metals, including elastic moduli, yield point, and hardness number (N) can be estimated from the amount of energy (ΔW) required to raise their temperature from the temperature of mechanical testing to the melting point (T_m) and then to melt them; i e , $\Delta W = W - W_T$ A linear relationship between N and ΔW is shown for Sn, Al, Ag, Cu, Ni, and Co over a wide range of temperatures greater than 0.5 T_m A linear relationship also found between W and ΔV, the activation energy for high-temperature creep which holds for Fe, Ni, Cu, Al, Zn, Bi, Sn, Pb, and Cd Data taken from wide variety of sources include activation energies from self-diffusion data Thus a close relation is established between the processes of creep, self-diffusion, and melting

(1204) Osipov, K A , and Fedotov, S. G , and Lozingsky, M G

On a "New" Mechanism of Plasticity of Metallic Solid Solutions (In Russian)

Doklady Akad Nauk S S S R 89 (1953) 57-61 (Translation No. NSF-tr-19)

Experimental data confirming the possibility that a nonslip mechanism of plasticity takes place in a solid solution of Cu and Pb. Papers by Wood, et al , have discussed the "new" mechanism of plasticity occurring during slow deformation at high temperatures of Al and Zn and characterized by absence of slip bands, formation of small perfect cells within the original grains, and low strength Hot hardness measurements of Cu-Pb alloys at temperatures of 20-800 C show that a similar type of deformation may occur in these alloys Below 425-525 C, normal slip was observed and the In hardness/temperature relationship was linear, but above this temperature range the hardness fell rapidly, no slip lines were observed, and cellular structures were developed The formation of the cells and the mechanism of deformation are discussed.

(1205) Osipov, K A , and Stolukhin, B P

Ther odynamic Criteria of Resistance to Plastic Deformation of Saturated Solid Solutions of Metals (In Russian)

Doklady Akad Nauk S S S R 80 (1951) 627 630

The criterion for the resistance to deformation is denoted by $W(=A_o/a_o$, where A_o is the work done by the deforming force in forming a nucleus of critical dimension $a_o)$ From the Becker theory, W is expressed in terms of the bond energy of the solid solution, the concentration of the initial solid solution and that of the precipitating phase, and the decrease in free energy of the alloy on formation of nuclei of the new phase. The resistance to plastic deformation is seen to be a maximum for compositions near the saturation limit

(1206) Osipov, K A , and Stolukhin, B P

Thermodynamic Considerations in the Resistance to Plastic Deformation of Two-Phase Metallic Alloys (In Russian)

Doklady Akad Nauk S S.S R 83 (1952) 439-442

In stressed two-phase alloys, the free energy is lowered mainly through decomposition of the phases that are supersaturated in the stressed state. Consideration of the free-energy relations of an alloy of an alpha- and gamma-phase, in stressed and unstressed slates as a function of the atomic composition, reveal the role of the grain sizes of the interacting phases under stress A second phase can have a hardening effect only if it is finely dispersed and its crystal size does not exceed a critical dimension; otherwise, diffusion to the boundaries of the grains of the second phase involves a decrease of the free energy and of the resistance to plastic deformation

(1207) Owen, E. A , Liu, T H , and Morris, D P.

Behavior of Stressed Aluminium at Room Temperature

Phil Mag 39 (1948) 831-845

The lattice spacing of a pure Al plate which has been relatively heavily compressed attains, on standing at room temperature, a steady value which is greater than that for the fully annealed metal This effect was investigated, using an X-ray beam normal to the surface The rate of recovery depends markedly on the degree of cold work A small fraction of the energy of deformation appears to be retained, accounting for the expanded spacing, and can only be released if energy is supplied The main conclusion is that the material between consecutive slip bands undergoes a shear strain, which is relieved on the removal of stress, but that the plastically deformed layers then support tangential stresses of some magnitude

(1208) Paganelli, M

Example of Slip on a Crystalline Plane of Low Atomic Density (In Italian)

Alluminio 26 (1957) 154-156

In an artificially aged, moderately deformed Al-5% Cu alloy, conditions caused by surrounding grains and subgrains formed by previous deformations can promote slipping.

(1209) Palm, J H

Stress/Strain Relations for Uni-Axial Loading

Appl Sci Research 1A (1948) 198-214

Criticizes the stress-strain equations of Ludwig and of Hollomon because, among other things, they predict an infinite stress at infinite strain Propose the symmetrical form of Hollomon's equation $S/S_m = (\eta/\eta_m)^{\eta_m}$, where s and η are the instantaneous values of stress and natural strain, while S_m and η_m are the values at the maximum load

(1210) Palm, J H

The Relation Between Indentation Hardness and Strain for Metals

Trans AIME 185 (1949) 904

The formula $S = S_t - (S_t - \acute{S}_e)e^{-\eta/\eta_c}$ expresses very well the relation between the true stress, S, and the true strain, η, for monatomic deformation of plastic metals in single tension and compression A similar

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formula, $H = H_t - (H_t - H_e)e^{-\eta/\eta_c}$, might be valid for the relation between the hardness and the strain. For Al, Cu, and several Cu alloys the second equation does agree very well with the experimental Vickers hardness/strain relation, from zero strain on up to the strain at fracture. Since η_c is, for several metals, fairly equal to η, then $H = C_1 + C_2S$, where C_1 and C_2 are constants during uniform uniaxial tension. This last equation has also been obtained for Cu by Voce [Metal Treatment 15 (1948) 53]. But, according to Hencky, the ratio of the Brinell or Vickers hardness and the yield stress (in kg/mm²) of a non-strain-hardening metal is about 2.8; therefore, if the equations given above are correct, the ratio H_t/S_t must accordingly be the same for all plastic metals and be equal to 2.8; experiments show that this ratio varies between 2.7 and 3.1, with a mean of 2.9. Considering that H_t and S_t can be obtained only by extrapolation from the range of rather low strains, the agreement with the theory is very satisfactory.

(1211) Palm, J H.

Relationship Between Stress and Strain in Plastic Metals (In English)

Metalen 5 (1950) 9-14

Recently, an equation has been derived by Palm [Appl Sci Research 1 (1948) 198] and by Voce [J Inst Metals 74 (1948) 537] expressing the stress, S, in terms of the strain, $x\eta$, in the form $S = S_\infty - (S_\infty - S_0)\exp(-\eta/\eta_c)$, in which S_0 and S_∞ are, respectively, the initial stress, and the asymptotic stress, and $x\eta_c$ is the characteristic strain necessary to raise the stress to its asymptotic value, assuming that the plastic modulus $dS/d\eta x$ remains constant. It is shown that this equation can be derived theoretically from a simplified two-dimensional model of the strain-hardening mechanism of metals. The derivation has to be modified in the case of metals fully anisotropic with respect to three stress directions, of for partially anisotropic metals stressed in one of the directions of equal properties

(1212) Pankowski, Fern, R

Dislocations in Metal Crystals and Their Influence on Mechanical Properties

Rev. gén sci appl (Brussels) 2 (1955) 15 pp

The concept of dislocations, evidence in support of their existence, their method of movement, and their place in theories of deformation, hardening, and aging are reviewed.

(1213) Pao, Y H , and Marin, J

Prediction of Creep Curves From Stress-Strain Data

Proc ASTM 52 (1952) 951-961

Develops a method for predicting tension creep-time relations for constant stresses from tensile stress-strain relations at various strain rates. The method was applied to test data obtained using Plexiglas, and agreement between actual and predicted creep-time curves was found to be good at the lower stresses. The proposed procedure given in this paper differs from other "equations of state" procedures in considering the creep strains and creep rates and not the total strains and total strain rates when using the stress-strain relations for predicting the creep-time curves. This is equivalent to suggesting that a mechanical equation of state exists for creep strains and creep rates alone

(1214) Pao, Y , and Marin, J

An Analytical Theory of the Creep Deformation of Materials

J Appl Mechanics 20 (1953) 245-252

An analytical theory of creep is proposed for an idealized material, and takes into account the initial elastic strain, the transient creep strain, and the minimum rate creep strain. It is capable of representing the simultaneous action of creep and creep recovery and may be used for conditions of varying as well as constant stresses. The new theory applies where high temperatures over short periods of time make the initial short-time creep strains of importance

(1215) Paranjpe, V G

Theories of Fracture

Tisco Rev (India) 3 (July, 1956) 144-152

Various types of fractures, divergence between theoretical and observed strengths, theories of brittle and ductile fractures, brittle fracture in normally ductile materials, fatigue and intercrystalline failures, effect of structural heterogeneity on initiation and propagation of fracture

(1216) Parker, E R

The Development of Alloys for Use at Temperatures Above 1000 degrees Fahr

Trans ASM 28 (1940) 797-810

Methods for increasing the resistance of a metal to deformation are discussed. It is suggested that factors which affect the deformation of a metal at low temperatures are also effective at high temperatures, but the influence of temperature on the various factors must be considered in an analysis of high temperature strength. A critically dispersed precipitate offers the maximum resistance to deformation at both low and high temperatures. At low temperatures, the precipitate remains in the critical dispersion, and high strength is maintained for long periods of time. High temperatures cause the precipitated phase to agglomerate with a consequent weakening of the material. Carbides agglomerate relatively rapidly at temperatures above 1000 F, but certain intermetallic compounds (e.g., Fe_3Cb_2 and Fe_3Mo_2) are more stable, higher temperatures and longer times are necessary for agglomeration. An alloy containing a critically dispersed stable compound should possess the greatest high-temperature strength. Rupture tests were made at 1100 F on precipitation hardening iron-base alloys containing Mo and Cb. The tests results indicate that such alloys have greater high-temperature strength than alloys which depend upon carbides for strength

(1217) Parker, E. R

Intercrystalline Cohesion of Metals

Trans ASM 33 (1944) 150-162

The investigations and theories concerning high-temperature intercrystalline failures are reviewed. New data are given which illustrate the various types of high-temperature fractures. The theories of the structure of crystal boundaries are discussed and their limitations cited. A new suggestion is made concerning the mechanism of intercrystalline failures, i e , that they are due to discontinuities at the boundaries as a consequence of stress concentrations

(1218) Parker, E. R.

Creep of Metals

Paper from High Temperature Properties of Metals, Am Soc Metals, Cleveland (1951) 1-40

Mechanism of deformation, creep theories, metallurgical factors, creep properties of various metals and alloys, effect of environment, and trends in the development of creep-resistant materials

(1219) Parker, E R

Effects of Grain Size, Solid Solution and Other Metallurgical Factors on Strength

Paper from Proceedings of the 1955 Sagamore Research Conference on Strength Limitations of Metals, OTS, U.S. Dept Commerce, PB 131280 and PB 131281 (1955) 71-83

To harden a metal it is necessary to introduce many barriers which are either impermeable to dislocations or through which dislocations can pass only at high stress levels. There are several very effective barriers, namely grain boundaries, clusters of solute atoms, precipitated particles, and piles of tangled dislocations. Effect of each of these

(1220) Parker, E R.

Experimental Evidence for Behavior of Dislocations

Paper from Science of Engineering Materials, John Wiley and Sons, Inc , New York (1957) 179-195

Dislocation theories related to mechanism involved in work hardening in creep and in strain aging of metals

(1221) Parker, E. R.

Role of Grain Boundaries in Creep

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Creep tests were made on polycrystalline Cu having a variety of grain sizes and with controlled amounts of preferred orientation. The boundary angle between adjacent grains plays a controlling role in creep. Grain size effects and boundary angle effects are closely interrelated. This new work clearly shows the importance of boundary angle (i e , degree and kind of preferred orientation).

(1222) Parker, E. R., and Hazlett, T H

Creep of Alloys

Progress Report, USAEC Publ COO-61 (1952) 4 pp

The ultimate tensile strength and lattice parameter of Ni are relatively unaffected by additions of Co up to about 9 at %, but both are increased regularly by Fe additions. Results to date indicate that the d-level electron interactions have very slight influence on the plastic properties. The shape of the creep curve for solid-solution alloys of Ni is given by $\epsilon = \epsilon_0 + At^b$, where ϵ = total true strain, ϵ_0 = instantaneous true strain at zero time, and t = time. The values of b increase linearly with at % alloy addition and log A decreases linearly with alloy content. The creep curve for an alloy with 0.5 at. % is given by $\epsilon - \epsilon = Ce^{-Q/RT}t^b\sigma^n$ in the range 650 to 800 C

(1223) Parker, E. R , and Hazlett, T H

Principles of Solution Hardening

Paper from Relation of Properties to Microstructure, ASM, Cleveland (1954) 30-70

Solid solutions are invariably stronger than pure metals and the yield point always increases with alloying content. The slope of the stress/strain curve is usually, but not always, increased by the addition of a solute element. In dilute ternary alloys, each solute seems to contribute the same increment of strength that it did in the binary alloy. The difference in size between the solute and solvent is an important factor influencing solution hardening, while the difference in the number of free electrons in the two components is also important. Solution hardening cannot be explained by the interaction of dislocations and the stress fields surrounding randomly dispersed solute atoms, and it is almost certainly the result of the interaction of dislocations and groups of solute atoms. The Cottrell mechanism of hardening seems to be confirmed experimentally, while the Suzuki mechanism, based on chemical interaction of solute and solvent, also appears to be a possible mechanism. The Fisher mechanism, involving the energy required to disorder short-range ordered regions, undoubtedly contributes to the hardening of certain alloys, especially in concentrated solution. Clustering may also contribute to hardening, but to a lesser degree than short range order. Clustering and short range order can contribute to hardening even more by separating regions of high local strain in the lattice to distances such that dislocations no longer act as rigid lines but curve around the highly strained regions. The dislocation type of subboundaries often strengthens the alloy to a greater degree than solution hardening. The increment of strength conferred by a given number of solute atoms is not fixed, but varies with temperature often in a complicated manner. Structure and solution hardening effects are largely additive. Since substructures are always present in wrought alloys and to a degree different from that in the pure solvent, it is necessary to differentiate between these two effects when considering the degree of solution hardening.

(1224) Parker, E R , and Smith, E A

High-Speed Tensile Impact Tests on Single Crystal and Polycrystalline Bars of Copper

Trans AIME 156 (1944) 142-146

Published reports have shown that the tensile strength, yield strength, and elongation generally increase with increasing strain rate. The investigation reported herein is an attempt to determine the reason for this increase in strength and elongation

(1225) Parker, E R , and Washburn, J

Deformation of Single Crystals

Paper from Modern Research Techniques in Physical Metallurgy, Am Soc Metals, Cleveland (1953) 186-204

Several new techniques are discussed. Acid machined Zn single crystals tested in shear give excellent reproducibility. Creep, recovery, anisotropy of strain hardening, solid-solution hardening, diffusion during plastic flow, surface coatings, transparent crystals, and formation and motion of dislocation boundaries discussed primarily with respect to shear tests on Zn single crystals

(1226) Parker, E R , and Washburn, J

Effects of Impurities and Imperfections on Mechanical Properties

Paper from Impurities and Imperfections, Am Soc Metals, Cleveland (1955) 145-161

Experiments were undertaken to better understand work hardening, creep, and the yield point phenomenon. The main causes of work hardening are back stresses generated by dislocations held up at barriers to flow, interaction of dislocations moving on different slip systems, and formation of small-angle boundaries by plastic bending. The creep process seems to be governed by the dislocation "climb" mechanism, which in turn is controlled by the rate of self-diffusion. A major factor in the yield phenomenon is the interference to dislocation motion by anchored dislocation subboundaries

(1227) Parker, E R., and Washburn, J

Role of the Boundary in Creep Phenomena

Paper from Creep and Recovery, Am Soc Metals, Cleveland (1957) 227-250

The effects of external surfaces, grain boundaries, substructure boundaries, grain-boundary shearing, impurities, and second phases are reviewed in relation to the dislocation climb mechanism in high-temperature creep.

(1228) Pashkov, P O

Resistance to Deformation During Plastic Flow of Polycrystalline Metals (In Russian)

Zhur Tekh Fiz 19 (1949) 251-270

The possibility of formulating a single criterion for strength of polycrystalline metals under marked plastic deformation. Bibliographic data and the author's experiments confirm the acceptability of the proposed criterion

(1229) Patel, J R

Delay Time of Plastic Flow in Germanium

Phys Rev 101 (1956) 1436-1437

The effects of delay time upon the compressive stress/strain graphs of Ge subjected to plastic deformation under compression at 400-500 C were studied, much longer delay times than those found by Gallagher were observed. Plastic deformation occurs only at temperatures where thermal fluctuations are large enough to aid the applied stress to free the locked sites. The value of the activation energy is Q = 39,000 cal/mol. The limiting time, T_0, for the initiation of plastic flow (10^{-9} sec) predicted by Seitz's theory, agrees closely, but probably fortuitously, with the experimental value 3×10^{-10} sec

(1230) Patel, J R

Arrangements of Dislocations in Plastically Bent Silicon Crystals

J Appl Phys 29 (1958) 170-175

Single crystals of Si were plastically bent at an elevated temperature. The average etch pit density after deformation is approximately two to three times higher than the calculated dislocation density. Prolonged annealing close to the melting point results in polygonization or the alignment of etch pits perpendicular to the active slip pits perpendicular to the active slip planes. Satisfactory agreement was obtained between the densities of etch pits in the annealed and polygonized specimens and the predicted dislocation densities

(1231) Patel, J R , and Alexander, B H

Plastic Deformation of Germanium in Compression

Acta Met 4 (1956) 385-395

The effect of temperature, orientation, impurity content, and annealing on the compressive stress/strain characteristics of Ge single crystals was investigated. The deformation characteristics resemble the plastic behavior of fcc metals. The strain hardening decreases very rapidly as the temperature is increased, but does not fall to zero as the melting point is approached. An increase in impurity content from 1×10^{-7} to 7×10^{-5}% does not affect the stress/strain characteristics at elevated temperature

(1232) Paterson, M S

Intrinsic Block Structure and the Strength of Metals

Phil Mag. 41 ser 7 (1950) 410

Criticizes recent paper "On the Strength of Quasi-Isotropic Solids" [ibis , 40 (1949) 1227] by R Fürth, which discusses the idea of an "intrinsic block structure". Doubts whether mechanical properties of a metal are influenced by the structure proposed by Fürth. Fundamental difference between Bragg's and Fürth's theories. The theory by Fürth would predict a decrease of X ray line broadening and strength with decrease of temperature, which is contrary to experiment

(1233) Paterson, M S

Plastic Deformation of Single Crystals

J Australian Inst Metals 1 (October 1956) 112-124

Literature review includes discussion of ductility of crystals and nature of slip and twinning. Section on crystallography and geometry of slip. Covers observations on nature of slip bands and deformation bands. Part on slip mechanics discusses sharp yield points, easy glide, effect of surface conditions, time, temperature, and the application of dislocation theory to yielding and strain hardening.

(1234) Pauling, L.

The Nature of the Bonds in Metals and Intermetallic Compounds

Paper from Proceeding XIth International Congress of Pure and Applied Chemistry, 1 (1947) 249-257

Conception formulated mainly on empirical arguments. Magnetic properties of transition metals, interatomic distances, and structure

(1235) Pauling, L

The Metallic State

Nature 161 (1948) 1019-1020

Resonating-valence-bond theory of the electronic structure of metals

(1236) Pauling, L

The Electronic Structure of Metals and Alloys

Paper from Theory of Alloy Phases, Am Soc Metals, Cleveland (1956) 220-240

The properties of metals indicate that the metallic valence increases steadily from 1 to 6 in the sequence from K to Cr, remains constant at 6 to Ni, and then decreases, with values about 5.56 for Cu, 4.56 for Zn, etc. The magnetic properties of the ferromagnetic transition metals support this conclusion, which is given additional support by the consideration of interatomic distances and the electron-atom ratio in certain phases

(1237) Pavlov, V A

Formation of Microscopic Cracks in Aluminum During Plastic Deformation (In Russian)

Doklady Akad. Nauk S S S R 78 (1951) 677-679

The formation of microcracks as stress was applied to specimens of Al was observed through a microscope. Microcracks were formed along the slip planes after plastic deformation had reduced the tensile strength of the metal, these cracks were oriented perpendicular to the direction of applied stress. The orientation was changed by continued deformation, and the presence of the cracks resulted in localized stresses which formed a new set of microcracks oriented parallel to the slip planes

(1238) Pavlov, V A

On the Nature of Viscous Destruction of Metals (In Russian)

Doklady Akad Nauk S.S S R 91 (1953) 253-255

In order to study the occurrence in viscous fracture of regions of loosened crystal lattices and of cracks, the impact strength of a number of steels was plotted as a function of preliminary deformation in tension. The fractures were all ductile, and the general trend was for a fall to occur in impact strength with prior deformation with a region of unstable strength in the curve, which is interpreted as corresponding to the formation of highly distorted regions in which crack formation is facilitated.

(1239) Pavlov, V A.

Problem of the Nature of the Fracture Strength of Metals (In Russian)

Doklady Akad. Nauk S S S R 91 (1953) 253 255

Studies were made of change of metal properties during plastic deformation by measuring ratio of impact strength to magnitude of plastic deformation

(1240) Pavlov, V A.

Influence of Decomposition of Supersaturated Solid Solution Induced by Plastic Deformation on Mechanical Properties of Aluminum Copper Alloy (In Russian)

Doklady Akad Nauk S S.S R 95 (1954) 1201 1204

Temperature dependence of mechanical properties of pure Al and Al-Cu alloy The behavior of the Cu alloy was attributed to diffusion processes occurring during the formation and precipitation of the new phase in the nonuniformly stressed lattice. The presence of nonuniform stresses is known to facilitate diffusion at low temperatures

(1241) Pavlov, V A., Gaydukov, M G , Grin', A V , and Pereturina, I A

The Effect of Static Distortions of the Crystal Lattice on the Mechanical Properties of Alloys of the α Solid Solution of Aluminum with Magnesium (In Russian)

Paper from Research on Heat Resistant Alloys (Moscow) 2 (1957) 257-265

Mechanism of plastic deformation affecting strength of alloys depends on character, amount, and distribution of distortions, and on the amount and characteristics of the cohesive forces of the crystalline lattice The resistance to deformation increases with growth of amount of small dissimilar heterogeneities which promote a more uniform distribution of internal stresses through volume of the crystal, and thereby increase the effectiveness of the use of the cohesive force

(1242) Pavlov, V A , Kryuchkov, N F., and Fedotov, I D.

The Temperature-Dependence of the Modulus of Elasticity of Alloys of Alpha Solid Solution of Magnesium in Aluminum (In Russian)

Fiz Metal i Metalloved. Akad. Nauk S.S.S R , Ural' Filial, 3 (1956) 555-557

A dynamic method is described for measuring Young's modulus (E) in the temperature range 77 to 680 K Experiments on pure Al and on Al plus 0 12, 1 11, and 2.2% Mg show that E falls linearly with increasing temperature and that E(T) is independent of the composition of the alloy

(1243) Pavlov, V A., and Vshivtseva, K A.

Some Regularities of Plastic Deformation and Fracture of Metals Under Tension (In Russian)

Fiz Metal i Metalloved. Akad. Nauk S S.S.R., Ural' Filial, 1 (1955) 261-268

Experimental data on temperature relation of complete and uniform elongations, and on variation in the character of fracture during tensile stressing of metals

(1244) Pavlov, V A., and Yakutovich, M. V

Nature of "Viscous" Fracture (In Russian)

Doklady Akad. Nauk S.S.S.R 77 (1951) 49-50

An investigation was made into the influence of plastic deformation on the formation and growth of microcracks in Plexiglas, in which such cracks are more easily observed than they are in metals Sheet specimens were tested in tension, nonuniform stress distributions being produced by necks or holes Microcracks formed in places of maximum shear stress (i e , where the plastic deformation is most intense), and were always perpendicular to the line of action of the normal tensile stress Microcracks can be formed in regions of elastic deformation, and in this case they close up on unloading. They are always formed by the action of tensile normal stress Plastic deformation increases the probability of their formation, even in anisotropic substances Microcracks form only at the surface

(1245) Paxton, H W

Dislocation Theories of Mechanical Properties

Paper from Science of Engineering Materials, John Wiley and Sons, Inc , New York (1957) 161-178

Relationship of dislocation theories to yield strength as influenced by work hardening, precipitation hardening, recrystallization, and purity

(1246) Paxton, H W , and Churchman, A T

The Effect of Temperature and Composition on the Deformation of Single Crystals of Iron

Acta Met 1 (1953) 473-479

Single crystals of Fe containing 0 0005 and 0.003% C were prepared by the strain-anneal method, followed by decarburization and carburization, respectively Tensile tests were made at temperatures from -180 to 1213 C The specimens with 0 003% C showed large load drops, sharp yield point, repeated yielding, and completely smooth stress/strain curves at successively higher temperatures The low-C specimens gave similar results, but

repeated yielding was not observed, and the magnitude of yield point drop and the rate and magnitude of strain-aging effects were much less. These results are interpreted on the assumption that the amount of C is insufficient to fully saturate the dislocations, at least after a small amount of strain The temperature dependence of the initial yield stress for carburized specimens is compared with theoretical relations best agreement is obtained with a formula ; A exp (Q/RT), where A is a constant and Q is an activation energy, proposed by Cottrell and Bilby [Proc Phys Soc (London) 62 (1949) 49]

(1247) Paxton, H W , and Cottrell, A H

Work Hardening in Stretched and Twisted Aluminum Crystals

Acta Met 2 (1954) 3 10

The effects of plastic twisting on the tensile deformation of Al crystals are examined. After such a twist the tensile stress needed to continue tensile straining is sharply increased and, in some cases, this is followed by a period of increased work hardening These effects are most pronounced when the twisting is applied during the period of "easy glide" in crystals oriented for single slip in tension, but they also appear in crystals which undergo multiple slip and work harden more severely during tensile straining. An explanation of the results is proposed in terms of the difficulty which those dislocations producing the tensile strain have in cutting through intersecting dislocations introduced during the twisting. The observed magnitude of the stress increment following a plastic twist can be predicted reasonably well by means of a formula deduced from theory, and the results provide evidence in favor of the view that multiple slip is a cause of work hardening

(1248) Pearson, G L., Read, W T , Jr., and Feldmann, W L

Deformation and Fracture of Small Silicon Crystals

Acta Met 5 (1957) 181-191

Both whiskers grown from the vapor and rods cut from bulk Si were tested in bending over a range of temperature. At 25 C, whiskers around 20μ in diameter deformed elastically up to fracture at elastic strains as high as 2.6% The fracture strength of cut rods increased as size decreased and was equal to that of whiskers for the same cross-sectional area Introducing dislocations by bending at high temperature had little or no effect on the room-temperature fracture stress Above about 600 C, both whiskers and rods deformed plastically with a sharp yield point, which could be recovered by aging. The behavior is similar to Fe containing C, except that the yield stress decreases more rapidly with increasing temperature The results indicate that even the smallest of these specimens contains many dislocations which are locked by impurities Fracture is apparently due to defects, other than dislocations, that are not present in the smallest samples tested

(1249) Pearson, W B

Lattice Distortion in Terminal Solid Solutions of the First Long Period Transition Metals and Copper

Can J Phys 35 (1957) 358-362

No correlation was found between solid solubility and lattice distortion for the metals with one another or with Cu

(1250) Peierls, R

The Size of a Dislocation

Proc Phys Soc (London) 52 (1940) 34-37

Calculations are made of the size of a simple dislocation in an imperfect crystal lattice, and of the critical shear stress for its motion The extension of a dislocation, i e , the width which contains all atoms whose displacements with respect to their neighbors exceed, say, d/4, where d is the atomic distance, is not appreciably larger than d, and depends on Poisson's ratio. The critical shear stress necessary for movement of the dislocation depends strongly on Poisson's ratio, the calculated value is smaller by several powers of ten than the so-called theoretical shear stress, or stress required for uniform slip.

(1251) Pell, Walpole, W T

The Effect of Grain-Size on the Tensile Strength of Tin and Tin Alloys

J Inst Metals 69 (1943) 131-146

The tensile strength of Sn and certain of its alloys is shown to be influenced by grain size The controlling factor is the number of grains in the cross-sectional area In rolled material, an increase in tensile strength is found as the grain size decreases from 1 to 20-30 grains in the cross section Over this range, elongations are constant Further reduction in grain size produces only a slight increase in tensile strength, but elongations increase rapidly With case materials consisting entirely of columnar grains, tensile strengths increase continuously with reduction of grain size over the whole region investigated. Elongations are either constant or increase, but slightly The true stress for rolled material is shown to increase continuously over the whole range of grain size A theory based on noncrystalline deformation has been put forward to explain these results

(1252) Perryman, E. C

Intercrystalline Fracture of Aluminum Zinc Alloys (In French)

Compt rend. 235 (1952) 881 886

Experiments confirm hypothesis that these alloys, when aged at room temperature, exhibit an exterior grain zone which is less hard than the interior, creating a mechanism which retards intercrystalline fracture

(1253) Perryman, E. C.

Recovery of Mechanical Properties

Paper from Creep and Recovery, Am Soc Metals, Cleveland (1957) 111 145

Recovery of plastically deformed single crystals and cold worked polycrystals, effects of alloying elements on the separate recovery and recrystallization processes, effects of recovery and recrystallization on creep, relationship between recovery substructures and mechanical properties

(1254) Petch, N J

The Cleavage Strength of Polycrystals

J Iron Steel Inst 174 (1953) 25 38

Determination of the cleavage strength, σ_c, of unnotched specimens of mild steel, ingot Fe, and spectrographic Fe by means of tensile tests in liquid N has shown that $\sigma_c = \sigma_0 + kl^{-1/2}$, where l is the grain diameter, and σ_0 and k are constants The same relationship has been derived theoretically by identifying the Griffith cracks with glide planes on which dislocation movement has been held up at a grain boundary This indicates that the cleavage strength of polycrystals is controlled by the theoretical cleavage strength in the grain-boundary region, which opens up the possibility of subtle composition effects in this special region, by the grain size, which determines the stress-concentration fractor, and by σ_0 The amount of plastic strain at fracture will increase with finer grain sizes and lower strain-hardening rates

(1255) Petch, N J

The Fracture of Metals

Progress in Metal Physics V, Edited by B. Chalmers and R King, Interscience Publishers, Inc , New York (1954) 1-52

Theories of the fracture of metals are reviewed. Matters discussed include Griffith's theory of the fracture of glass, types of metallic fracture; criteria for the fracture of single-crystal and polycrystalline material the influence of the stress system, whether uni-, bi-, or triaxial, on fracture Griffith cracks in metals; Griffith-type fracture under bi- and triaxial stresses; initiation and propagation of cleavage, metallurgical features of cleavage and intercrystalline fracture, adiabatic, delayed, and plastic fracture, fatigue fracture, and size and statistical effects A theory of fatigue fracture, associated with the formation of local plastic regions and the increase of stress in and around these during cyclic loading, is given [see Orowan, Proc. Roy Soc (London) 171 (1939) 79]

(1256) Petch, N J

The Ductile Fracture of Polycrystalline Alpha-Iron

Phil. Mag. 1 ser. 7 (1956) 186-190

Tensile tests at -196, -115, and +18 C showed that, in all cases fracture stress σ_f was related to grain diameter l by the relation $\sigma_f = \sigma_0 + kl^{-1/2}$. The values of k at the three temperatures were nearly the same At -196 C the fracture was by cleavage, whereas at the other two temperatures it was ductile and σ_f was the maximum true stress deduced by Bridgeman's method This result suggests that the mechanism of fracture in the two cases is similar, in that dislocation arrays in one grain must be pressed against a grain boundary until their stress field in the neighboring grain either starts a Griffith crack (cleavage) or a crack whose stress concentration is sufficient to start Frank-Read sources ahead of itself, which lead to further plastic deformation, further crack formation, and failure (ductile fracture) The similarities and differences in mechanism consistent with the observed frunctional similarity of the dependence of fracture stress on grain diameter are discussed

(1257) Petch, N J

The Lowering of Fracture-Stress Due to Surface Adsorption

Phil Mag 1 ser. 8 (1956) 331-337

Gibb's adsorption equation and the Griffith and dislocation theories of fracture are used to calculate this lowering Discusses possibility that H_2-adsorption causes embrittlement of Fe Good agreement shown with measured fracture stresses

(1258) Petty, E R

Hardness and Other Physical Properties of Metals in Relation to Temperature

Metallurgia 56 (1957) 231 236

Mode of deformation in the "equicohesive range" used to explain the form of the hardness temperature relationship for pure metals A simple correlation between hardness and creep properties is shown for a variety of metals The correlation between hot hardness, tensile strength, and creep rupture, developed by Underwood [discussion, Trans ASM 49 (1957) 401-103] is probably the most practicable method of correlation to date

(1259) Pevzner, L. I

The Connection Between the Change in Static and Impact Strengths and Physico Chemical Processes in Metal (In Russian)

Zavodskaya Lab 12 (1946) 583 595

Most mechanical properties are complex functions of some simple basic property, such as modulus of elasticity, elastic limit, coefficient of rigidity, tearing strength, and shearing strength The relation between such complex functions and physicochemical processes in the metal is very complicated. Analysis of the approximate equation between the strength of a smooth sample under strain and the basic properties indicates that the special points on the strength curve do not always have corresponding special points on the curves of basic properties Thus, even in the simplest cases, the course of the complex curve is not indicative of any physicochemical processes Analysis of curves of the more complex mechanical properties, e g., the impact strength, is even more difficult

(1260) Pfützenreuter, A , and Masing, G

Increase in the Velocity of Plastic Flow of Metals in Electrolytes During Electrochemical Polarization

Z Metallk 42 (1951) 361-370

A study was made in air, and in CKl or KNO_3 electrolytes at room temperature - of Pb foil, and wires of high-purity Zn, Ag, Au, and Pt, The results show that under cathodic and anodic (for Au and Pt) polarization, the flow rate is increased up to a factor of ten, depending on the metal and the electrolyte, while the yield point is decreased. The observations, therefore, confirm and extend the scope of those made by Rehbinder on Sn. The phenomenon is discussed in relation to previously published hypotheses as to its origin, none of which afford an adequate explanation. It is suggested that the effect is probably associated with the formation of an electrochemical double layer at the metal/electrolyte interface; there is an electrocapillary reduction of the surface energy which leads to a corresponding decrease in the activation energy for slip in the surface of the specimen.

(1261) Phelps, L A

Physical and Metallurgical Aspects of Creep. I Physical Considerations II. Metallurgical Considerations

Metal Treatment 23 (1956) 311-314, 349-352

Various theories of the mechanism of creep in metals are discussed Mechanism of deformation is considered in terms of various dislocation theories

(1262) Philibert, J

Dislocations and Plastic Properties of a Solid (In French)

Métaux (Corrosion-Inds) 31 (1956) 153 166

Theoretical elastic limit, whiskers, brittle fracture, movement of dislocation, strain aging, and formation of Cottrell atmospheres

(1263) Phillips, D. J , and Thompson, N

Surface Effects in Creep or Cadmium Crystals

Proc Phys Soc (London) 63B (1950) 839-847

The changes in creep rate are recorded when the chemical environment of a stressed Cd crystal is altered. Experiments were made with aqueous solutions of a number of inorganic salts of Cd. The observations are explicable in terms of variations in the thickness of a surface film of Cd $(OH)_2$ the presence of such a film having the effect of reducing the creep rate by an amount depending on its thickness Measurements were also made on the effect of very thin films, formed by immersion in distilled water When the films were removed with dilute sulphuric acid a sudden small strain increment was observed, the magnitude of which depended on the film thickness Possible explanations are discussed.

(1264) Pickus, M R , and Parker, E R

Creep Behavior of Zinc Modified by Copper in the Surface Layer

Trans AIME 191 (1951) 792-796

Creep tests on single crystals and polycrystalline Zn with and without a Cu coating. Results with single crystals showed creep rate decreased in the presence of a thin Cu layer When the Cu was removed the creep rate increased to the value obtained for the unplated specimen The effect of Cu plating on polycrystalline material was negligible within the limits of experimental accuracy The differences in behavior are linked to the fact that dislocations can be generated more easily at the surface than in the interior of the metal

(1265) Pickus, M R and Parker, E R

Creep as a Surface Dependent Phenomenon

Paper from Symposium on Corrosion of Materials at Elevated Temperatures Spec Tech Publ No 108, ASTM, Philadelphia (1951) 26-33

Published researches on effects of surface conditions on plastic flow of metals are briefly reviewed and effects on secondary creep rates for Zn and "A" Ni were investigated. Both single-crystal and polycrystalline Zn were studied. For the single-crystal Zn specimens a marked increase in the resistance to creep was found when the surface layer contained Cu. No such effect was found for polycrystalline Zn. Cu in the surface layer affected the temperature dependence of steady state creep for single crystal but not for polycrystalline Zn. The resistance to high temperature creep of "A" Ni was found to be much greater in air than it was in H_2. The presence of W on the surface of "A" Ni, however, had no affect upon the creep rate of this material. The temperature dependence of the steady-state creep rate of "A" Ni is shown to be insensitive to conditions at the surface.

(1266) Piercy, G. R., Cahn, R. W., and Cottrell, A. H.

A Study of Primary and Conjugate Slip in Crystals of Alpha Brass

Acta Met. 3 (1955) 331-338

When a single crystal of alpha-brass is strained in tension, the conjugate slip system does note become fully active until the tensile axis has "overshot" the (100)-(111) symmetry line appreciably. Experiments on such crystals show that the amount of overshoot is substantially independent of the temperature and rate of straining, and is unaffected by intermediate strain aging treatments. Easy glide in these crystals is accompanied by the passage of Lüders bands along the specimen and so cannot be distinguished from yield elongation. When two Lüders bands on different slip systems meet, each forms a barrier to the passage of the other which is impenetrable until the applied stress reaches the level at which conjugate slip normally propagates. An explanation of latent hardening and overshoot is proposed on the basis of these results.

(1267) Pines, B. Ia.

Sintering, Creep, Relaxation, Recrystallization, and Other Phenomena Connected With Self Diffusion in Crystalline Bodies (In Russian)

Uspekhi Fiz. Nauk 52 (1954) 501-559

Influence of plastic deformation on recrystallization and creep of amorphous bodies.

(1268) Pines, B. Ia.

On the Diffusional Creep of Solids (In Russian)

Zhur. Tekh. Fiz. 27 (1957) 2314-2320

Using the vacancy theory of diffusion, the creep of a solid due to the motion of individual atoms is considered for various states of stress. It is shown that creep by directed self-diffusion is possible for all states of stress except uniform hydrostatic pressure, and that the first and second coefficient of viscosity of a solid should be of the same order of magnitude. Diffusional motions near a spherical pore, due to stresses caused by the surface tension, are considered.

(1269) Pines, B. Ia.

Development of "Embryonic" Cracks Affecting Brittle Strength of Substances (In Russian)

Zhur. Tekh. Fiz. 25 (1955) 1399-1404

Lack of agreement between values of "brittle strength", observed experimentally and those estimated according to magnitude of cohesive forces, has long been explained by the hypothesis of the presence in solid substances of so-called embryonic cracks which bring about premature failure. The author attempts to trace the origin of these cracks to molecular and atomic forces, the movement of vacancies, and diffusion peculiarities.

(1270) Podszus, E.

Energy Conditions and Changes in Deformation and Fracture (In German)

Z. Metallk. 41 (1950) 23-31

Shows that only about 1% of the energy applied to deformation and fracture of a piece of material is absorbed by the material, while the remainder is evolved as heat. This heat – which can affect the material the same as heat treatment and may even exceed the melting point of the material – is said to be responsible for the difference between theoretical and the actual mechanical properties of worked materials.

(1271) Polakowski, N. H.

Softening of Metals During Cold-Working

J. Iron Steel Inst. 169 (1951) 337-346

A theory relating indentation hardness and energy stored in a cold-worked metal is put forward as a tentative explanation of both the Bauschinger effect and work softening. To satisfy this theory, quenched and tempered steels should soften during the early stages of cold working, and they are shown experimentally to do so. The softening effect provides an explanation of the recrystallization and mechanical properties of single and polycrystalline metals after reversed deformation.

(1272) Polanyi, M.

A Type of Lattice Distortion Which Might Render a Crystal Plastic (In German)

Z. Physik 89 (1934) 660-664

If a lattice distortion be conceived in which n atoms in one lattice atomic layer are opposed to n+1 atoms in the other, then the shear resistance in the slip plane is reduced to about 1/n of its value in the undisturbed lattice.

(1273) Pomeroy, C. D.

Creep in Coal at Room Temperature

Nature 178 (1956) 279

Studied the deflection of cantilever specimens of bituminous coal, which could be described by d = A + B log t + Ct, where d is the deflection, t is the time, and A, B, C are constants. This is the same expression found by Griggs [J. Geol. 47 (1939) 225] for the case of a cube of rock subjected to uniaxial compression. Recovery of the cantilever is expressed by d = A + B log t. No creep was observed with anthracite coal.

(1274) Pomey, J., Royez, A., and Georges, J. P.

Metallurgical Uses of Hot Hardness (In French)

Compt. rend. 245 (1957) 1424-1427

In a test of isothermal hardness under a constant load, creep can be measured by the sinking of the penetration as a function of time. A correlation is shown between transient creep and the hardness curve. This new method using hardness is rapid and needs little material.

(1275) Poncelet, E. F.

Fracture and Comminution of Brittle Solids

Trans. AIME 158 (1944) 333-334

Attempts to analyze the phenomena involved in the fracture of brittle solids by simple compression.

(1276) Poncelet, E. F.

Nature of Strength and Failure in Brittle Solids

Colloid Chem. 6 (1946) 77-88

An ideal brittle solid can be visualized as a collection of identical particles held at definite spacings by electrostatic bonds. The Morse curve is the graph representing the resultant of the simultaneously existing and changing attractions and repulsions. A broken bond arises when a critical distance between particles is exceeded. The following factors are considered: the physical nature of failure, failure under tension, fracture under compression; mixed stresses; the physical nature of strength in solids, and the fundamental difference between viscous and plastic flow. The "flaws" assumed by Griffith, Smekal, Orowan, and others are not essential to fracture. Compressive strength exceeds tensile strength eight times or more (in glass between nine and fifty times).

(1277) Poncelet, E. F.

A Theory of Static Fatigue for Brittle Solids

Papers from Fracturing of Metals, Am. Soc. Metals, Cleveland (1948) 201-227

There is a definite relation between the intensity of the stress to which a brittle solid is subjected and its duration necessary to produce a fracture. This important and well-established fact cannot be reconciled with any of the classical theories of strength of brittle solids, which do not take the duration factor into consideration. The difficulty can be avoided by assuming the structure of the solids to be particulate, and composed of ions. Such a structure is not directly amenable to thermodynamic formulas, but is easily subjected to the ordinary laws of statistical mechanics. The factor of time is introduced into the expression which determines strength of brittle solids. It is indicated that the old concept of "strength" as "ability to withstand stress" must be abandoned, since brittle solids begin to fracture the instant a stress is applied.

(1278) Pond, R. B., and Harrison, E.

Grain-Boundary Movement in Bicrystalline Aluminum

Trans. ASM 50 (1958) 994-1005

The plastic deformation of bicrystalline Al specimens having grain boundaries perpendicular to the specimen axis was studied. The method of production by localized melting of a single crystal and rotation and translation of the still solid remainder is described. Stress/strain diagrams show that the strain-hardening index of bicrystals having such boundaries is lower than that for single crystals of the parent orientation. In tensile and compression specimens having the [121] pole in the slip plane and 90 degrees from the slip direction, the boundary moved during deformation causing the bicrystal to assume a V shape. No significant bending of slip planes occurred in either tension or compression.

(1279) Popov, E. P.

Correlation of Tension Creep Tests With Relaxation Tests

Trans. ASME 69 (1947) A 135 – A 142

A satisfactory relaxation graph may be obtained from the usual tension creep curves. The validity of methods for simple relaxation is demonstrated on the basis of experimental agreement between calculated and test results. Inadequacy of the usual methods of computations are pointed out. Analytical schemes that appear satisfactory are extended for relaxation with the elastic follow up.

(1280) Portevin, A.

A Formula for Creep Curves

Metal Progr. 33 no. 3 (1938) 285-286

Presents an empirical equation due to deLacombe representing the various shapes of creep curves, i. e., $y = y_0 + at^m + bt^n$, where y = elongation, t = time, and y_0, a, b, m, and n are constants. Usually, m < 1 (0.3 – 0.5) and n > 1 (1.8 – 2.2).

(1281) Pöschl, T.

The Theory of Hard Drawn Materials, on the Basis of the Theory of Plasticity (In German)

Arch. Eisenhüttenw. 16 (1943) 425-429

By the extension of a hardness formula, derived for elastic deformation, to the case of plastic deformation, the Brinell hardness in the plastic range is related to the quantity V, which represents the mean slope of the stress-strain curve. The Brinell hardness if proportional to Vd/D, where d and D are, respectively, the diameters of the impression and the indenting ball. Knowing the relation between the load and d/D, it is possible to derive by integration, from hardness measurements, the stress-strain curve for the material in compression.

(1282) Pospisil, R.

Evaluation of Creep Tests (In Czech.)

Hutnické listy 11 (1956) 547-552

Enlarges on the method proposed by Larson and Miller for evaluation of tests in several alloy steels.

(1283) Prager, W.

Exploring Stress-Strain Relations of Isotropic Plastic Solids

J. Appl. Phy. 15 (1944) 65-71

Combined torsion and tension on thin-walled tubes consitutes one of the few testing arrangements in which a fairly general state of uniform stress can be realized without too great experimental difficulties. A graphical representation of such tests is used to discuss, in geometrical terms, some stress-strain relations of the mathematical theory of plasticity. It is shown that the theories of Saint-Venant, Levy, and Mises lead to physically unacceptable conclusions unless the material is supposed to be rigid as long as the stress has not reached the yield limit. The predictions of the theories of Prandtl, Reuss, Hencky, and Nadai are compared with the results of experiments on mild steel, the possible effects of viscosity and strain hardening are discussed.

(1284) Prager, W.

Strain Hardening Under Combined Stresses

J. Appl. Phy. 16 (1945) 837-840

Experimental investigations of the strain hardening of metals under combined stresses are usually conducted so that the directions of the principal stresses as well as the ratios of their magnitudes remain constant during any one test. The paper is concerned with incompressible isotropic materials which are stressed in this manner and deform in accordance with certain postulates. The most general stress-strain relation which can arise under these circumstances is established and some special cases of this relation are discussed.

(1285) Prager, W.

Theory of Plastic Flow versus Theory of Plastic Deformation

J. Appl. Ph. 19 (1948) 540-543

The theories of plasticity proposed for metals in the strain-hardening range are of two types: (1) theories of plastic deformation, based on the assumption that for continuous loading, the state of strain is uniquely determined by the state of stress, and (2) theories of plastic flow, which assume that the increment of strain is uniquely determined by the existing stress and the increment of stress. A concept of neutral change of stress is proposed, as a limiting case of loading or unloading. It is shown that theories of plastic flow satisfy the condition that the stress-strain relationships for both loading and unloading should predict the same change of strain when applied to a neutral change of stress, whereas this condition is not satisfied by theories of plastic deformation.

(1286) Pranatis, A. L., and Pound, G. M.

Viscous Flow of Copper at High Temperatures

Trans. AIME 203 (1955) 664-668

Measurements were made of the changes in length of Cu foils of various thicknesses and grain sizes under low stresses and high temperatures, such that creep was predominantly the result of a flow of vacancies between grain boundaries and surfaces, as postulated by Herring. Results are in good agreement with the values predicted by Herring's theory of diffusional viscosity, and suggest that in these experiments, slip, kinking, offsetting, and grain-boundary sliding made only a limited contribution to deformation.

(1287) Prandtl, L.

A Model to Explain the Kinetic Theory of Solid Masses (In German)

Z. angew. Math. u. Phys. 8 (1928) 85-106

The following assumptions can be made in considering the mechanism of deformation. Two more or less irregularly bounded lattices are drawn one over the other whereby molecules bound elastically with one lattice are drawn through the variable field of force of the other lattice. This idea can be illustrated by means of a simple mechanical model that shows, at least qualitatively, the phenomena of hysteresis, of the Bauschinger effect, of relaxation, and of after working.

(1288) Pratt, P. L.

Similar Glide Processes in Ionic and Metallic Crystals

Acta Met. 1 (1953) 103-104

The strain-hardening curve of NaCl is parabolic when single glide occurs, and linear when double glide occurs. The results are compared with those for metallic crystals. Hexagonal metals show single glide and give linear curves, while for fcc crystals the shape of the hardening curve should depend on the initial orientation, which determines whether or not double glide is present from the beginning of deformation. Experimental evidence in favor of this prediction is summarized.

(1289) Pratt, P. L., and Pugh, S. F.

The Movement of Twins, Kinks, and Mosaic Walls in Zinc

Acta Met. 1 (1953) 218-222

Zn discs were subjected to steadily increasing bending stresses while the cleaved surfaces were observed under an opaque-stop microscope. Formation of twins and accommodation kinks was observed. The movement under stress of the curved (macro) mosaic walls, and a simultaneous increase in the misorientation of the mosaic elements were also observed. The results are discussed in terms of dislocation theory.

(1290) Predvoditelev, A. A., and Smirnov, B. A.

Theory of Dynamic Creep (In Russian)

Vestnik Moskov. Univ. 8 no. 8 (1953) 79-86 (Translation NACA TN 1330)

The theory is based on the following assumptions: (1) the instantaneous creep rate depends on the rate of change of the stress; (2) variable stresses may accelerate structural changes such as aging and recrystallization; (3) dynamic loads may facilitate forms of lattice deformations which differ from the modes of deformation caused by static loads; (4) under cyclic loads mechanical hysteresis phenomena cause a dissipation of energy which is partially transformed into heat, thus causing local increase in temperature over the slip planes. A theory is developed, modifying the Becker theory of the aftereffect.

(1291) Preobrazhenskaya, Yu. A.

The Influence of the Degree of Preliminary Deformation on the High-Temperature Strength of Alloys (In Russian)

Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh. Nauk, no. 12 (1957) 30-37

Binary alloys of Al with Cu, Fe, Mg, Si, Ni, and several standard alloys were investigated. The high-temperature strength was determined by measuring the extension under a load after long periods and by long-time hardness measurements (the indentation under a load after more than 1 hour). The measurements were made at 250 to 300 C. The long-time hardness of pure metals and solid solution is the same in cast and preliminarily deformed samples whereas the long-time strength decreases with increasing deformation. This indicates that a change takes place in the grain boundaries during deformation. With heterogeneous alloys, however, the long-time hardness and long-time strength both decrease with increasing deformation, indicating that a structural change takes place within the grains. The highest values of high-temperature strength are shown by alloys in which there is a network of fine precipitate within the grains, usually found in cast and hardened alloys after stabilization. Coalesence of the particles leads to a decrease in high-temperature strength. The compounds of $FeAl_3$, $NiAl_3$, and the X (Fe-Si-Al) phase tend not to coalesce on heat treatment. The resistance to deformation depends on the form of the precipitate and the strength of the bonds between it and the matrix.

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(1292) Presnyakov, A. A.

The Effect of Plastic Deformation on the Rate of Diffusion (In Russian)

Zhur. Tekh. Fiz. 27 (1957) 575-576

Ni of commercial purity was rolled by various amounts ranging from 2.5 to 70%. The specimens were then heated at 700 C for various times (15 to 60 minutes) in S vapor. Diffusion of S into Ni was measured by metallographic observation of the Ni-S alloy layer under the surface. After 15 minutes of heating time the thickness of this layer rose slightly with deformation then fell sharply and vanished altogether. Similar results, though less clearly defined, were observed with longer heating times. Presnyakov concludes that in exceptional cases lattice disarrangement, the result of plastic deformation, may slow up diffusion.

(1293) Prokhorov, N. N.

Intercrystalline Strength of Metals During Welding (In Russian)

Izvest. Akad. Nauk S S S R , Otdel. Tekh. Nauk, no. 11 (1956) 31-49

Relation between deformation rate and plasticity of metals. Stages of fracture or failure in relation to temperature.

(1294) Prosvirin, V. I.

Plasticity in Creep Conditions and A Mechanism of Precipitation Hardening (In Russian)

Vestnik Mashinostroeniya 33 no. 1 (1953) 42-47

Theoretical discussion of plasticity and creep.

(1295) Pry, R. H., and Hennig, R. W.

On the Use of Electrical Resistivity as a Measure of Plastic Deformation in Copper

Acta Met. 2 (1954) 318-321

Load/time curves of Cu wires were recorded at constant strain rate. The electrical resistance of the wires was also measured before straining, and after annealing. This cycle was repeated for each additional 2% of plastic strain. The results showed that although the stress/strain curves at 78 K were appreciably altered by the room-temperature anneal, the stress/resistivity curves are independent of this treatment. Further experiments in which wires were deformed alternately at 78 and 286 K confirmed that the tensile stress for plastic flow was a singlevalued function of the electrical resistivity (which effectively measures the degree of cold work), the strain rate, and the temperature. Some tests were also made on partially recovered specimens, and on specimens given a preliminary deformation by twisting, and the above results were found to be still valid.

(1296) Pugh, S. F.

Relations Between the Elastic Moduli and the Plastic Properties of Polycrystalline Pure Metals

Phil. Mag. 45 ser. 7 (1954) 823-843

Correlations between plastic properties and elastic moduli of metals are proposed on elementary theoretical grounds. For metals with a given lattice structure melting above 1000 C, Gb/B is a constant, while for lower melting point metals, it is a function of melting point. High malleability is correlated with high values of K/G and a high Poisson's ratio. (In the above formula, G is the shear modulus, K the bulk modulus, and b the Burgers vector.)

(1297) Pugh, S. F.

Plasticity of Hexagonal Metals and Its Variation with Temperature (In French)

Rev. met. 51 (1954) 683-692

Although the plastic properties of the hexagonal metals differ greatly from one metal to another and even in a given metal with variations of temperature, their fundamental behavior is the same in several regards. The reasons for this were analyzed by studying the plastic properties common to all hexagonal metals, and relating alterations in mode of deformation at fairly high temperatures to the appearance of phenomena caused by heat. The following conclusions were reached: (1) the relative malleability of hcp metals can be deduced from the elastic constant and (2) the choice of the slip plane is dependent upon the elastic constants of the single crystal having regard to the energy of the dislocations situated in various directions of the crystal.

(1298) Puttick, K. E., and King, R.

Boundary Slip in Bicrystals of Tin

J. Inst. Metals 80 (1952) 537-544

Specimens of Sn consisting of two crystals meeting in a straight boundary were stressed in shear to cause relative movement of the crystals at the boundary. Relation between relative movement and time under steady stress was examined at a number of stresses and temperatures, for a standard type of specimen in which the c-axes of the crystals were at right angles to one another and at 45 degrees to the boundary.

(1299) Puttick, K. E., and Thring, M. W.

The Dynamic Theory of Yield

Iron and Steel 25 (May 1952) 155-159

Certain temperature- and velocity-sensitive properties of metals can be interpreted in terms of the dynamic theory of plastic yield, which views the onset of plastic flow as being determined by an activation energy supplied by a combination of strain energy and thermal fluctuations. Yield occurs when thermal fluctuations can provide the additional energy necessary to surmount the potential barrier in the time available.

(1300) Rabotnov, Y. N.

Some Problems of the Theory of Creep (In Russian)

Vestnik Moskov. Univ. no. 10 (1948) 81-91 (Translation NACA TM 1353)

The different equations proposed for an analytical expression of creep curves may be divided into two groups: $p = S(\sigma)T(t)$ and $p = g(t) + S(\sigma)$, [illegible], where p = plastic creep strain, σ = stress, t = time. Based on an analysis of 100,000-hour data by Robinson, Rabotnov suggests the formula [illegible], where ε is the total creep strain under constant stress and α is about 0.7 and X varies widely for different materials. After analyzing the theories of constant rate, aging, and strain hardening, Rabotnov proposes a new theory which represents an extension of the theory of elastic heredity of Volterra. This new theory is applied to the problems of relaxation, reverse creep, creep-bending of bars, and creep of a pipe under internal pressure. Finally, a special class of three-dimensional problems is considered.

(1301) Rabotnov, Y. N.

The Effect of Changing Loads During Creep

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 221-225

One-dimensional creep in tension is analyzed mathematically and a formula is developed for the creep-recovery process on unloading after tensile creep. The theory is tested by reference to short-time creep tests on commercial Cu at 165-235 C. It is considered that both the theory developed and that of strain hardening give satisfactory reproduction of the results.

(1302) Rachinger, W. A.

Relative Grain Translations in the Plastic Flow of Aluminium

J. Inst. Metals 81 (1952) 33-41

The respective contributions of grain elongation and relative grain movements to the deformation have been determined for various conditions of temperature and strain rate. At higher temperatures and lower rate of deformation the grains do not elongate in conformity with the aggregate, but tend to remain equiaxed, the external deformation being due to the relative movements of the grains. The mechanism of plastic flow at the surface is found to be quite different from that in the interior, the transition taking place in a region of only 0.010-inch thickness.

(1303) Rachinger, W. A.

Deformation Sub-Structures in Aluminium

Bull. Inst. Metals 1 (1952) 125

The existing experimental observations on, and explanations of, the formation of crystal blocks or cells in plastically deformed Al are reviewed. The cell size, which appears to be mainly dependent on the rate and temperature of deformation, can be adjusted to be <, =, or > the grain size of the material, resulting in the formation of a substructure, no change in structure, or grain growth, respectively. The width of deformation bands, from which the cell structure arises, varies with rate and temperature of deformation in the same way as the cell size. Theoretical explanations are needed.

(1304) Rachinger, W. A.

The Effect of Grain-Size on the Structural Changes Produced in Aluminum by Slow Deformation

J. Inst. Metals 80 (1952) 415-418

X-ray diffraction and metallographic methods were used to study the internal derangement of Al polycrystals of various grain sizes after slow deformation at elevated temperatures. The present work indicates that for a given temperature and rate of straining the effect of an increase in grain size is roughly equivalent to a decrease in temperature or an increase in strain rate. Further evidence is produced to confirm the existence of a deformation-induced substructure within the grains.

(1305) Rachinger, W. A.

Glide in Lead Telluride

Acta Met. 4 (1956) 647-649

The occurrence of <100> glide in PbTe has been verified by means of prismatic punching. Rocksalt, which has the same crystal structure, glides in <110> directions. This may be explained in terms of the bonding energies of the compounds. At low bonding energies, as in PbTe, slip occurs by the movement of coupled partial dislocations of the type 1/2 a [001]. In ionic salts, however, these partials could not exist and perfect dislocations of the type 1/2 a [110] are effective in producing slip.

(1306) Raimes, S.

Plasma Oscillations and the Electron Theory of Metals

Research 9 (1956) 374-380

Account of electronic interactions and their effects on metal properties. Theories for calculating energies and the improvement afforded by the plasma oscillation concept.

(1307) Ramsey, J. A.

Structure of a Deformed Metallic Grain

Nature 166 (1950) 867-868

Experiments on polycrystalline Zn indicate that upon deformation the grains break down into a number of fragments. The degree of perfection, and probably the size, of the fragments increase with increasing temperature of deformation.

(1308) Ramsey, J. S.

Some Observations on the Deformation of Polycrystalline Zinc

J. Inst. Metals 80 (1951) 167-171

Polycrystalline Zn, when deformed, behaves in a similar way to Al in that, both at elevated temperature and at slow strain rates, it tends to form a subgrain or cell structure within the grains. Evidence is presented in support of the view that the cell structure is produced directly by deformation and cannot be adequately explained by the same mechanism as that suggested for polygonization.

(1309) Ramsey, J. A.

The Sub-Grain Structure in Aluminium Deformed at Elevated Temperatures

J. Inst. Metals 20 (1952) 215-216

Sub grain structures in coarse-grained Al deformed at elevated temperatures are shown by metallographic and X-ray examination to be associated with bands similar to kink bands.

(1310) Ratner, S. I.

Problems in the Theory of Plasticity (In Russian)

Izvest. Acad. Nauk S S S R , Otdel. Tekh. Nauk (March 1950) 435-450

Critical review and correlated discussion of recent literature (including non-Russian work). Tabular data for various common metals and alloys subjected to various heat treatments.

(1311) Rauzin, Ya. R., and Zheleznyakova, A. R.

The First Stage in the Plastic Deformation of Polycrystalline Metals and the Influence of Grain Size. I. Aluminum. II. Iron (In Russian)

Fiz. Metal i Metalloved. 3 Akad. Nauk S S S R , Ural' Filial (1956) 146-161

I. The first stage of deformation of polycrystalline Al is by grain boundary movement of whole grains over each other. The next stage is by deformation of individual grains by slip. The limiting strain at which grain-boundary movement gives way to slip depends on the conditions of the deformation, composition of the grain-boundary layer, and grain size; slower deformation, higher temperatures, and smaller grains move the limit to higher strains; pure metal and larger grains move the limit to lower strains or even zero strain. The mechanism of the two types of deformation is discussed. There must be an optimum grain size for optimum strength (resistance to deformation); this optimum is the limiting grain size at which grain-boundary deformation gives way to slip. II. Attempt the same methods for Fe, but the situation is much more complex than in Al. There is a limiting deformation at which slip lines first appear, and this depends on grain size. The effect of grain size on plasticity (extension for given stress) is summed up by the rule: any factor which reduces the ability of the Fe to deform by grain-boundary movement reduces plasticity.

(1312) Read, W. T., Jr.

Experimental Information on Slip Lines

Paper from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc., New York (1952) 129-151

A brief review of experimental information, no attempt being made at interpretation. For the most part, the results refer only to metal single crystals; the various metals are considered one after another. Investigations reported were on slip direction and slip plane, form of the slip lines, spacing of the various classes of slip lines, and amount of slip per line. Techniques for study of influence of experimental conditions on slip lines.

(1313) Read, W. T., Jr.

Dislocations and Plastic Deformation

Phys. Today 6 (November 1953) 10-13

Reviews fundamental concepts concerning the above in certain ductile materials. Reports that small and exceedingly rare defects in structure of solids are "weak links" that determine strength of materials.

(1314) Read, W. T., Jr.

Dislocation Theory of Plastic Bending

Acta Met. 5 (1957) 83-88

The macroscopic stress (average stress in a volume containing many dislocations) in a uniformly bent crystal is related to the dislocation density by a simple differential equation analogous to Poisson's equation. Differences between bending and tension tests give information about the dislocation mechanism of deformation. A material that has a flat stress-strain curve in tension may show a yield point in bending if the stress required to move dislocations is substantially less than the stress required to generate dislocations.

(1315) Read, W. T. Jr., and Pearson, G. L.

Deformation and Fracture of Silicon

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 537-544

Purpose of the investigation was to study the stress-strain behavior of perfect crystals in the plastic range. The mechanism of plastic deformation in Si and the dominant effect of impurities even in the purest Si now available. The behavior is strikingly similar to that of Fe containing C. There is a pronounced yield point at the beginning of plastic flow, the lower yield stress being less than half the upper yield stress.

(1316) Read, W. T., Jr., and Shockley, W.

Dislocation Models of Crystal Grain Boundaries

Phys. Rev. 78 (1950) 275-289

The manner in which grain boundaries can be built up out of dislocations is considered in detail. Relationships are derived for the dependence of energy upon the relative angle between grains, and these seem to be consistent with experiment. Grain boundaries of the type discussed can permit intercrystalline slip and may act as stress raisers for the generation of dislocations.

(1317) Read, W. T., Jr., and Shockley, W.

On the Geometry of Dislocations

Paper from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc., New York (1952) 77-94

Dislocations are one of the few types of defects which naturally occur in crystalline substances. All dislocation types are classified according to a simple scheme which makes use of the Burgers circuit and the Burgers vector. Both complete and partial dislocations are illustrated, and a dislocation theory of straight versus wavy slip bands is suggested. The intersection of dislocations is shown to result in kinks or jogs in the dislocation lines which impede the slipping motions and may create vacancies and interstitial atoms. The Frank-Read mechanism of dislocation multiplication is reviewed.

(1318) Read, W. T., Jr., and Shockley, W.

Role of Dislocations in Crystal Growth and Grain Boundary Phenomena

Paper from Dislocations in Metals, Edited by M. Cohen, Am. Inst. Mining Met. Engrs., New York (1954) 37-68

The dislocations theory is applied to crystal growth and grain boundaries. Frank's theory of the growth of an imperfect crystal is given and evidence for the theory is presented and discussed. Also included is a dislocation model of a simple grain boundary, the derivation of an equation for the energy of a grain boundary, and the description of motion of small-angle grain boundaries.

(1319) Recorder

Mechanism of Creep

Metal Ind. 92 (1958) 88-96

Studies of theoretically possible creep mechanisms demonstrated that no one theory fully covers the data available, but two theories have not yet been shown to be erroneous. One suggests that concentration gradients of vacant lattice sites are set up in a creep specimen under the influence of the applied stress. Vacancies move in accordance with the gradients, setting up a net flow of vacancies causing elongation in the direction of the applied stress. The second theory suggests that the generation and movement of dislocations give rise to an observed strain.

(1320) Recorder II

Intercrystalline Failures During Creep. II.

Metal Ind. 84 (1954) 554

Factors which influence grain boundary movement during creep are temperature, rate of straining, and grain boundary precipitation. Discusses the theory of precipitation of vacancies at the boundaries as a mechanism of intercrystalline cracking.

(1321) Reed-Hill, R. E., and Robertson, W. D.

Deformation of Magnesium Single Crystals by Non-Basal Slip

Trans. AIME 209 (1957) 496-502

High-purity Mg single crystals, oriented to suppress (0002) basal slip and $(10\bar{1}2)$ twinning, were stressed parallel to the basal plane and in a $\langle 10\bar{1}0 \rangle$ direction, between -190 and 286 C. X-ray analysis of the lattice rotations, the two-dimensional nature of the plastic strain, and the slip bands which are visible on surfaces nearly parallel to the basal plane all indicate that plastic deformation at all temperatures is accomplished primarily by conjugate slip along $\langle 11\bar{2}0 \rangle$ slip directions.

(1322) Reed-Hill, R. E., and Robertson, W. D.

Pyramidal Slip in Magnesium

Trans. AIME 212 (1958) 256-259

Slip on $11\bar{2}2$ planes, which do not contain a close-packed direction, has been identified on crystals strained at -190 C. Evidence also shows that $10\bar{1}1$ pyramidal slip is a mode of deformation at 25 C in a limited orientation range.

(1323) Rehbinder, P.

New Physico-Chemical Phenomena in the Deformation and Mechanical Treatment of Solids

Nature 159 (1947) 866-867

A report dealing with recent Russian research on the effect of surface-active substances on the mechanical properties of solids. In general, the resistance of solids to stress is reduced by surface-active materials. Mica in dry air deforms instantaneously under external forces and recovers instantaneously on removel of load. Moisture, however, causes deformation and recovery to be slow; the effect is enhanced by the addition of organic substances which are readily absorbed on mica. The yield value of Sn single crystals is halved owing to sorption by the strained metal of surface-active organic materials; the number of slip bands increases, and the distance between them decreases. At the same time, the electrical conductivity falls abruptly. Similar effects are found with Zn and Cu. This behavior is due to the absorption of material on the inner surfaces of microcracks which develop on straining a solid, which thus behaves as a labile absorbent, the newly formed surface of which disappears again after unloading.

(1324) Reiner, M.

Deformation and Flow. An Elementary Introduction to Theoretical Rheology

H. K. Lewis & Co., Ltd., London (1949) 346 pp

Basic concepts and numerical examples of application of theory

(1325) Reitz, J. R., and Smith, C. S.

Calculation of the Elastic-Shear Constants of Magnesium and Magnesium Alloys

Phys. Rev. 104 (1956) 1253-1259

Leigh's theory of the elastic-shear constants of cubic metals, e.g., Al is extended to include metals of lower symmetry, more especially to hcp crystal structures, viz., Mg and dilute Mg alloys. Extension of Leigh's results to room temperature shows that the predicted change of shear constant is much more gradual as one goes through the critical electron:atom ratio. The experimental graph relating the shear constant to the electron:atom ratio in dilute alloys of Mg with Ag, In, or Sn, follows the theoretical graph fairly well.

(1326) Resnick, R., and Seigle, L.

Nucleation of Voids in Metals During Diffusion and Creep

Trans. AIME 209 (1957) 87-94

Experimental evidence is presented which proves that voids formed during diffusion in brass are heterogeneously nucleated. When the nuclei, probably ZnO, are removed by remelting, practically no voids form upon subsequent dezincification. Brass, freed of void nucleation catalysts, exhibited reduced tendency for grain-boundary cracking during creep and increased stress-rupture life.

(1327) Rhines, F. N.

Mechanism of Grain Boundary Displacement and Its Relation to the Creep Process as a Whole

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 47-57

The creep strain of pure Al bicrystals was measured by the displacement of a grid photoengraved on the specimen. The process consisted of an immediate plastic and elastic elongation of the specimen followed by an induction period before grain-boundary gliding began at a maximum rate. The gliding gradually stopped, to be followed by further cycles of motion and rest. The rate of gliding is controlled largely by the relative orientation of the conjugate crystals. The mechanism of grain-boundary gliding is interpreted in terms of the bending of crystals impinging on a grain boundary during the induction period. When sufficient energy has been stored, recovery occurs by polygonization. The metal in the recovered zone is now softer than that remote from the grain boundary, and rapid yielding occurs parallel to the grain boundary. Slip through the subgrains will restore the mechanical state for polygonization to occur. This hypothesis is discussed in relation to the creep process as a whole.

(1328) Rhines, F. N., Bond, W. E., and Kissel, M. A.

Grain Boundary Creep in Aluminum Bicrystals

Trans. ASM 48 (1955) 919-951

Grain-boundary shearing at high temperature and low tensile stress is found to be spasmodic, beginning with an induction period. Its direction depends exclusively upon that of the maximum shear stress in the grain boundary, but its rate depends as well upon the orientation relationships of the conjugate crystals. The over-all gliding rate is constant with the cube root of time, bears an Arrhenius relationship to the temperature, and its logarithm is approximately proportional to the stress. A mechanism for the process is proposed.

(1329) Rhines, F. N., Bond, W. E., and Kissel, M. A.

Grain-Boundary Behavior in Creep of Aluminum Bicrystals

NACA TN 3556 (1955) 56 pp

Al bicrystals were tested in tensile creep. Extension of each grain and strain across the boundary, as well as total extension, was measured. It is concluded that grain-boundary gliding consists of an alternation of coordinated slip and recovery in a physically continuous chain of subgrains existing along the boundary. The results and conclusions can be applied as a criterion to develop high-temperature creep-resistant alloys.

(1330) Rhines, F. N., Bond, W. E., and Kissel, M. A.

Influence of Alloying Upon Grain-Boundary Creep

NACA TN 3678 (1956) 16 pp

Bicrystals of single-phase Al-Cu alloys containing 0.1, 0.2, 0.3, 0.4, 0.5, 1, 2, and 3% Cu were subjected to creep tests at elevated temperatures and displacements across the boundaries were measured. The minimum temperature and stress for initiation of grain-boundary sliding increased progressively with Cu content. The creep rate as a whole decreased slightly with Cu addition. For high-purity Al, the grain-boundary yielding was linear if measured parallel to the applied stress and spasmodic if measured perpendicular to the applied stress.

(1331) Rhines, F. N., and Cochardt, A. W.

Preview of Behavior of Grain Boundaries in Creep of Aluminum Bicrystals

NACA TN 2746 (July 1952) 40 pp

Gliding of Al bicrystals along their mutual boundary was studied during creep tests at 200 to 650 C and 1 to 100 psi.

(1332) Rightmire, B. G.

Mechanism of Steady-State Creep in Metals

Phys. Rev. 75 (1949) 1627

The experimental results of Dushman show that in the steady-state creep of metals the logarithm of the strain rate varies linearly with stress. From the slopes of these curves he deduces that the unit of flow comprises about 1000 atoms. It is here pointed out that Dushman's values of energy of activation suggest that the unit of flow contains only about 10 atoms. To explain this apparent contradiction, it is proposed that the flow units are dislocations that move segmentally, rather than as rigid structures. Each segment is assumed to be one atomic diameter in length. It is postulated that if one of these segments jumps to a new position of equilibrium the others follow in tandem. With the aid of this concept, absolute-reaction-rate theory enables one to estimate the number of atoms per dislocation, and the concentration and velocity of the dislocations. Computations have been made for Al, Ag, and Pt. It is found that Al contains relatively few fast-moving dislocations, which may account for the observed slip bands.

(1333) Riparbelli, C.

On the Relation Among Stress, Strain, and Strain Rate in Copper Wires Submitted to Longitudinal Impact

Proc. Soc. Exp. Stress Anal. 14 (1956) 55-70

Data from exploratory tests of tensile impact are used for the interpretation of the mechanism of plastic deformation caused by longitudinal impact. Hypothesis that the velocity of propagation of an elastic strain wave does not depend on the presence of plastic flow is substantiated by experiment. The rate of plastic flow results in a steadily increasing function of the stress. The stress measured in the presence of plastic flow is higher than the stress corresponding to the elongation present according to the static stress-strain relation.

(1334) Ripling, E. J., and Baldwin, W. M., Jr.

Rheotropic Embrittlement of Steel

Trans. ASM 43 (1951) 778-810

Previous work has shown that the brittleness which metals not crystallizing in the fcc system exhibit at low temperatures and high strain rates, under severe notching conditions, can be prevented by prestraining under conditions where the metal is ductile, i.e., the brittleness is rheotropic. The present experiments were performed to ascertain whether prestraining in compression would also prevent the brittleness. It was found that prestraining in both tension and compression tended to eliminate the brittleness otherwise present. It was therefore concluded that the earlier explanation of the rheotropic behavior is untenable.

(1335) Ripling, E. J., and Sachs, G.

The Effect of Strain-Temperature History on the Flow and Fracture Characteristics of an Annealed Steel

Trans. AIME 185 (1949) 78-90

All ferrous alloys can be made brittle by straining at sufficiently low temperatures. However, the changes in mechanical properties for different ferrous materials with decreasing testing temperatures do not appear to follow any universal law. In particular, complex effects of testing temperature have been observed if cold-worked steels were subjected to tensile tests at low temperatures. Effect of prestraining was investigated with regard to a mechanical equation of state.

(1336) Roberts-Austen, W. C.

On Certain Mechanical Properties of Metals Considered in Relation to the Periodic Law

Phil. Trans. Roy. Soc. London 179A (1888) 339-349

Various amounts (from 0.186 to 0.2905) of 17 elements added separately to Au. Tensile strengths plotted versus atomic volume of solute give a generally decreasing curve, as do elongations. Found that "the metals which diminish the tenacity and extensibility" of Au have high atomic volumes while those which increase these properties have either the same atomic volume as Au or a lower one.

(1337) Roberts, C. S.

Creep Behavior of Extruded Electrolytic Magnesium

Trans. AIME 197 (1953) 1121-1126

Creep mechanisms and kinetics of fine-grained Mg were studied from 200 to 600 F. As a result of a photographic study of microstructural changes, transient and steady-state creep components were correlated with slip, subgrain formation, and cyclic deformation at the grain boundaries.

(1338) Roberts, C. S., Carruthers, R. C., and Averbach, B. L.

The Initiation of Plastic Strain in Plain Carbon Steels

Trans. ASM 44 (1952) 1150-1157

Studies with a series of six C-steels having various metallographic structures showed a separate elastic limit at a lower stress than that of the lower yield point and a region of continuous plastic flow prior to discontinuous yielding. Prior plastic deformation had little effect on the elastic limit. A steplike behavior was found in the initial plastic-strain curves of the steels which contained no free ferrite.

(1339) Roberts, I.

Prediction of Relaxation of Metals From Creep Data

Proc. ASTM 51 (1951) 811-831

Controversy over evidence that relaxation rates of metals can be predicted from tension-creep data by means of the strain-hardening assumption. A theoretical discussion which should help to clarify some of the confusion. Experimental data show that the strain-hardening assumption yields accurate results not only for Cu but also for C steel and for the alloy S-816.

(1340) Robertson, W. D.

Correlation of Mechanical Properties and Corrosion Resistance of 24S-Type Aluminum Alloys as Affected by High-Temperature Precipitation

Trans. AIME 166 (1946) 216-228

The initial change of the ultimate maximum mechanical properties, as well as the initial, maximum, and ultimate susceptibility to intercrystalline corrosion can be expressed by equations of the type $t \times K10^{m/T}$. This equation enables a large volume of data to be summarized conveniently. The results are discussed with reference to grain boundary and general precipitation, and practical applications are given.

(1341) Robinson, A. T., Tietz, T. E., and Dorn, J. E.

The Functions of Alloying Elements in the Creep Resistance of Alpha Solid Solutions of Aluminum

Trans. ASM 44 (1952) 896-928

Creep data at 422 K revealed that the creep resistance of a series of high-purity binary alpha solid solutions in Al decreased in the order Al-Mg, Al-Cu, Al-Ag, Al-Ge, and Al-Zn. The highest creep-resistant alloys Al-Mg and Al-Cu were those which exhibited the highest solid-solution strengthening in tension, the greatest Cottrell effect, and the highest resistance to recovery. Correlation of tensile and creep data is shown to be possible.

(1342) Robinson, E. L.

Effect of Temperature Variation on the Long-Time Rupture Strength of Steels

Trans. ASME 74 (1952) 777-781

A method of computing the factor of safety of a structural member with reference to a stated life while operating under stress at high temperature when the temperatures or stress vary moderately according to some definite pattern.

(1343) Rodes, R. C.

Brittle and Ductile Fractures; Micromechanism of the Rupture of Metals (In Spanish)

Inst. hierro acero. 4 (1951) 209-219

Intergranular and transcrystalline fractures, deformation and rupture of metals, brittleness, and micromechanism of brittle fracture are analyzed theoretically.

(1344) Rohm, F., and Diehl, J.

Mechanism of Tensile Deformation of Monocrystals (In German)

Z. Metallk. 43 (1952) 126-128

Experiments on high-purity Al single crystals deformed in tension show that the strain-hardening curves consist of two portions, viz., a flat portion at the beginning, where the strain hardening increases linearly with the amount of strain, followed by a relatively steep portion when rapid strain hardening sets in. The first portion corresponds to the predominance of slip in a single-slip system and the second portion when slip occurs on two or more slip systems simultaneously.

(1345) Rohner, F.

Criteria of Incipient Slip in Polycrystalline Metals (In German)

Z. angew. Math. u. Phys. 3 (1952) 383-390

It is shown that slip is possible without bonds being disrupted or energy being spent against bonding forces. Determinations of the elastic limit of wrought and sintered pure Al are in accordance with this theory.

(1346) Roos, A.

Deformation, Rupture, and Dislocations in Crystalline Structures of Metals (In French)

Génie civil 134 (1957) 198-205

Study of rupture caused by tensile tests, impact tests, and corrosion; deformation caused by strain and cold working. These phenomena can be explained, in certain phases, by the "theory of dislocations".

(1347) Roos, A.

Atomic Chemistry and Metallurgy (In French)

Chim. ind. agr. biol. 70 (1953) 666

The extended application of Hume Rothery's rules to various solid solutions and to mechanical properties such as malleability, strength, and ductility is discussed. A study of aging on the same principles yields a quantitative relationship.

(1348) Roscoe, R.

The Plastic Deformation of Cadmium Single-Crystals

Phil. Mag. 21 (1936) 399-406

Observations of the bending of single-crystal wires show that, when the stress over the glide planes of a crystal is not uniform, slip begins when the maximum values of the resolved shear stress reach the critical value for deformation under uniform stresses. Surface oxidation of Cd single crystals produces an increase in their resistance to plastic deformation, which is probably due to healing of submicroscopic cracks by the oxide film.

(1349) Rosenthal, D., and Woolsey, C. C., Jr.

The Effect of Strain Rate on Twinning and Brittle Fracture

Welding J. 31 (1952) 475s, 492s

Relationship of strain rate, temperature, and brittle fracture in low-carbon steel as determined in simple tension. For each strain rate a threshold temperature for the occurrence of twins (Neumann lamellae) in the microstructure and loss of ductility (transition temperature for brittle fracture) were determined. The results of this investigation could be fitted for the process of twinning by a reaction-rate equation down to a critical temperature of approximately -170 F. At that temperature, the process of twinning appears to be insensitive to rate of deformation. Above -170 F an activation energy of 4200 (±400) cal/mole has been determined. The process of brittle fracture was found to be practically insensitive to strain rate over the range employed; an increase of only 25 F in the brittle transition temperature was found for a 10,000-fold increase in strain rate. The occurrence of a critical temperature for twinning could be derived from a criterion patterned after Bragg's criterion for slip. Likewise, a correct order of magnitude for the activation energy was obtained from the analysis of the twin-slip process.

(1350) Rosi, F. D.

The Plastic Behavior of Silver Single Crystals at Various Temperatures

J. Metals 188 no. 10 (1950) 1217

The plastic properties of Ag single crystals were investigated for small amounts of extension. Values of the critical resolved shear stress and the coefficient of shear hardening increase with a decrease in temperature, and these properties are consistent with the Schmid law of critical shear stress governing the initiation of the slip process. Plastic flow occurs suddenly, and there is an almost linear rate of strain hardening, the latter increasing after definite values of shear stress and shear strain which are independent of orientation. Short time creep tests (maximum 3 min) show interesting data correlating the rate of creep with both the rate of strain hardening and the temperature of testing.

(1351) Rosi, F. D.

Stress-Strain Characteristics and Slip-Band Formation in Metal Crystals: Effect of Crystal Orientation

Trans. AIME 200 (1954) 1009-1020

Analysis of the stress/strain curves of Ag and Cu crystals and of the slip-band patterns at various stages in the deformation process has enabled changes in slip-band development to be correlated with variations in the general shape of the stress/strain curves, critical shear stress, and strain-hardening coefficient. The over-all shape of the shear stress/shear diagram in the early stages of flow is markedly dependent upon crystal orientation. Depending upon the complexity of the slip process following the onset of flow, it is possible to obtain either a high parabolic hardening--coincident with multiple glide--or a low linear hardening--associated with slip on a single system; this leads to the conclusion that the law of shear hardening is not valid for fcc metals in the early stages of flow. Increasing impurity contents in solid solution increase the region of low hardening, and this is accompanied by a higher yield point. A possible explanation for the main source of hardening is the strain associated with pile-up dislocations at sessiles which are formed at intersecting slip planes.

(1352) Rosi, F. D.

Surface Effects on Plastic Properties of Copper Crystals

Acta Met. 5 (1957) 338-350

Surfaces were either Ag plated or alloyed with Ag by a diffusion process. The effect of surface alloying on the plastic properties of metal crystals was similar to that for bulk alloying in that the critical shear-stress for flow and the amount of easy glide were increased, and the shear hardening for the entire stress/strain curve was decreased. It is suggested that dislocations at the surface are largely responsible for the breakdown of Hooke's law and the advent of plastic flow.

(1353) Rosi, F. D., and Mathewson, C. H.

A Study of the Plastic Behavior of High-Purity Aluminum Single Crystals at Various Temperatures

Trans AIME 188 (1950) 1159-1167

The plastic properties of Al single crystals were investigated in the temperature range 77 to 353 K. Both the critical resolved shear stress and coefficient of shear hardening were found to increase with a decrease in temperature and were consistent with the Schmid law of critical shear stress governing the initiation of the slip process Measurements were also made on the density of slip bands, which was found to increase with decreasing temperature in a manner similar to the shear-hardening coefficient. Some observations were made on the appearance of slip bands on etched and unetched electrolytically polished surfaces and on the general complexity of the slip process.

(1354) Rotherham, L.

Creep of Metals

Physics in Industry Series, London (1951) 80 pp

Treats the characteristics of the creep curve, crystalline flow, metallographic features of creep, grain-boundary creep, three stages of creep, and the development of creep-resistant alloys. Various theories are reviewed.

(1355) Rotherham, L., Smith, A D. N., and Greenough, G B

Internal Friction and Grain-Boundary Viscosity of Tin

J Inst. Metals 79 (1951) 439-454

The internal friction of high-purity Sn has been studied over the temperature range 15-150 C. Both polycrystalline specimens and bars consisting of a very few crystals have been examined A peak in the curve of internal friction plotted against temperature, ascribed to viscous relaxation at the grain boundaries, is found to exist for the former type, but not for the latter The activation energy is consistent with that for steady-state creep of single crystals, but differs greatly from the value for self-diffusion in Sn. This is contrary to a theory put forward by Ke that all three values should be the same. [Phys. Rev. 71 (1948)]

(1356) Rotherham, L., and Tottle, C R.

The Effect of Alloying on the Creep of Metals

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London, (1956) 175-189

Theories of creep are briefly summarized The effect of alloying on creep strength is reviewed for simple binary alloys and for more complex systems. For the former, it is possible to make several generalizations, but for complex systems, interaction between the solute atoms may make predictions unreliable Diffusion and intercrystalline cracking are discussed, and suggestions are made for future work

(1357) Rovinskii, B M

Generation of Stresses of the Second Order During Plastic Deformation (In Russian)

Zhur. Tekhe Fiz. 18 (1948) 1273-1281

Use of simple experimental methods On the basis of X-ray investigation, the presence of two different types of second-order stresses in crystals during plastic deformation was established

(1358) Rovinskii, B M

Contribution to the Theory of the Hardening of Metals (In Russian)

Zhur Tekh. Fiz. 22 (1952) 63

The effects of electron density and chemical defects in the lattice of the solid solution of Al in Cu are considered

(1359) Rovinskii, B M

The Mechanism of Stress Relaxation in Metals (In Russian)

Izvest Akad Nauk S.S.S R Otdel Tekh Nauk no 2 (1954) 67-71

Data from tests on Al and Cu show departure from true elasto-viscous flow.

(1360) Rovinskii, B M

Relation Between Mechanical Properties of Solids and Reaction of Atoms In Lattice (In Russian)

Izvest Akad Nauk S S.S.R Otdel Tekh. Nauk no. 9 (1956) 55-64

Attempt to determine the relation between mechanical properties of solids and bond strength of atoms in the lattice.

(1361) Rovinskii, B M , and Lintsai, V G

Structural Changes in Pure Metals During Stress Relaxation (In Russian)

Izvest. Akad. Nauk S.S.S.R. Ser. Fiz 20 (1956) 636-638

During relaxation in Al and Cu irreversible structural changes develop in the crystallites similar to those during small plastic deformation.

(1362) Rovinskii, B M , and Rybakova, L. M.

Breaking Down of Crystal Blocks and Appearance of Microstresses in the Metal During Plastic Deformation (In Russian)

Izvest Akad Nauk S.S.S R Otdel. Tekh. Nauk no. 10 (1952) 1483-1487

In the plastic deformation of metals, profound structural changes occur, particularly the widening of X-ray lines. In rolling and in simple compression of metal specimens the increase in width of the interference lines depends on the magnitude of the residual deformation. The present paper is concerned with an investigation of the character of the processes in steel specimens for simple tension.

(1363) Rovinskii, B. M , and Rybakova, L. M

Structural Changes in Metal During Creep (In Russian)

Izvest. Akad. Nauk S.S.S.R. Otdel. Tekh. Nauk no. 9 (1953) 1241-1247 (Brutcher Translation No. 3224)

Studied Armco Fe and Ti stabilized 18-8 steel at various temperatures and residual deformations. X-ray analysis of the structural changes occurring during creep show their similarity to those accompanying ordinary plastic deformation. Also, in both cases, increased residual deformation leads to fragmentation of blocks and the development of microstresses In the case of creep, these processes are retarded with increasing temperature, expecially the fragmentation of blocks.

(1364) Rovinskii, B. M , and Rybakova, L. M.

Change in Substructure of Aluminum in Small Plastic Deformation and in Creep (In Russian)

Izvest Akad. Nauk S.S.S R Ser Fiz. 20 (1956) 646-649

Interference-spot X-ray pictures show that structural changes within crystallites during creep are qualitatively similar to those during simple tension Application of a load directly increases the completeness of crystallites

(1365) Rovinskii, B. M , and Tagunova, T V.

Plastic Deformation and the Size of the Lattice Unit Cell (In Russian)

Zhur Tekh. Fiz 17 (October 1947) 1137-1142

Results of experimental investigation of various metal and alloy powders annealed at different temperatures indicate that the size of the unit cell does not change as a result of plastic deformation. Therefore, phase transformations are not related to nonelastic changes in the size of cell nuclei However, connection with preceding lattice distortion is believed possible

(1366) Rozenberg, A M , and Khvarostukhin, L. A

Hardness and Stresses in a Plastically Deformed Body (In Russian)

Zhur Tekh. Fiz 25 (1955) 313

The relationship between hardness and yield strength determined experimentally was linear and universally applicable to a variety of ferrous and nonferrous metals deformed in tension, compression, and torsion. Extended to deformation by cutting operations

(1367) Rozovskii, M I.

Nonlinear Equations for Creep and Relaxation of Materials in Complex Stressed State (In Russian)

Zhur Tekh. Fiz 25 (1955) 2339-2354

Relation of instantaneous modulus of elasticity to degree of deformation Relation of relaxation time to stress

(1368) Rubenstein, C.

The Influence of Creep on the Measured Hardness of Soft Metals

Proc. Phys. Soc. (London) 67 ser. 7 (1954) 563-568

Using the Dushman equation for viscous creep, derives an expression for the variation of Meyer hardness, p, with the diameter of the indenter, d, and shows that a plot of p against log (pd) should be a straight line. This is found to be so, from various work on In, Pb, Sn, and Zn. The slope of the line is related to one of the constants in Dushman's equation, and values so obtained are in good agreement with those of other workers. It is concluded that the Meyer index is inapplicable where creep during indentation is pronounced.

(1369) Rutter, J., and Reekie, J.

The Effect of Cold Working on Electrical Resistivity of Copper and Aluminum

Phys Rev. 78 (1950) 70-71

Annealed Cu and Al rods were given increasing amounts of cold working and the electrical resistivity measured. The number of dislocations pairs/cm^2 estimated to occur in polycrystalline Cu reduced 50% in area should be revised to 2×10^{11}. This value is in satisfactory agreement with the estimates of Koehler from measurements of the energy stored during work hardening.

(1370) Rybakova, L. M

X-Ray Analysis of Structural Changes in Metals During Creep (In Russian)

Izvest. Akad Nauk S.S.S R. Ser Fix 20 (1956) 676-678

Varying degrees and rates of deformation in Armco Fe specimens at room temperature and 450 C

(1371) Rybalko, F. P.

Plastic Deformation and Fracture During Tension (In Russian)

Doklady Akad. Nauk S.S.S R 93 (1953) 471-473

Investigations were devoted to study of connection between plasticity of metals and appearance of macroevidence of deformation

(1372) Rybalko, F. P.

Plastic Deformation and Fracture of Metallic Single and Polycrystals, With Static and Repeated Torsion (In Russian)

Fiz Metal i Metalloved. 1 Akad Nauk S.S S.R , Ural'Filial (1955) 231-238

Tests reveal that fracture is preceded by localization of the deformation in zones of certain orientations Relation between rate of deformation and dislocation at different stages.

(1373) Rydberg, J R

The Hardness of Simple Substances (In German)

Z physik. Chem 33 (1900) 353-359

Hardnesses on Moh's scale (compared and estimated) show a periodicity in hardness with atomic number. Other properties, called the "Cohesion Group", also show periodicity, e g., the density, expansion, atomic heat, melting point, heat of melting, boiling point, and most of the elastic properties of the materials.

(1374) Sachs, G.

Flow of Metals

Iron Age 145 (Feb. 1, 1940) 34-37; (Feb. 8) 36-39

Abstract and correlation of present knowledge on plastic flow of metal, fundamental stress-strain relationships, resistance to flow; power consumption; path or course of deformation in different working processes considered; effect of friction and lubrication.

(1375) Sachs, G.

Some Fundamentals of Flow and Rupture of Metals

Trans. AIME 143 (1941) 13-29

Law of similarity, as derived from classical theory of plasticity, appears to be valid for plastic behavior of a metal; theories of plasticity; effect of hydrostatic pressure on plastic flow; stress and strain of single crystals and polycrystalline aggregates; strain hardening, effects of tool contact and friction on plastic flow; speed and impact effects

(1376) Sachs, G

Summary of Strength Limitation Phenomena

Paper from Proceedings of the 1955 Sagamore Research Conference on Strength Limitations of Metals, OTS, U. S Dept Commerce, PB 131280 and PB 131281 (1955) 11-35

Effect of C content, H, and O on tensile strength, yield strength, and ductility of constructional steel.

(1377) Sack, R. A

Extension of Griffith's Theory of Rupture to Three Dimensions

Proc. Phys Soc (London) 58 (1946) 729-736

Griffith's theory is extended to materials containing circular cracks It is found that (1) the tensile strength of brittle material in one direction is not affected by stresses at right angles to it; (2) the result differs from Griffith's by a factor depending on Poisson's ratio of the material and lying between 1.57 and 1 81

(1378) Sadovsky, V D.

Summary of Discussion on Temper Brittleness (In Russian)

Metalloved. i Obrabotka Metal. 6 (1957) 24-42 (Brutcher Translations 3980 and 4043)

Temper brittleness appears to be the effect of segregation of the phases in the solid state at the grain boundaries and also within the grains, or mosaic-like blocks, resulting from prolonged cooling, or sudden cooling, from high temperatures

(1379) Saibel, E.

A Thermodynamic Criterion for the Fracture of Metals

Phys. Rev. 69 (1946) 667

The difficulties in accounting for the difference between the calculated and observed strengths of metals are outlined. A new theory by Saibel is based on the following assumptions: (1) All of the strain energy is available for the abolition of cohesive strength. (2) The heat of fusion is uniformly partitioned throughout the volume of the substance. (3) The quantity of energy required for the abolition of cohesive strength is that fractional part of the energy of fusion which is associated with the change in volume on passing from the solid to the liquid state. These assumptions enable the criterion for fracture to be expressed in the form $U = JQ\Delta V/V$, where U is the strain energy/unit volume, Q is the latent heat of fusion in cal/mol, V is the volume occupied by a mole of the substance, ΔV is the change in volume/mol on passing from solid to liquid, and J is the mechanical equivalent of heat Good agreement is shown for some substances which fail by brittle fracture; reasonable agreement where plastic flow precedes fracture

(1380) Saibel, E.

A Thermodynamic Theory of the Fracture of Metals

Trans AIME 171 (1947) 639-664

General theory for the fracture of metals from the thermodynamic point of view Saibel believes that purely brittle fracture never occurs and that there is always some plastic flow, although this may be highly localized. A theory is developed which, as in the work of Furth [Proc. Roy. Soc. (London) 177 (1941) 217], relates the fracture process to the phenomenon of melting. On the basis of a simple model of the liquid state, the critical condition is derived. The critical condition is applied to the case of (1) a purely brittle fracture, and the results agree with earlier calculations, and (2) fracture preceded by plastic flow, for which a reasonable agreement is obtained with results for actual metals Saibel concludes that there is no discrepancy between the calculated and observed strengths of metals and that hypotheses of microcracks are unnecessary.

(1381) Saibel, E.

Effect of Prior Tensile Strain on Fracture

Trans. AIME 172 (1947) 363-373

In the thermodynamic theory of the fracture of metals [Saibel, Trans AIME 171 (1947) 629], it was shown that a critical strain energy per unit volume exists which is characteristic of the material and may be calculated from basic thermodynamic theory. According to Ludwig, a material has two fundamental properties: (1) a resistance to flow, and (2) a resistance to fracture. These ideas are used to analyze the method in which specimens are strained to varying degrees at room temperature and then pulled to fracture at a lower temperature The theory is in general agreement with the variation of fracture strength with prior tensile strain.

(1382) Saibel, E

Speed of Propagation of a Fracture Crack in Metals

Phys. Rev. 72 (1947) 534

Saibel recently proposed a thermodynamic theory of the fracture of metals which relates fracture to the melting phenomenon. From this point of view and with the use of the Eyring "hole" theory of the liquid state, the rate of formation of the "hole" structure is calculated from chemical reaction rate theory, the reactant being the material before fracture and the product of the reaction being the holes Since the abolition of cohesive strength is attributed to the formation of the holes, the rate at which they are formed gives directly the rate of propagation of the crack. The effects of temperature and of stress system are also indicated.

(1383) Saibel, E.

Application of Reaction Rate Principles to Some Mechanical Properties of Materials

Trans. N Y Acad. Sci. 11 (1949) 135-147

How the above has been accomplished in several cases. Such phenomena as creep, viscosity, and fatigue can only be fully explained by application of physical principles analogous to those of chemical reaction. Discussion of theory of the rate of propagation of fracture cracks in metals

(1384) Saito, K.

Theory of Plastic Deformation and Maximum Shearing Stress and Aluminum (In Japanese)

Nippon Kinzoku Gakkaishi 22 (1956) 321-327

Theory of plasticity based on the maximum shearing stress in the triaxial deformations of metals is established, using the experimental results as to the work hardening properties by pure shearing. Comparison of experimental results.

(1385) Salomon, G.

Brittle Fracture and Its Phenomena (In Dutch)

Metalen 11 (1956) 122-131

Theoretical considerations on the initial state of a fracture, from the elastic deformation of the brittle state.

(1386) Samoilov, O. Ia

Change of Coordination Number During Melting of Metals (In Russian)

Doklady Akad. Nauk S.S.S.R 83 (1952) 437-450

Previously published data are used for a theoretical discussion of the change of structures of metals as the melting point is approached. Data are tabulated and charted for a series of nonferrous metallic elements.

(1387) Sato, M

On the Characteristics of the Weakening Effect (In English)

Arkiv för Fysik 10 no. 1 (1956) 34-44

The theoretical basis of Benedicks's effect, i.e., the change in ultimate tensile strength of brittle solids when they are immersed in various liquids, is discussed and the importance of the surface tension of the liquid is emphasized. For small surface tension, the per cent weakening effect is proportional to the surface tension, but if the latter is too great, the material again approaches its dry strength. The effect is tentatively interpreted in terms of Taylor's [J. Appl. Phy. 18 (1947) 943] theory of fracture. According to this, a balance is struck between increase in elastic energy and increase in surface area of cracks spreading from the surface of the specimen until these cracks are large enough to cause fracture. The influence of liquids on the specific surface energy, which is related to the surface tension of the liquid, could account for the effect.

(1388) Sauter, W., Kochendorfer, A., and Dehlinger, U

The Laws of Plastic Deformation in Metals Under Multiaxial Stresses. I Theoretical Considerations II Combined Tension-Torsion Experiments on Aluminum Tubes (In German)

Z. Metallk 44 (1953) 442-448; 553-565

I The theories of plasticity for metals in the strain-hardening range--theories of plastic deformation and theories of plastic flow--are discussed. The types of stress/strain relationships which can arise under multiaxial stresses are considered in relation to the work of Taylor and Quinney. II. Combined tension-torsion experiments on rods and tubes of commercial and high-purity Al were carried out. The results are analyzed and discussed in detail; under all conditions of loading they satisfy, to within ±3%, the theory of plastic flow.

(1389) Savitskii, E. M

On the Plasticity of Intermetallic Phases (In Russian)

Doklady Akad. Nauk S.S.S.R 62 (1948) 349-351

Extrusion tests on MgZn, $MgZn_2$, and $MgZn_5$, compression tests at 400 C on beta and gamma phases in the Mg-Al system, and microhardness tests at various temperatures on Cu-Zn alloys containing up to 40% Zn show that all these materials are plastic at elevated temperatures. Phases of the beta type soften more with increasing temperature than do those of the gamma type. The rapid increase in plasticity with rise of temperature is thought to be greater than can be accounted for simply by the increasing amplitude of vibration of the atoms, and some change in the lattice of the intermetallic phases is presumed.

(1390) Savitskii, E. M.

Plasticity of High-Temperature Modifications of Polymorphous Metals (In Russian)

Doklady Akad. Nauk S.S.S.R. 71 (1950) 945-947

Studied theoretically and experimentally for a large number of metals. Crystalline modifications at high and low temperatures are described qualitatively for La, Ce, Be, Ca, Sr, Li, Cs, Pr, Nd, Ti, Zr, Hf, Cr, U, Mn, Fe, Co, Tl, and Sn. As a rule, the high-temperature modification has the greatest plasticity.

(1391) Sawkill, J., and Honeycombe, R. W. K.

Strain Hardening in Face-Centered Cubic Metal Crystals

Acta Met. 2 (1954) 854-864

An attempt was made to deform Au single crystals in simple shear, using an apparatus similar to that described by Rohm and Kochendorfer [Z. Metallk 41 (1950) 265]. Au and Al single crystals of various comparable orientations were tested in tension; shear-stress/shear-strain curves were plotted, and the specimens examined metallographically and

by X-ray methods. In general, similar behavior was found for the two metals. Orientations with tensile axis near (100) strain hardened rapidly, but no kink bands were observed. Crystals with tensile axes in the center of the stereographic triangle had an easy glide region. Kink bands were found in Al but not in Au. Present ideas on deformation bands and on strain hardening are discussed.

(1392) [illegible], B.

Analysis of the Creep Process in Refractory Alloy (In German)

Arch. Eisenhüttenw. 28 (1957) 145-152

Tabulates various formulae for describing creep curves and gives his own version.

(1393) [illegible], A.

Atomistic Concepts of Deformation and Recrystallization Processes in Metals (In German)

Arch. Eisenhüttenw. 25 (1954) 621-627

Mathematical discussion with consideration of vibrations, stresses, and lattice distortions

(1394) Schmid, E. and Boas, W.

Plasticity of Crystals With Special Reference to Metals

F. A. Hughes & Co. Ltd., London (1950) 353 pp

A translation of the German text. Elasticity, production, and determination of orientation of crystals. Geometry of mechanisms of crystal deformation, plasticity and strength of metal and ionic crystals, theories of crystal plasticity and strength, and properties of polycrystalline materials in relation to the behavior of the single crystal. There are 703 references in related work in this field.

(1395) Schmid, L. A

Valence Bond Calculations

Am. J. Phys 22 (1954) 255-263

The nature of the binding in molecular and ionic crystals and in metals is briefly discussed from an intuitive point of view. The salient features of the Slater-Pauling theory of the valence bond are developed by generalizing the results of the Heitler-London treatment of the H molecule. The application of the theory to the cohesive energy of diamond, the classic example of a valence crystal, is discussed.

(1396) Schoeck, G.

Theory of Creep

Paper from Creep and Recovery, Am. Soc. Metals (Cleveland) (1956) 199-226

Basic principles of phenomenological aspects of creep; geometrical aspects of plastic deformation; structural details of creep deformation likely to occur under different conditions and characteristic differences between various metals.

(1397) Schoeck, G

Moving Dislocations and Solute Atoms

Phys. Rev. 102 (1956) 1458-1459

In the stress field of a moving dislocation, stress-induced local rearrangement of solute atoms occurs. From this rearrangement there results a frictional force dependent on the velocity of the dislocation. It is suggested that it should be possible to detect this effect in creep, more especially in microcreep, experiments free from a background of internal friction due to external force.

(1398) Schoeck, G.

Theory of High Temperature Deformation of Metals

Paper from High Temperature Materials, Their Strength Potentials and Limitations, Fourth Sagamore Ordnance Materials Research Conference (1957) 1-21

The purpose of this paper is to report the present stage of the theory of high temperature deformation of metals. In recent years considerable progress has been made in understanding the elementary processes which occur during the deformation of metals. This progress is mainly due to the impact of dislocation theory and to careful experimental observations on relatively pure metals. In the first section some of the basic features of dislocations are recalled. There exist a great number of review papers or books which give a very detailed picture of these features. In the present paper only those properties are mentioned which are essential for the understanding of high temperature deformation. The second section deals with the mechanisms by which deformation of a polycrystalline metal is accomplished especially at high temperatures. Some the creep deformation with which we are here mainly concerned is always due to thermal activation, the third section discusses which thermally activated processes can be rate controlling during creep. A review of recent developments in the theory of creep has been given recently elsewhere. Finally in the fourth section there is a discussion of how much or how little theory can, at the present stage, tell about the behavior of such complicated structures as exist in commercial creep resistant alloys.

(1399) Schoeck, G., and Seeger, A

Activation Energy Problems Associated With Extended Dislocations

Report of the Conference on Defects in Crystalline Solids, Phys. Soc., London (1955) 340-346

An improved method for calculating line energies of dislocations on the basis of Peierls' model, which supplements the elastic method of Burgers, is outlined. It is applied to the calculation of the energy of constrictions in extended edge and screw dislocations in Al and Cu. Using the results obtained by Seeger and Schoeck on such extended dislocations, the energy increase due to a constriction is obtained by a variational method. An application of these results is given to the problem of cross-slip of screw-dislocations in fcc lattices

(1400) Schreckenbach, M

Brittle Fracture of Crystallized Substances as a Surface Phenomenon (In German)

Technik (Berlin) 7 (1952) 65-73

Inadequacy of orthodox explanation of brittle fracture. Such fracture occurs when the energy required to form a fracture surface is available in a plastically transmittable manner, and fracture occurs as soon as this energy has become great enough.

(1401) Schwab, G. M

Some New Aspects of the Strength of Alloys

Trans. Faraday Soc. 45 (1949) 385-396

Temperature coefficient of the Brinell hardness of metals can be represented by a biexponential formula, leading to the assumption of two different processes with different activation energies of which the larger one, E_2, is connected with the formation of new perturbation centers. The Brinell hardness of α, β, γ, ϵ, and η phases of Cu-Zn, Cu-Sn, Ag-Zn, and Ag-Cd were measured from 20-450 C. The following expression was obtained: $1/H = A\exp(-E_1/RT) + B\exp(-E_2/RT)$

(1402) Schwab, G. M., Tsipuris, J., and Tsipuris, M

Evaluation of the Electronic Theory of Mechanical Strength (In German)

Z. physik. Chem. 14 (1958) 65-75

The hardnesses of Hume-Rothery alloys Cu-Sn, Cu-Zn, Ag-Zn, and Ag-Ca were measured to temperatures up near the melting point. An earlier extrapolation was confirmed whereupon not only the hardness but also the temperature coefficient and thereby the energy of formation of dislocations exhibited maxima in the γ-phases of the alloy systems. Insofar as the electronic structure of the metal influenced the strength, it plained by the zone theory.

(1403) Schwartzbart, H., and Low, J. R., Jr.

The Yielding and Strain-Aging of Carburized and Nitrided Single Crystals of Iron

Trans. AIME 185 (1949) 637-645

Investigations on single crystals of Fe containing small amounts of C and N show that these elements lead to the appearance of a yield point. The yield point in polycrystalline Fe is thus not necessarily to be attributed to the presence of a grain-boundary film. In the presence of C and N, single crystals show the phenomenon of strain aging. The yield-point effect is increased by strain aging in single crystals, as in the case of polycrystalline Fe

(1404) Schwarzl, F. A

A Theoretical Interpretation of Fracture (In Dutch)

Metalen 11 (1956) 470-476

Fracture in metal was studied in relation to the order of magnitude of the ultimate stress and cohesion energy, the influence of nonhomogeneous factors on strength, the statistical character of the ultimate stress, and time

(1405) Schwope, A. D.

Structure and Alloy Design

Paper from Relation of Properties to Microstructure, Am. Soc. Metals, Cleveland (1954) 108-130

Effects of alloying and subsequent structure on strength. Deformation mechanisms. Strength of solid solutions

(1406) Schwope, A. D. (Chairman)

Conference on Creep of Metals

Battelle Memorial Institute (June 10, 1953) sponsored by NACA, 102 pp

Talks by H. C. Chang, E. R. Parker, F. N. Rhines, and R. D. Johnson on various aspects of their current work on creep behavior were followed by an extensive discussion period.

(1407) Schwope, A. D., and Jackson, L. R

A Survey of Creep in Metals

NACA TN 2516 (November 1951) pp 66

Summarizes numerous theories relating to creep phenomena and the extent of current knowledge on the subject. Various possible mechanisms by which creep occurs both in single crystals and in polycrystals

(1408) Scott, G. W., and Callyn, J. E

An Application of the Theory of Quasi-Properties to the Treatment of Anomalous Strain-Stress Relations

Phil. Mag. 40 (1949) 80

The idea of quasi properties proposed in an earlier paper is extended to cover anomalous strain-stress relations. Certain experiments on relaxation of plastics at constant stress were selected on account of their exceptional divergence from the Nutting relaxation law, and it was shown that for the less serious anomalies, an equation integrated from the strain-stress fractional differential in some cases fitted the data better than the corresponding strain-time equation

(1409) Sears, G. W., and Brenner, S. S

Metal Whiskers

Metal Progr. 70 (November 1956) 85-89

The strength of small metal whiskers is close to the theoretical value. Strength decreases as size increases although many other of the unusual properties are retained.

(1410) Sears, G. W., Gatti, A., and Fullman, R. L.

Elastic Properties of Iron Whiskers

Acta Met. 2 (1954) 727-728

The properties of Fe whiskers believed to contain a single axial screw dislocation are briefly reported. Elastic strains in bending of up to 1.4 per cent were obtained, corresponding to an ultimate tensile strength of about 2.7×10^5 psi. X-ray diffraction showed that an Fe whisker consists of alpha-Fe bounded by four (100) planes parallel to the axis. The whiskers are believed to grow by the mechanism previously proposed by Sears for Hg whiskers [ibid. 1 (1953) 457]

(1411) Seeger, A

The Temperature-Dependence of the Critical Shear Stress and of Work-Hardening of Metal Crystals

Phil. Mag. 45 ser. 7 (1954) 771-773

The experimental data on the temperature and strain-rate dependence of critical shear stress and work hardening can be explained on a dislocation model. The critical shear stress and work hardening are attributed to: (1) elastic stresses round dislocations, which depend on temperature through the elastic constants, and which may not be a unique function of strain if recovery occurs, and (2) the stress necessary to push dislocations through crossing screw dislocations and hence form jogs. This theory predicts a linear decrease of critical shear stress with increasing temperature above a temperature T_0, and also explains why work hardening is less dependent on temperature in the easy glide region.

(1412) Seeger, A

Theory of Crystal Plasticity I Principles of the Theory (In German)

Z. Naturforsch. 9A (1954) 758-775

Work hardening of a single fcc crystal is divided into three stages easy glide, interaction hardening, and a final stage of low hardening rate ending in fracture. The basic hardening in the easy-glide region is due to the difficulty of moving screws through other screws intersecting the glide plane, and is therefore much less in the hcp metals. Interaction hardening may be attributed to the formation of sessile dislocations at the intersection of two slip systems

(1413) Seeger, A

Theory of Crystal Plasticity II The Basic Structure of Close-Packed Metals and Its Effect on Plastic Properties (In German)

Z. Naturforsch. 9A (1954) 856-869

The energetics of dissociation of dislocations lying in close-packed planes is dealt with in detail, the energy being finally determined by assuming an analytical form for the displacements in the solid and using a variational principle to determine the best values of the parameters. The physical constants entering the calculations are the crystal elastic constants and stacking-fault energy (assumed equal to twin interface energy). Creep in fcc metals is attributed to the activation of intersections of dislocations in different glide planes

(1414) Seeger, A

Theory of Crystal Plasticity III The Temperature- and Velocity-Dependence of Crystal Plasticity (In German)

Z. Naturforsch. 9A (1954) 870-881

The temperature dependence can be divided into three ranges: (1) the elastic interactions of the pre-existing dislocations are involved, and is little influenced by temperature, (2) the intersection of dislocations is an activated process and depends strongly on temperature; (3) the effect of recovery has to be considered. In cubic crystals the intersection processes are thermally activated only at low stresses and low extension rates. High velocities occur under such a high stress that activation is not required, and there are no temperature effects. In the hexagonal and rhombohedral crystals with only one principle slip system, it is possible to deduce the density of dislocations intersecting the basal plane, the activation energy for crossing, and the density of dislocations in the slip plane from measurements of the velocity and temperature dependence of the critical shear stress and the work-hardening curve

(1415) Seeger, A

The Generation of Lattice Defects by Moving Dislocations, and its Application to the Temperature Dependence of the Flow Stress of F. c. c Crystals

Phil Mag 4th ser 7 (1955) 1194-1217

The mechanisms by which vacancies and interstitial atoms can be produced by moving dislocations and the creation of lines by moving dislocations are discussed. The creation of lines of point defects behind jogs in screw dislocations is an athermal process, whereas the formation of individual point-defects from a jog which moves along the screw dislocation line is a process capable of thermal activation. For a metal of low stacking fault energy the defects may be attached to one of the partial dislocations and taking this into account, the energy of formation of vacancies by this process is calculated. In such a metal, the flow stress at low temperatures is determined by the ability of edge dislocations to cut through the forest intersecting screw-dislocations, as the screw dislocations are unable to move when jogged. As the temperature is raised, the creation of individual point-defects becomes possible and screw dislocations become the more mobile components. After a temperature range in which the flow stress falls off rather sharply the ability of screw dislocations to cut crossing screw-dislocations becomes the rate-controlling process, and this has a smaller temperature dependence again. These predictions agree both qualitatively and quantitatively with the experiments of Adams and Cottrell on Cu (ibid., p 1187) and can be used to correlate results on Ag, Au, Ni, and Pt. In Appendices the stacking-fault energies of Ni and other transition metals and the energies of lattice defects in Cu, Au, Ni, and Pt are discussed

(1416) Seeger, A

Stacking Faults in Close-Packed Lattices

Paper from Defects in Crystalline Solids, Phys Soc, London (1955) 328-339

From considerations of the electronic structures it is concluded that monovalent metals and Co should have low stacking fault energies whereas Al, Mg, Zn, Cd, Ni, Pd, and Pt should have high stacking fault energies

(1417) Seeger, A.

Theory of Lattice Imperfections (In German)

Handbuch der Physik 7 Part 1 Kristallphysik I, Julius Springer Verlag, Berlin (1955) 383-665

Extensive theoretical treatment of atomic defects, radiation damage, dislocations, stacking faults, and grain- and phase-boundaries

(1418) Seeger, A

Jogs in Dislocation Lines

Report of the Conference on Defects in Crystalline Solids, Phys Soc, London (1955) 391-401

An investigation is made into the geometrical properties of jogs in dislocation lines in various lattices. The concepts of "intersection jogs" and "diffusional jogs" are introduced. It is shown that in different lattices these two types will in general have different energetical and geometrical properties. Theoretical estimates of job energies, based on the results of Seeger and of Shoeck and Seeger on stacking-fault energies and energies of constrictions in extended dislocations, are compared with experimental results in which jog formation is believed to be an essential feature, namely the temperature dependence of the critical shear stress of single crystals and high-temperature creep of metals. The comparison gives a fair agreement between the experimental data and the theoretical expectations. A qualitative discussion of processes connected with dislocations is given in which jogs may possibly play an important part, including the formation of a latent image along dislocation lines in AgBr

(1419) Seeger A

Dislocations and Allotropic Transformation II (In German)

Z. Metallk. 47 (1956) 653-660

A comparison based on dislocation theory between plastic deformation of crystals and allotropic transition with special reference to the nucleation problem

(1420) Seeger A

Theory of Crystal Plasticity IV Strengthening and Glide Mechanism of Close-Packed Metals and Alloys (In German)

Z. Naturforsch. 11A (1956) 985-998

The characteristic processes of plastic behavior of the hexagonal metals Zn, Cd, and Mg are reviewed according to a general theory of crystal strengthening. The theory is developed in the following manner. The theory of the basic structure of the undeformed crystal, calculation of the flow stress for a given dislocation distribution, study of changes caused by the dislocation distribution on glide in the crystal. It is shown, for these metals in the neighborhood of room temperature, that the basic process for "dynamic recovery" is identical with that for "static recovery" and probably is the climb of dislocations, first considered by Mott. The corresponding behavior for fcc metals was treated in full in another place [Seeger, et al, Phil Mag 2 (1957) 323]. In the present paper, homogeneous fcc alloys are mentioned in connection with the pure metals. The suppression of slip bands by many alloys, as well as the latent strengthening and the "overshoot" of metals and alloys, is discussed in detail

(1421) Seeger, A

New Mathematical Methods and Physical Results on Crystal Plasticity (In German)

Paper from Deformation and Flow of Solids, Edited by R Grammel, Springer Verlag, Berlin (1956) 90-116

The internal stresses arising during elastic and plastic deformation are analyzed mathematically, as is the general distortion state. The glide mechanisms and surface phenomenon in close-packed crystals are those treated from the dislocation standpoint

(1422) Seeger, A

The Origin of the Small Angle Scattering of X-Rays in Plastically Deformed Metals (In German)

Acta Met 5 (1957) 24-28

The view that additional small angle scattering of X-rays in plastically deformed metals is not caused by dislocations, but by submicroscopic voids, is refuted. It is shown that accepted dislocation densities can explain both the absolute intensity of the small angle scattering and its dependence on the scattering angle, by indicating nonlinear terms in the stress-strain relationship

(1423) Seeger, A

Some Effects of the Non-Linearity of the Elastic Laws in the Environment of a Dislocation Line

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc, New York (1957) 504-507

The volume increase round a dislocation line, due to the large shear, is discussed in connection with the electrical resistivity of a dislocation line and the low-angle scattering of cold-worked crystals

(1424) Seeger, A.

Stored Energy and Resistivity Changes in Cold-Worked Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc, New York (1957) 347-349

If stacking faults and the change in density due to the dislocations are considered, the dislocation density calculated from stored energy, change in density, and electrical resistivity agree reasonably well

(1425) Seeger, A

Mechanism of Glide and Work Hardening in Face-Centered Cubic and Hexagonal Close-Packed Metals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc, New York (1957) 243-329

A theoretical picture is given for the dislocation processes governing the plastic properties of fcc metals and alloys and of hexagonal metals with basal glide. It is based on the similarities and dissimilarities of the dislocations in fcc and hcp structures and in metals and alloys with low- and high-stacking fault energies. It accounts for the critical shear stress of pure metals and dilute alloys, work hardening, recovery, surface markings (slip bands) and creep

(1426) Seeger, A, and Bross, H

Electron-Theoretical Investigations of Defects in Metals II Association Energy of Vacancy Couples in Monovalent Metals and in Transition Metals (In German)

Z Physik 145 (1956) 161-183

Quantum mechanical calculations are based on Friedel's [Advances in Physics 3 (1954) 446] model of an impurity (or vacancy) in terms of free electrons of effective mass differing from the rest mass, and enclosed in a box of constant potential. An expression for the energy gain from the association of two vacancies into a pair is deduced. Theoretical treatment of the relaxation of atoms neighboring to a vacancy shows that there is very little "collapse" of these atoms into the vacancy, contrary to earlier views. A further corollary is that the elastic-stress field near a vacancy is very small, and plays only a negligible part, compared with electronic factors, in determining the association energy of a vacancy pair

(1427) Seeger, A, Diehl, J, Mader, S and Rebstock, H

Work-Hardening and Work-Softening of Face-Centred Cubic Metal Crystals

Phil Mag 2 ser 8 (1957) 323-350

The present paper discusses the experiment and theory of mechanisms governing work-hardening, work-softening and slipband formation in fcc metals. The rapid hardening stage (Stage II) of the stress-strain curve is studied by flow-stress measurements at different temperatures, combined tensile and torsion experiments, and by the observation of the length of slip lines as a function of prestrain. Stage III is investigated with the electron microscope, showing that the principal surface patterns (slip bands, fragmentation) are due to cross slip. In Stage II the slip distance is decreased continually by the formation of Lomer-Cottrell dislocations. This also accounts for various observations on the end of the easy glide region. The temperature dependence of work hardening in Stage III is caused by screw dislocations circumventing the sessile Lomer-Cottrell dislocations by cross slip. The mechanisms through which cross slip causes glide band formation and fragmentation are discussed in some detail

(1428) Seeger A, Donth, H, and Kochendörfer, A.

Theory of Dislocations of One-Dimensional Atom Rows III Dislocations, Eigen-Motions, and Their Interaction (In German)

Z. Physik 134 (1952-1953) 173-193

An analysis is made of the interaction between dislocations and sound waves in the one-dimensional Frenkel model. Dislocations are desirable as translational eigen motions. The relation of the results to the still largely unsolved problem of the energy dissipated by a moving dislocation and its limiting velocity is briefly discussed

(1429) Seeger, A., Donth, H., and Pfaff, F

The Mechanism of Low-Temperature Mechanical Relaxation in Deformed Crystals

Molecular Mechanism of Rate Processes in Solids, Discussions Faraday Soc 23 (1957) 19-30

The authors discuss how dislocations cause energy losses in crystals by hysteresis, resonance, and relaxation. The internal-friction measurements of Niblett and Wilks [Phil Mag. 1 (1956) 415] are considered. The relaxation peak is thought to be due to dislocations overcoming the Peierls stress by thermally activated kink formation. Detailed calculations are reported on the rate and the activation energy of such a process, the relaxation time is derived from the theory of stochastic processes; account is taken of the thermal stresses and the radiation losses governing the dislocation movement. The theory is compared with experimental results reported by various workers on Pb, Al, Ag, and Cu; the magnitude of the Peierls stress deduced from internal-friction measurements agrees with theoretical predictions

(1430) Seeger, A., and Haasen, P

Density Changes of Crystals Containing Dislocations

Phil. Mag 3 (1958) 470-475

Zener's theory of the volume expansion of self-strained elastic bodies is applied to screw and edge dislocations in isotropic media. The important physical parameters entering are the pressure dependence of the shear modulus, and to a lesser extent, that of the bulk modulus. Numerical results are given for a number of materials

(1431) Seeger, A, and Kochendörfer, A.

Theory of Dislocations in One-Dimensional Atom Rows II. Arbitrary, Arranged, and Accelerated Dislocations (In German)

Z. Physik 130 (1951) 321-336

Further work on the Frenkel one-dimensional model is described. Solution for the static interaction of dislocations is obtained in closed form by a perturbation method, and interaction with a surface is also considered. Solutions are also found for accelerated motion, and for the effect of a time-dependent force, this is used to discuss the damping of dislocations by thermal waves. The relation of the method of solution to the Peierls integral equation, used in three-dimensional problems, is briefly considered.

(1432) Seeger, A, and Schöck, G.

The Splitting of Dislocations in Metals With Close-Packed Lattices (In German)

Acta Met 1 (1953) 519-530

The theory of the elastic field of a straight dislocation line in a crystal of arbitrary symmetry is developed. The usual resolution into pure edge components and pure screw components is possible only if the direction of the line is an even symmetry axis. The splitting of lattice dislocations into half dislocations in close-packed planes is treated. Numerical results are given for Cu, Al, and Co. The width of the stacking fault is considerably greater for edge dislocations than for screw dislocations

(1433) Seeger, A., and Stehle H

Electron-Theoretical Investigation of Defects in Metals IV The Electrical Resistance of Dislocations (In German)

Z Physik 146 (1956) 242-268

The effect of screw dislocations on electrical resistivity is estimated by quantum-mechanical methods, starting from the effects of nonlinear strains discussed in Part III (ibid., p 217). Mattiessen's rule is not satisfied according to the theory. The calculated changes are too small. This is provisionally attributed to the neglect of stacking faults associated with dislocations. This problem is treated in a provisional manner. Stacking faults are believed to be responsible for strong deviations from Mattiessen's rule.

(1434) Segawa, W

Stress/Strain Relations for Visco-Elastic Large Deformations

J Phys Soc Japan 12 (1957) 996-998

Alfrey's relations for Maxwellian and Voigtian material are extended to the case of large deformations. The results are applied to the cases of constant stress, constant strain, and constant strain rate

(1435) Seitz, F

The Modern Theory of Solids

McGraw-Hill Book Company, Inc, New York (1940) 698 pp

This is a very valuable book and, although it appeals primarily to the mathematical reader, a great deal of information can be gained by reading the text and ignoring the details of the mathematics. The book begins with a chapter headed "The Empirical Classification of Solid Types", which includes a brief survey of the structures of metals and alloys. The author deals with theoretical work and descriptive matter, and the references to the original sources are invaluable

(1436) Seitz, F

Dislocations and the Theory of Creep

Phys Rev 59 (1941) 477

It is pointed out that two different qualitative pictures can be used to discuss creep in single crystals on the basis of the theory of dislocations

One of these is based on the notion that the rate of creep is determined primarily by the relatively slow motion of dislocations present in the solid; the other is based on the notion that the dislocations move almost instantaneously and that creep is tied up primarily with the rate of generation of dislocations. The equations associated with each of these pictures are, respectively, $dS/dt = \lambda v N$, and $dS/dt = \lambda L\, dN/dt$. Here dS/dt is the rate of strain, N is the number of dislocation lines per unit area, λ is the slip distance associated with the passage of one dislocation. Examinations of the meager available creep data for a quantitative comparison of the merits of these equations indicate that neither furnishes a completely satisfactory correlation of all experimental material. The first meets difficulty because the required velocity v must be unreasonably low for reasonable values of N; the second meets with difficulty at low temperatures and stresses because the assumed values of dN/dt are unreasonably high

(1437) Seitz, F

On the Formation of Dislocations from Vacancies

Phys Rev 79 (1950) 890-891

If there are insufficient dislocations present to absorb surplus vacancies, on cooling, vacancies might condense onto certain lattice planes to form plates or disks. These condensations would be expected to lead eventually to the formation of dislocation rings having some of the characteristics needed to explain the slip properties of crystals

(1438) Seitz, F

Generation of Vacancies by Dislocations

Phys Rev 79 (1950) 1002-1003

Satisfactory explanations of several phenomena, including the Kirkendall effect, require that a large number of dislocations be generated within a small volume of a crystal. A mechanism having a relatively low activation energy is proposed, by which kinks in edge dislocations can act in this way. A mechanism is also suggested whereby screw dislocations can give rise to spiral prismatic dislocations, which can readily generate large numbers of vacancies.

(1439) Seitz, F

Spiral Prismatic Dislocations and the Origin of Slip Bands

Phys Rev 79 (1950) 1003-1004

On cooling, surplus vacancies may condense onto screw dislocations and generate spiral prismatic dislocations. Dislocations of the type likely to be formed may: (1) contribute to the formation of a mosaic structure within the crystal, and (2) in conjunction with the Frank-Read mechanism for the multiplication of dislocations (ibid. 722) provide an explanation of the regularity of slip bands.

(1440) Seitz, F

The Theory of Plastic Flow in Single Crystals

Paper from Symposium on the Plastic Deformation of Crystalline Solids, OTS, U S Dept Commerce (1950) 1-36

The theory and characteristics of plastic flow in single crystals are reviewed in considerable detail. The most striking experimental facts relating to the plasticity of single crystals are: (1) their low shear strength; (2) the increase of shear strength by dissolved impurities; (3) the anisotropy of plastic strain even in cubic metals, (4) the apparent concentration of strain displacement in well-defined regions (slip bands); and (5) the phenomena of work hardening, stored energy, lattice distortion, and internal friction. Experimental results and theories based thereupon are briefly reviewed

(1441) Seitz, F

Imperfections in Nearly Perfect Crystals: A Synthesis

Paper from Imperfections in Nearly Perfect Crystals, John Wiley and Sons, Inc, New York (1952) 3-76

The various types of crystal imperfections are discussed from a unified viewpoint. Six primary types of imperfections, viz, phonons, electrons and holes, excitons, vacant lattice sites and interstitial atoms, foreign atoms in either interstitial or substitutional positions, and dislocations, are discussed with a brief account of the historical introduction of each type; other kinds of imperfections may exist in materials with specialized properties. Two or more imperfections of the same or different types may interact to generate other imperfections, the whole forming a closely interlocked family. This feature of imperfections is regarded as an essential part of their behavior, intimately related to the normal properties of the imperfections. A classified scheme of the available experimental information concerning the interaction of imperfections is given, emphasis being laid both on characteristics of imperfections and their means of generation

(1442) Seitz, F

On the Generation of Vacancies by Moving Dislocations

Paper from L'Etat Solide Report of the 9th Solvay Conference, Brussels, Edited by R Stoops (1952) 377-413

The experimental evidence suggesting that vacancies are generated by cold work is reviewed. It is shown that this is more likely to occur through the geometrical interaction of pairs of dislocations than through intense thermal transients. Such interactions are described in some detail. A mechanism for vacancy generation at a jog (i e, cross slip one atom-spacing wide) on a rapidly moving dislocation is also proposed. The marked influence of cold work on subsequent precipitation-hardening is put down to an acceleration of diffusion by the extra vacancies. The ways in which the generation or presence of vacancies can impede the action of dislocation sources (work-hardening), and affect creep, are reviewed

(1443) Seitz, F

On the Generation of Vacancies by Moving Dislocations

Advances in Physics 1 (1952) 43-90

New experiments seem to confirm the view that vacant lattice sites, and possibly interstitial atoms, are generated during plastic flow in ductile crystals, particularly in metals. The average temperatures near a moving dislocation are probably not sufficiently high to evaporate vacant lattice sites or interstitial atoms as a result of thermal effects alone. Instead, imperfections are apparently generated either by purely geometrical means during the looping of dislocations about appropriate obstacles, or in very high thermal pulses or "spikes" A pair of vacancies is probably stable near room temperature and may diffuse more rapidly than a single vacancy. Vacancies retained during quenching of Al-Cu alloys and those generated by cold-work play an important role in the precipitation process. The origin of work hardening in single crystals, the importance of prismatic dislocations formed by condensation of vacancies, and the role of stored energy and decrease in density in processes such as creep and the hardening of latent slip planes are discussed. Experiments are proposed which could prove decisive in isolating the influence of vacancies

(1444) Seitz, F , and Read, T A.

Theory of the Plastic Properties of Solids

J Appl Phy 12 (1941) 100-118; 170-186; 470-486; 538-554

The plastic properties of solids are classified as those of slip, creep, rupture, and fatigue. The theories of lattice imperfections are applied to single-crystal phenomena. The properties of single crystals are discussed, with reference to work-hardening, resoftening, effect of impurities, precipitation-hardening, and asterism in Laue photographs. The creep, rupture, and fatigue of single crystals are considered. The mechanical properties of polycrystalline solids are discussed with reference to the preceding theory

(1445) Semmel, J W , Jr , and Machlin, E. S

The Driving Force for Recrystallization in Bent Single Crystals of Silver

Acta Met 5 (1957) 582-596

The major source of the driving energy for recrystallization is associated not with dislocations but with the excess-point defects produced by bend deformation. The defects are considered to be vacancies. Two annealing stages were found during which the driving energy for recrystallization decreased to a value below that necessary to achieve recrystallization on subsequent heating to higher temperatures. This process was called "degradation" Specimens bent to 12% outer-fiber strain or less degraded much more rapidly than specimens bent more. It is postulated that the vacancy sinks are not infinite and that the longer degradation time is a measure of the time required for the excess vacancies to diffuse to the specimen surface

(1446) Servi, I. S. , and Grant, N J

Creep and Stress Rupture as Rate Processes

J Inst. Metals 80 (1951) 33-37

Creep data for an Fe-Co-Cr-Ni alloy are analyzed according to the rate-process theory of plastic flow. The data indicate that the theory can be applied over only a limited range of creep rates. An empirical equation, which related applied stress and the temperature to minimum creep rate, is suggested for analysis of creep data. This equation is valid only in the absence of structural instabilities

(1447) Servi, I. S , Grant, N J.

Structure Observations of Aluminum Deformed in Creep at Elevated Temperatures

Trans AIME 191 (1951) 917-922

Creep tests on three grades of Al were performed and gave the following results: (1) The conditions of creep testing at which a change in slope occurs in the log-log plot of stress versus minimum creep rate or stress versus rupture time correspond to the beginning of grain boundary flow (equicohesion), but are not directly related to the absence of slip bands (2) Grain boundary migration occurs in high-purity Al tested under high temperature conditions. The grain boundaries move away from their center of curvature, as in the case of annealing after cold working (3) As a first approximation, for deformed specimens, the spacing of the slip bands observed is inversely proportional to the applied stress (4) Absence of slip bands ("slipless flow") occurs when the grain size is smaller than the average slip spacing observed in a coarser grained specimen tested under the same applied stress (5) The deformation of Al is less localized the higher the temperature, or the slower the strain rate. Subgrains were observed in some specimens tested at high temperature. The dimensions of these subgrains are of the same order of magnitude as the average slip spacing (6) The dimension, shape, and regularity of the subgrains observed in high-purity Al suggest that the subgrains are related to the slip process or to other less known deformation processes such as kinking. The subgrain formation appears to be the effect, not the cause, of plastic deformation.

(1448) Servi, I S , and Grant, N J

Creep and Stress Rupture Behavior of Aluminum As a Function of Purity

Trans AIME 191 (1951) 909-916

Minimum creep rates and rupture times for high-purity and commercial Al confirm the existence of a transition range from low-temperature type to high-temperature type behavior. The data are analyzed in line with the suggested theories of deformation of metals

(1449) Servi, I S , Norton, J T , and Grant, N J

Some Observations of Subgrain Formation During Creep in High Purity Aluminum

Trans AIME 194 (1952) 965-971

Coarse-grained high-purity Al was tested in creep at temperatures of 400-1200 F to develop subgrain structures. Measurements of subgrain size, distribution, and rotation were made from X-ray diffraction patterns

(1450) Shahinian, P , and Achter, M R

Comparison of the Creep-Rupture Properties of Nickel in Air and Vacuum

Paper presented at AIME Fall Meeting, Chicago (November 1957)

In a comparison of the creep-rupture properties of Ni in air and vacuum at 1200 and 1500 F, there is a reversal in relative strengths with variations in stress level (or strain rate). At low stresses the creep and rupture strengths are better in air, while at high stresses they are better in vacuum. The reversal point, at which the specimens tested in air become more creep resistant than in vacuum, is moved to a shorter time as the test temperature is raised from 1200 to 1500 F. At very low stresses, specimens tested in air at 1500 F undergo marked strengthening attended by extensive oxidation and virtual cessation of creep. At high stresses the relative creep strength of vacuum- and air-tested specimens may be reversed during the course of the test. In the early stages the specimen in vacuum has the higher creep rate but the one in air is creeping faster in the later stages. A tentative mechanism involving two competing processes is considered that qualitatively explains these observations. One process, oxidation strengthening, is dominant at low creep rates while the other, reduction of strength due to lowering of surface tension, is dominant at high creep rates. The atmosphere strengthening involves internal oxidation, which is a slow diffusion process and, therefore, in high creep-rate tests the competing process is controlling. It is proposed that the reduction of surface tension in air compared to vacuum facilitates crack propagation, and, after cracking is initiated, in short-time tests the air specimen starts to creep at a faster rate than the one in vacuum

(1451) Sharma, R. S.

The Equation of State of Solids

Proc Phys Soc (London) 69B (1956) 838-840

The suggested equation of state of solids [Dayal and Sharma, ibid , 68B (1955) 1049] is applied to calculate the static pressure, i e , the pressure due to the nonvibrating lattice at 0 K, for Li and Na. Excellent agreement is found for Li, agreement is not good in the case of Na at low temperatures, but very good up to 300 K

(1452) Shaw, M C

A Yield Criterion for Ductile Metals Based Upon Atomic Structure

J Franklin Inst. 254 (August 1952) 109-126

A strength theory for ductile metals is presented that takes into account short range inhomogeneities present in all commercial metals. Examples illustrate the shortcomings of conventional maximum shear-stress and distortion energy theories that result from failure of these theories to recognize the inhomogeneous nature of metals. Shows why a size effect is observed with torsion specimens but not with tensile specimens of usual size. The size effect in fatigue testing and harness testing by means of micro techniques. Relation of the new theory for ductile metals to the statistical theory of Weibull for brittle materials

(1453) Shchetinin, N N

Pure Bending in Bars During Creep of the Material (In Russian)

Izvest Akad Nauk S.S.S.R , Otdel Tekh Nauk no 8 (1956) 37-41

Bar is stressed by a constantly acting moment, solution of the problem of steady creep is obtained with a linearized equation of the theory of strain hardening.

(1454) Shepard, L. S., Starr, C D , Wiseman, C. D., and Dorn, J. E

Creep Properties of Metals Under Intermittent Stressing and Heating Conditions Pt 2 Intermittent Heating

OTS, U S. Dept Commerce, PB 131016 (July 1954) 38 pp

Intermittent heating, constant creep tests on Al alloys showed that in the absence of solid state reactions, creep under intermittent heating conditions can be predicted from ordinary isothermal creep data. Equal creep strains are produced in equal net times at test temperature in intermittent heating and isothermal creep testing. Thus intermittent heating creep strains at any time may be estimated by summing the net time at test temperature and determining the strain for an equal time from an isothermal creep test.

(1455) Shepard, L. A , and Dorn, J E

Delayed Yielding in a Substitutional Solid-Solution Alloy

Trans. AIME 206 (1956) 1229-1235

Tensile specimens of high-purity Al-base alloy containing Mg were annealed, prestrained in tension and then aged to produce a uniformly constant upper yield point at each low test temperature. They were then creep tested at 78 and 114 K, at constant stress. The results show that delayed yielding can be induced to occur in this strain-aged substitutional Al alloy, and occurs in three stages: (1) preincubation creep; (2) nucleation, spreading and impingement of Lüders bands, and (3) final creep. The delay time for yielding was found to depend on the product of separate stress and temperature functions, in disagreement with the theoretical models of Cottrell and Bilby, and Fisher, for the case of interstitially locked dislocations

(1456) Shepard, L. A , and Dorn, J E

The Role of Subgrains in High-Temperature Creep

WADC TR 58-63 (May 1958) 33 pp

The role of the subgrain structure in the high-temperature creep process is evaluated in the light of recent experimental and theoretical developments in creep theory. The origin of subgrains is discussed as well as the specific deformation modes which produce the variety of observable substructures. The effect of creep variables on the subgrain development, size, and structure is described. Finally, an attempt is made to analyze the manner in which the substructure affects creep rate, recovery and grain-boundary shearing. It is concluded that the contribution of the substructure to high-temperature creep resistance is small relative to other factors

(1457) Shepard, O. C.

Intercrystalline Failure of Metals at Elevated Temperatures

J Metals 4 (1952) 151

Stress-rupture tests were made on commercial metals in inert gases and air; and on pure Au in air and in vacuum

(1458) Sherby, O. C , Anderson, R. A., and Dorn, J R

Effect of Alloying Elements on the Elevated Temperature Plastic Properties of Alpha Solid Solutions of Aluminum

Trans. AIME 191 (1951) 643-652

Solid-solution alloying increases the plastic properties of Al at elevated temperatures by solid-solution strengthening, by restraining recovery and recrystallization, and by a Cottrell effect. When binary Al alloys are strained and aged at 194 to 300 K they develop a yield point. This is attributed to a migration of dislocations to solute atoms during aging

(1459) Sherby, O. D., and Dorn, J E.

Creep Correlations in Alpha Solid Solutions of Aluminum

Trans. AIME 194 (1952) 959-964

Stress-rupture and creep tests were carried out at various temperatures on pure Al and binary solid-solution alloys with Mg, Cu, and Zn. The results show that at temperatures above 400 K (when recovery becomes active), the creep and tensile data can be simply related by the Zener-Hollomon relation [J Appl Phy 15 (1944) 22] and that the activation energy (ΔH) for both primary and secondary creep is 35,800 cal/mole irrespective of grain size, alloy or composition, and structure. Below 400 K, however, more complex phenomena associated with strain hardening prohibit the unmodified application of the Zener-Hollomon concept. Tensile and creep data for commercial-purity Al can also be correlated by the Zener-Hollomon parameter, but the ΔH values obtained differ from one series of data to another, dependent upon the annealing conditions preceding creep. When creep strains for a stated creep stress are plotted in terms of a temperature-compensated time, θ = t exp (-ΔH/RT), where t is the time under stress, a single creep curve is obtained, independent of the creep temperature. This suggests a simple method for extrapolation of short-time creep data to longer service lives

(1460) Sherby, O. D., and Dorn, J E.

A Recovery Model for the High-Temperature Creep Process

U S Atomic Energy Comm , Np-4830 (1953) 12 pp

Current theories of creep are reviewed, and these are rejected because they do not appear to agree with experimental observations. A new model for creep is presented, wherein the rate-controlling process at high temperature is attributed to the recovery of barriers by a self-diffusion process

(1461) Sherby, O. D., and Dorn, J E.

Some Observations on Correlations Between the Creep Behavior and the Resulting Structures in Alpha Solid Solutions

Trans AIME 197 (1953) 324-330

For elevated temperature constant load creep tests of Al solid-solution alloys, the creep strain is a function of a temperature-compensated time parameter. The activation energy H is equal to about 36,000 cal/mole. The substructures resulting from a given creep strain condition are functions of the creep strain independent of temperature. Each new creep strain gives a new unique set of grain substructures, this is one of the factors responsible for the failure of the mechanical equation of state for creep.

(1462) Sherby, O. D , and Dorn, J E

An Analysis of the Phenomenon of High-Temperature Creep

Proc Soc Exptl Stress Anal 12 (1954) 139-154

A review of the high-temperature creep properties of stable metals and alloys. Creep strain/time curves are correlated by the relation, strain, ε = f[t exp(-ΔH/RT)], where ΔH is the activation energy for creep and found to be a structure-insensitive property. ΔH_c for a pure metal is approximately equal to the activation energy for self-diffusion. For a given structure, it is found that for dilute Al alloys, the log (creep rate) is a linear function of the true stress. The slope of the stress/log (creep rate) is constant for a given alloy, independently of the structural changes during creep. However, the slope increases linearly with at % of solute addition. A model for high-temperature creep is proposed which associated ΔH_c with the energy required for the removal of barriers to the motion of dislocations, the removal of these barriers being controlled by atomic diffusion properties

(1463) Sherby, O. D , Frenkel, R , Nadeau, J , and Dorn, J E.

Effect of Stress on the Creep Rates of Polycrystalline Aluminum Alloys Under Constant Structure

Trans AIME 200 (1954) 275-279

A method is described for determining the dependence of the creep rate of metals on applied stress under conditions of constant structure for Al and dilute solid-solution alloys with Ag, Cu, Ge, Mg, and Zn. The results show that the true creep rate, ε = S exp[-ΔH/RT] sinh Bσ, where ΔH and B are independent of the creep structure (i.e , depend on the metal), S is a parameter that depends on structure, and σ is the true stress. The value of 1/B increases with the at % of solute atoms, and as a function of low-temperature, solid-solution strengthening.

(1464) Sherby, O. D , Goldberg, A , and Dorn, J E.

Effect of Prestrain Histories on the Creep and Tensile Properties of Aluminum

Trans ASM 46 (1954) 681-700

Back-reflection X-ray methods were used to follow polygonization changes occurring during creep of pure Al. Creep and tensile strength increase with degree of polygonization during creep of annealed metal. Al cold worked to a high tensile and creep strength, however, initially possesses the least polygonized structure. During creep, the equilibrium structure and strength are approached, which are dependent only on stress.

(1465) Sherby, O. D., Lytton, J L., and Dorn, J E.

Activation Energies for Creep of High-Purity Aluminum

Acta Met 5 (1957) 219-227

Activation energies for creep were obtained over temperature ranges from 77 to 880 K by rapidly changing the temperature during creep at constant stress. From data, validity of theories that postulate stress or strain-dependent activation for creep is questioned.

(1466) Sherby, O. D., Orr, L., and Dorn, J E.

Creep Correlations of Metals at Elevated Temperatures

Trans AIME 200 (1954) 71-80

Creep data reported in the literature are analyzed, and it is shown that at temperatures above those at which rapid recovery occurs (above about 0 45 melting point) they can be correlated by means of simple equations. The stress does not enter the free energy of activation for the rate-controlling process for high-temperature creep. For a given metal, ΔH is a constant = the activation energy for self-diffusion, which suggests that the rate-controlling process for self-diffusion, in addition, ΔH appears to be a periodic function of the atomic number. The equations have been applied, successfully, to data for Al, Au, Cu, Fe, Ni, Pb, Pt, and Zn, as well as for simple alloys. Correlation of separate sets of creep data for Al, Pb, Pt, and Zn indicates that the activation energy for creep is insensitive to small differences in alloy content, metallographic structure, and pretreatment history

(1467) Sherby, O. D , Trozera, T A., and Dorn, J E.

The Effect of Creep Stress History at High Temperatures on the Creep of Aluminum Alloys

Proc ASTM 56 (1956) 789-806

Structural changes attending creep at high temperatures and high stresses are dependent on the preceding creep stress history. Results on Al solid-solution alloys indicate that initial plastic straining upon application of a constant stress decreases creep resistance, whereas straining during creep increases creep resistance. At low stresses the structural changes important to creep are minor. Neglecting transients observed upon change of stress, high temperature creep at low stresses obeys a mechanical equation of state

(1468) Shesterikov, S A

The Single-Variation Principle in the Theory of Creep (In Russian)

Izvest Akad Nauk S.S.S.R , Otdel Tekh Nauk no 2 (1957) 122-125

The principle as worked out by Rabotnov for any slowly moving continuous medium is applied to the theory of creep and equations for the strain rate produced.

(1469) Shestopalov, L. M

On the Calculation of Stress Relaxation in Metals (In Russian)

Zhur Tekh. Fiz. 26 (1956) 1021-1031

Stress relaxation in metals is a consequence of internal reorganization of the lattice which is not in equilibrium The mobility of atoms in such conditions is reduced with increasing interatomic binding and increased with increasing temperature The stress conditions determine the degree of thermodynamic instability of the system, and on this depends the rate of return to equilibrium The greater the rate or amount of plastic deformation, or both, the greater is the departure from equilibrium and the greater the rate of recovery, i e , the rate at which the stress falls. Phase changes, recrystallization, etc , which disturb the thermodynamic equilibrium of a system likewise influence the process of stress relaxation.

(1470) Shevandin, E. M

Agreement of Mechanisms of Fracture and Unit (Normal Strengths of Metals) (In Russian)

Zhur Tekh Fiz. 18 (1948) 863-874

Critically analyzes the theories of Davidenkov, Fridman, Kuntze, and Rebinder

(1471) Shibuya, Y

A Theoretical Study of Young's Modulus of Binary Solid Solutions (In Japanese)

Nippon Kinzoku Gakuai-Shi 16 (1952) 235-238

The relation between Young's modulus and the composition of solid solutions has been investigated Denoting the interaction energy force constant between A atoms, B atoms, and atoms of A and B by ϵ_{AA}, ϵ_{BB}, ϵ_{AB}, respectively, the following results are reported: (1) a linear relation between Young's modulus and composition when ϵ_{AB} = mean ϵ_{AA} and ϵ_{BB}; (2) a nonlinear relation when ϵ_{AB} = mean value, (3) the theoretical curves obtained with appropriate values of force constant agree well with those obtained by experiment; and (4) using the value of ϵ_{AA} obtained from measured values of lattice constant and the compressibility, the magnitude of Young's modulus of polycrystalline Mo has been estimated and found to agree to within approximately 10% with the measured value Mo-W, Ag-Pd, and Au-Pd systems have been investigated

(1472) Shishokin, V P , and Ageeva, V A.

Relationship Between Hardness and Composition of Dilute Solid Solutions (In Russian)

Fiz. Metal. i Metalloved Akad Nauk S S S R , Ural' Filial (1956) 176-180

The Hume-Rothery solubility rules were extended to explain the effect of composition, temperature, and strain rate on hardness Hardness in dilute solution is determined by lattice distortion. Two competing processes affect solubility: the relative size of the atoms and the polarization forces Increase of polarization forces, according to Hume-Rothery, leads to increased mutual solubility, i e , to reduction of hardness Increase of concentration of the solute atom leads to increased lattice distortion if the size ratio is unfavorable, i.e , to increased hardening, but it will also give larger polarization forces Hence, as the concentration of the solute increases hardness may increase, decrease, or pass through a maximum or minimum Increase of temperature does not affect relative sizes, but usually increases polarization forces Polarization forces should likewise be more effective at lower rates of strain These ideas were applied to solid solutions of Hg in Cd and Sn in Pb and provided a satisfactory explanation of the observed hardness behavior

(1473) Shishokin, V P , Ageeva, V A., and Vikhoreva, N. A

The Effect of Temperature on the Rate-of-Hardening Coefficient (In Russian)

Zhur Tekh Fiz 10 (1940) 491-499

The rate-of-hardening coefficient is defined as n in the equation $H = aT^n$, which gives the hardness H as a function of the loading time T The effect of temperature on the rate-of-hardening coefficient was studied in the case of Bi, Pb, and Sn, and various eutectic alloys The rate-of-hardening coefficient increases with increasing temperature, and increasing load, particularly for the eutectic alloys The relation between the temperature coefficient of hardness, α, and the time of loading T, is given by the function $T = Ke^{\beta a}$, where K and β are constants

(1474) Shishokin, V P , and Shestopalova, Yr V

Influence of the Time of Loading on the Strength of Metals and Their Alloys (In Russian)

Zhur Tekh Fiz 8 (1938) 1613-1628

The diameter of the indentation produced by a ball increases with time T of loading, viz , $d = aT^n$ The number m = 2n is termed "the velocity exponent of the hardness" It ranges, e g., between 0.016 for Al and 0 112 for Sn, increasing in the order Cu, Ag, Sb, Zn, Cd, Pb, and Bi It increases with load, e.g., for Pb the increase is 20% for a fourfold increase of the load Binary eutectics have higher, and ternary eutectics still higher, m values than the composing metals There are differences between the m values for cast and annealed eutectics. In the systems Bi-Sb (annealed at 200 C, Bi-Cd (annealed at 120 C), Bi-Pb (annealed at 100 C), and Al-Zn (annealed at 300 to 320 C) m varies almost parallel with the temperature coefficient of the hardness

(1475) Shivananda, S , and Purushottaman, C R

Equation of State of Zinc From Thermal Data

Current Sci (India) 25 (1956) 192-193

A method of deriving the equation of state of hcp solids from a knowledge of thermal expansion, specific heat, and elastic constants was developed by an extension of the work of Grüneisen. The equation was used to determine the effect of pressure on the lengths of Zn crystals in directions both parallel to and perpendicular to the hexagonal axis The calculated length changes agree closely with those determined experimentally by Bridgman.

(1476) Shockley, W

Half Dislocations

Phys Rev 73 (1948) 1232

Any dislocation can be resolved into two components for which the net displacement of a circuit about the dislocation is (1) perpendicular and (2) parallel to the dislocation axis The force between two parallel dislocations does not involve cross terms of types (1) and (2) These results are employed in analyzing the stability of a dislocation in the fcc lattice with a slip of (a/2) in the (111) plane compared to two "half-dislocations" of $(a/6)(11\bar{2})$ and $(a/6)(\bar{1}2\bar{1})$ which together produce the same net displacement across the (111) plane It is found that the repulsive forces due to the Taylor-like component of these dislocations overcome the attraction due to the screw components so that the half-dislocations tend to separate A consideration of the nature of the "half-slipped" plane shows that it will be greatly hardened for slip on planes cutting through it and that this effect may play a major role in the hardening as unused slip planes

(1477) Shockley, W

Localized Radiation-Damage as a Means of Studying Vacancies and Interstitials

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 581-585

After bombardment with, e g , rare-gas ions, if there is unbalance between the rates of recombination of vacancies and interstitials with the surface, there will be a net flow of one species toward the interior of the material This will produce observable change in the shapes of the dislocation lines

(1478) Shockley, W

Dislocation Models of Grain Boundaries

Paper from Solide Report to the 9th Solvay Conference, Brussels, Edited by R Stoops (1952) 431-485

There is a full presentation of the elastic theory involved in the calculation of the energy of low-angle boundaries as a function of orientation, leading to the basic equation. This is shown to apply not only to a simple array of edge dislocations (tilt boundary), but to a general boundary By extension it can be applied to a three-dimensional dislocation array as in cold-worked metal Comparison with experimental energy data is presented; agreement is shown to be significantly good

(1479) Shockley, W , and Read, W T

Quantitative Predictions From Dislocation Models of Crystal Grain Boundaries

Phys Rev 72 (1949) 692

Dislocation models of grain boundaries have certain quantitative consequences which are directly susceptible to experimental test, so that theoretical and experimental investigations of grain boundaries may furnish a direct proof of the presence of particular arrays of dislocations in solids Of particular interest are grain boundaries between crystallites differing by a small angular rotation about an important crystallographic direction

(1480) Shreiner, L. A , and Epifanov, G. I

Coefficient of Hardening of Metal Single Crystals (In Russian)

Doklady Akad Nauk S S S R 97 (1954) 85-87

For single crystals of Cd, Zn, and Sn, the relation between shear stress, τK, and specific crystallographic slip, a, is approximately linear $\tau K = c + \lambda a$ so that $\lambda = d\,\tau K/da$, the effective coefficient of hardening, is constant along the whole curve beyond the yield point

(1481) Sichikov, M F , Zakharov, B. P., and Kozlova, Iu V.

Determination of the Mechanical Properties of Steel Without the Use of Tensile Specimens (In Russian)

Zavodskaya Lab. 13 (1947) 1463-1471

Establish relationship with the four basic characteristics of the mechanical strength of steel (yield point, yield strength, relative elongation, and relative contraction) by means of pressing in a cone with a 90-degree apex angle, or better, 120 degree

(1482) Siebel, E.

Mechanics of Materials (In German)

Z. Ver deut Ingr 94 (1952) 465-471

The mechanical behavior of crystalline materials under tensile stress can be ascribed to the interaction between shear strength and slip, flow, and fracture resistances. Thermal motion of the atoms reduces slip resistance and coherence of the material Differences of effects of tension and compression under alternating stress.

(1483) Siegfried, W

Stress Distribution and Fracture During Creep Loading (In German)

Schweiz. Arch. angew Wiss u. Tech. 9 (1943) 1-14

Many of the phenomena of creep can be explained by the amorphous intergranular cement hypothesis and by the existence of an equicohesive temperature but to account for the shape of the load-time curves and the occurrence of "necked" or "brittle" fractures, it is necessary to consider the distribution of stresses between the grains and the boundary material, the transfer of material from the ordered to the disordered state, work hardening, and recrystallization. This, Siegfried proceeds to do. He considers first the stress distribution in a substance in which the boundary material is much harder than the grains, then in a substance in which the reverse is the case, and finally in a substance in which both yield. He goes on to discuss the effects of temperature, of time at constant temperature, hardening, and recrystallization, and shows, by reference to published experimental work on creep, how the shape of the curves and the appearance of the fractures agree with his deductions.

(1484) Siegfried, W

Failure From Creep as Influenced by the State of Stress

J Appl Mechanics 10 (1943) A202-A212

As early as 1912, it was pointed out by Rosenhain and Eqin that the behavior of metals at high temperatures could be explained by the combined action of the crystals and the so-called grain boundaries With the aid of the Rosenhain-Ewen conceptions, he attempts to reconcile discrepancies between recent observations on the occurrence of intercrystalline fractures after long test periods His evaluation of the theories cited offers an explanation of various phenomena which previously could not be interpreted, and also furnishes a basis for determining the risk of failure with creep in a three-dimensional system of stress

(1485) Siegfried, W

Creep Tests and Extrapolation of Their Results to Long-Time Tests (In French)

Fourth International Congress on Industrial Heating, Paris (1952) 19 pp

A detailed study was made of the relation between actual stress and rate of flow in long-time tests Relationships between theoretical and experimental stress-rupture values are discussed.

(1486) Sinclair, G M , and Craig, W J

Influence of Grain Size on Work Hardening and Fatigue Characteristics of Alpha Brass

Trans ASM 44 (1952) 929-948

The relationship between microstructure and the strength properties of metals has long been a problem of practical interest to the metallurgist. In the present paper a relation between metallurgical grain size and the strength properties of 70-30 cartridge brass has been discussed from the viewpoint of the "fragmentation" theory of work hardening The results of hardness, tensile, and fatigue tests performed on the brass appear to be consistent with the concepts of this simple hypothesis.

(1487) Sines, G., and Kikuchi, R

The Elastic Interaction Between Point Defects and Clusters of Point Defects in Metals

Acta Met. 6 (1958) 500-508

A model is proposed and calculated for the elastic interactions between two single-point defects, between string-clusters with single-point defects, and between platelet clusters with single defects The analysis of the elastic model shows no interactions between single defects but appreciable interactions between single defects and clusters The interaction energy is calculated and plotted as a function of the relative position of the two defects The asymptotic behavior of the interaction potential between a point defect with either type of cluster varies inversely with the third power of the distance separating them

(1488) Slater, J C

The Equations of State of Solids

Chapter XII of Introduction to Chemical Physics, McGraw-Hill Book Co., Inc , New York (1939) 199-221

Lays the foundations for a statistical study of the equation of state of solids, without the use of a model, so cannot compute the desired thermodynamic quantities Confines the discussion to the case of hydrostatic pressure, in which the volume and temperature are the independent variables

(1489) Slater, J C

Band Theory of Bonding in Metals

Paper from Theory of Alloy Phases, Am. Soc. Metals, Cleveland (1956) 1-12

Past and present methods of calculating the energy bands of atoms or crystals, the approximations involved, and the way in which these studies and the theory of metals are reviewed and discussed. It is pointed out that metallurgists should make use of recent developments in the theories of metals of which most of them seem to be unaware

(1490) Sleeswyk, A W

On the Ductility of Iron at 4 2 K

Acta Met. 5 (1957) 764-765

In a comparison of tensile tests carried out in different media, the effect of the boiling point must be considered. The type of apparatus is important; "soft" machines tend to mask serrations in the stress/strain curve and "point-to-point" observations are of little use in this study. Sleeswyk concludes that the work of Smith and Rutherford supports the hypothesis mentioned by Basinski and Smith (ibid., 176)

(1491) Slibar, A , and Vitovec, F

Concerning the Effective Range of Strain Hardening (In German)

Schweiz. Arch. angew Wiss u Tech. 16 (1950) 80-84

Theoretical mathematical analysis of the extent to which crystalline layers surrounding a given grain obstruct slip of this grain. Effects of orientation and distance from the grain of the layers

(1492) Slifkin, L., and Kauzmann, W

An Unusual Effect in the Creep of Zinc Single Crystals

Phys Rev. 78 (1950) 631-632

Describes the "rest-hardening" effect in the creep of Zn single crystals The Zn crystal after softening somewhat at 35 C upon resting, rehardens again upon further resting. This effect bears some similarity to Orowan's thermal-hardening effect, with some differences, e.g , the absence here of softening upon further deformation.

(1493) Slutzky, L J , and Garland, C W

Lattice Dynamics of Hexagonal Close-Packed Metals

J Chem Phys 26 (1957) 787-793

Assuming that the atoms interact with central forces, the lattice dynamics of hcp metals were examined theoretically Atomic-force constants were related to the elastic constant by the method of homogeneous deformation in which the contribution of the electron gas to the elastic constant is assumed to arise from an isotropic volume-dependent term in the energy Relations are developed for the propagation of acoustical waves in hexagonal crystals which permit calculation of the elastic constant from ultrasonic pulse-velocity measurements

(1494) Smallman, R E , and Westmacott, K. H

Stocking Faults in Face-Centered Cubic Metals and Alloys

Phil. Mag 2 (1957) 669-693

Stacking faults on the (111) planes of several fcc metals and alloys have been introduced by cold work, and estimates of the stacking fault probability have been obtained from changes produced in the Debye-Scherrer spectrum The faulting probability increases on alloying, from one plane in 300 in Cu, to one plane in 25 for some high solute content alloys containing Zn, Al, Sn, or Ge Both neutron irradiation and "quenched-in" vacancies have little significant effect on the faulting parameter

(1495) Smallman, R. E , Williamson, G. K., and Ardley, G.

Yield Points in Aluminum Alloy Single Crystals

Acta Met 1 (1953) 126-130

Experiments were made to compare tensile behavior of some Al alloy single crystals which contained Cu, Zn, or H_2, with that of superpure Al crystals

(1496) Smirnova, T N , and Terminasov, Iu S

X-Ray Study of the Plastic Deformation of Metals During Static and Dynamic Compression (In Russian)

Izvest Akad Nauk S S.S R Ser Fiz. 20 (1956) 664-670

Mechanism of distortions of the atomic crystal lattice of metals subjected to compression Negative role of residual distortions of crystal lattice as far as later fracture of the metal is concerned

Declassified in Part - Sanitized Copy Approved for Release @ 50-Yr 2014/01/27 : CIA-RDP81-01043R003200240005-1

(1497) Smith, A. A.

Creep and Recrystallization of Lead

Trans. AIME 143 (1941) 165-178

Creep tests on high-purity Pb do not always proceed uniformly, but sometimes occur by intermittent steps. Recrystallization occurs at the higher rates of extension, but could not be detected at low rates When recrystallization is a factor, the creep rates are greater than would be obtained by extrapolation from the low-rate part of the log rate-log stress curve Kanter proposed an energy analysis of the creep process from which an energy value can be calculated which is of the same order of magnitude as the heat of diffusion of the metal The value obtained is 16,500 cal/mole and is lower than the heat of self diffusion (28,000 cal/mole)

(1498) Smith, A D. N

A study of Some Factors Influencing The Young's Modulus of Solid Solutions

J Inst Metals 80 (1951-1952) 477-482

The values of Young's modulus for a series of binary solid solutions based on Cu or Ag have been measured dynamically at room temperature It was found that, in any one system, the modulus decreases approximately linearly with the at % of the solute although the rate of decrease differs for each system This rate of decrease depends not only on the difference in atomic radii of the solute and solvent, as suggested by Zener [Acta Cryst 2 (1949) 163] but also on the difference in valency between the two constituents It appears that this latter effect may be proportional either to the square of the valency of the solute or to the electron concentration of the solution, the experimental evidence slightly favoring the former A close relation is found to exist between the rates of decrease of the modulus and of the solidus temperature for any given solution of Cu or of Ag

(1499) Smith, C S

A Theory of Transient Creep in Metals

Proc Phys Soc (London) 61 (1948) 201-206

A new approach to the theory of transient creep in metals is described and the relation ϵ = constant $T(1-\exp^{-Ct})$ t deduced, connecting the creep strain ϵ, the absolute temperature T, and the time t. C is a constant This relation is compared with experimentally obtained curves The movement of trapped dislocations released by thermal fluctuations is considered to be the elementary process of flow. The transient character of the creep is ascribed to the progressive exhaustion of dislocations requiring low activation energies for release

(1500) Smith, C S.

Hardness Changes Accompanying the Ordering of Beta Brass

Trans AIME 152 (1943) 144-151

In 50:50 beta-brass, ordering commences at about 450-470 C and is about complete at 100 C. The softest condition assumes that hardness is related to ordering and that at room temperature represents completely ordered structure

(1501) Smith, D. P.

Note on the Role of Rifting in Cold Work and a Possible Measure of Plastic Deformation

J Appl Phy 20 (1949) 1186-1187

It is believed that plastic deformation of crystalline metallic bodies is accompanied by opening of lattice structure Various such evidences of "rifting" afforded by the behavior of metals with H Some probably connections between rifting and deformation.

(1502) Smith, G. S

The Mechanism of Brittle Fracture

Metallurgia 33 (December 1945) 55-58

Evidence of the actual process of fracture of brittle materials is not easy to obtain, but recent study of the subject has introduced a new conception of fracture which assists the acceptance of a theory developed 25 years ago. Various aspects of the subject are revised and particular attention is directed to recent work the results of which appear to establish, with certain kinds of materials, the role of external and internal defects during fracture and the order of formation of the parts of the new surfaces

(1503) Smith, G. V

Strain Hardening--Effects of Alloying Elements and Microstructure

Paper from Cold Working of Metals, Am Soc Metals, Cleveland (1949) 2-30

The effects of grain size, temperature, alloying in solid solution and heterogeneous structures on the rate of strain hardening of metals and alloys are somewhat uncritically considered Special attention is drawn to the (scanty) available evidence, which suggests that increase of temperature may actually increase the rate of strain hardening of some materials although with others it may decrease it

(1504) Smith, G V

Properties of Metals at Elevated Temperatures

Combustion 21 (April 1950) 65-67, (May 1950) 51-53

Part I Metal strength at elevated temperatures, working stresses that may be applied, characteristics of creep, and the relation between stress and time for rupture A typical design chart for a stainless steel Part II Effects of nonconstant stress and temperature, metallurgical variables, microstructural and surface changes, and scaling and corrosion

(1505) Smith, G V

Properties of Metals at Elevated Temperatures

Mech Eng. 72 (1950) 799 804

Properties are classified in the broad categories strength, other physical properties such as thermal expansivity or conductivity, elastic moduli, and the like resistance to scaling or other corrosive attack changes in microstructure occurring during service, and effect of these on properties

(1506) Smith, G V

Metallurgical Aspects of Strength at Elevated Temperatures

Proc Soc Exptl Stress Anal 12 (1954) 155-162

Effects of metallurgical variables and changes during service on properties

(1507) Smith, R L , and Rutherford, J L.

Further Considerations on the Ductility of Iron at 4 2 K

Acta Met 5 (1957) 761-762

The effects of purity and grain size are discussed in relation to results obtained by Basinski and Sleeswyk (ibid., 176) with particular reference to the form of the stress/strain curve

(1508) Smith, S L , and Wood, W A

A Stress-Strain Curve for the Atomic Lattice of Mild Steel in Compression

Proc Roy Soc (London) 181A (1943) 72-83

A stress-strain curve was obtained for the atomic lattice of mild steel subjected to compression A set of atomic planes is selected perpendicular to the direction of the stress, and the change in spacing is measured as the applied stress is varied The lattice curve is compared with the corresponding stress-strain curve for the external dimensions in the compression test, and also with the lattice stress-strain curve previously obtained for the same material when subjected to tensile stress The results suggest that the mechanics of the metallic lattice involve the principle that, after the lattice yield point, in a given direction the lattice systematically assumes a permanent strain in such a sense as to oppose the elastic strain induced by the applied stress

(1509) Smith, S L., and Wood, W A

Internal Stress Created by Plastic Flow in Mild Steel and Stress Strain Curves for Atomic Lattice for Higher Carbon Steels

Proc Roy Soc (London) 182 (1944) 404-414

It is shown that externally applied stress above yield is no longer balanced primarily by simple displacement of atoms but also by new type of secondary internal stress brought about by plastic flow

(1510) Smoluchowski, R

Theory of Grain Boundary Motion

Phys Rev 83 (1951) 69 70

The mobility of grain boundaries in metals is considered from a point of view similar to that used by Mott in the theory of viscosity of grain boundaries By introducing a factor dependent on surface tension of the grain boundary and inserting the experimental activation energy, one obtains satisfactory agreement with experiment

(1511) Smoluchowski, R

Dislocations in Solids

Paper from Science of Engineering Materials, John Wiley and Sons, Inc , New York (1957) 142-160

Nature, source, and movement of dislocations in metals and crystals Application of dislocation theory in the study of the basic mechanisms in plastic deformation

(1512) Soderberg, C R

Mechanical Properties in Relation to Design Requirements

Paper from Metallurgical Reviews, Inst of Met , London 1 (1956) 31-63

Competently discusses areas of knowledge and ignorance in fields of ductile failure and fracture, Mohr's theory of brittle failure, fatigue, and high-temperature material behavior. The mechanics of crack formation and propagation are reviewed historically and experimentally

(1513) Sokolov, L. D.

Investigation of the Influence of Grain Size on the Relationship Between Compression Rates and Stresses During Plastic Deformation (In Russian)

Zhur. Tekh Fiz. 18 (1948) 89-92

Cylindrical specimens of Al of different grain size were compressed at rates between 0 01 and 1 mm/sec. It was found that the "rate of coefficient" has a lower value for specimens with smaller grain size The dependence of rate coefficient behavior on the increase of deformation in the case of high- and low-melting metals and alloys

(1514) Sokolov, L D

Systematic Investigation of the Rate and Temperature Dependence of Resistance to Deformation of Single Phase Metals (In Russian)

Doklady Akad. Nauk S S S R (1950) 839 841

Investigation for Pb, Sn, and Cu from room temperature up to their respective melting points and for various rates of deformation

(1515) Sokolov, L. D

Theory of the Influence of Rate on the Resistance of Metals to Plastic Deformation (In Russian)

Zhur Tekh Fiz 20 (1950) 447-457

Discusses analytical expressions of the relation between resistance to plastic deformation and rate of deformation on the basis of some modern theories of plasticity The most suitable relation, and that corresponding most closely to experiments, is obtained by comparing athermal and thermal plasticity. Dislocation theories based on considerations of microplasticity give correct relations for small deformations The validity of Zener and Hollomon's formula [J Appl Phy 15 (1944) 22] is confined to regions of low homologous temperature From examination of Vitman and Stepanov's [Zhur Tekh Fiz 9 (1939) 1070] as well as Sokolov's own formulae, it appears that these are suitable and convenient for practical calculations

(1516) Späth, W

On the Concept of Strain Hardening (In German)

Metall 7 (1953) 774-778

Work hardening in metals is critically discussed in relation to plastic flow and dislocation theories The results lead to the conclusion that a better understanding of the phenomenon can be obtained if the properties of an "ideal elastic" body are considered rather than those of an "ideal plastic" body Then, real metals can be considered to soften under plastic flow as compared with an ideal plastic body In such circumstances, increasing rate of strain does not signify increased work-hardening but decreased softening, due to the smaller amount of time available for it to take place Similarly, with increasing temperature, there is a greater amount of softening rather than a smaller amount of work hardening. Although applicable in the first place to single crystals, the fundamental principles of the new concept must govern the behavior of polycrystalline materials, although in the latter case there are many factors which cause complications

(1517) Späth, W

Physics of Permanent Deformations (In German)

Metall 7 (1953) 679-683

Certain fundamental phenomena of flow, thermoelectric effects, internal damping, equilibrium processes, metallurgical microprocesses, and tendency toward brittle fracture by metals

(1518) Späth, W

The Origin of Slip Bands in Plastically Deformed Metal Surfaces (In German)

Metalloberfläche 7A (1953) 119-121

The regular spacing of slip bands in metals is discussed, and it is considered that if the formation of the bands is due to slip taking place preferentially at the sites of lattice defects, then the random nature of the latter would of itself lead to irregularities in the slip-band spacing. These considerations lead to the conclusion that during the flow of plastically deformed metals ultrasonic vibrations are generated which suffer reflection at crystal surfaces, grain boundaries, and inhomogeneities within the crystal, which leads to interference phenomena and thermal and electrical effects Interference results in oscillations of sufficient magnitude to produce preferential slip. The spacing (Slp) of individual slip lines in a slip band (or cluster) can be ascribed to the effects of hypersonic vibrations Conversely, measurements of slip spacings can be used to calculate the frequency of the vibrations set up during plastic flow

(1519) Späth, W

Flow Phenomena in Stressed Metals

Metall 10 (1956) 910 915

Discusses and broadens his theory that during the flow of plastically deformed metals ultrasonic vibrations are generated which suffer reflection at crystal surfaces, grain boundaries, and inhomogeneities within the crystal, which lead to interference phenomena and thermal (local hot spots) and electrical effects

(1520) Spitko, N K

A Theory of Strength of Metals Based on Their Structures (In Russian)

Zhur Tekh Fiz 18 (1948) 857-862

Assumes that the deformation of polycrystals proceeds by deformation of the individual grains On this basis, a method for averaging of yield points is proposed and validated experimentally for three types of alpha-Fe, for Cu, and for Zn Influence of structural state of the material

(1521) Sproule, K

Predicting Creep Strength of Metals

Metal Progr 51 (March 1947) 441-442

Stress versus temperature, plotted on semilog paper, gives nearly straight lines One known value for Cu was used to predict other values by drawing a line roughly parallel to curves for other metals and alloys

(1522) Stehle, H , and Seeger, A.

Electron Theoretical Investigations Concerning Defects in Metals III The Influence of Dislocations on the Crystal Density, and Related Problems (In German)

Z Physik 146 (1956) 217-241

The observed fractional changes in density of metals on heavy cold working cannot be explained by dislocation theory if attention is restricted to linear elasticity theory. If, however, nonlinear terms (strains related to higher powers of the stresses) are taken into account, both screw and edge dislocations are found to be dilated in comparison with the undisturbed lattice For a screw dislocation, computation gives a dilation of 3/4 atomic volume/lattice plane/dislocation line It is estimated that the computed density change will be reduced by not more than 10% through the influence of stacking faults Preparatory calculations are presented on the influence of nonlinear strains scattering of electrons, with a view to calculating resistance changes due to dislocations

(1523) Steijn, R P , and Brick, R M

Flow and Fracture of Single Crystals of High-Purity Ferrite

Trans ASM 46 (1954) 1406-1448

Slip behavior of high-purity Fe containing C or Ti was investigated by tensile and compressive tests at room and low temperature, the slip elements being investigated micrographically and by X-ray studies Slip can occur on planes in the <111> zone, the resistance to slip varying continuously between (110) and (112) The critical shear stress for slip was investigated down to -150 C, and the nature of fracture studied and shown to be dependent on temperature and orientation Mechanical twinning was observed below -75 C. A theory of slip on high-index planes in bcc materials is developed from a consideration of a hard-sphere model

(1524) Stepanov, A V

Phenomenon of Cleavage (In Russian)

Zhur Tech Fiz 19 (1949) 492-506

Presents detailed theoretical study, considering that this property is universal and is present in all types of crystals including those of metals, minerals, salts, and even organic compounds Data of investigation indicate that anisotropy of elastic properties is necessary for cleavage

(1525) Stepanov, A V

Dislocation Theories of Strength and Plasticity (In Russian)

Izvest Akad. Nauk S S S.R. , Otdel Tekh Nauk, no 9 (1954) 90-107 [Translation in Research 9 (1956) 227]

The fundamental principles underlying existing dislocation theories discussed and critized; an alternative approach to the study of strength and plasticity of crystals proposed.

(1526) Steurer, W H

The Stability of Microstructures and Related Physical Properties at Elevated Temperatures

Paper from High Temperature Materials, Their Strength Potentials and Limitations, Fourth Sagamore Ordnance Materials Research Conference (1957) 70-89

The general trend in several fields of engineering, particularly those connected with high speed flight, toward shorter service times and higher temperature calls for a new approach to the strength improvement of metallic materials While the conventional long-time applications are confined to the moderate strength of stable microstructures, shorter times permit the utilization of the transient strengthening effects associated with unstable structures, as they are encountered at high degrees of strengthening treatment Of particular interest is the metastable range, where high mechanical properties can be obtained for short periods of heat exposure, representing a compromise between strength improvement and stability The life time of these structures is related to strengthening and temperature the higher the degree of strengthening or the higher the temperature, the lower the stability, i e , the shorter the service time The use of these highly strengthening metastable treatments not only produces unusually high mechanical properties for limited times, but also permits the applications of alloys so far considered unsuitable for high temperature service

(1527) Stowell, E Z

A Phenomenological Relation Between Stress, Strain Rate, and Temperature for Metals at Elevated Temperatures

NACA TN 4000 (1957) 19 pp

The following phenomenological relation is suggested

$$\dot{\epsilon} = \frac{d}{dt}\left(\frac{\sigma}{E}\right) + \alpha\frac{dT}{dt} + 2\kappa T \exp\left(-\frac{\Delta H}{RT}\right)\sinh\frac{\sigma}{\sigma_0},$$

where $\dot{\epsilon}$ = strain rate, σ = stress, E = Young's modulus, α = linear-expansion coefficient, T = temperature, t = time, κ = constant, ΔH = activation energy, and σ_0 = constant This general equation is simplified for steady-state creep, creep rupture, stress/strain curves, and rapid-heating curves The theory is compared with data on 7075-T6 Al alloy sheet, and a reasonable agreement is obtained.

(1528) Stroh, A N

A Theoretical Calculation of the Stored Energy in a Work-Hardened Material

Proc Roy. Soc (London) 218A (1953) 391-400

An attempt is made to calculate the amount of energy stored in a cold-worked metal, in terms of Mott's theory of work hardening in which dislocations are assumed to pile up against obstacles in the slip planes The stored energy may be due to (1) piled-up groups of dislocations and (2) vacant lattice sites formed by the moving dislocations The potential energy of (1) is attributed to (a) the energy of dislocations of the same group, and (b) the energy due to the interactions of different groups of dislocations It is found to be only a small proportion of the total work done in deformation and to be approximately proportional to the total strain For large strains these predictions are in reasonable agreement with experimental results on pure metals deformed in various ways For small strains much of the stored energy may be due to the formation of vacancies and interstitial atoms, i e , (2) Thermal softening of recovery may be interpreted as a dispersal of piled-up groups, and the theory shows that much of the stored energy can be released before there is much effect on the hardness or flow stress

(1529) Stroh, A N

The Mean Shear Stress in an Array of Dislocations and Latent Hardening

Proc Phys Soc (London) 66B (1953) 2-6

Following work of Taylor and Mott, the shear stress on a slip plane is taken as a measure of the work hardening on that plane Stroh calculates the possible work hardening of a latent glide system in terms of an array of screw or of edge dislocations on an operative system The results are shown to be independent of the distribution of dislocations Since the rate of work hardening in duplex glide is as high as in simple glide, he concludes from his calculation that edge dislocations account for the greater part of the hardening process

(1530) Stroh, A. N

The Formation of Cracks as a Result of Plastic Flow

Proc Roy Soc (London) 223A (1954) 404-414

Stresses around a piled-up group of dislocations investigated with reference to initiation of a crack A crack should form when group consists of about 1000 dislocations in a cold-worked metal

(1531) Stroh, A N

The Formation of Cracks in Plastic Flow – II

Proc Roy. Soc (London) 232A (1955) 548-560

In the earlier work on the possibility of a crack being formed near a pile up of dislocations the pile up was treated as a whole, and no attention was paid to the part played by individual dislocations The mechanism involved is now considered in greater detail, and it is suggested that a crack arises from the short-range, non-Hookian interactions of a few dislocations at the head of the pile up. The rest of the dislocations serve mainly to produce the high stress-concentration required to force the leading dislocations together they play a secondary role in crack formation, and can, in principle, be replaced by any other stress concentrator The possibility of relieving the stresses round the pile up by slip on the perfect lattice instead of by fracture is considered Finally, it is shown that the dislocations are equally efficient in producing a stress concentration – and so helping to initiate a crack – when they are distributed over several slip planes, provided certain conditions are satisfied. In a heavily cold-worked ductile material a number of small cracks can be expected to be formed fracture will ultimately occur when these link up

(1532) Stroh A N

Brittle Fracture and Yielding

Phil Mag. 16 ser 7 (1955) 968-972

A piled up group of dislocations, e g., at a grain boundary, causes a stress concentration in its neighborhood If the maximum tensile stress at a distance r from the pile up is equated to the stress needed for a Griffith crack to spread, the theory of brittle fracture is obtained that predicts correctly the relation between stress and grain size, and also the constant of proportionality in Fe and Zn. At a higher temperature, it is found that the lower yield point also depends on the grain size in Fe The theory can be used to predict the ductile brittle transition and the temperature in Fe is calculated as 300 K A similar temperature is calculated as that at which a crack already moving will stop.

(1533) Stroh, A. N

The Strength of Lomer-Cottrell Sessile Dislocations

Phil Mag 1 ser 8 (1956) 489-502

A Lomer-Cottrell sessile dislocation at the head of a piled-up group of dislocations may give way under the combined action of stress and temperature Depending on its combined action of the group, the dislocation may yield either by recombining and slipping on a (100) plane or by dissociation into the two dislocations from which it was formed The size of the group required for both these mechanisms is obtained as a function of stress, but the results depend rather sensitively on the structure of the dislocation core

(1534) Stroh, A N

The Existence of Microcracks After Cold-Work

Phil Mag 2 ser 8 (1957) 1-4

It is suggested that changes in density and electrical resistance on cold work may be due to the formation of microcraks To fit the experimental values of Claresbrough, et al , 8×10^4 cracks/cm^2 are needed, each 1 3 x 10^{-3} cm in length

(1535) Stroh, A N

A Theory of the Fracture of Metals

Adv Phys 6 (1957) 418-465

A development and discussion of a theory of transcrystalline fracture of polycrystalline materials The article attempts to show how the principal features observed follow from a simple model Included is a discussion of brittle fracture, the lower yield point, the ductile brittle transition, propagation of cracks, and ductile fracture

(1536) Stroh, A N

The Cleavage of Metal Single Crystals

Phil Mag. 3 (1958) 597-606

A model of cleavage applicable to metals cleaving on the slip plane is developed in which a crack is initiated at the end of a low-angle tilt boundary terminating inside the crystal The strength of the metal is determined by the difficulty of growth of the crack Satisfactory agreement is obtained with the experimental results of Zn

(1537) Suiter, J W , and Wood, W A

Deformation of Magnesium at Various Rates and Temperatures

J Inst Metals 81 (1952-1953) 181-184

It is shown by X-ray and metallographic studies that polycrystalline Mg, when deformed, behaves in a similar way to Al and Zn in that, at both elevated temperatures and slow strain rates, a subgrain or cell structure is formed within the grains The work, however, brings out a new feature, namely that it appears necessary to postulate the formation of crystallite "debris" at the grain boundaries in order to correlate the X-ray and metallographic observations

(1538) Sully, A H

Metallic Creep

Research 1 (October 1947) 19-24

The phenomenon its measurement, physical significance, and metallurgical aspects, and the development of creep-resistant alloys

(1539) Sully, A H

Metallic Creep and Creep Resistant Alloys

Interscience Publishers New York (1949) 278 pp

Practical and theoretical aspects Development of the existing theory of the strength of metals with special reference to creep, and certain metallurgical factors affecting creep Experimental techniques and creep properties of ferrous and nonferrous alloys

(1540) Sully, A. H

The Creep of Metals and Creep-Resistant Alloys

Murex, Ltd. Rev. 1 (1951) 211 228

Analyzes creep in metals Factors which influence creep, and compositions of creep resistant alloys Utilization of creep-test data as it affects engineering design. Structural phenomena and physical theory of creep.

(1541) Sully, A. H

Recent Advances in Knowledge Concerning the Process of Creep in Metals

Paper from Progress in Metal Physics, VI, Interscience Publishers, Inc , New York (1956) 135-180

The principal contributions to the knowledge of creep behavior published in the last 5 years are considered in detail and interpretations of the phenomena are discussed

(1542) Sully, A H , Cale, G N , and Willoughby, G

Creep of Metals Subjected to Compression Stress

Nature 162 (1948) 411-412

Results of some creep tests under constant compression load on creep-resistant Cr-Ni alloys Primary, secondary, and tertiary creep were observed, as in the case of tension creep testing Suggests that, in both tension and in compression, tertiary creep is initiated by atomic rearrangement in the most heavily strained zones adjacent to the crystal boundaries, the onset of which may be determined by the amount of strain which the specimen has undergone

(1543) Sumino, K

Interaction of Dislocation With Atomic Order in Solid Solutions

Sci Repts Research Insts , Tôhoku Univ 10 (1958) 283-298

A mechanism of the interaction between a dislocation and the atomic order, which is due to the coupling of the stress field of the dislocation with lattice distortion accompanied by ordering in superlattice alloys, is proposed The interaction energy and the locking force against the motion of the dislocation are calculated for the superlattice of the beta-brass type by using the quasi-chemical treatment developed by Iwata. The effect of thermal motion on the locking force is also considered on the basis of H Suzuki's treatment, The interaction energy and the locking force for an edge dislocation reveal a sharp peak at the Curie point of order-disorder transformation, while such a sharp peak is absent in screw dislocation. The values for a screw dislocation are found to be from 1 to 10 per cent of those for an edge dislocation Furthermore, the short-range order hardening is expressed in terms of order parameters for the superlattice of the beta-brass type

(1544) Summerton, J. M

Theories of Metallic Creep

J Birmingham Met Soc. 37 (1957) 537-552

Characteristic creep curves, time laws, and theories of creep. Note on structural changes during creep.

(1545) Suzuki, H

Theory of Breaking Strength I Static Strength (In Japanese)

Nippon Kinzoku Gakkaishi 16 (1952) 19-23

By thermodynamic consideration of a model, a formula connecting the breaking strength of a crystal with its thermodynamic functions was obtained In the case of a simple tensile test of an internal-stress-free polycrystalline specimen at 0 K, the formula agrees with that of Fürth [Proc Roy Soc (London) 177A (1941) 217]. The formula is successfully applied to tensile tests on a specimen with internal stress or under hydrostatic pressure, but it fails to evaluate the strength in the compression test

(1546) Suzuki, H

Chemical Interaction of Solute Atoms With Dislocations (In English)

Sci Repts Research Insts Tôhoku Univ 4A (1952) 455-463

A mechanism of interaction between a dislocation and dissolved atom is outlined. It is shown to account reasonably for the difference in mechanical behavior between fcc and bcc crystals on the basis of the differing locking mechanisms operative in the two types of crystal; in the former case there is a weak but wide interaction range, while in the latter there is a strong, narrow valley of potential energy, the so-called "Cottrell atmosphere" As a result, in fcc crystals there is a low critical shear in stress which is almost independent of strain, whereas in bcc crystals, there is a very high critical shear stress at low temperatures which decreases rapidly with rise of temperature.

(1547) Suzuki, H

A Theory of the Formation of Slip Bands in Face-Centered Cubic Crystals (In English)

J Phys Soc Japan 9 (1954) 531 540

A theory of slip band formation in fcc crystals is based upon the following three concepts (1) a Frank Read source multiplying dislocations in successive atomic planes, (2) cooperative action of such sources; and (3) the different distribution of dislocations near the free surface compared with the interior of the crystal It is shown that about 1000 dislocations can be produced from each source by the critical shear stress of the source Experimental studies of the production and orientation of slip bands by optical and electron microscopes, and evidence indicating a definite width of a slip layer are reviewed

(1548) Suzuki, H

The Slow Motion of a Dislocation in a Face Centered Cubic Crystal (In English)

Sci Repts Research Insts Tôhoku Univ 7A (1955) 194-203

The slow motion of an extended dislocation accompanied by heterogeneous distribution of solute atoms in a hexagonal layer of an alloy is studied on the basis of the interaction mechanism between solute atoms and dislocations proposed by Suzuki [ibid., 4A (1952) 455] In the case of a very small stress an expression for the velocity, v, of the dislocation is derived in the form: $v = 0.4\,Df/bf_0$, where D is the diffusion coefficient of the alloy, b the strength of the (perfect) dislocation, f the applied shear stress, and f_0 the critical shear stress of the alloy due to the locking force of solute atoms. The motion may be stable under an applied force less than 0 6 - 0.8 f_0, according to the width of the dislocation The slow motion is not responsible for the microcreep of fcc metals at high temperatures.

(1549) Suzuki, H

Thermal Etching of Dislocations

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 172-175

Thermal etching technique can be applied to most metals and alloys, except for some metals having high vapor pressure at high temperatures, such as Zn, Cd, Mg, and their alloys. Some examples of Fe-Ni alloys which were oxidized at 1100 C for 30 minutes are shown.

(1550) Suzuki, H

Yield Strength of Binary Alloys

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 361-390

Yield strength depends on the interaction force between sources as well as on the force required to tear a dislocation from its locked site. The yield strength determined in experiment is usually the transition point at which the tangent in a stress-strain curve decreases considerably The yield strength in theory, therefore, is reasonably determined from the theoretical stress-strain curve

(1551) Suzuki, H , Ikeda, S., and Takeuchi, S.

The Deformation of Thin Copper Crystals

J Phys Soc Japan 11 (1956) 382-393

Tensile stress/strain curves were determined for Cu single-crystal wires of various diameters and the dependence of work hardening upon crystal orientation and radius of the wire was studied Two linear sections of stress and strain correspond to regions of easy glide and rapid hardening Marked dependence upon crystal orientation is found for 2-mm-diameter wire particularly in the easy-glide region The range of easy glide increases considerably with decrease of wire radius, depending upon orientation Hardening rate in the rapid-hardening range depends slightly on wire radius, but, in the easy-glide range, shows marked dependence on wire radius The results are discussed in terms of the "mean free path of dislocations" The logarithmic range of easy glide is related linearly to the radius of the wire

(1552) Suzuki, H , Ideka, S., and Takeuchi, S.

Deformation of Thin Metal Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 548-549

The effect of crystal radius on the deformation of single crystals of Cu [J Phys Soc Japan 11 (1956) 382] and alpha-brass, and, in particular, the effect on the range of easy glide, was studied.

(1553) Suzuki, T

Surface Sources and Plastic Flow in Potassium Chloride Crystals

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc , New York (1957) 215-229

Crystals were polished so that birefringence bands corresponding to single and double slip could be observed with polarized light parallel to the slip direction. Work-hardening and internal treatment is given The plastic behavior of polished and unpolished crystals is discussed in terms of the length of surface sources

(1554) Suzuki, T

A Theory of Slip Band Formation and Work Hardening in Face Centered Cubic Metal Crystals (In English)

Sci Repts Research Insts Tôhoku Univ 6A (1954) [illegible]

The theory of network dislocation in a fcc lattice, due to temperature and H Suzuki (read before International Conference Theoretical Physics, Japan, September 1953), is extended to account for slip band formation and the production of work hardening Elements of the network, retained in an annealed crystal for a sufficient time, behave as slip sources emitting dislocation spirals in successive planes Pole dislocations can form sessile dislocations with the operative slip dislocation near the node, when they move a short distance with the help of stress induced by the dislocation spirals Soon after yielding, an equilibrium distribution of dislocation loops is probably formed around a segment of the sessile dislocation, Experimental results relating to the work hardening of high purity Al crystals are discussed and compared with the theory. Fine slip bands are formed from surface sources, and, in accordance with the theory, remain localized in surface layers of the crystal

(1555) Swann, W F G

Shear Modulus and Viscosity Relations in Plastic Materials

J Franklin Inst 259 (1955) 11-16

The so-called elastic constants, viz , the shear and bulk moduli, η and κ, respectively, derived from stress/strain data relating to the experimental deformation of plastic materials under periodic alternating stress, are not, in general, their true values, but functions of the test piece, dependent upon the frequency of the applied stress Mathematical suggestions relating to directions in which present theory may be developed to make calculated results fit the experimental facts are discussed.

(1556) Sweetland, E D , and Parker, E. R

Effect of Surface Condition on Creep of Some Commercial Metals

J Appl Mechanics 20 (1953) 30-32

Some experimental work is described to determine the effect of the oxide surface layers on the creep properties of 2S Al and commercial drawn Cu It was found that the presence of an oxide layer increases the creep strength of these metals. The possible causes for the change in creep rate are briefly discussed.

(1557) Swift, H W

Plastic Flow in Metals

Metallurgia 21 (1940) 75-76

Various factors entering into phenomenon of plastic flow Present state of knowledge; consideration of possible correlation of stress and strain circle diagrams; torsion and bending and the nature and effects of plastic flow; theories of strain hardening advanced by workers in this field, including mosaic theory, dislocation theories, and Bilby theory

(1558) Swift, H W

Deformation of Metals

Metallurgia 31 (1944) 53-63

Problems involved in this subject and of the contributions which can be made to it by the application of mechanical principles.

(1559) Swift, H W

On the Foot-Hills of the Plastic Range

J Inst. Metals 81 (1952) 109-120

Present state of knowledge and the extent research is able to make its contribution to various technological processes involving plastic deformation. Suggests the most profitable directions of inquiry appropriate to mathematicians, metal physicists, and engineers An appeal is made to the metal physicist for a more realistic model of lattice structure, and for a systematic study of stress-strain relations on a wider front than heretofore

(1560) Swift, I H , and Tyndall, E P T.

Elasticity and Creep of Lead Single Crystals

Phys. Rev 61 (1942) 359-364

The rigidity modulus and Young's modulus of single crystals of lead were measured by static methods. The elastic parameters agree with those determined dynamically by Goens and Weerts The elastic limit under longitudinal stress occurred when the resolved shear stress on the most favorably placed octahedral plane was approximately 2×10^6 dynes/cm^2

(1561) Sylwestrowicz, W D

Temperature Dependence of the Yield Stress for Copper and Aluminum

Trans AIME 212 (1958) 617-624

Establishment of a fundamental relation between an applied load and deformation of metals has been attempted by many investigators In the most simple form this relation is presented as a stress strain curve in tension The popularity of this form or presentation is due partly to the greater ease of performing experiments and partly to the comparatively simple interpretation of the data obtained In turn it suggests the acceptance of strain as synonymous with the deformation Eventually an equation of state was proposed where stess is taken as a function of strain, rate of straining, and temperature Experimental evidence has since been presented showing the dependence of the stress strain relation on the previous history of the specimen Such dependence cannot be accounted for in this equation of state While the equation of state relating stress to strain has to be modified, it now appears that at temperatures where no recrystallization change or appearance of new phase occur, a unique relation still may exist between yield stress and the plastic behavior of metals a metal of a given yield stress should have subsequent properties independent of its previous history. In other words, two specimens deformed by different paths to the same yield stress should have at the same temperature the same rate of work hardening for the same rate of straining and, in the case of change of temperature, should have the same rise or drop of the yield stress

(1562) Tabor, D.

A Simple Theory of Static and Dynamic Hardness

Proc Roy Soc (London) 192A (1948) 247-274

When a spherical indenter is pressed into a softer metal, plastic flow occurs The permanent indentation is spherical in shape, but its radius of curvature is greater than that of the indenter This is believed to be due to release of elastic stresses. The energy involved in elastic recovery is found to account for the energy of rebound of the indenter This analysis explains a number of empirical relations observed in dynamic-hardness measurements The results also show that dynamic hardness of very soft metals is very much higher than static hardness and indicates that forces of a quasi-viscous nature are involved. Finally, a simple theory of hardness based on the theoretical work of Hencky and Ishlinsky is presented. It is shown experimentally that for a material incapable of appreciable work hardening, the mean pressure required to produce plastic yielding is related to the elastic limit by an empirical relationship.

(1563) Tabor, D

The Hardness of Metals

Oxford University Press, London (1951) 176 pp

Hardness measurements by spherical indenters, deformation and indentation of ideal plastic metals and of metals which work harden, the practical considerations of "shallowing" and elastic recovery, use of conical and pyramidal indenters, dynamic or rebound hardness, and area of contact between solids Six appendices deal with Brinell, Meyer, and Vickers hardness measurements and their conversion factors, the connection between hardness and ultimate tensile strength, and typical hardness values

(1564) Tabor, D

The Hardness and Strength of Metals

J Inst Metals 79 (1951) 1-18

Using a spherical indenter of fixed diameter to make hardness indentations, as in the Brinell test, it was found that the load necessary to produce an indentation of a certain chordal diameter is given by a relationship which depends on degree of work hardening of the metal Shows that the stress-strain curve of the metal may be derived from the hardness measurements A series of curves shows the variation of the ratio of tensile strength to hardness with Meyer index Materials as diverse as tool steel, work-hardened Ni, and annealed Cu all lie near the theoretical curves. A similar analysis is given for pyramidal indenters such as used in making Vickers hardness measurements

(1565) Tabor, D.

Hardness and Strength Properties of Metal (In French)

Rev mét. 49 (1952) 208-210

A brief theoretical discussion of the relation between the elastic limit and the hardness of metal

(1566) Tabor, D

Hardness of Solids

Endeavour 13 (1954) 27

Proposes a relationship between Vickers indentation hardness, H, and ultimate tensile strength, T_u, of an ideal plastic material $T_u = 0.33\,H$

(1567) Tabor, D

Hardness of Solids

S African Mining Eng J 65 (March 13, 1954) 41-43, 45, 47

Investigations show indentation hardness of metal if related to its plastic yield stress. Further study shows a simple physical explanation of familiar Mohs scratch-hardness scale for minerals.

(1568) Takeuchi, S., and Suzuki, H.

Correlation Between Lattice Transformation and Plastic Flow in Metals (In Japanese)

Nippon Kinzoku Gakkaishi-Si 13 (April 1949) 14 18

Two assumptions on the basis of which a thermodynamic theory of plastic deformation was developed in a preceding report are discussed from the viewpoint of a dislocation model

(1569) Takeuchi, S., and Suzuki, H.

Theory of Plasticity I. Correlation Between Lattice Transformation and Plastic Gliding in Metals II Critical Shear Stress of Binary Alloys (In English)

Sci. Repts, Research Insts Tôhoku Univ 2A (1950) 50-59, 60-67

I. Two fundamental relations, which are essential for expressing the resistance to plastic gliding in terms of thermodynamic functions, were derived by considering the structure of dislocations One relation connects the free-energy difference dissipated during lattice transformation with the mechanical energy required for plastic gliding II Critical shear stresses of Au-Ag, Cu-Ni, and Cu-Zn binary alloys were calculated by means of the two relations derived in Part I. Curves of critical shear stress were plotted against the concentration of the alloys and took various forms depending on the thermodynamic functions applied

(1570) Tamhankar, R., Plateau, J , and Crussard, C

Study of the Elevated-Temperature Plastic Deformation of a Soft Iron and of a Stable Nickel-Iron Austenite (In French)

Rev. mét 55 (1958) 383-400

The elevated-temperature mechanical properties and structural modifications accompanying deformation have been studied by means of tensile, torsion, creep, and internal-friction tests on two single-phase steels, an austenite of very low C content with 35 per cent Ni and 10 per cent Cr, and a decarburized Armco Fe The principle was to vary the experimental conditions as regards temperature, rate of deformation, and grain size through a wide range Study of the Portevin-le Chatelier effect resulting from segregations set up during the course of the test itself and the influence of this phenomenon on the mechanical properties General equation for creep, relating deformation, load, temperature, and time Determination of the heats of activation by various methods over a wide range of temperature Slip and intercrystalline decohesion become preponderant above the equicohesive temperature. This temperature, which is easily determined in the case of the austenitic steel, is not apparent with Fe. Interpretation of the foregoing results by means of microexamination and X-rays makes it possible to establish the part played by intercrystalline slip, by slip and diffusion at grain boundaries, and by polygonization and recrystallization.

(1571) Tapsell, H J., Forrest, P G., and Tremain, G R

Creep Due to Fluctuating Stresses at Elevated Temperatures

Engineering 170 (August 25, 1950) 189-191

A theory regarding the behavior of materials under simultaneous fatigue and creep conditions is discussed, and supporting experimental results are given The authors assume, to a first approximation, that for any instantaneous value of a varying stress, the creep rate will be the same as in a static creep test at that stress, at the same time from the beginning of the test An expression is proposed and close agreement with experimental results on a 0 26% C steel at 400 C is shown, when the creep occurring during the initial 2 hr of the test is disregarded. The necessity for this provision is ascribed to experimental difficulties at the beginning of the test.

(1572) Tarasenko, I I.

On the Condition of Failure of Metals (In Russian)

Zhur Tekh. Fiz. 21 (1951) 1336-1344

To combine the generalized stress/strain curves for different methods of loading, Tarasenko introduces the concept of a "constant modulus of plasticity" for the equivalent state of stresses, such as yield point, ultimate tensile strength, fracture, etc., by which he means that equivalent points of all curves lie on a single line through the origin Then he introduces the concept of a coefficient of nonlinearity relating appropriate equivalent yield stresses for each method of loading to the yield stress of the simple tension curve and accepts this coefficient for the plastic part of the curve as constant. In these considerations he assumes the colinearity of deviator of stress and strain vectors and the incompressibility of the metal

(1573) Tardif, H P., and Erickson, W

Strain-Aging, Work-Hardening, and Inhomogeneous Deformation in Armco Iron After Static and Dynamic Deformation

J. Appl Mechanics 25 (1958) 285-287

Under compression impact the work hardening produced is less than that produced by the same amount of statically applied strain Hardness is not uniform throughout the length of the specimens

(1574) Taubert, P

Contribution to the Theory of Hardening (In German)

Arbeitstag Festkorperphysik II (1955) 45-48

The following matters are discussed (1) kinematics of the deformation of single crystals, (2) Frank Read sources; (3) theories of hardening; (4) Taylor's, Kochendorfer's, and Mott's theories; (5) recovery, recrystallization, and rate of hardening, and (6) deformation due to twinning. The process of hardening is considered to comprise the following steps: (1) plastic deformation attributed to the presence of Frank-Read sources which cause the production of stress-zones on the hard regions and so hinder the production of further displacement rings (2) an increase in the stress necessary to produce deformation is thereby effected; (3) further hardening takes place by interaction between Frank-Read sources in different slip planes, and, in general, this exceeds the amount of hardening due to the first hardening process; and (4) hardening due to the interaction contemplated in Mott's theory plays its part

(1575) Taylor, G I

The Mechanism of Plastic Deformation of Crystals

Proc Roy Soc (London) 145, 362 (1934) 362-387; 388-404

The fact that the macroscopic distortion of metal crystals is a shear parallel to a crystal plane and in a crystal direction, even when the distortion is large, shows that the plastic strain must be due chiefly to the sliding of one plane of atoms over its immediate neighbor It is shown that this type of plastic strain gives rise to elastic stresses near the two dislocations which occur at the two ends of each of these lengths L The assumption that such dislocations will migrate through the crystal, owing, possibly, to temperature agitation, then leads to a definite picture of the mechanics of plastic distortion. This theory of strain hardening gives a parabolic relationship between stress and plastic strain which agrees well with results obtained with metals crystallizing in the cubic system L is found to be of the order 10^{-4} cm, agreeing with the order of magnitude of faults found in metals and rock salt The system of faulting or mosaic structure limits the free motion of centers of dislocations The actual strain occurs inside the "blocks" of the mosaic structure, and the crystallographic nature of the faults is immaterial from the point of view of the theory

(1576) Taylor, G I

Strength of Rock-Salt

Proc Roy Soc (London) 145 (1934) 405-415

His theory of the strength of metals is applied to rock salt and shown to lead to a parabolic relationship between tensile stress and plastic strain This relationship involves L, which is the mean free path between centers of dislocations For rock salt, good agreement is found, and L is shown to be of order of magnitude 10^{-4} cm This is the order of magnitude of the distance between faults in the structure of rock salt It is concluded that the strain in rock salt occurs in the parts where the crystal order is perfect, and that the strength is determined by the mean free path L of the centers of dislocations L is determined by the distance apart of the faults and by the temperature The theory therefore assigns a definite function to the faults in determining the strength of crystals irrespective of their actual crystallographic or atomic nature

(1577) Taylor, G I

A Theory of the Plasticity of Crystals (In English)

Z Krist. 89 (1934) 375-385

The experimental facts indicate that plastic distortion usually consists of the sliding of one plane of atoms over its immediate neighbor so that a perfect crystal is reformed after each jump. It is assumed that slipping occurs over limited lengths, L, of the slip plane giving rise to "dislocations" at the ends of those lengths; this avoids the need for assuming large forces to account for the displacement of the whole slip plane at once At sufficiently high temperatures, these dislocations can migrate through the crystal under the smallest shear stress, and in this way, a picture of the mechanics of plastic distortion is obtained The theory gives a parabolic relation between stress and strain, and this is confirmed experimentally for metals which crystallize in the cubic system. The migration of the dislocation is assumed to be stopped by an internal fault surface, and in this way, the theory is connected with those involving mosaic or lineage structures

(1578) Taylor, G I

Plastic Strain in Metals

J Inst. Metals 62 (1938) 307-324

The work of Taylor and Elam on the straining of metallic single crystals is described and the application of the results to polycrystalline aggregates is discussed Shows that, for the latter, glide on five systems is, in general, necessary for a crystal to deform in conformity with the change in shape imposed by the other crystals

(1579) Taylor, G. I

A Connection Between the Criterion of Yield and the Strain Ratio Relationship in Plastic Solids

Proc Roy Soc (London) 191A (1947) 441-446

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The assumption that the work involved in small plastic strains reaches a maximum when the yield-stress criterion is varied leads to a relationship between the yield-stress and the strain-ratio relationship. It is usually assumed that the stress-strain relationship is one of simple proportionality Experiments, however, show that this assumption is not true for metals The observed relationship is used in conjunction with the assumption of maximum work during a given strain to calculate the criterion of yield It is found that this is very close to, but not identical with, the Mises-Hencky criterion

(1580) Taylor, G. I., and Quinney, H

Latent Energy Remaining in a Metal After Cold Working

Proc Roy Soc (London) 143 (1934) 307-326

Measurements of the latent energy remaining in metal rods after severe twisting are described Very much more cold work can be done on a metal in torsion than in direct tension. It is found that, as the total amount of cold work which has been done on a specimen increases, the proportion which is absorbed decreases. The absorption of latent energy and the increase in strength with increasing strain both cease when the same amount of cold work has been applied This suggests that the strength of pure metals may depend only on the amount of cold work which is latent in them.

(1581) Taylor, N. W

Mechanism of Fractures of Brittle Solids

J. Colloid Sci 2 (1947) 185

A theory is proposed which connects the stress f required to break a brittle material in simple tension with its duration of application t. The theory shows why a solid object does not have a single characteristic breaking strength and how it adjusts its fracture mechanism to whatever stress is applied. Applicability of the theory to certain aspects of the fatigue of metals under stress-corrosion conditions is indicated.

(1582) Taylor, N. W

Mechanism of Fracture of Glass and Similar Brittle Solids

J Appl Phy. 18 (1947) 943-955

Proposes a theory which connects the stress, f, required to break a brittle material in simple tension, with duration of application, t: $\log t = \log k_0 + (E\alpha/2.3kT)/f$, where t = fracture time; k = Boltzmann constant, T = absolute temperature; α and k_0 constants, E = Young's modulus; and f = stress

(1583) Terai, S

Deformation Resistance of High-Temperature Steels at 800, 900, and 1000 C

Sumitomo Metals 8 (1956) 221-228

Strain-time curves at various temperatures under the different stresses, and the determination of deformation resistance based on the assumption that transient creep would be slight at testing temperature

(1584) Terminasov, S., Jr., and Galperin, E Z.

Structural Changes in Steel Due to Cold Working and Heat Treatment

Acta Cryst. 10 (1957) 771

Changes of different structural characteristics, such as dispersity, elastic and static distortions of the alpha-phase lattice, characteristic temperature, and carbide-phase state, were examined in the course of plastic deformation and heat treatment of Si steel 5502 Effects of fragmentation and elastic distortions, responsible for the diffraction-line widening, were separated analytically and by means of harmonic analysis Both methods give a satisfactory coincidence of the elastic-distortion data Static distortions of the atomic lattice were rated according to changes in the diffraction-line intensity of two lines No regular intensity changes were found in the course of plastic deformation, which apparently proves the absence of a direct connection between static distortions and $\sqrt{U^2 st}$. An attempt was made to state a relationship between the structural characteristics of the samples examined and their mechanical properties, e g , microhardness. It was found that the hardening of deformed steel is due essentially to submicroscope structural nonuniformities appearing in the course of the alpha-phase fragmentation and the formation of severely distorted boundary regions

(1585) Thielsch, H

Lamellar and Mosaic Structures – X-Ray and Thermodynamic Evidence

Trans. AIME 166 (1946) 48-54

Reviews the most important of the results obtained by other investigators, especially in Germany, where a great deal of attention has been given to mosaic structure during the last three years.

(1586) Thomas, G , and Nutting, J

The Plastic Deformation of Aluminium and Aluminium Alloys

J Inst Metals 85 (1956-1957) 1-7

The electron microscope was used to study the metallography of slip in pure Al and Al alloyed with up to 7% Mg, 5% Ag, and 4% Cu It has been found that the presence of Mg and Cu hinders the formation of lamellae within the slip bands, while the presence of Ag favors lamellae formation, but lowers the lamellae displacement. It was also found that alloying elements influence the development of duplex slip. The results are interpreted in terms of the mechanism for lamellae formation outlined by Diehl et al [Z Metallk 46 (1955) 650]. It is concluded that those elements which greatly distort the solvent lattice prevent the formation of slip lamellae and make more difficult the process of duplex slip Consequently, the alloys work harden more readily

(1587) Thomas, G , and Nutting, J (Appendix by P B. Hirsch)

The Plastic Deformation of Aged Aluminium Alloys Appendix. The Interpretation of the Slip Pattern in Terms of Dislocation Movements

J Inst Metals 86 (1957-1958) 7-14

The electron microscope was used to study the metallography of the slip characteristics of aged and plastically deformed Al alloys containing 4% Cu and 7% Mg In Al-4% Cu alloys, the slip bands change from coarse, single slip lines to lamellated slip during the sequence: G P. (1) → G P. (2) → θ'. In Al-7% Mg alloys, slip always occurs in single steps, the slip displacements of which increase during aging. The results are interpreted in terms of depletion of solute from the matrix Plastic deformation of alloys aged to produce coherent precipitates results in the slip lines passing through the particles, whereas when noncoherent phases are present, the slip lines bend through them. When preferential precipitation occurs at grain boundaries, plastic deformation may be confined to the adjacent, solute-denuded region A description of the possible dislocation movements which would occur during the bending of a slip line around noncoherent precipitates is given in an appendix.

(1588) Thompson, D O.

Creep of Zinc Single Crystals

J. Appl Phy 23 (1952) 1277-1278

Creep in tension of pure Zn crystals obeys an equation of state. $s = at^m$, where s is strain and t is time m ≈ 0.5 at room temperature, reproducibly. The index m depends on temperature exponentially, with an activation energy of about 3400 cal/mol The critical stress for creep is temperature independent.

(1589) Thompson, F C., and Stanton, L. R

Some Observations on the Austempering and Isothermal Transformation of Steels, With Special Reference to the Production of Martensite

J. Iron Steel Inst. 151 (1945) 133P-180P

Relation suggested between duration of incubation period during isothermal treatment and the creep strength of the steel. If the induction period is, as the authors suggest, a period of stress relaxation, it might be expected that it should bear some relationship to the creep properties of the steel. A comparison is made for five steels between creep limit and time for first detectable breakdown of the austenite, at temperatures near 500 C, i e , at which the transformation is generally most rapid The longer the incubation time, the higher the creep limit

(1590) Thompson, N

Dislocations in Face-Centered-Cubic Lattices

Paper from Defects in Crystalline Solids, Phys Soc , London (1955) 153-158

Considers limitations imposed by the geometry of the crystal lattice on the nature and configuration of dislocations in a fcc lattice, with particular reference to the form and properties of "jogs" in dislocation lines

(1591) Thompson, N , and Millard, D J

Twin Formation in Cadmium

Phil Mag 43 ser 7 (1952) 422-440

Experiments on the formation of twins in single-crystal wires of Cd under tension demonstrate the essentially discontinuous nature of the process of twin growth and produce evidence in favor of a critical resolved shear stress law for twinning Twinning can contribute to creep at room temperature but not at 90 K Dislocation mechanism for the growth of a twin

(1592) Thomson, R

The Nonsaturability of the Strain Field of a Dislocation by Point Imperfections

Acta Met. 6 (1958) 23-28

It is shown that a dislocation strain field is not saturated by point imperfections when the dislocation dilatation is exhausted Elastic saturation effects are possible because of the direct elastic interaction between the point imperfections but are probably rare The saturation problem is equivalent to the problem of nucleation of precipitates and thus should be discussed in terms of the short range nonlinear and electronic forces between the imperfections.

(1593) Thornton, P R., and Hirsch, P G

The Effect of Stacking Fault Energy on Low Temperature Creep in Pure Metals

Phil Mag 3 ser 8 (1958) 738-761

The low-temperature creep behavior before and after a small stress change is interpreted in terms of barriers due to intersecting dislocations Using the data available on the temperature dependence of the flow stress in conjunction with these experimental results, estimates of jog energies are derived and compared with values obtained from flow stress data alone Relative dislocation widths for various metals are also deduced. From the theoretical analysis relating dislocation width to stacking fault energy, tentative values are suggested for the stacking-fault energies of Au, Ag, Al, Ni, Pb, Zn, Cd, Co, and Pt, relative to that of Cu These values are in reasonable agreement with previous estimates where available, thus confirming the hypothesis that low-temperature creep is controlled by the proposed mechanism The significance of these results is discussed in terms of the exhaustion and work-hardening theories of low-temperature creep It is shown that the experimental observation that the apparent activation energy is insensitive to stress and prestrain can be explained quite naturally on theories based on stress-aided activation and that it does not invalidate such theories

(1594) Tietz, T. E , and Dorn, J. E

The Effect of Strain Histories on the Work Hardening of Metals

Paper in Cold Working of Metals, Amer Soc. Met , Cleveland (1949) 163-179

Temperature of straining as a factor in determining the amount of work hardening in metals crystallizing in bcc and cph systems. Effect of strain rate on strain hardening when temperature is held constant Some preliminary tests on the effect of thermal-mechanical history on recovery rates Their possible significance in identifying the influence of temperature of straining

(1595) Tietz, T. E , and Dorn, J E.

Creep of Copper at Intermediate Temperatures

Trans AIME 206 (1956) 156-162

Creep of OFHC Cu was studied over the temperature range 348-469 K under constant stress. In the temperature range studied, crystal recovery was negligible ΔH is about 37,000 ± 3000 cal/mol, independent of the total strain from ε ≈ 0 03 to 0 38, and of the applied stress for σ = 9,900 to 38,300 psi Thus, neither the Becker-Orowan, Mott-Nabarro, nor the Kauzmann-Seitz types of creep theory apply to creep in the intermediate range of temperature. The insensibility of ΔH to stress or strain is reminiscent of high-temperature creep. However, ΔH for high-temperature creep is expected to be that for self-diffusion, viz., about 48,000 cal/mol for Cu. The value obtained here suggests that a somewhat different mechanism for creep applies over the intermediate range of temperature; the dislocation climb model for high-temperature creep does not appear to afford a satisfactory explanation of intermediate-temperature creep.

(1596) Tipper, C F

The Fracture of Metals

Metallurgia 39 (1949) 133-137

Fracture of mild steel is divided into three types, the first corresponds to parting along a shear plane, the second along two intersecting planes, giving a wedge-shaped fracture; and the third along a plane quite different from the shear plane, often at right angles to the tensile stress. The main conclusion is that fracture begins simultaneously at different locations, a fact confirmed by the work of Bridgman.

(1597) Toaz, M W., and Ripling, E J

Flow and Fracture Characteristics of Binary Wrought Magnesium-Lithium Alloys

J Inst Metals 85 (1956) 137-144

Tensile properties of alloys with hexagonal, mixed hexagonal, and cubic structures were studied as functions of testing temperature and strain rate. Each of the alloys displayed an embrittling temperature which was strain-rate sensitive The embrittlement was most severe for the completely cubic alloy

(1598) Tomaszcyk, W

Theory of Dislocations and Properties of Metals (In Polish)

Prace Inst. Ministerstwa Hutnictwa 6 (1954) 98-104

An interpretation of strain hardening, recrystallization, creep, and other related phenomena is given in terms of the theory of dislocations

(1599) Trapetsnikov, V A , and Nemnonov, S. A

Studies of Cohesive Forces in Iron-Molybdenum Solid Solutions From Fine Structure X-Ray Absorption Spectra (In Russian)

Fiz. Metal i Metalloved. Akad Nauk S.S.S.R , Ural' Filial 3 (1956) 314-320

Alloying Fe with 2% Mo increases the cohesive forces from 2 to 4% Mo there is no further change

(1600) Trifan, D

Stress Theory of Plastic Flow

J Math and Phys 35 (1956) 44-52

Mathematical theory of plastic flow for incompressible, isotropic, strain-hardening materials exhibiting a gradual transition from the elastic to the plastic state

(1601) Trofimov, V I

Local Development of Plastic Deformations in Low-Carbon Steels (In Russian)

Izvest Akad Nauk S.S.S.R , Otdel Tekh. Nauk no 11 (1955) 58-61

Varying character of plastic deformation in various portions of test pieces subject to tensile stress, extensions of areas affected

(1602) Trotter, J.

Electron-Microscopic Studies of Slip in Aluminum During Creep

J. Inst Metals 80 (1952) 521-523

Slow deformation of a specimen of pure Al at 200 C was studied by means of the electron microscope, using the plastic replica process Shows that slip zones do not consist of bundles of long parallel slip lamellae of the type found by Heidenreich and Shockley in room-temperature deformation but of intimate segments of primary and cross slip.

(1603) Trozera, T A., Sherby, O. D., and Dorn, J E

Effect of Strain Rate and Temperature on the Plastic Deformation of High Purity Aluminum

Trans ASM 49 (1957) 173-188

The effects of temperature and strain rate on the stress-strain curves of Al were obtained over the ranges of temperature, T, from 78 to 818 K and strain rates, ε, from 0 0035 to 600/hour The stress-strain curves formed a homologous set illustrating that identical stress-strain curves were obtained for constant values of the Zener-Hollomon parameter For a series of low stress-strain curves, ΔH had the constant value of 35,000 cal/mole Since this agrees with the activation energy for self-diffusion in Al, it is believed that in these cases the mechanism of deformation is controlled by a dislocation climb process Higher stress-strain curves gave correspondingly lower activation energies. The rather sharp transition from constant values of ΔH to decreasing values of ΔH as the stress-strain curve increases suggests a change in the rate-controlling process for deformation. The lower values of ΔH obtained in this range further suggest that, for the higher stress-strain curves, more of the energy necessary for deformation is supplied mechanically and therefore the contributions due to thermal fluctuations decrease

(1604) Truszkowski, W.

Deformation of Plastic Metals in the Tensile and Hardness Test (In English)

Bull acad polon. sci 3 (1955) 93-97

A relation between stress and degree of cold work is given for a metal with a defined degree of cold work A formula is deduced for the dependence of Meyer's coefficient on cold work and is confirmed by tensile and hardness measurements on Au, Ag, Cu, Ni, Al, 70·30 brass, Monel metal, and Cr-Ni austenitic steel Another formula is deduced for alloys with upper and lower yield points and is verified by tests on steels containing C

(1605) Truszkowski, W.

Three Stages in the Deformation of Plastic Metals (In English)

Bull acad polon. sci 1 ser 4 (1953) 65-68

The dependence of yield point on the degree of cold work was determined for Al, Cu, and Monel metal Measurements were made of the thermo emf of CuZn alloy, drawn to various degrees of deformation and annealed at 375 C; a sudden change was observed at the strain limit, 76 per cent deformation

(1606) Tucker, J., Jr.

The Maximum Stresses Present at Failure of Brittle Materials

Proc ASTM 45 (1945) 961-975

It is shown by a statistical theory of strength how stresses with magnitudes much beyond those usually considered as the strength of the material may be present in a portion of test specimen. It is theoretically demonstrated that the modulus of rupture as usually calculated should be much greater than the tensile strength. Analysis demonstrates that the load at failure of a cement briquet does not have a fixed ratio to the tensile strength of the material It is also shown that in a concrete cylinder tested in compression, with ends restrained against lateral expansion, the tensile stresses present in a small portion of the volume are too small to cause a tensile failure

(1607) Tung, S K , and Maddin, R

Shear Along Grain Boundaries in Aluminum Bicrystals

Trans AIME 209 (1957) 905-910

Al bicrystals having a pure tilt boundary about the <110> axis were subjected to creep stresses along their boundary at various temperatures Mechanism for grain-boundary shear is considered to be a combination process involving slip and grain-boundary self-diffusion

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(1608) Turkalo, A M., and Low, J. R

Effect of Carbide Dispersion on the Strength of Tempered Martensite

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The carbide dispersions in three essentially plain C martensitic steels (0.42, 0 56, 0 75 per cent C) have been studied after varying tempering treatments (400 - 1250 F). The purpose of the study was to verify existing quantitative data on the relationship between carbide spacing and tensile properties and to extend this earlier data to finer structures by the use of electron microscopy. In contrast to the earlier data, a linear relationship between the logarithm of the mean interparticle spacing (mean free ferrite path) and the yield strength does not hold for the entire range of tempered martensite structures. However, linearity is obtained throughout this range of structures if one considers the ferrite grain boundaries in the measurement of the mean free path in the structures containing the very coarse dispersions (highly tempered) where the carbides occur almost entirely as large spheroids scattered at grain boundaries. The method of calculating ferrite grain size in tempered martensites from the carbide particle diameters, as proposed by several investigators, was found to be valid only for the very coarsest carbide dispersions and not over the full range of tempering temperatures examined.

(1609) Turner, F H., and Blomquist, K. F.

A Study of the Applicability of Rabotnov's Creep Parameter for Aluminum Alloy

J. Aeronaut. Sci 23 (1956) 1121-1122

Calls attention to Rabotnov's article (Translated in NACA TN 1353) which postulates a function, $\phi(\epsilon)$, which correlates isochronous stress-strain curves, $\phi(\epsilon) = \sigma(1 + at^{1/3})$, with temperature constant: a = constant characteristic of the metal and temperature, σ = stress, ϵ = strain, and t = time. Thus, for every given value of the strain ϵ, the equation shows the relation between the stresses σ_i and the corresponding times t_i.

(1610) Tyndall, E.P T.

Creep of Zinc Crystals

Paper in Symposium on Plastic Deformation of Crystalline Solids, OTS, U S. Dept. Commerce (1950) 49-59

The creep (S) vs. time (t) relation of the form $S = at^m$ for Zn crystals with a secondary orientation close to zero. This relation is similar to, and may even be regarded as a special case of, the relation proposed by Andrade. No indication was found of any sudden onset of slip nor of a critical shear stress for its occurrence The parameter a of the creep equation depends on the resolved shear stress, while m appears to have substantially the constant value 1/2. In the discussion, A. H. Cottrell pointed out that Hollomon and Fisher, working with single crystals and small strains, did not confirm the $t^{1/3}$ law obtained by Andrade, who worked with polycrystals and large strains, whereas he himself, working with large strains and single crystals, confirmed Andrade's $t^{1/3}$ law. He suggested that Andrade's law holds for large creep strains produced quickly

(1611) Tyndall, E P.T., Artman, R A., Wert, C. A., and Eisner, R.

Creep of Zinc Crystals

J. Appl Phy 26 (1955) 286-294

Studies of plastic deformation in the region just beyond the elastic limit.

(1612) Tyte, L. C

Rate of Viscous Flow of Metals. Part I. Tin

Proc. Phys Soc. (London) 50 (1938) 153-175; disc 311-312

A new method of determining the dependence of the rate of viscous flow of metals on the deforming force and its variation with temperature It has been found that, for very small extensions, the velocity of viscous flow can be considered independent of time, but is connected by exponential relations with the stretching load P for any given temperature and with the absolute temperature T for any given load. The loads for transition from single to double glide and the breaking loads are shown to be connected with the corresponding temperatures by a hyperbolic expression. Finally, the behavior of the Sn wire is shown to be in general agreement with the results obtained from single crystals.

(1613) Tyte, L. C.

Rate of Viscous Flow of Metals Part II. Lead

Proc Phys Soc (London) 51 (1939) 203-221

Experiments previously reported for Sn have been extended to Pb. Relationships of the same form have been obtained for the rate of viscous flow of Pb. Four sets of constants are obtained, which can be attributed to (1) single or double glide in untwinned crystals, (2) single or double glide in twinned crystals, (3) extension during the recrystallization period and production of annealing twins, and (4) extension when strain hardening is considerably diminished by self-annealing The elastic limit, transition, and breaking loads are shown to be connected with the corresponding temperatures by hyperbolic expressions.

(1614) Uemura, Y

Coupled Dislocations Along a Grain Boundary (In English)

J Phys Soc Japan 11 (1956) 479-484

Coupleddislocations along a grain boundary in Ge crystals were observed by means of etch pits The dislocations are of the edge type with Burgers vectors in the <110> direction The arrangement of etch pits satisfies the condition that the small angle of misfit near the coupled dislocations is not very different from that in the regular array Quantitative verification of the law of interaction between edge dislocations is obtained It is concluded that the condition determining separation of dislocations is the equilibrium of forces of interaction of dislocations perpendicular to the boundary.

(1615) Umanskij, J , Yelutina, V , Kagan, A , and Pivovarov, L

X-Ray Investigation of Changes in Micromosaics Occurring During Disintegration of Supersaturated Solid Solutions

Acta Cryst 10 (1957) 822

Disintegration of supersaturated solid solutions, as shown by means of X-rays, is followed by changes in mosaic structure in Ni-Be and Cu-Be alloys. Minimum dimensions of solid-solution micromosaic correspond in both cases to maximum hardness Coagulation of the precipitate leads to an increase in size of the blocks with corresponding decrease in hardness According to the hypothesis suggested by one of the authors, age hardening is caused to a great extent by the decrease in the size of the solid-solution blocks, whereas the decrease of hardness after overaging is due to their coagulation.

(1616) Umstätter, H

Rheological Consideration of Creep of Steel (In German)

Arch. Eisenhüttenw. 23 (1952) 119-126

Relaxation time is a measure of the velocity with which a material can absorb impressed elastic stresses Since viscosity and relaxation time differ numerically by a factor of 10^{22-24}, they are much more suitable for the characterization of the mechanical behavior than the usual qualities, such as gliding modulus The relation between the magnitudes used in rheology is expressed by an equation derived from the general Maxwell formula for the behavior of materials

(1617) Umstätter, H.

On Creep and Relaxation (In German)

Schweiz. Arch. angew. Wiss u Tech. 19 (1953) 184-191

Chemically related substances may have very different stress-strain diagrams while the stress-strain diagrams of chemically different substances may be quite similar

(1618) Unchel, H A.

The Influence of Structure on Hardness with Special Reference to Steels

Metallurgia 45 (1952) 115-120

Considered the shearing forces acting in successive layers below the plane of application of the deforming stresses Proposed that the force K necessary for deformation of the aggregate could be related to the mean particle spacing by $K = Ae^{-By} + C$, where C = strength of matrix and A + C = deformation strength of second phase The constant B is dependent on the way in which the shear forces decrease with distance from a particle

(1619) Unckel, H A.

Grain Size Key to Mechanical Properties

Iron Age 170 (December 18, 1952) 148-152

Mechanical properties of metals and alloys show a marked rise or fall with changes in grain size Tensile strength, yield point, hardness, and reduction of area show varying degrees of change and differences in Al, Cu, and brass due to combined effects of orientation and porosity concentration along crystal boundaries

(1620) Underwood, E. E.

Creep Properties from Short Time Tests

Materials Methods 45 (April 1957) 127-129

A straight-line relationship is shown between ultimate tensile strength or creep-rupture stress and hot hardness; time and temperature effects are correlated by means of the Larson-Miller parameter.

(1621) Underwood, E. E., Elsea, A. R., and Manning, G. K.

The Principles of Dispersion Hardening Which Promote High-Temperature Strength in Iron-Base Alloys

OTS, U S Dept Commerce, PB 121455 (June, 1956) p 68

Creep strengths, tensile strengths, and hot hardness were measured at 80 to 1200 F in single-phase ternary alloys with base composition of Fe with 20% Cr Ternary additions were Ti, Be, or B. Hardnesses of ternary alloys were correlated by a function of lattice strain and relative valence A straight-line correlation is proposed for tensile strength or rupture strength versus hot hardness, for combinations of time and temperature

(1622) Underwood, E E , and Marsh, L L , Jr

Effects of Alloying Elements on Plastic Deformation in Aluminum Single Crystals

Trans AIME 206 (1956) 477-481

Dilute alloy single crystals of Al alloyed with Cu or Mg were subjected to constant-stress creep tests, tensile tests, and hot-hardness measurements within a temperature range of 300 to 866 K The flow stress was correlated by a function of atomic size of the solute and relative valence changes The activation energy for creep in Al single crystals was found to be about 27,000 cal/mole

(1623) Urie, V M , and Wain, H L.

Plastic Deformation of Coarse-Grained Aluminium

J Inst Metals 81 (1952-1953) 153-159

A fine grid, photographically reproduced on the specimen surface, was used to measure local elongations in the individual grains of deformed specimens of coarse-grained Al. In agreement with previous workers, it was found that the elongation varied from grain to grain and within the individual grains of the aggregate The elongation was generally restricted in the vicinity of grain boundaries, and the form of the restriction appeared to depend on the orientation relationships between neighboring grains The occurrence of deformation bands in the specimen during elongation produced corresponding fluctuations in the elongation curves which increased in magnitude with the over-all elongation of the specimen.

(1624) Uzhik, G. V

Uniformity of Conditions of Strength and Plasticity (In Russian)

Doklady Akad Nauk S.S.S R 64 (1957) 471-474

Analyzes the above, taking into consideration the resistance of metals to fracture under conditions of elastic deformation, a factor not considered in contemporary theories of strength of materials

(1625) Uzhik, G. V

A New Criterion of Brittleness and Plasticity of Metals (In Russian)

Doklady Akad. Nauk S S.S R. 64 (1949) 1037-1039

Proposes evaluation of the above on the basis of ratio of tensile strength and resistance to shear Mathematical analysis showing validity of this criterion.

(1626) Uzhik, G. V

Concerning the Bases of the Theory of Strength and Plasticity (In Russian)

Izvest Akad Nauk S.S S.R., Otdel Tekh. Nauk, 3 (1949) 1433-1455

Analyzes modern theories Application to solution of problems connected with determination of strength of materials A reassessment of the Ludwik-Davidenkov scheme of mechanical behavior of ductile metals (shear-stress condition for plastic deformation, tensile-stress condition for brittle fracture) Ductile fracture, identified with shear fracture, is believed to obey a critical shear-strain condition.

(1627) van Bueren, H G.

The Formation of Lattice Defects During Slip

Acta Met. 1 (1953) 464-465

A theoretical explanation of the elementary structure observed on strain Al crystal surfaces

(1628) van Bueren, H G.

Relation Between Plastic Strain and Increase of Electrical Resistivity of Metals

Acta Met. 1 (1953) 607-609

The increase in electrical resistivity after plastic deformation is attributed to increase in the number of lattice vacancies, interstitial atoms, and dislocations Assuming that the atomic defects are formed in the wake of "jogs" their density is proportional to $(strain)^{3/2}$, while the total length of dislocation line is proportional to $(strain)^{1/2}$ Unpublished results of Manintveld on wires of Cu, Ag, and Au show that the fractional increase in resistivity is proportional to $(strain)^{3/2}$, so that the extra resistance may be attributed almost entirely to vacancies and interstitial atoms The recovery of the electrical properties takes place in two stages, the room-temperature change being attributed to diffusion of vacancies and interstitial atoms to dislocations, and the higher temperature change to the disappearance of the incipient defects adsorbed on the dislocations, rather than to the disappearance of the dislocations themselves

(1629) van Bueren, H G

Lattice Imperfections and Plastic Deformation in Metals I. Nature and Characteristics of Lattice Imperfections, Notably Dislocations

Philips Tech. Rev 15 (1954) 246-257

Geometrical aspects and behavior under shear stress

(1630) van Bueren, H G

Lattice Imperfections and Plastic Deformation in Metals II Behavior of Lattice Imperfections During Deformation

Philips Tech Rev 15 (1954) 286-295

Phenomena of practical importance in work hardening, aging of alloys, and variations of electrical resistance

(1631) van Bueren, H G.

Theory of the Formation of Lattice Defects During Plastic Strain

Acta Met 3 (1955) 519-524

Theory to show relation between plastic strain and concentration of vacancies, dislocations and interstitials; studies behavior of dislocation sources under a varying applied shear stress Compares theoretical deductions and the strain dependence of the electrical resistivity of copper

(1632) van Bueren, H G

Electrical Resistance and the Plastic Deformation of Metals (In German)

Z. Metallk 46 (1955) 272-282

A critical survey is made of current information on the electrical resistance of plastically deformed metals (Fe, Mo, Ni, W, and mainly, Cu) and an attempt is made to offer a theoretical interpretation of the results so obtained. In both single-crystal and polycrystalline metals, the increase in electrical resistance bears a simple relationship to the degree of plastic deformation and, therefore, must be attributed to the formation of lattice defects during deformation, i e., vacant lattice sites, vacant lattice-site doublets, interstitial atoms, and dislocations (simple and screw) As the general properties of these defects are reasonably well known, it is possible to determine their relative influence on the electrical resistance Increasing resistance occurs mainly by the formation of defects other than dislocations, these latter having comparatively little effect The recovery of electrical resistance resulting from heating a metal plastically deformed at lower temperature can be compared with analogous phenomena in irradiated metals or quenched from high temperatures Five distinct stages of recovery can be defined of interstitial atoms, the decrease in resistance

(1633) van Bueren, H. G.

Influence of Lattice Defects on the Electrical Properties of Cold Worked Metals

Philips Research Repts 12 (1957) 1-45; 190-239

Treats the properties of lattice defects, plastic deformation of metals; electrical resistivity and magnetoresistivity of plastically strained metals; and recovery effects.

(1634) van Bueren, H G., and Jongenburger, P.

Resistivity Changes by Plastic Deformation of Polycrystalline Metals

Nature 175 544-545

Annealed polycrystalline wires of Cu and Ag were plastically deformed in extension and in torsion at 20 and 77 K The extra resistivity depends on extension according to a power law It is concluded that point defects can be held responsible for nearly all the resistivity increase caused by plastic deformation of polycrystalline metals, and that the direct effect of dislocations plans only a minor part in this respect.

(1635) van der Merew, J H

On the Stresses and Energies Associated With Intercrystalline Boundaries

Proc Phys Soc (London) 63A (1950) 616-637

Models based on the assumptions introduced in dealing with a single dislocation are used in calculations on three types of intercrystalline boundaries, namely: (I) a boundary due to a difference of atomic spacing, (II) a twist boundary, and (III) a symmetrical tilt boundary The outstanding feature of the interfacial energy is that it increases initially very rapidly with the angle of tilt An application of the results to the theory of oriented overgrowths is described. The validity of the assumptions and approximations involved and the advantages of the treatment are discussed

(1636) Varley, P C

The Recovery and Recrystallization of Rolled Aluminium of Commercial Purity

J Inst Metals 75 (1948) 185-202

A study was made, by means of ultimate tensile strength determination, of the process of recovery and recrystallization of polycrystalline Al sheet within the temperature range 200 to 325 C The isothermal annealing curves, in which ultimate tensile strength is plotted against the log of the time, are continuous curves exhibiting no discontinuity corresponding to the onset of recrystallization X-ray diffraction patterns show that recrystallization commenced at the level of 7-1/2 tsi for all samples of hard-rolled Al examined.

(1637) Vasil'ev, L. I

On the Dependence of the Velocity and Relaxation Coefficients of Aluminium on the Rate of Plastic Deformation (In Russian)

Zhur. Tekh. Fiz. 25 (1955) 687-690

Defines a velocity coefficient ϵ, and a relaxation coefficient α. ϵ and α were measured for Al specimens deformed in various rates The results indicate that the α/v and ϵ/v curves are S-shaped, i e , at high and low velocities both coefficients increase slowly with v At intermediate velocities, the variation is much more rapid This confirms previous results

(1638) Valil'ev, L. I. , Vylina, A. S. , and Zagrebennikova, M P

On the Effect of Change in Deformation Rate on Plastic Deformation (In Russian)

Doklady Akad. Nauk S S.S.R. 90 (1953) 767-769

Specimens of polycrystalline Cu and Sn wires were tensile tested at room temperature The testing speed could be changed in about 1 second. Two strain rates were used, and several combinations of these rates were applied The explanation for the results is that the extension causes both stable and unstable deformations, the latter being discharged on changing the rate, but those of increased stability preventing the gradual coincidence of the curve with that for the low rates The current value of the stress in the general case is not a single-valued function of the instantaneous values of the deformation, its speed, and the temperature; thus, the mechanical equation of state is restricted and approximate [cf. Dorn, et al., Trans AIME 180 (1949) 205]

(1639) Vidal, G.

Conditions for the Occurrence of Fracture During Creep Tests (In French)

Métaux Corrosion - Inds 27 (1952) 201-215

Causes for acceleration of creep and of fracture; influence of various factors on type of creep fracture and upon the time required for fracture, and for extension of the fracture

(1640) Vidal, G.

On Periodic Creep of Heat-Resistant Alloys (In French)

Rev mét. 53 (1956) 485-496

Experiments on Nimonic alloys to study the distinctive characteristics of a fatigue effect and a periodic creep, and to determine the constant stress equivalent to a given periodic variation of stress He constructed from theoretical considerations three diagrams relating to stresses varying in terms of time according to sinusoidal, rectangular, or triangular laws From the moment that a heat-resistant alloy is subjected at elevated temperature to a constant stress and to an alternating stress, it is susceptible to fracture under two different effects: that of periodic flow and that of true fatigue. The higher the mean stress, the more probable the effect of periodic creep. The phenomena of periodic creep and true fatigue are essentially distinct in their effects. In periodic creep one can consider an effective stress equal to a constant stress

(1641) Vidal, G. , Lescope, P , and Raymondin, L.

Influence of Temperature on the Elastic Constants of Metals and Alloys (In French)

Rev mét. 48 (1951) 864-874

Brief discussion from the physical, metallographic, and mechanical points of view

(1642) Vinogradov, I. N , and Yagn, Yu. I.

On the Laws of Plasticity (In Russian)

The application of a theory of plasticity due to Ratner, et al., to the deformation in tension of pure Fe, Al bronze, and Cu-Be is described

(1643) (I) Vitman, F F , Zlatin, A , and Ioffe, B S (II) Vitman, F F , and Zlatin, A

Resistance of Metals to Deformation of Rates of 10^{-6} to 10^{-2}. (In Russian)

Zhur Tekh. Fiz. 19 (1949) 300-326

Simple method and apparatus for investigating the relationship of deformation resistance to deformation rate Data for Pb, Al, Cu, mild steel, and Duralumin Results indicate the existence of three different regions within the above range of rates of deformation in which the character of the deformation process is fundamentally different from the other two

(1644) Vitovec, F

Effect of Temperature and Rate of Deformation on Critical Shear Stress (In German)

Z Metallk. 43 (1952) 128-130

It is shown that the Becker-Orowan equation,

$$D = C \exp[-V(\tau_o - \tau_a)^2/2GkT],$$

where D = the velocity of the deformation process, V = the volume subjected to the stress, τ_o = the value of the critical shear stress for slip at absolute zero, τ_a = the applied stress, G = the shear modulus, and T = the absolute temperature, must be modified if it is to be applicable to high shear-stress values as well as low The equation then takes the form

$$D = C \exp -Q(1-(\tau_a/\tau_o)^2)/kT] - \exp -Q(1 + (\tau_a/\tau_o)^2)/kT)],$$

where Q = the activation energy When this equation is applied to the critical shear stress of Cd and of Zn as a function of the rate of deformation at various temperatures, good agreement is found between the theoretical values obtained and the experimental results reported in the literature, without the necessity of including the concept of flaws acting as stress raisers, i e , the introduction of a stress-concentration factor.

(1645) Vitovec, F , and Nowotny, H

The Theory of Plastic Deformation (In German)

Z Physik 131 (1951) 41-47

Dependence of critical shear stresses on rate of deformation as derived by R. Becker contradicts some data. A new equation yields results which agree satisfactorily with most test results Becker's theory of glide is modified giving a critical shear stress (τ_a)/ temperature (T) dependence of the form $\tau_a = \tau_o [1 - KT]^{1/2}$ where K is a constant depending on the glide velocity

(1646 Vitovec, F , and Slibar, A.

Effect of Free Surface on Resistance to Deformation of Polycrystalline Materials (In German)

Schweiz. Arch. angew Wiss u Tech. 16 (1950) 76-80

Theoretical discussion of forces that oppose deformation of polycrystalline materials

(1647) Vivian, A C

The Relationship of Rheology to Strength of Materials

Metallurgia 30 (1944) 237-240

The new study of rheology, which seeks to examine and standardize on a sound basis certain properties of matter and materials appertaining to flow or to shape change due to force, is considered in relation to recent conceptions on the strength of materials which deal with the true stress-strain curve characteristic of all a material's reaction to force, and applicable to material whose reactions are entirely plastic or viscous.

(1648) Vivian, A. C.

A New Version of Strength of Materials

Metallurgia 45 (1952) 29-37

The present generally accepted system of "strength of materials" is severely criticized A new conception of the subject is outlined, and the case for the new version presented.

(1649) Voce, E.

The Relationship Between Stress and Strain for Homogeneous Deformation

J Inst Metals 74 (1948) 537-562, Discussion, 760-771

A simple relationship was found to connect stress with strain for a series of homogeneous compression curves At large deformations each of the curves becomes asymptotic to a definite stress, and the difference between this final stress and the threshold stress at which plastic deformation begins to become appreciable may be regarded as the total stress capacity of the materials The difference between any applied stress and that which is finally attained is the stress capacity remaining available after the application of that stress Defining the plastic modulus, comparable with the elastic modulus as the rate of change of stress with respect to true (logarithmic) strain, it is shown that the plastic modulus at any instant is proportional to the available stress capacity The same relationship appears to hold for tension as well as for compression as long as the deformation remains homogeneous

(1650) Voce, E

The Strain-Hardening of Metals

Engineer 195 (1953) 23

The stress/strain relationship for materials which work harden approximates to a simple power function (with indices other than 2) only for limited ranges of plastic deformation. Over extended ranges, double log plots invariably give elongated S-shaped curves An exponential function is derived, relating the yield stress with the original yield stress and the yield stress attained after all deformation sites have been blocked

(1651) Voce, E.

A Practical Strain-Hardening Function

Metallurgia 51 (1955) 219

Outlines progress in connection with exponential strain-hardening function (1948), and discusses the advantages over the well-known power function of Ludwik. After considerable strain there is generally a change of regime, consistent with the change in the mechanism of deformation reported by Cook and Richards The relationship between stress and hardness was analyzed in the light of the exponential function The pressure on the indenting tool becomes directly proportional to the yield stress of the material, as required by elastic theory For cones and pyramids (as Vickers) the hardness number is a direct measure of the pressure on the indenter When D.P H N is plotted directly against the true stress for the same degree of cold work, the result is a straight line which extends at least throughout the first regime of strain hardening.

(1652) Voce, E.

The Two Regimes of Strain-Hardening

Bull Inst Metals 4 (1958) 50-52

If the strain hardening of ductile metals and alloys takes place by two distinctly different mechanisms, the strain-hardening curve can be expressed by two consecutive regimes of the exponential function, merging smoothly into each other The present article attempts to explain the derivation of the composite equation, since it is of considerable theoretical importance if the strain-hardening behavior of metals can be explained quantitatively on the basis of two mechanisms occurring simultaneously instead of consecutively

(1653) Vogel, F L. , Jr

Dislocations in Plastically Bent Germanium Crystals

Trans AIME 206 (1956) 946-949

Densities and distributions of dislocations in plastically bent Ge crystals before and after annealing.

(1654) Vogel, F L. , Jr

On the Orientation Effect in the Polygonization of Bent Silicon Crystals

Acta Met 6 (1958) 532-534

Experiments on the bending of Si crystals at elevated temperature show that the ease with which polygonization occurs depends on the orientation of the bending crystal If the crystal is oriented so that only one slip system operates in a given region, homogeneous aggregation of dislocation is produced, and this climbs readily If, however, intersection sets of dislocations are produced locally, the possibility of forming Lomer-Cottrell barriers is present, climb is inhibited, and polygonized arrays do not appear.

(1655) Volkov, S. D.

Generalized Conditions for Plasticity (In Russian)

Doklady Akad Nauk S S S.R. 79 (1951) 213-216

Deduces expressions for the limiting conditions for the plastic behavior of metals

(1656) Volkov, S D.

Single Statistical Theory of the Strength of Solid Bodies III (In Russian)

Zhur Tekh Fiz. 24 (1954) 2250-2260

A review of theories due to Volkov, Davidenkov, van Mises, Hencky, Yakutovich, and others with special reference to the theory of ductile fracture The influence of micro- and macrostresses on mode of fracture is discussed

(1657) Vosskühler, H

The Influence of Precipitation Processes Upon the Determination of Creep Resistance of Light-Metal Alloys (In German)

Metall 5 (1951) 475-479

Time/elongation curves at various temperatures up to 300 C, with and without loading of the specimen, have been obtained for Mg-9 % Al and Al-9 % Mg alloys If the alloy under test is not in its equilibrium condition, dimensional changes may take place, purely as a result of precipitation which may be greater than the elongation that occurs from creep alone Therefore, negative creep curves may be obtained Experimental determination of the changes in dimensions due to precipitation are always much greater than the theoretical values derived from considerations of the structural changes and the phase diagram of the system Recommends fully heat treating the specimens at the temperature at which the tests are to be performed, before carrying out the tests themselves

(1658) Vreeland, T , Jr , Woodk, D. S. , and Clark, D S

A Study of the Mechanism of the Delayed Yield Phenomenon

Trans ASM 45 (1953) 620-637

Experimental investigation of behavior of an annealed low-C steel subjected to a rapidly applied constant stress and to repeated short-duration stress pulses Effect of time of aging on number of stress pulses to induce yielding was determined Effects observed are discussed in terms of the dislocation theory of yielding.

(1659) Vreeland, T , Jr. , Wood, D S , and Clark, D. S

Preyield Plastic and Anelastic Microstrain in Low-Carbon Steel

Acta Met. 1 (1953) 414-421

An experimental investigation of the behavior of an annealed low-C steel subjected to rapidly applied constant stresses less than the static upper yield stress Sensitive measurements of plastic and anelastic microstrain were made, and the relationship between stress and equilibrium microstrain was determined. The experimentally observed microstrain is quantitatively explained by a dislocation-generating mechanism The equilibrium number of dislocation loops produced by a Frank-Read source is estimated as a function of the applied stress and the dislocation source length Comparison of the theory and the experimental data leads to the determination of a characteristic length of dislocation which agrees with previous concepts of a mosaic block structure

(1660) Wachtman, J B. , Jr.

Creep of Crystalline Non-Metals

Paper from Creep and Recovery, Am Soc Met , Cleveland (1957) 344-360

Creep of single crystal and polycrystalline ceramic oxides. Available data indicate that creep occurs at much higher temperatures in oxide ceramics than in metals and with the same complexity of behavior

(1661) Wachtman, J B. , Jr. , and Maxwell, L. H

Factors Controlling Resistance to Deformation and Mechanical Failure in Polycrystalline (Glass-Free) Ceramics

WADC TR 57-526 (December 1957)

Temperature-dependence of creep behavior, modulus of rupture, Young's modulus, and internal friction were studied to determine factors controlling resistance to deformation and failure in polycrystalline Al_2O_3 and MgO.

(1662) Wagner, C N J

X-Ray Study of Low-Temperature Cold Work in Silver and Aluminum

Acta Met 5 (1957) 477-482

X-ray measurements on cold-worked filings were made at -160 C and showed a peak shift and an asymmetric peak broadening due to the presence of deformation and twin stacking faults on the (111) of Ag An appreciable part of the small, anisotropic particle-size broadening resulted directly from stacking faults which annealed out at 0 to 100 C Neither peak shift nor asymmetry were shown by the cold-worked Al, indicating that the stacking-fault density was very low, but a peak broadening was observed This indicated an appreciable particle size and strain broadening, both of which were isotropic. The results agree with theory

(1663) Wain, H. L.

Some Observations on the Yield Point in Zinc

Proc. Phys. Soc. (London) 65B (1952) 886-896

Evidence confirming the fact that yield point of Zn is due to N in solution. Theoretical prediction that a yield point should appear in a susceptible crystal without prior deformation is verified experimentally, and an explanation is given of the appearance of yield point in a specimen even though free dislocations have been introduced subsequent to aging.

(1664) Wain, H. L., and Cottrell, A. H.

Yield Points in Zinc Crystals

Proc. Phys. Soc. (London) 63B (1950) 339-345

Sharp yield point can be produced in crystals of Zn containing N. Strain-aging treatments are needed to develop the yield point clearly, but once it is developed, it returns at the same level after each successive treatment at the same temperature. General conditions for producing yield point in metals of common crystal structures.

(1665) Walker, H. L., and Bhattacharya, D. L.

Stored Energy and Recrystallization

J. Indian Inst. Sci. 37B (July, 1955) 179-185

Parabolic relation between stored energy and magnitude of the deformation is suggested and a formula relating recrystallized grain size with deformation is derived which agrees with the empirical rule formulated by Walker.

(1666) Warren, B. E., and Warekois, E. P.

Stacking Faults in Cold Worked Alpha-Brass

Acta Met. 3 (1955) 473-479

Stacking faults on the (111) planes of a fcc metal produce a broadening and shifting of the X-ray peaks from which the stacking fault probability can be directly determined. Measurements were made from cold-worked filings of composition 90-10, 80-20, 70-30, and 65-35. The stacking-fault probability increases with increasing Zn content, reaching alpha ≈ 0.039 for the composition 65-35. Root-mean-square strains and coherent domain sizes were obtained from the peak broadening. An appreciable part of the particle size broadening results directly from stacking faults. The root-mean-square strains are of the order of the yield strength divided by Young's modulus, and the product of strain and domain size is approximately a constant of the order of 1A. It is suggested that the intersection of stacking faults on different (111) planes is an important part of the work hardening in alpha-brass.

(1667) Washburn, J.

Effect of the Structure of Dislocation Boundaries on Yield Strength

Trans. AIME 203 (1955) 675-681

A report of a study of the effects of dislocation boundaries on the flow stress in Zn single crystals, under the following conditions: (1) substantially pure shear deformation and (2) boundaries of controlled angle, orientation, and number. Introduction of a pair of 0.05 deg simple-edge dislocations caused a 25% increase in yield strength; further increases in boundary angle were accompanied by smaller increments in strengthening effect, until a saturation value of 50% increase in yield strength was approached for boundary angles above 1 deg. For a given boundary angle the strengthening effect was determined by the temperature at which the specimen containing a boundary had been annealed. The results lead to the following conclusions: (1) concentrations of dislocations on a macroscopic scale forming isolated small-angle boundaries help to determine the yield strength of a metal crystal, (2) the small linear rate of hardening of hexagonal crystals is due to a process occurring on a submicroscopic scale, (3) the detailed structure of a small-angle boundary, as determined by prior strain and thermal history, determines its effectiveness as a barrier to slip, (4) boundary intersections do not appear to be a necessary condition for the strengthening effect of a substructure, and (5) climb of dislocations does not occur in Zn crystals when heated to 400 C.

(1668) Washburn, J., and Parker, E. R.

Kinking in Zinc Single-Crystal Tension Specimens

Trans. AIME 194 (1952) 1076-1078

Kinking was observed under conditions of low stress and high temperature. Relationship to other plastic bending phenomena on basis of dislocation theory is shown. Experiments on stress-induced motion of small-angle boundaries.

(1669) Webb, W. W.

The Interaction of Solutes with Dislocation Walls

Acta Met. 5 (1957) 89-96

Calculation of the elastic interaction of solutes with dislocation walls indicates that atmospheres of excess solute atoms may form at small angle grain boundaries but are subject to saturation effects accompanied by a distinctive temperature dependence. Comparison is made with some available experimental data. Approximate calculations indicate that moving dislocation walls may lose their solute atmospheres gradually during motion at velocities up to a critical maximum above which the atmosphere is entirely left behind.

(1670) Webb, W. W., Dragsdorf, R. D., and Forgeng, W. D.

Observations of Dislocations in Whiskers

Acta Cryst. 10 (1957) 821

The filamentary crystals of exceptional strength called "whiskers" are devoid of dislocations, except possibly for one axial screw dislocation. Eshelby has shown that an axial screw dislocation should produce a lattice twist around the whisker axis that is measurable in sufficiently small whiskers. High-resolution X-ray methods were developed sufficiently to detect a lattice twist one twentieth of that expected in typical whiskers. In some whiskers, no twist has been detected; in others, quite large lattice twists are evident.

(1671) Webb, W. W., and Forgeng, W. D.

Mechanical Behavior of Microcrystals

Acta Met. 6 (1958) 462-469

Bend tests have been carried out on small crystals chemically extracted from two-phase alloys and on some whiskers and other small crystals grown from liquid or vapor phases. Crystals of β-Mn, Mn_5Si_3, α-Si_3N_4, α-Al_2O_3, Cr_3O_4, Cr_2N, Cr, and Fe_3C were studied. All of these materials could be bent to relatively large elastic strains, and the calculated strengths of most of them approach theoretical values. The results are discussed in some detail, and it is concluded that although metal whiskers are unique because of the absence of edge dislocations, the occurrence of other crystals with nearly theoretical strength is not unusual. There is some evidence that dislocations have little effect on the mechanical properties of hard or brittle microcrystals, and it appears that a distinction should be made between those crystals eventually failing by brittle fracture and those that fail by plastic deformation.

(1672) Weertman, J.

Theory of Steady-State Creep Based on Dislocation Climb

A. Appl. Phy 26 (1955) 1213-1217

Recent reviews of published creep-rate data have shown that, for pure metals, the activation energy for creep rate is the same as that for self-diffusion. Also, at low stresses, the creep rate depends on the stress according to a simple power law. The present theory leads to these relationships. The rate-controlling process is the climb of dislocations which have been held up at a sessile dislocation to a height sufficient to allow them to bypass the obstacle under the action of the applied stress (magnified by other dislocations pressing from behind). The rate of climb, and, therefore, the rate of creep, is limited by the rate of transfer of vacancies between those dislocations creating vacancies during climb and those absorbing them. This in turn depends on the coefficient of self diffusion. The above model, which applies only for comparatively low stresses, is worked out in detail. At higher stresses, the creep rate is higher than predicted by the theory. The exponent of stress in the power law relating creep rate and stress is calculated to be 3 to 4, which agrees with experimental data for Al and dilute solid solutions of Mg in Al and rather less well for other metals. Absolute rates as calculated from the theory also agreed reasonably well with experimental data for Al and Al-Mg alloys. In metals in which dislocations are decomposed into half-dislocations, climb may be so much impeded that the theory does not apply.

(1673) Weertman, J.

Creep of Polycrystalline Aluminum as Determined From Strain Rate Tests

J. Mech. and Phys. Solids 4 (1956) 230-234

Tests of high-purity Al over a wide temperature range lead to an expression between maximum stress, strain rate, and temperature, such that strain rate = A (stress)4.4 exp (-Q/RT), where A is a constant and Q is an activation energy equal to 36,000 cal/mole. The results are compared with those of Servi and Grant on constant stress creep tests and shown to be almost identical.

(1674) Weertman, J.

Creep of Aluminum Single Crystals

J. Appl. Phy 27 (1956) 832-834

Creep measurements were made on Al specimens, cut from one single crystal, from 157 to 616 C. The stress range was 2.5×10^6 to 1.9×10^8 dynes/cm^2. Determination of the active slip systems was made by an optical goniometer, the findings being in keeping with earlier results. The creep rate is proportional to (stress)$^{4.6}$ exp (-Q/KT), where Q is the activation energy of creep (36,000 cal/mol), and this is compared with two theoretically derived laws of high-temperature creep.

(1675) Weertman, J.

Dislocation Damping at High Temperatures

J. Appl. Phy. 28 (1957) 193-196

Weertman extends an unpinned dislocation damping model [ibid., 26 (1955) 202, W. and Salkovitz, Acta Met. 3 (1955) 1] based on the Mott-Nabarro solution-hardening theory, to explain high-temperature internal friction observed in the kc/s/range for measurements made at very low strain amplitudes. Damping due to dislocation climb is also considered.

(1676) Weertman, J.

Compressional Creep of Tin Single Crystals

J. Appl. Phy 28 (1957) 196-197

Compressional creep tests were run on single crystals oriented so that the direction of compression was along the C axis. Two activation energies of creep were found, approximately 24,500 cal/mol above 120 C and 12,000 cal/mol below this temperature.

(1677) Weertman, J.

Steady State Creep Through Dislocation Climb

J. Appl. Phy 28 (1957) 362-364

A dislocation climb creep model which does not require the production of immobile dislocations is considered. Creep rate is expressed as a function of stress and activation energy. The creep equation that results from the analysis is creep rate = A σ^3 sinh (B $\sigma^{1.5}$/kT) exp (-Q/kT), where A and B are constants, σ is the stress, Q is the activation energy of creep, and kT has its usual meaning. This equation is very similar to one previously proposed.

(1678) Weertman, J.

Creation of Dislocations in Lithium Fluoride at Low Stresses

J. Appl. Phy. 28 (1957) 1068-1069

Suggests that a suitable etching reagent may reveal the presence of Seitz's vacancy collapse sources in the LiF samples of Gilman and Johnston [ibid., 27 (1956) 1018]. These sources are activated at about 1 kg/mm^2 and would explain Gilman and Johnston's results of the creation of dislocations apparently without sources.

(1679) Weertman, J.

Steady-State Creep of Crystals

J. Appl. Phy 28 (1957) 1185-1189

An expression is derived for the high-temperature creep rate of crystals for two rate-controlling processes: (i) viscous motion of dislocations; and (ii) a Peierls stress mechanism. The creep rate is calculated from the average velocity of dislocation loops and the number of dislocation loops that can exist at a given stress level in a given distance (the distance that the dislocations spread from the Frank-Read sources before annihilation by climbing). (i) gives ε proportional to σ^3; this mechanism may be important in alloys in the stress range between the critical shear stress of a pure metal and that of an alloy. (ii) gives ε proportional to $\sigma^{2.5}$ for low stresses; this mechanism can be used to explain Gilman's [Trans. AIME 206 (1956) 1326] data on the prismatic creep in high-purity Zn.

(1680) Weertman, J.

Effect of Alloying on the High-Temperature Creep Properties of Metals

Paper presented at AIME Fall Meeting, Chicago (November 1957)

At high temperatures the steady-state creep of metals is described by the following equation which is valid for stresses up to 1000 - 10,000 psi

$$\text{Creep Rate} = C\sigma^n \exp(-Q/kT)$$

where σ is the stress, Q is an activation energy, kT has its usual meaning, and n and C are constants. For pure metals the value of n is about 4.5. By alloying, the value of n can be reduced to values in the range of 3.0 to 3.5. If dislocation climb is the rate-controlling creep process the values of C and Q will change upon alloying, but the value of n ought to remain constant. Since n can be reduced by alloying it appears that processes other than dislocation climb can control the creep rate of alloys. It can be shown that a dislocation climb model which predicts that n = 4.5 when climb is rate controlling will also predict that n = 3.0 if any microcreep mechanism controls the rate of motion of the dislocations. For a typical substitutional alloy it appears that climb will control the creep rate for alloy contents up to 1 atomic per cent, that Cottrell-Jaswon or Suzuki microcreep may control the creep for alloy contents in the range 1 to 10 per cent, and that Schoeck microcreep or the microcreep mechanism inherent in Fisher's short-range-order hardening theory may control the creep at high-alloy contents. However, if the diffusion constant of the alloying element is many orders of magnitude larger than that of the host element, dislocation climb may be the rate-controlling process up to high alloy contents.

(1681) Weertman, J., and Shahinian, P.

Creep of Polycrystalline Nickel

Trans. AIME 206 (1956) 1223-1225

99.75% Ni was tested under constant load creep conditions at 350-30,000 psi in the range 400 to 1100 C. Oxidation and grain refinement affected some of the high temperature tests in air. The data obtained on minimum creep-rate and the strain region in which this occurred and rupture time are presented and discussed. Below a stress of 7×10^8 dynes/cm^2 the minimum creep rate is proportional to (stress)$^{4.6}$ exp (-Q/RT), where Q = 65,000 cal/mol; this value of Q, the activation energy of creep, lies close to a reported value of 69,000 cal/mol for the activation energy of self-diffusion in Ni. This stress dependence is almost the same as that found for Al at low stresses. Above this stress there is a rapid rise in the creep rate as a function of stress. The results are in qualitative agreement with a theory of steady-state creep which is based on Mott's dislocation-climb mechanism.

(1682) Wei, C. T., and Beck, P. A.

Structure of Bent Zinc Crystals

J. Appl. Phy 27 (1956) 1508-1518

The structure of the crystals bent to various radii, either round mandrels or by applying a concentrated load in a direction perpendicular to the basal plane, was studied by X-ray diffraction techniques. Subgrains are reported in crystals bent to radii of <5 cm, the average disorientation between neighboring subgrains being ≳ 3'. With radii >8 cm, the substructure becomes increasingly less well-defined on bending. When bending is done by a concentrated load, the radius is large, and no substructure is observed. The effect of annealing is also described.

(1683) Weibull, W.

A Statistical Theory of Strength of Materials

Proc. Roy. Swed. Inst. Eng. Research no. 151 (1939) pp 45

Part I. The classical theory of strength is incompatible with results of experimental research. This discrepancy may be bridged over by considering an an essential element of the problem the scatter obtained in experimental measuring of the ultimate strength. Viewed from this standpoint, the ultimate strength of a material cannot be expressed by a single numerical value as has been done heretofore, and a statistical distribution function will be required for this purpose. The fundamental formula allows the computation of the influence of the volume on the ultimate strength, the relation between tensile, bending, and torsional strength, etc. An experimental substantiation of the theory is provided by observations obtained from tensile, bending, and torsional tests on rods made of stearic acid and plaster of Paris. Part II. A description is given of the graphic method used for the statistical treatment of the observations and of some measuring series relating to strength of materials under the action of mechanical and electrical forces.

(1684) Welk, H., and Masing, G.

The Relationship Between Orientation and Plastic Deformation of Single Crystals of Aluminum Subjected to Small Elongations (In German)

Z. Metallk 45 (1954) 417-428

Creep phenomena measured under constant and increasing loads, up to total elongation of 0.2%, in high-purity Al single crystals of various orientations, produced by a strain-annealing technique. The nature and the interpretation of the flow curves and of the strain-hardening curves obtained are discussed at length. In general, crystals with orientations tending towards <110> strain harden much more than crystals with orientations toward the middle of the standard projection triangle. This extra hardening of the <110> crystals appears to be the result of additional slip taking place on latent glide planes. Analysis of the flow curves confirms the observations of Haasen and Leibfried on the parabolic ($s = Ct^m$) and log ($s = A \log t + B$) flow laws for <100> crystals. In many instances, log flow precedes parabolic flow; sometimes, and particularly with the S-shaped flow curves of crystals with orientations toward <110>, parabolic flow is absent, while in other cases the two types of flow are clearly superimposed.

(1685) Weinberg, F.

Grain Boundary Shear in Aluminum

Acta Met. 2 (1954) 889-891

Creep tests on tricrystal test pieces show alternate shear and grain-boundary migration. The observed behavior of the boundaries under shear suggests that a mechanism analogous to the "strain induced boundary migration" described by Beck could be operative. Following Beck's mechanism, when the difference in strain of the crystals at the boundary becomes sufficiently large, the boundary will move in such a manner that the less strained crystal will grow at the expense of its more highly strained neighbor, stopping when it has swept through the strained region. Further shear would then take place at this new boundary position and the process would be repeated. This could then account for the periodicity of the boundary shear and migration process observed. It could also account for the irregular shape of the boundary traces, the orientation of the material swept through by the boundary, and that occasionally no boundary movement occurs on segments of the initial boundary when sheared. The slip lines observed above could be a manifestation of the strains in the vicinity of the boundary produced during shear.

(1686) Weiner, L. C.

The Temperature Dependence of Flow and Fracture in Coated Zinc Single Crystals

Trans. AIME 212 (1958) 253-256

For Zn single crystals, a surface coating raises both the cleavage and yield strengths over a large temperature range. The "brittle temperature", associated with slip after completion of twinning, does not coincide with the point of intersection of the flow and cleavage curves, which is associated with twinning. A surface film has no effect on the brittle temperature.

(1687) Weinig, S., and Machlin, E. S.

Low-Frequency Studies of Dislocation Interactions with Solute Atoms

Acta Met. 4 (1956) 262-267

An investigation of the internal friction of pure Cu and Cu binary alloys with up to 1 at. % Al, Ni, and Si was performed at 40 C at a 1 cps frequency of vibration. Ni was almost ineffective in diminishing the logarithmic decrement, whereas the Si and Al lowered the decrement. The rate of decrease with concentration was most rapid for the Cu-Al alloy. Calculation of the elastic interaction energy between a solute atom and an edge type of dislocation reveals that there should be negligible binding energies for Ni and Si solutes in Cu due to their very small atomic size difference. However, computation of the electrical interaction between a solute atom and a dislocation results in an appreciable binding energy for a Cu-Si alloy. The summation of the various interaction energies for the binary constituents indicates that the order of effectiveness in pinning dislocation singular lines in Cu should be Al, Si, and Ni in the ratio of 4.9 2.8.1. This analysis is in agreement with the experimental results and gives additional support for an electrical interaction between solute atoms and dislocations.

(1688) Werner, O., and Hunger, J.

Electron Miscroscope Studies of Fractured Steel Surfaces (In German)

Arch. Eisenhüttenw. 27 (1956) 645-656

Notch-bending specimens of unalloyed structural steels were examined at time of receipt, in the normalized and aged state. Explanation of underlying structures on fracture surfaces of brittle broken crystallites.

(1689) Wessel, E. T.

Abrupt Yielding and the Ductile-to-Brittle Transition in Body-Centered-Cubic Metals

Trans. AIME 209 (1957) 930-935

Abrupt yielding and transition from a ductile-to-brittle behavior are shown to be closely related to one another and to a common origin. Mechanism is described as follows (1) Prior to an abrupt yield or brittle fracture, many dislocations move through the lattice but are subsequently piled up at barriers. An appreciable amount of plastic strain is associated with the piling up of these dislocation groups. The magnitude of this plastic strain increases with decreasing temperature, reaching a maximum at the transition temperature, below which the plastic strain decreases with decreasing test temperature. (2) At temperatures above the transition temperature, abrupt yielding occurs when the stress concentrations that are present in the vicinity of piled-up dislocation groups become sufficiently high to overcome the resistance to deformation and activate other sources in the adjoining material, triggering a general catastrophic yielding. (3) At temperatures below the transition temperature, the resistance to plastic deformation is so great that the stress concentrations in some of the regions of piled-up dislocation groups become sufficiently high to initiate microcracks in these areas. The achievement of these high localized stresses and the resulting formation of some microcracks together with some plastic deformation trigger a combined general catastrophic yielding and crack formation terminating in complete brittle fracture.

(1690) Westbrook, J. H.

Temperature Dependence of the Hardness of Pure Metals

Trans. ASM 45 (1953) 221-248

Reviews published information on the variation with temperature of the hardness of pure metals and makes a number of generalizations. The temperature dependence of the hardness, H, is well represented by the relation $H = A \exp(-BT)$, where A and B are constants. At low temperatures, where slip is the primary deformation mechanism, A and B have one set of values, at high temperatures, where viscous flow or other mechanisms predominate, the constants have another set of values. The transition between low- and high-temperature behavior of the indentation hardness occurs at about $0.55T_m$, where T_m is the melting point in K. In the low-temperature range, A is simply related to the crystal structure and the heat content of liquid metal at the melting point. B is related in a complex manner to the rate of change of heat content with temperature. The relations given enable the hardness of a pure metal to be calculated approximately as a function of temperature up to about half the absolute melting point, provided the crystal structure, specific heat, and heats of fusion and transformation are known.

(1691) Westbrook, J. H.

Note on the Temperature Dependence of Hardness of the Transition Metal Monocarbides

Acta Met. 3 (1955) 103-106

An empirical equation for the hardness of metallic solids, $H = K[(T_m - T)/MV^{2/3}]^{1/2}$, where T_m is the melting point and M and V are the mol. wt and volume, respectively, has been proposed by Nowotny and Vitovec [Plansee Proc (1952) 39]. Data for Mo, however, are better fitted by an equation $H = A\exp(-BT)$. The hardness of TiC as a function of temperature does not agree with either of the above expressions.

(1692) Westbrook, J. H.

Structure and Property Studies in Ni-Cr-Al Solid Solution Dispersion Hardened by Ni_3Al

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Many of the leading nickel-base high temperature alloys depend for their strength on dispersions of the compound Ni_3Al. Since these are relatively complex alloys, it is difficult to assess the effects of composition, heat treatment and processing variables in terms of parameters pertinent solely to the dispersion hardening of Ni_3Al and independent of the effects of other compounds, solid solution hardening, etc. It is apparent that what is needed are studies of simplified or prototype systems where factors leading to such ambiguities are eliminated or reduced. The Ni-Cr-Al system is perhaps the simplest system that approximates the successful complex commercial alloys. Previous structures and property studies on this system are limited to the phase diagram determinations by Taylor and Floyd and Kornilov and Mints, the exploratory investigations of Guy and limited stress rupture studies by Nordheim and Grant.

(1693) Westbrook, J. H.

Defect Structure and the Temperature Dependence of Hardness of an Intermetallic Compound

J. Electrochem. Soc. 104 (1957) 369-373

The intermetallic compound AgMg was studied from -190 C to the solidus temperature over the entire homogeneity range. The effect of structure on hardness at high homologous temperatures differs radically from that at low temperatures. Results appear to rationalize previously contradictory studies of the effect of defect structure on the room-temperature strength of intermetallic compounds.

(1694) Whelan, M. J., and Hirsch, P. B.

Electron Diffraction From Crystals Containing Stacking Faults: I and II

Phil. Mag. 2 (1957) 1121-1142, 1303-1324

Part I. The dynamical theory of electron diffraction is applied to the case of a plate-like crystal containing a stacking fault. The effect of the fault is to produce a phase difference in the electron waves diffracted by the two parts of the faulted crystal. Expressions for the wave functions and for the corresponding intensities, predicting interference fringes in the region of overlap of the two parts, are derived. Part II. The theory of Part I is applied to the case of stacking faults in close-packed lattices. Electron optical experiments of thin foils of stainless steel are described, the results of which are in good agreement with theory.

(1695) Whelan, M. J., Hirsch, P. B., Horne, R. W., and Bollmann, W.

Dislocations and Stacking Faults in Stainless Steel

Proc. Roy. Soc. (London) 240A (1957) 524-538

Further experiments by transmission electron microscopy on thin sections of stainless steel deformed by small amounts have enabled extended dislocations to be observed directly. The arrangement and motion of whole and partial dislocations have been followed in detail. Many of the dislocations are found to have piled up against grain boundaries. Other observations include the formation of wide stacking faults, the interaction of dislocations with twin boundaries, and the formation of dislocations at thin edges of the foils. An estimate is made of the stacking-fault energy from a consideration of the stresses present, and the properties of the dislocations are found to be in agreement with those expected from a metal of low stacking-fault energy.

(1696) White, G. N., Jr., and Drucker, D. C.

Effective Stress and Effective Strain in Relation to Stress Theories of Plasticity

J. Appl. Phy. 21 (1950) 1013-1021

Shows that the stress-strain relations of a recent theory of plasticity provide a convenient means of defining and studying effective stress and effective strain. The strong theoretical and practical limitations of such concepts are indicated, and the calculation of specific plastic work is discussed for both isotropic and anisotropic metals.

(1697) Wiedersich, H. W.

Discussion to paper by Trozera, T. A., Sherby, O. D., and Dorn, J. E., on Effect of Strain Rate and Temperature on the Plastic Deformation of High Purity Aluminum

Trans. ASM 49 (1957) 185-188

Applies a modified form of Seeger's equation relating strain rate to temperature and stress to an analysis of the author's data. It represents a correlation of test variables with a single activation energy, and is derived from a specific dislocation model with isolable constants which can be individually checked against theory.

(1698) Wigner, E. P., and Seitz, F.

Qualitative Analysis of the Cohesion Metals

Solid State Physics Advances in Research and Applications, Academic Press, Inc., New York (1955) 97-126

Cohesive energy of alkali metal regarded as composed of 3 quantities (1) the boundary correction, due to altered boundary condition at Brillouin Zone of the crystal (2) kinetic energy of the free electrons (3) that energy arising from contributions associated with various "holes" in the electron distribution. Cohesive energies, plotted against atomic number, exhibit periodicity similar to physical and mechanical properties.

(1699) Williamson, G. K., and Smallman, R. E.

Dislocation Densities in Some Annealed and Cold-Worked Metals From Measurements on the X-Ray Debye-Scherrer Spectrum

Phil. Mag. 1 ser. 8 (1956) 34-46

Two basic equations are derived for deducing the dislocation density in powdered materials from the particle size and strain breadth measured from the Debye-Scherrer spectrum.

(1700) Williams, R. O.

Origin of Strengthening on Precipitation. Ordered Particles

Acta Met. 5 (1957) 241-244

A theory is developed to show that the presence of order in one or more structures which form on aging, in an age-hardening system, can give an increase in strength, even in the absence of strain. The Al-Ag system may owe its aging properties to this mechanism.

(1701) Williams, R. O.

Theory of Precipitation Hardening: Isotropically-Strained System

Acta Met. 5 (1957) 385-392

Calculations are presented to show that appreciable strengthening can result from the hydrostatic interaction between edge dislocations and isotropically strained matrix and precipitate resulting from a certain type of precipitation. This theory seems adequate to explain the strengthening observed on precipitation in the Fe-Cr system.

(1702) Wilman, H.

The Slip, Twinning, Cohesion, Growth, and Boundaries of Crystals

Proc. Phys. Soc. (London) 64 (1951) 329-350

Nature and stability of intercrystalline boundaries and conclusions as to preferred relative orientations illustrated. Electron-diffraction evidence from crystals of layer-lattice, ionic, metallic, and van der Waal types shows that crystal pairs and symmetrical or unsymmetrical triplet of multiplet crystal groupings occurs, having a common lattice row, but in relative azimuthal orientations at intervals agreeing with the predictions. The seven types of electron-diffraction patterns observed and the nature of the specimen preparation suggest that origin of these groupings is mechanical deformation of the crystals during or after growth by a process of "rotational slip". Such slip is demonstrated macroscopically as a deformation process in nonmetallic materials.

(1703) Wilms, G. R.

Some Observations on the Tertiary Stage of Creep of High-Purity Aluminum

Trans. AIME 200 (1954) 1291-1296

Structural changes are caused by deformation but do not influence creep rate. Intercrystalline fissures may be cause of increased strain rate. Graphs, micrographs, diffraction patterns. Metallographic and X-ray diffraction studies were made of structural changes in polycrystalline Al during tertiary creep. The basic mechanism of deformation established in the second stage of creep shows no significant alteration on entering, or during, the tertiary stage. Therefore, as the rate of strain increases in the final stages of the teritary creep, there is a continuing tendency for the grains to form a finer substructure. The main difference between the secondary and the so-called tertiary stage appears to be the formation of fissures in localized areas during the latter stage. These tend to increase in size and number on further elongation, concentrating especially in the region where necking occurs; the fissures are fewer and less pronounced at higher temperatures when the stage of boundary microflow predominates. Such fissures might tend to cause an accelerated rate of strain owing to local stress concentrations. Surface imperfections seem to promote the formation of fissures and intercrystalline fracture.

(1704) Wilms, G. R.

Some Observations on the Creep of Prestrained Aluminum

J. Inst. Metals 83 (1954-55) 427-432

X-ray and metallographic observations have been made during the creep of specimens of high purity Al after preliminary deformations to produce initial substructures of a known type. The experiments were carried out under constant tensile loads at different temperatures and the results compared with those obtained on annealed material strained under the same conditions of load and temperature. The initial substructure grows within the grains until it becomes comparable in size to the equilibrium structure produced during secondary creep of the corresponding annealed specimen. This equilibrium structure appeared to be attained by a two-stage process the first stage is associated essentially with the removal of lattice distortion and perfection of the elements of the substructure, and the second stage with a marked growth of the substructure. The creep rate remains approximately constant during the first stage, while during the second stage the creep rate increases and continues to increase until it becomes comparable to that of the corresponding annealed specimen. Creep deformation if far more effective in activating growth of the substructure than is the heating alone. The structural changes produced during creep deformation of prestrained metal tend to resist recrystallization.

(1705) Wilms, G. R., and Wood, W. A.

Mechanism of Creep in Metals

J. Inst. Metals 75 (1949) 693-706

It is shown how the mechanism by which a metal deforms at elevated temperature differs from that operating at normal temperature and how the difference depends on the rate at which the deformation takes place. At normal temperature, deformation occurs mainly by the familiar mechanism of slip and the breakdown of the grains to crystallites of submicroscopic size. As the temperature is raised and the rate of deformation diminished, this mechanism is increasingly replaced by one in which the grains dissociate into comparatively coarse units and permit flow by the relative movement of these units within the parent grains. The units, which are termed "cells", can be observed and measured. They are considered to be responsible for the continuous deformation under stress which characterizes the phenomenon of creep.

(1706) Wilsdorf, H. G. F.

Impurity Substructures in Zinc Single Crystals

Paper presented at AIME Fall Meeting, Chicago (November 1957)

Single crystals of Zn, 30 cm long and 1 cm in diameter, were grown at various speeds in a vertical furnace according to the Bridgman method. Three types of specimen containing less than 0.03, 0.001, and 0.0001 per cent impurities respectively have been investigated, and sections of the crystals parallel and perpendicular to the axis of growth at various positions were examined metallographically. While no substructure was detected in crystals with a purity of 99.999 per cent or better, specimens of 99.97 per cent Zn showed three types of substructure: lineage structure, cell structure, and lamellar structure. A pronounced orientation dependence of the lineage structure pattern with respect to the axis of growth was found and also a uniform variation in block size over the length of the crystal. Following the theory of Teghtsoonian and Chalmers and of Frank, the boundaries of the lineage structure are interpreted as the result of vacancies condensing into sheets, thereby forming concentric dislocation loops. The dislocation density in the boundaries of the lineage structure was determined. Results with regard to the cell structure and the lamellar structure are discussed, and it appears that these substructures develop completely independent of the lineage structure.

(1707) Wilson, J. E., and Thomassen, L.

X-Ray Investigation of Lattice Recovery of Metals After Cold-Working

Department of Chemical Engineering, University of Michigan

Cu, Ni, Fe, and a number of alloys were studied to find the time-temperature relationship of X-ray line sharpening on annealing. The line broadness of Ni was investigated as a function of annealing time at a constant temperature. After an initial drop, the broadness is constant for a certain time, then decreases to its original value. For constant annealing time, individual metals vary widely both in temperature of initial line sharpening and in temperature range of the complete recovery process. For completion of the second stage of line sharpening, an expression $T = K_1/(\log t + K_2)$ is found, where T is annealing temperature in degrees absolute, t is annealing time in seconds, and K_1 and K_2 are characteristic constants of the metal. Results have been correlated with hardness measurements and available data on electric and magnetic recovery from cold work. These stages of recovery and recrystallization have been interpreted on basis of reformation of undisturbed outer shells and difference in rates of diffusion of atoms.

(1708) Wintenberger, M.

Relation Between the Nature of the Plastic Deformation of Aluminum and the Appearance of the Laue Spots (In French)

Compt. rend. 244 (1957) 2716-2718

In an X-ray study of pure Al, the Laue diagram showed fine striations of the diffraction spots whose direction corresponds to the orientation of the slip lines. The number of striations, about 10, corresponds to the number of slip bands seen micrographically in the irradiated region.

(1709) Winter, J

Grain Boundary Adsorption of Solutes and Its Effect on the Creep Properties of Alpha Titanium

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The grain boundary adsorption of substitutional solute elements in alpha Ti was studied using internal friction techniques Bureau of Mines "super purity" Ti was used as the solvent and the binary constituents were Al, V, Zr, Cb, and Au. The adsorption was studied as a function of both the bulk concentration of solute and the solution temperature An Arrhenius type of equation was found to describe accurately most of the data. From the variation of the internal friction peak magnitude and the observed activation energy for grain boundary stress relaxation, it was possible to calculate the interaction energy between a solute atom and the grain boundary. The value of the energy interaction, although varying as a function of the type of solute atom was in the range of 0 1-0 3 ev. Grain boundary solute adsorption was observed to occur for alloying elements of both positive and negative size factors The amount of adsorption was found to be dependent upon the degree of elastic misfit for the particular solute. Subscribing to the theory of there being energetically favorable sites at the grain boundary for solutes of both positive and negative size deviations, ternaries containing combinations of alloying elements were investigated. Cumulative effects were observed for the solute adsorption at the grain boundaries Corroboratory creep studies were performed in which the direct grain boundary contribution to the total creep strain was measured It was found that the grain boundary contribution to creep varied as a function of the solute adsorption. Since a linear relation between the grain boundary elongation and the total creep strain is observed it is expected that the grain boundary adsorption of solutes having both negative and positive size factors will have a profound effect on the high-temperature creep characteristics of metals

(1710) Wiseman, C.

Substitutional Solution Hardening in Copper Alloys

Paper presented at AIME Fall Meeting, Chicago (November 1957)

The object of this investigation was to determine the cause of substitutional solid solution strengthening. Shear tests were conducted on single crystals of high-purity Cu and of Cu-Mn and Cu-Al alloys Each specimen was tested at room temperature after anneals at various temperatures The specimens were next deformed in a manner that introduced substructure and then tested again after various anneals An attempt was made to interpret the results in terms of current theories of solution strengthening. It was concluded that solution strengthening was due to the interaction of solute atoms with the substructure in the metallic lattice Solution strengthening was found to be structure sensitive and hence it was not possible to find a simple law defining this phenomenon

(1711) Wiseman, C. D., Sherby, O D., and Dorn, J E.

Creep of Single Crystals and Polycrystals of Aluminum, Lead, and Tin

Trans AIME 209 (1957) 57-59

Using the cyclic-temperature technique, the following activation energies (in cal/mole) for high-temperature creep were determined for high purity: Al, polycrystalline 35,000, single crystal 34,500; Pb, polycrystalline 26,000, single crystal 24,800; Sn, polycrystalline 22,700 Thus, single-crystal and polycrystalline specimens have the same high-temperature activation energies, which are equal to the respective activation energies for grain-boundary shearing.

(1712) Wood, D S.

Dependence of Strength on Loading Speed and Loading Time

Paper from Proceedings of the 1955 Sagamore Research Conference on Strength Limitations of Metals, OTS, U.S. Dept. Commerce, PB 131280 and PB 131281 (1955) 103-124

The effect of rate and time of loading on the conventional stress-strain characteristics; influence of wave propagation phenomena

(1713) Wood, D. S.

A Comparison of Preyield Microstrain in Steel With Dislocation Theory

Paper from Dislocations and Mechanical Properties of Crystals, John Wiley and Sons, Inc., New York (1957) 413-418

If a stress is suddenly applied to the material and maintained constant thereafter, the initial rate of plastic straining should be proportional to the rate of release of dislocations from atmospheres Experimental record of tensile load and preyield inelastic microstrain versus time for several values of applied tensile stress less than the upper yield stress (40,000 psi) the microstrain asymptotically approaches some equilibrium value

(1714) Wood, W A

Crystalline Structure and Deformation of Metals

Paper from Internal Strains in Solids, Proc Phys. Soc. (London) 52 (1940) 110-116

The changes in crystalline structure of polycrystalline metals and large single crystals subjected to deformation by cold work and by static and cyclic stressing are surveyed The grains may be dispersed into crystallites characterized by a lower limiting size depending on the metal and internal lattice strains, considered to be related to the process of strain hardening, can be observed. The response of the crystalline structure is shown to depend on the manner and particularly the speed of application of stress, and it is thus possible to inhibit the dispersed crystallite formation and suppress the true yield point of a metal, thus varying the hardness independently because of the external deformation.

(1715) Wood, W A

X-Ray Diffraction and Deformation of Metals

J Sci Instruments 18 (1941) 153-154

Brief survey of principal changes in structure of metal during deformation as revealed by application of X-ray diffraction methods

(1716) Wood, W. A.

The Behaviour of the Lattice of Polycrystalline Iron in Tension

Proc Roy Soc (London) 192A (1948) 218-231

Stress-strain characteristics of Fe in tension were investigated by X-ray methods Earlier observations that the metallic lattice under stress ceases to conform with Hooke's law when external plastic deformation occurs are confirmed, but deviation differs in two cases. The elastic range for the (211) spacing appears to be greater than for the (310) spacing On removal of stress in excess of the "lattice yield", the two types of spacing show a residual strain of opposite sign to the strain under stress, but the magnitude is different

(1717) Wood, W A

Intrinsic Crystalline Structure and the Strength of Metals

Phil Mag. 42 ser 7 (1951) 310-312

Wood points out that the objections raised by Paterson [ibid., 41 (1950) 410] to the block theory of strength are not conclusive It is suggested that it is necessary to distinguish between the "disoriented elements" which determine the mechanical strength and the X-ray line broadening and the ultimate intrinsic blocks, whose size variation with temperature has been discussed theoretically Disoriented elements may contain several intrinsic blocks The suggestion is supported by experimental evidence that at a given temperature the size of the disoriented elements varies with the strain rate

(1718) Wood, W A.

Dislocation Theories

Bull. Inst Metals 1 (1953) 198

Wood replies to a remark by Weill [Mém. artillerie francaise 26 (1952) 41] that his previous interpretations of results of work on plastic deformation do not agree with theories of dislocations and polygonization The three main observations, viz., the formation of a substructure, the dependence of the size distribution of the elements on the deformation conditions, and the dependence of strain hardening on the size distribution are discussed and shown to be consistent with the general dislocation theory

(1719) Wood, W A.

Creep Processes

Paper from Creep and Fracture of Metals at High Temperatures, Her Majesty's Stationery Office, London (1956) 59-71

The problem of creep is regarded as one particular aspect of the relation between mechanical properties and deformation The structural changes occurring in creep are divided into stress recovery, equilibrium flow, and boundary flow Extension during creep is composed of boundary flow and grain elongation. These principles are related to the conventional creep curve.

(1720) Wood, W A

Strain-Hardening of a Metal by Laminar or Turbulent Flow

Phil Mag 46 (1955) 1028-1030

Polycrystalline Cu extended 5% in tension has a hardness of 66 VPN; X-ray back-reflection photographs show that the grains are disordered in that the spots have spread out into continuous rings The same material subjected to 10^5 cycles of alternating tension and compression at ±7 tsi has reached the same hardness, but X-ray investigations show that the grains are hardly detectably disordered as the spots are still sharp. It might be expected, on the theory of strain hardening due to Taylor and Mott, that a "turbulent" flow would harden the material more effectively than a "laminar" one, but this does not seem to be the case The main difference between the two materials, apart from the disorientations, is in their annealing. The disoriented material recrystallizes at 350 to 400 C and does not soften below this point, while an undisordered specimen softened from 63 to 44 VPN at 600 C with no recrystallization and finally recrystallized only at 650 C. These results are interpreted in terms of different dislocation arrays in the two cases.

(1721) Wood, W. A , and Rachinger, W. A

Strength of Metals

Nature 162 (1948) 891-892

Progressive deformation of an annealed metal breaks down the grains into smaller crystallites which have a minimum size characteristic of the metal. Measurements of this limiting size were made for the bcc metals, Fe, Ta, Mo, and W, by an improved X ray diffraction technique The values thus obtained were related to maximum tensile strengths

(1722) Wood, W. A , and Rachinger, W A

The Mechanism of Deformation in Metals

J. Inst Metals 76 (1949) 237-253

A study was made of changes in crystalline structure produced at various temperatures when a metal was subjected to the slow rate of strain typical of creep process and also to the relatively rapid rate associated with ordinary mechanical testing Measurements were also made at the same time of strength under various conditions of deformation The object was to investigate the relation of deformation by creep to that by slip. Results show that the grains develop a substructure of a size determined by temperature and rate of strain. The mechanism of deformation changes from slip to creep as the elements of the substructure exceed a certain size

(1723) Wood, W. A , and Rachinger, W A.

Crystallite Theory of Strength of Metals

J Inst Metals 75 (1949) 571-594

Evidence is presented for the belief that the metallic grain contains a fundamental unit of structure below which it cannot be broken down by plastic deformation at room temperature The lower limiting size of the unit, termed "crystallite", has a characteristic value for a given metal. This size was determined for a group of bcc metals, Fe, Mo, Ta, and W, and ultimate tensile strengths were calculated on the basis of the above hypothesis Measurement of crystallite size was accomplished by X-ray diffraction methods which utilize two recent developments to avoid complications of internal strains

(1724) Wood, W A., and Scrutton, R F.

Mechanism of Primary Creep in Metals

J. Inst. Metals 77 (1950) 423-434

Previous work on the deformation of metals at elevated temperature [ibid., 75 (1948-1949) 571, 693; 76 (1949-1950) 237] had shown that the grains dissociated into a substructure of elements whose size tended to an equilibrium value depending on the temperature of deformation and rate of strain, and this equilibrium condition was identified with secondary creep. The process of breaking down itself appeared therefore to be associated with primary creep and the details of this process have been studied in the present work on annealed Al It is shown that the mode of breakdown is determined by the rate of strain. At the higher rates, the dissociation of the grain is accompanied by a disordering of the structure which is then removed on continued deformation to reveal the fundamental substructure; this is referred to as a two-stage recovery mechanism and is associated with a progressive softening of the metal At the lower rates, the dissociation of the grain proceeds directly without intermediate disordering: this is referred to as the cell mechanism and is associated with a progressive hardening of the initially annealed grains until the equilibrium of the secondary phase is reached. The actual primary creep curve is regarded as the resultant of the two mechanisms

(1725) Wood, W A , and Segall, R L.

Softening of Cold-Worked Metal by Alternating Strain

J Inst Metals 86 (1958) 225-228

Specimens of cold-worked Cu, Ni, and Al were subjected to alternating-torsion tests, and measurements were made of the proof stresses required to impose successive reversals of plastic strain. Further strain hardening occurs as the first reversals are applied, but this hardening soon reaches a peak which is followed by softening. The latter is the more marked as the preliminary cold working is heavier and the plastic amplitude smaller This observation of softening is taken to indicate that alternating strains tends to relax excessive internal stresses rather than to build them up in the manner suggested in various theories of fatigue. A mechanism is proposed whereby stress relaxation would occur at the surface of a specimen because the fine to-and-fro slip movements in alternating strain may build up slip bands with notch-like contours.

(1726) Wood, W A , and Suiter, I W

Stress Recovery in Aluminium

I Inst. Metals 80 (1951) 501 506

The changes in strength and structure were observed during the deformation of Al in which the grains had already been broken down to a fine substructure by previous straining. Growth of the fine substructure could be initiated within the grains, and could be controlled by suitably altering the temperature and the rate of strain Further, the growth produced by such simultaneous heating and straining was of an order of magnitude greater than that obtainable by heating alone and sometimes termed "recovery". The new effects are therefore termed "stress recovery" Finally, the strength of the metal under particular conditions of deformation was proved to be inversely proportional to the size of the substructure. A general interpretation of the phenomenon is given on the view that the conditions of deformation determine the nature of the substructure, which in turn governs the strength of a metal.

(1727) Wood, W. A , and Tapsell, H J

Mechanism of Creep in Metals

Nature 158 (1946) 415-416

Experiments indicate that a difference in the fundamental process of breakdown of the grains might be a factor distinguishing the normal short-time deformation of a polycrystalline metal in a tensile test with increasing stress from a continuous deformation at the much slower rate during creep.

(1728) Wood, W. A , Wilms, G. R , and Rachinger, W. A

Three Basic Stages in the Mechanism of Deformation of Metals at Different Temperatures and Strain-Rates

J. Inst Metals 79 (1951) 159-172

As temperature of deformation of Al is increased, or as rate of strain at any one temperature is decreased, the mechanism of slip is replaced by a second mechanism termed "cell mechanism" By further reduction in strain rate at an elevated temperature, the cell mechanism is in turn superseded, this occurs when the cells become comparable in size with the grain itself This third stage is termed "boundary microflow". Implications in relation to the mechanism of deformation, strain hardening, and creep.

(1729) Woodard, D H

Stages in the Deformation of Monel Metal as Shown by Polarized Light

Trans. AIME 185 (1949) 722-726

Previous investigations involving the use of polarized light have been restricted to annealed metals In this paper it is shown that inhomogeneous plastic deformation which results in lattice bending and development of deformation bands, experienced by individual grains in polycrystalline Monel, is revealed in the microstructure This interpretation of the microstructure was confirmed by a study of slip lines formed after prior plastic strain

(1730) Woolley, R. L.

Work-Hardening in Polycrystalline Pure Metals

Paper from Report of a Conference on Strength of Solids, Phys. Soc London (1948) 51-56

Observation of the plastic deformation of metals when the direction of stressing is reversed gives additional means of checking various theories of work hardening. Experimental results for Cu can be explained by each of three theories, suitably modified.

(1731) Work, C. E , and Dolan, T. J

The Influence of Strain Rate and Temperature on the Strength and Ductility of Mild Steel in Torsion

Proc ASTM 53 (1953) 611-626

SAE 1018 steel was tested in torsion at temperatures from 400 to 1000 F and rates of strain from 0.001 to 12.5 sec^{-1} Results were compared with several theories proposed to express mathematically the effects of strain rate and temperature on mechanical properties By proper selection of empirical constants, several equations, involving a general relation for flow stress or parameters based on temperature and strain rate, expresses approximately some of the variations obtained in mechanical properties

(1732) Wu, T. L., and Smoluchowski, R

A New Criterion of Slip in Thin Single Al Crystals

Phys Rev 75 (1949) 345

Observations of slip in thin flat specimens of Al single crystals under tension show that the Boas and Schmid criterion of maximum resolved shear stress does not apply in this case Rather it appears that in such specimens slip occurs in the direction in which the resolved shear divided by the thickness of the specimen in that direction is maximum. A corresponding formula is derived and compared with experimental data, which confirm it without exception. At higher elongations a new slip system sets in, and this also complies with the new formula In one case duplex slip has been observed corresponding to simultaneous slip in two directions, both of which satisfy the new criterion A possible reason for this dependence of slip mechanism on the thickness of specimens is suggested.

(1733) Wusatowski, Z

New Methods for the Determination of Coefficients in Plastic Deformation (In German)

Neue Hütte 1 (1956) 275-279

Derivation of general relations for plastic deformation processes.

(1734) Wyatt, O. H.

Transient Creep in Pure Metals

Nature 167 (1951) 866

When an annealed pure metal is loaded beyond the yield point, deformation continues after the load is applied. At constant stress Andrade has shown that the creep curve consists of strain on loading, followed by decelerating or transient creep, and finally steady-rate creep. Two different equations have been suggested for the transient creep curve. Measurements were made with Cu, Al, and Cd between -196 and 170 C, for a wide range of stresses. It was found that one equation (logarithmic) fits at low temperatures and another (exponential) at high temperatures, with a composite equation fitting the intermediate range.

(1735) Wyatt, O. H

Transient Creep in Pure Metals

Proc Phys. Soc. (London) 66 B (1953) 459-480

Polycrystalline Cu and Al have been investigated between -196 C and 140 C. At low temperatures, the creep curves fitted $\epsilon = \alpha \log t + c_1$; at higher temperatures they fitted $\epsilon = \beta t^{1/3} + c_2$. These are called α and β creep, respectively. In an intermediate temperature range the curves fitted $\epsilon = \alpha \log t + \beta t^{1/3} + c_3$. The results have been confirmed for Cd and commercially pure Al and also for Al with only a few grains/specimen. In a series of increment tests the stress was altered by small amounts at various times during a creep curve; in the α range only, the curves after the increments were similar to segments of the parent curve. The effect of testing a specimen at increasing stresses and different temperatures was also investigated; in the α range only, an equation of state, that is $F(s, \epsilon, d\epsilon/dt, T) = 0$, was obeyed. A theory of α creep is developed: an exhaustion theory is applied to a metal whose strain hardening is defined by a reference curve. The rise of activation stress during a creep curve and the slope of the reference curve are deduced from the increment and creep tests; and the slope agrees numerically with the stress-strain curve at -196 C. From an equation of state, values of the mean activation energy at a strain rate of 10^{-4} sec, and the frequency of thermal fluctuations are obtained

(1736) Wyon, G.

Study of the Structural Changes in Aluminum and Its Alloys During Creep, I, II, III (In French)

Métaux (Corrosion-Inds.), 28 (1953) 143-151; 203-221; 244-261

(I.) Structural changes that take place in Al and Al alloys during creep comprise the appearance of slip lines and deformation bands, kinking, boundary movements, and fragmentation of metal grains into sub-grains of more or less perfect structure (II.) The following subjects were studied: the behavior of grain boundaries; various aspects of slip; kinking and inter-crystalline contours; effect of polygonization annealing upon "channelling"; deformation bands; intergranular folding; fragmentation contours; and grain-boundary migration. It is considered that grain-boundary migration is produced by the simultaneous occurrence of tangential displacement (viscous flow), and discontinuous normal displacement, with intervals during which only tangential displacement occurs. (III.) Three possible causes of slip are suggested, and the following matters are discussed: variation of crystal disorientation as a function of creep; the variation of total dis-orientation as a function of the area of surface irradiated by X-rays; the migration of contours formed by creep at 330 C. Creep at high temperature introduces certain fragmentation boundaries in the form of very mobile dotted contours. Grain fragmentation into slightly distorted sub-blocks facilitates creep and assists deformation.

(1737) Wyon, G., and Crussard, C.

Modifications of the Structure of Aluminum During Creep (In French)

Rev. mét 48 (1951) 121-130

Micrographic studies of intracrystalline structures formed during creep at 250-310 C revealed several modifications of deformation. Slow-moving boundaries, valley formation on the surface, large angular and net bending, and networks of swelling in the finest grains or near the boundaries of large grains were some of the effects observed.

(1738) Wyon, G., and Crussard, C.

Changes in Structure of Aluminum During Creep (In French)

Métaux (Corrosion-Inds.) 27 (1952) 446-457

The fragmentation of Al grains into subgrains or cells of more or less perfect structure during creep has been observed by Crussard [Rev. mét. 43 (1946) 307], using X-ray analysis, and by Wilms and Wood by micrography [J. Inst. Metals 75 (1948-49) 693]. The interpretation of the phenomenon is still a matter of discussion, one school contending that the subgrains are undeformable cellules sliding tangentially upon one another, while another school contends that the phenomenon has to do with a particular type of polygonization with progressive kinking occurring during creep. A micrographic study of intercrystalline contours produced during creep of Al and examination of contours after deformation in the cold and after annealing, lead the authors to favor the second school. A new phenomenon was observed, viz., the migration of grain boundaries during creep due to recrystallization or kinking; this is observed more especially at high temperature.

(1739) Yagn, Y. I., and Chaplinsky, I. A.

Resistance of Metals to Plastic Deformation (In Russian)

Doklady Akad. Nauk S.S.S.R 90 (1953) 1023-1026

Fe, steels, and Al bronze were subjected to tensile and compression tests comprising linear tension, plain biaxial and triaxial compression tests, the last under two equal stresses and a third half as large. The results show the inadequacy of the theory of maximum shearing stress, and of Mohr's theory, which do not take into account the intermediate principal stress. It is suggested that a criterion corresponding to that given by Yagn is the simplest method of discussing large plastic deformations of bodies when the average normal stress affects the resistance to deformation.

(1740) Yakovleva, E. S.

The Mechanism of Plastic Deformation and the Mechanical Properties of Aluminum. I.-An Investigation of the Mechanism of Plastic Deformation of Aluminum by Means of the Traces Produced on Its Surface by Extension. II.- Block Formation Within Aluminum Grains as a Result of Plastic Deformation (In Russian)

Fiz. Metal i Metalloved. Akad. Nauk S. S. S. R., Ural'Filial, 4 (1957) 141-150

(I.) The mechanism of deformation was studied by surface observation of slip bands and grain-boundary movements. Measurements were made of the slip-band spacing a, the slip-step height b, and the grain-boundary movement B as functions of temperature T, strain rate $\dot{\epsilon}$, and strain ϵ. b and a both increase with T, and a increases with ϵ. With increasing $\dot{\epsilon}$, B decreases (II.) Measurements were made of the break-up of X-ray Laue spots by deformation under the same conditions as (I.) The disorientation of the newly formed subgrains for given total ϵ increased rapidly with $\dot{\epsilon}$ at -196 C, much less rapidly at the higher temperature. At the higher T and lower $\dot{\epsilon}$ the block size becomes equal to the grain size.

(1741) Yakovleva, E. S.

The Mechanism of Plastic Deformation and the Mechanical Properties of Aluminum III.--The Role of the Mechanism of Plastic Deformation in the Formation of the Mechanical Properties of Aluminum (In Russian)

Fiz. Metal i Metalloved Akad. Nauk S.S.S.R., Ural' Filial, 4 (1957) 306-309

Stress/strain curves were obtained for pure polycrystalline Al extended at various strain rates and temperatures. The differences in the observed curves are correlated with observed differences in the geometry of deformation, i.e., with slip-band spacing, relative amounts of grain-boundary and intragranular slip, polygon size, grain size, etc.

(1742) Yakovleva, E. S., and Yakutovich, M. V

The Role of Grain Boundaries in the Plastic Deformation of Aluminum (In Russian)

Doklady Akad Nauk S.S.S.R 90 (1953) 1027-1029

The deformation in tension at various strain rates and temperatures of samples of pure Al, consisting of single crystals in cross-section and several in length, was investigated visually. The main conclusions are: The effect of grain boundaries on deformation varies with the conditions; at low temperature and high strain rate they hinder shear and at higher temperatures and low strain rate they are sources of weakness; the difference is caused by a change in the mechanism of plastic deformation from cooperative shear in the first case to atomic diffusion plasticity in the second; the nature of flow of Al at high temperatures supports the existence of a transition layer at the boundaries of single crystals.

(1743) Yamamoto, M., Hayami, S., and Nishiyama, Z.

Local Distribution of Strain in Plastically Deformed Aluminum Crystals. II --Changes Due to Heating (In Japanese)

Nippon Kinzoku, Gakkaishi 21 (1957) 128-131

X-ray diffraction methods were used to study strain distribution to clarify recrystallization and polygonization processes. X-ray micrographs showed evidence of reversion and subgrain formation. In crystals showing deformation bands the subgrains were parallel to the bands, where deformation bands did not appear, the subgrains were almost parallel to the slip bands

(1744) Yamamoto, Y

A General Theory of the Plastic Behavior of Metals

Proc 1st Japan Natl Congr Appl Mechanics (1952) 93-96

A general stress/plastic-strain law is introduced, which is a generalized form of that given by Prager. Moreover, it is effective for material which shows the Bauschinger effect. Yamamoto recognizes fracture as a sort of instability phenomenon which depends upon the property of the aeolotropic tensor

(1745) Yampol'sky, B Ya., and Amfitreatrova, T A

An Investigation of the Deformation of Metals Under Small Stresses I Some Regularities of the Creep of Copper and Aluminium (In Russian)

Fiz Metal i Metalloved Akad Nauk S S S R, Ural' Filial, 4 (1957) 131-140

According to the creep theory of Likhtman [Doklady Akad Nauk S S S R 72 (1950) 1079] the stress (P) to produce flow is a function of strain ϵ, strain rate $\dot{\epsilon}$, and time τ of the form $P = P_0 + \lambda\epsilon + \eta\dot{\epsilon} - \chi\tau$, where P is assumed to be small, P_0 is the "creep limit", λ the work-hardening coefficient, η the coefficient of internal friction ("creep viscosity"), and χ the "coefficient of recovery". At temperatures << melting point the recovery term can be neglected and the equation of the creep curve becomes $\epsilon = \epsilon_0\eta[1 - \exp(-\lambda\tau/\eta)]\lambda$. Experiments are described to measure P_0, λ, and η for Cu and Al polycrystalline wires. All these quantities increase with decrease of grain size. With increase of temperature, recovery processes become more important and P_0, λ, and η all fall. However, at higher temperatures, grain-boundary (viscous) flow becomes increasingly important relative to intragranular slip

(1746) Yen, M K.

A Proposed Microbending Mechanism of Plastic Deformation

Trans AIME 185 (1949) 1003-1004

Hypothetical "microbending sites" in mosaic crystals are discussed. They may be described as atomistically dislocated local curvatures which act as nuclei for the slip process. It is considered that slip will start at those places where the location of such "microbending sites" happens to be close enough to form a sub-microscropically wavy layer which is composed of a number of curved surfaces each having a low resistance to shear. As soon as the external force reaches this magnitude, slip takes place along the slip direction in the manner of a sequence of local processes. Once slip commences the distortion produced in the adjacent lattice may destroy the regular pattern of the "microbending sites". This results in the phenomenon of strain-hardening, which tends to prevent further gliding along the same plane. If, however, the external stress increases sufficiently to overcome the barriers between the sites which have relatively large malalignment at the ends, new slip markings are produced between the old ones

(1747) Yen, M K., and Hibbard, W R., Jr.

The Transverse Bending of Single Crystals of Aluminum

Trans AIME 185 (1949) 710-720

Previous studies of plastic deformation of metals have emphasized the important role of bending and constraints during strain under relatively pure stresses. Some new phenomena such as early conjugate slip and polygonization are intimately concerned with the relief of bending stresses, the former by slip and the latter by a process analogous to recrystallization.

The transverse bending mode of testing, using the two-point loading method, was selected because the center portion of the specimen may be considered as under a theoretically pure bending stress with a uniform bending moment. Considerable attention was given to both the lattice distortion and flow characteristics of the crystals during deformation.

(1748) Yokobori, T

Failure and Fracture of Metals as a Nucleation Process

J Phys Soc Japan 7 (1952) 44-47

Discontinuous plastic phenomena in metals, e g, yielding and brittle fracture, are regarded as Markoff processes, and are discussed mathematically from the standpoint of nucleation theory. Among matters discussed are: (1) the relation between strength and deformation or stress velocity; (2) the temperature dependence of strength, (3) the size-effect; (4) the transition temperature from ductile to brittle fracture, (5) fluctuation characteristics of strength, and (6) theoretical criteria of failure and fracture of polycrystalline metals

(1749) Yokobori, T

Creep Fracture of Copper as a Nucleation Process

J Phys Soc Japan 7 (1952) 48-51

The creep fracture of Cu wire was studied experimentally, and the results are interpreted by the aid of the theory developed elsewhere [ibid, p 41]. In accordance with the theory, a linear relation was found between the log of the breaking stress, S, and the log of the time, t, required for fracture. The reciprocal of the temperature, T, and the log of t were found to be linearly related, in accordance with the equation $\log t = \Delta F/KT + C$, where ΔF is the free energy of activation for the motion of a dislocation, and C is a constant. The dependence of t upon the length of the wire, and the fluctuation characteristics of creep fracture are studied and interpreted in terms of nucleation theory.

(1750) Yokobori, T

Failure and Fracture of Metals as a Rate Process

J Phys Soc Japan 7 (1952) 122-123

Mathematical deductions from a theory of the failure and fracture of metals which regards yielding as a process of nucleation and the growth and movement of dislocations are shown to be in good agreement with many experimental data relating to the fracture of the harder metals. Creep fracture after necking is better explained as a growth process of a crack nucleus than as a nucleation process.

(1751) Yokobori, T

(I) Failure and Fracture of Metals From the Standpoint of the Stochastic Theory. (II) Ductility Transition and Cold Brittleness (III) Fatigue Fracture From the Standpoint of the Stochastic Theory

J Phys Soc Japan 8 (1953) 104-106; 107-109; 265-268

(I) A mathematical theory of the failure and fracture of metals, treated as a Markoff or chain process [ibid 7 (1952) 122] is developed. In fundamental types of failure, transition probabilities are found to correspond to nucleation or reaction rates. The following features are treated on a unified basis: (1) the dependence of strength on stress or deformation velocity and temperature; (2) the dependence of the time for creep fracture on stress and temperature; (3) features of the endurance limit, and the dependence of the number of repeated cycles preceding fatigue fracture on the stress range, (4) size-effect, fluctuation characteristics, and ductility transition phenomena (II) The transition from ductile to brittle fracture is studied by stochastic theory, failure and fracture being treated as reaction-rate processes. The relation between deformation velocity, V_D, and absolute temperature, T, is derived in the form $\log V_D = C_0 \cdot Q/RT$, where C_0 is a constant, and Q is a function of yield strength and microscopic stress characteristics. The effects of notch radius, size, and the scatter of brittle strength on the transition are discussed. The Cottrell-Bilby mechanism of yielding and nucleation are regarded as rate-determining for brittle fracture and values of the yield and brittle fracture strengths are deduced from the theory (III) Experimental results relating to fatigue fracture of mild steel under reversed torsion and compression are discussed according to the theory developed in a previous paper [ibid. 6 (1951) 81]. Good agreement is found between experimental results and theoretical anticipations. The occurrence of fracture is interpreted as growth of a crack nucleus.

(1752) Yokobori, T

Delayed Yield and Strain Rate and Temperature-Dependence of Yield Point in Iron

J Appl Phy. 25 (1954) 593-594

An explanation of the experimental results of Wood and Clark relating to the phenomena of the time-delay of yielding under constant stress [Trans ASM 43 (1951) 571] based on Cottrell's locking theory is developed, with internal stress being taken into account. The energy of a dislocation necessary to fit existing data is small compared with the value theoretically estimated by Mott and Nabarro. The distance, calculated from the internal stress, between dislocations, assembled at a grain boundary, is of a reasonable order of magnitude. It is suggested that the mechanism of yielding may be changed from the Cottrell to the Mott-Nabarro or Frank-Read type when the applied stress falls below a limiting value

(1753) Young, F A.

Polygonization of Copper

J Appl Phy 29 (1958) 760-764

Dislocations can be revealed as etch pits in Cu crystals doped with a small amount of Te. The progress of polygonization of such Cu after bending was followed with etch pits and X-ray diffraction. Climbing occurred at 500 C and polygonization was complete after 2 hours at 1000 C. In similar experiments with three samples of nominally 99.999 per cent Cu, the one which was probably purest did not polygonize, while the other two did so. This indicates that an impurity is necessary for polygonization, only a very small amount is required.

(1754) Zaat, J H

Hardness and Plasticity of Metals (In Dutch)

Metalen (1954) 353-358; 373-380

Shows that hardness is not a genuinely constant property of a metal. A close relationship has been found between the plastic properties, as given by a universal stress/deformation curve, and the hardness measurements; each hardness measurement actually represents a point on the curve. Hardness measurements made with indenters giving uniform indentation at a varying load always give the same point on the curve, irrespective of size. Where different indentations result at varying load, the points will vary. Calculations have been made to find approximate values for determining the stress/deformation curve from hardness measurements, but it is emphasized that these values are only approximate.

(1755) Zackay, V. F

Contribution of α-Level Electrons to the Plastic Properties of Nickel Alloys

U S Atomic Energy Comm Publ (1953) (AECU-2523) 10 pp

Study of whether alpha-electrons (in transitional elements) contribute to plastic properties of alloys. An experimental study was made with Ni-Fe and Ni-Co alloys by creep and hot-tensile tests.

(1756) Zaikov, M A

Strength of Carbon Steels at High Temperatures (In Russian)

Zhur Tekh. Fiz. 19 (1949) 684-95

Establishes relationship of yield strength to temperatures of annealing and melting point by experiments on fracture of test specimens of C steels containing 0 12-1 19 per cent C. Formulas are presented for computation of mechanical constants. Experimental method is described. Results for structural tool steels for different temperature regions (20-1300 C) are tabulated.

(1757) Zaitsev, G P.

Brinell Hardness as a Function of the Parameters of Plasticity of Metals (In Russian)

Zavodskaya Lab. 15 (1949) 704-717

The relation between constants specific for ball impression and the corresponding constants under tensile stress, i e , yield strength and elongation, were theoretically investigated. Brinell hardness and conditional stress were also found to be interrelated. Equations of dependence are derived on the basis of theoretical considerations. Zaitsev attempts to relate hardness quantities to the tensile strength and uniform deformation in the simple tensile test. By means of an analysis of the local and average deformation in the indented area, he shows that a close parallelism exists between the stress-strain diagram in simple tension and the hardness test.

(1758) Zaitsev, G P

Some Observations on the Intensities of Stress and Deformation (In Russian)

Fiz Metal i Metalloved Akad. Nauk S S S.R , Ural' Filial 3 (1956) 537-539

Calculations of finite stress and strain based on energy considerations give results in better agreement with experiment than do calculations based on other theories of plasticity.

(1759) Zaitsev, G P.

The Strength of a Metal and the Internal Stresses of the Second Kind Produced by a Lowering of Temperature (In Russian)

Fiz. Metal i Metalloved Akad. Nauk S.S.S R , Ural' Filial 2 (1956) 494-503

Calculation of the variation with temperature of the internal stresses in a two-phase alloy leads to a discussion of the conditions causing brittle fracture at low temperature.

(1760) Zaitsev, G P.

Fundamental Formulae for Calculations of Finite Elastic-Plastic Deformation (In Russian)

Fiz. Metal i Metalloved. Akad. Nauk S.S.S R , Ural' Filial 2 (1956) 120-124

Derives the basic formulae required for theoretical work on angular deformation and other problems in elasticity and plasticity. Formulae which give the ratio of the differences of the principal stresses to the differences of the corresponding principal strains are a consequence of the principle of superposition.

(1761) Zaitsev, G P

Finite Elastic-Plastic Angular Deformations in Basic, Logarithmic, and Other Systems of Units (In Russian)

Fiz Metal i Metalloved Akad Nauk U S S R , Ural' Filial 2 (1956) 125-136

A system of measurement of variable quantities is defined to be "basic" if the changes in these quantities are always referred to the initial magnitudes. It is logarithmic if changes are referred to current magnitudes. Since the modern tendency is to use so-called "true" systems, Zaitsev derives formulae for types of deformation in both systems and also some new relationship between them. For calculations both systems must be used together.

(1762) Zakharov, M V

Heat Resistance of Certain Binary Copper Alloys (In Russian)

Izvest Akad Nauk S S.S R , Otdel Tekh Nauk (January 1949) 124 130

The influence of degree of heterogeneity on relative heat resistance of a series of alloys of the Cu-Zn, Cu-Sn, Cu-Al, and Cu-Be systems. Phase diagrams, upon which are superimposed curves of hardness versus composition at various temperatures.

(1763) Zakharov, M V

On Various Diagrams of the Effect of Alloying Additions on the Strength of Binary Copper Alloys at Elevated Temperatures (In Russian)

Doklady Akad Nauk S.S.S.R 65 (1949) 337-339

Three diagrams are given showing the effect of certain alloying elements on the relative strength of binary Cu alloys at elevated temperatures. The first (with Cr, Ca, or NiAl) shows that relative strength increases in every case with increase of alloying element. The second (with Zr, Si, Sb, or Be) shows that although a progressive increase of relative strength with increase in alloying element is maintained at 20 C, at 500 C, the curve rises to a maximum at the optimum concentration of the alpha solid solution, and then decreases. The third (with Al or Sn) shows that whereas the 20 C curve is much the same as in the other two cases, the 500 C curve takes on an S-form with a maximum in the alpha solid solution range followed by a minimum and then another increase.

(1764) Zakharov, M. B

Principles of Making Heat-Resistant Nonferrous Alloys (In Russian)

Paper from Strength of Metals, Izd -vo Akad Nauk S.S.S.R , Moscow (1956) 82-90

On the basis of available experimental data on alloys, the author presents some basic requirements and procedures used in making heat-resistant nonferrous alloys.

(1765) Zakoshchikova E. P.

Creep of Tin Single Crystals (In Russian)

Doklady Akad Nauk S S.S.R 95 (1954) 575-577

The process of creep in Sn single crystals subjected to tensile stresses below the yield point was studied at room temperature. The curves showed the occurrence of the tertiary stage of creep. The increased rate of creep did not lead to the breaking of the specimen, in contrast to tests with polycrystals, but after a time the rate would drop approximately to its value before the beginning of the tertiary stage. The slowing down of the rate of creep was explained on the basis of simultaneous increase of strength (due to strain hardening) and relaxation phenomena. Experiments performed in oil and in oil with addition of a surface-active agent (oleic acid) showed a 4 to 10-fold increase of the rate of creep in the presence of the oleic acid.

(1766) Zapffe, A

A New Theory for the Solid State

Trans ASM 42 (1950) 387-398

The solid state in general, and for metals in particular, is a condition of aggregation of subcrystalline units of colloidal dimensions, tentatively termed micelles, originating or existing within the previous liquid or gaseous state and carrying aspects of their definition and separateness into the solid state as an inherently discontinuous structure on a colloidal scale. All mechanical physical phenomena depend upon and/or involve intermicellar surfaces and chemical phenomena.

(1767) Zapffe, C A , and Landgraf, F K

Method of Identifying the Crystallographic Characteristics of Deformation and Fracture in Polycrystalline Solids (In French)

Rev mét 48 (1951) 811-821

"Fractographic" procedure. The crystallographic characteristics of Bi and Sb were studied.

(1768) Zener, C

Work-Hardening and Recrystallization

Trans AIME 147 (1942) 361-368

The density of a metal usually decreases with cold work, and subsequently annealing restores the original density. Cold working may be regarded as a breaking up of the original grains into a large number of perfect crystallites somewhat randomly oriented with respect to one another. According to this viewpoint, the mere introduction of a large intercrystallite surface induces a net volume expansion. Another school regards cold working primarily as a distortion of the grains. It is not obvious that the second viewpoint will lead to a net volume expansion. This paper shows that this is indeed the case, and this expansion is of the right order of magnitude to explain existing experimental data.

(1769) Zener, C

Anelasticity of Metals

Trans AIME 167 (1946) 155-191

An outline of the mathematical theory of anelasticity is followed by a general review of the various physical origins of the phenomenon, considered in general terms as a relaxation of stress. Relaxation of shear stress across localized regions, which behave in a viscous manner and are surrounded by an elastic matrix, gives rise to anelasticity which is shown up by elastic after-effects, internal friction, and dependence of Young's modulus on experimental conditions. Grain boundaries and freely formed slip bands behave in a viscous manner, and anelasticity may be used for studying their properties. Anelasticity may also be caused by thermal, atomic, or magnetic diffusion. Examples of the operation of these effects are discussed, and the practical importance of stress relaxation emphasized. Among the phenomena involved are stress relief, primary creep, and dimensional changes at room temperature. The relation of stress relaxation to fracture is discussed in terms of the generation of microcracks by relaxation within slip bands and across grain boundaries.

(1770) Zener, C

A Theoretical Criterion for the Initiation of Slip-Bands

Phys. Rev 69 (1946) 128-129

Relief of shear stress within a slip-band results in a large concentration of shear stress just ahead of its advancing edge, which may be called the spearhead. The condition for propagation of the slip-band is that this concentration of stress is sufficient to produce plastic deformation in front of the spearhead. Zener deduces a relation between yield strength and atomic spacing, grain diameter, and shear modulus. Data for Cu alloys support the general views.

(1771) Zener, C.

A Thermodynamic Criterion for the Fracture of Metals. A Criticism

Phys Rev 70 (1946) 225-226

A criticism of a proposed thermodynamical criterion for the fracture of metals. The criterion is U = L, where U is the strain energy at fracture and L is a function of certain thermodynamical variables. The strain energy absorbed prior to fracture is, however, dependent upon the conditions of test, and, under constant test conditions, is structure sensitive. The quantity L is not dependent upon these factors. It is claimed, therefore, that the proposed criterion contradicts well-established principles regarding fracture.

(1772) Zener, C.

The Micro-Mechanism of Fracture

Paper from Fracture in Metals, Amer. Soc Met , Cleveland (1948) 3-31

Review of Griffith's contributions to the role of microcracks in brittle materials. Danger in utilizing the Griffith crack concept to interpret fracture phenomena in metals, because of the fundamental difference between them and amorphous materials, on account of the keying action of the grain corners. The initiation of cracks by slip bands and other theories regarding fracture. It is concluded that fracture is initiated by the act of deformation. Results of an investigation of fracture of armor plates under static and dynamic loading.

(1773) Zener, C

Dynamics of Slip Bands

Paper from Cold Working of Metals, Amer Soc Met , Cleveland (1949) 180-196

Slip is regarded as a viscous-like process, but the strain-rate increases more rapidly than the stress – probably by an exponential relationship. The influence of previously formed slip bands on deformation is discussed mathematically, with special reference to stress-relaxation effects. The views developed are applied to explain (a) the influence of frequency on internal friction, (b) certain creep phenomena, and (c) the removal of residual stresses by cyclic stressing.

(1774) Zener, C.

Relation Between Residual Strain Energy and Elastic Moduli

Acta Cryst 2 (1949) 163-166

Presence of residual strain energy necessarily results in a lowering of the over-all tensile and shear moduli. A quantitative relation is derived between density of residual strain energy and decrease in tensile and shear moduli. Interprets recent observations of Köster that solute atoms of only a small solubility lower the tensile modulus when they are atomically dispersed.

(1775) Zener, C

Role of Inhomogeneity in Plastic Deformation

Paper from High Temperature Properties of Materials, Dept Engr. Mech., Pennsylvania State Univ. (1954) 1-8

Illustrates homogeneous and inhomogeneous deformation under various conditions.

(1776) Zener, C.

Metallurgical Designing for Designing for Strength

Tech Eng. News 38 (November 1956) 52-57

Atomic structure and deformation of metals; design principles.

(1777) Zener, C , and Hollomon, J. H

Effect of Strain Rate Upon Plastic Flow of Steel

J. Appl Phy 15 (1944) 22-32

A previously proposed equivalence of effects of changes in strain rate and in temperature upon the stress-strain relation in metals is found valid for the typical stress investigated. Behavior in these steels at high rates of deformation may be obtained by tests at moderate rates of deformation performed at low temperatures. Aside from changing the isothermal stress-strain relation, an increase in strain rate tends to change the conditioning from isothermal to adiabatic. At low temperatures the adiabatic stress-strain relation in the plastic range is radically different from the isothermal, having an initial negative rather than a positive slope. This initial negative slope renders unstable homogeneous plastic deformation.

(1778) Zener, C., and Hollomon, J. H.

Plastic Flow and Rupture of Metals

Trans ASM 33 (1944) 162-235

This paper constitutes an attempt to coordinate and interpret the present knowledge of the plastic flow and rupture of metals. Certain of the data found in the literature required the introduction of new concepts for their explanation. New models have been suggested which appear to coordinate better the existing knowledge in this broad field. Two systems have been in common use for specifying (a) the conditions for the initiation of plastic flow, (b) the precise nature of flow under a given stress pattern, and (c) the relation between the strain hardening occurring in different types of flow. In this paper these two systems are discussed in detail, and a comparison is made between their predictions and the experimental observations. A new theoretical treatment is given of the application of these systems to the problem of strain hardening. Almost insuperable difficulties prevent the direct determination of the relation between stress and strain at high rates of strain. An indirect method is proposed whereby this information may be easily obtained. Inexplicable phenomena in metals frequently have been disposed of by the assumption of imperfections. In this paper many phenomena not previously understood are shown to be explicable in a qualitative manner by a single type of imperfection which may be quite precisely defined, namely by the concept of microscopic cracks. A quantitative analysis, first suggested by Griffiths, is applied to these cracks. This analysis attempts a correlation of the fracture stress with the size of these microcracks which are correlated with certain elements of the microstructure.

(1779) Zener, C , and Hollomon, J. H

Problems in Non-Elastic Deformation of Metals

J Appl Phy. 17 (1946) 69-82

A general article assessing the potentialities of the various paths along which further research may profitably proceed. Temperature and rate of strain are primary factors which determine in what manner a crystalline material will deform. As the temperature increases, or the rate of deformation decreases, resistance to deformation by slip decreases rapidly, resistance to deformation by twinning decreases less rapidly, if at all. Stress gradients and composition also influence type of deformation which occurs. Anelastic phenomena are discussed, and the mechanism of plastic deformation by twinning and slipping is described in general terms. The possibility of a mechanical "equation of state" is dealt with in detail. Emphasis is laid throughout on unsolved problems and deficiencies in existing knowledge, and some specific recommendations for future research are made.

(1780) Zhdanov, V. A., and Tikhonova, I.

Concerning Stability of Crystal Lattices (In Russian)

Zhur. Eksp. i Teoret Fix 18 (1948) 552-558

The stability of monoatomic fcc lattices under unilateral tensile and compressive stresses The destruction of the lattice is shown to possess different characteristics under tension and under compression stress, that is, its resistance to compression stress is considerably less than to tension

(1781) Zhdanov, V A, and Vishnevskaya, N L.

Theory of Stability of Binary Lattices (In Russian)

Zhur Eskp. i Teoret, Fix. 19 (1949) 231

Stability of a binary fcc lattice is considered Shown that, during transformation from a monoatomic lattice, unstable because of the absence of shear resistance to a binary lattice, high resistance to shear appears even at very small differences of atomic dimensions

(1782) Zhurkov, A. N, and Sanfirova, I P

Temperature-Time Dependency of the Strength of Pure Metals (In Russian)

Doklady Akad Nauk S.S.S.R 101 (1955) 237-240

The activation energy for the temperature-time dependence of strength coincides with the sublimation energy Thus, the process of rupture is considered to be a gradual violation of the interatomic bond, leading to the formation of local rupture (cracks) and ending finally by the rupture of the specimen.

(1783) Zhurkov, S. N, and Tomashevsky, E. E.

Investigation of the Strength of Solids II. Dependence of the Life on Stress (In Russian)

Zhur Tekh Fix 25 (1955) 66-73

In (I) [Zhurkov and Narzullaev, ibid, 23 (1953) 1677] it was shown that for most materials the life τ (the time from the first application of stress) was related to the applied stress (σ) by the relationship: $\tau = Ae^{-\alpha\sigma}$, where A and α were parameters determined by the properties of the material under test, the temperature, and the nature (e.g., chemical) of the surroundings This relationship had been tested for time varying from a few seconds to several months In (II) the time scale is extended by means of impact testing and cathode-ray oscillographic recording down to 0.005 second, and the formula still holds for a variety of materials It is not to be expected that the formula can hold for much shorter times nor for vanishingly small stresses

(1784) Zirinsky, S

The Temperature Dependence of the Elastic Constants of Gold-Cadmium Alloys

Acta Met 4 (1956) 164-171

Temperature dependence of the dynamic elastic constants of bcc alloys that undergo diffusionless phase change determined as a function of composition variation within the beta phase and heat treatment prior to measurement

APPENDIX B

AUTHOR INDEX

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APPENDIX C

CLASSIFICATION OF THE NUMBERED REFERENCES
IN APPENDIX A BY NUMBER

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APPENDIX C

CLASSIFICATION OF THE NUMBERED REFERENCES IN APPENDIX A BY NUMBER

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Experimental and Phenomenological Methods of Predicting Properties

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Experimental Observations of Factors Influencing Strength Properties

1, 2, 3, 4, 6, 7, 8, 11, 12, 14, 17, 19, 28, 31, 33, 34, 35, 36, 39, 41, 42, 44, 47, 48, 50, 51, 55, 56, 58. 60, 61, 62, 63, 64, 65, 67, 69. 71, 72, 76, 77. 78, 79, 81, 82, 83, 84, 85, 86, 87, 88, 92, 93, 97, 99, 104, 105, 107, 114, 128, 129, 130, 131, 133, 134, 135, 136, 137, 138, 140, 141, 142, 143. 144, 145, 146, 147, 150, 152, 157, 158, 163, 164, 166, 170. 171, 182, 183, 184, 186, 187, 188, 189, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 208, 209, 210, 212, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 231, 235, 236, 237, 238, 239, 240, 243, 244, 245, 246, 247, 248, 249, 250, 251, 253, 255, 257, 258, 259, 260, 263, 264, 265, 266, 267, 271, 272, 273, 274, 276, 277, 278, 280, 282, 284, 285, 304, 305, 308, 309, 311, 312, 314, 315, 316, 317, 319, 320, 321, 324, 325, 326, 327, 329, 330, 331, 333, 337, 339, 340, 342, 348, 353, 355, 360, 363, 365, 366, 368, 373, 374, 378, 380, 381, 383, 388, 389, 390, 395, 399, 400, 401, 402, 404, 405, 408, 413, 416, 421, 422, 423, 424, 429, 430, 431, 450, 453, 456, 457, 466, 468, 469, 470, 479, 481, 483, 484, 486, 494, 495, 498, 499, 500, 501, 509, 511, 512, 513, 514, 516, 517, 519, 521, 522, 524, 525, 526, 528, 529, 531, 533, 534, 535, 536, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 551, 552, 555, 557, 559, 561, 568, 570, 572, 574, 579, 580, 581, 582, 584, 585, 587, 590, 591, 592, 602, 603, 605, 606, 610, 611, 615, 616, 617, 618, 619, 624, 625, 626, 629, 630, 632, 634, 635, 637, 640, 641, 642, 643, 648, 649, 650, 651, 653, 654, 655, 656, 661, 662, 663, 667, 669, 671, 672, 673, 674, 677, 680, 681, 683, 684, 689. 690, 694, 695, 696, 697, 698, 699, 701, 702, 703, 704, 705, 706, 707, 716, 717, 718, 721, 722, 725, 726, 730, 732, 733, 734, 735, 741, 742, 743, 744, 745, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 772, 779, 785, 786, 788, 789, 790, 791, 792, 794, 795, 797, 799, 800, 801, 802, 803, 804, 805, 806, 808, 809, 810, 811, 813, 814, 816, 818, 820, 821, 828, 833, 835, 837, 843, 844, 846, 847, 849, 852, 853, 854, 855, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 871, 875, 878, 881, 882, 883, 884, 885, 886, 887, 889, 890, 891, 892, 895, 896, 897, 898, 899, 900, 901, 902, 904, 906, 907, 908, 909, 910, 918, 919, 920, 922, 925, 926, 927, 928, 929, 930, 931, 932, 940, 943, 944, 947, 949, 950, 952, 953, 954, 955, 958, 959, 961, 962, 963, 965, 966, 967, 968, 970, 971, 972, 974, 975, 976, 978, 979, 980, 981, 983, 984, 993, 994, 995, 996, 997, 1000, 1001, 1002, 1003, 1004, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1013, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1025, 1027, 1028, 1030, 1031, 1032, 1033, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1046, 1047, 1048, 1049, 1050, 1051, 1052, 1053, 1056, 1058, 1060, 1061, 1062, 1064, 1066, 1067, 1068, 1069, 1070, 1072, 1073, 1102, 1103, 1104, 1106, 1121, 1122, 1123, 1125, 1126, 1127, 1129, 1130, 1131, 1132, 1133, 1034, 1135, 1136, 1139, 1152, 1153, 1158, 1159, 1162, 1163, 1164, 1167, 1168, 1169, 1195, 1196, 1197, 1198, 1201, 1203, 1206, 1207, 1208, 1210, 1211, 1216, 1218, 1219, 1220, 1221, 1224, 1225, 1226, 1228, 1229, 1230, 1231, 1234, 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1243, 1244, 1245, 1246, 1247, 1248, 1249, 1251, 1252, 1253, 1256, 1258, 1259, 1260, 1262, 1263, 1264, 1265, 1266, 1267, 1271, 1274, 1275, 1278, 1279, 1286, 1289, 1291, 1292, 1293, 1295, 1296, 1297, 1298, 1302, 1303, 1304, 1305, 1306, 1307, 1308, 1309, 1311, 1321, 1322, 1326, 1327, 1328, 1329, 1330, 1331, 1334, 1336, 1337, 1338, 1342, 1343, 1344, 1346, 1347, 1348, 1349, 1350, 1352, 1353, 1355, 1357, 1358, 1359, 1360, 1361, 1362, 1363, 1364, 1365, 1366, 1369, 1370, 1371, 1372, 1389, 1390, 1391, 1400, 1402, 1403, 1409, 1410, 1411, 1422, 1423, 1424, 1425, 1427, 1433, 1446, 1447, 1448, 1449, 1450, 1454, 1455. 1456, 1457, 1458, 1459, 1461, 1462, 1463, 1464, 1465, 1466, 1467, 1471, 1472, 1473, 1474, 1485, 1486, 1490, 1491, 1492, 1495, 1496, 1497, 1498, 1500, 1501, 1502, 1503, 1504, 1505, 1506, 1507, 1508, 1509 1512, 1513, 1514, 1517, 1518, 1523, 1524, 1526, 1537, 1542, 1549, 1551, 1552, 1553, 1556, 1557, 1560, 1561, 1562, 1564, 1565, 1566, 1567, 1570, 1571, 1573, 1583, 1584, 1586, 1587, 1589, 1591, 1593, 1594, 1595, 1596, 1597, 1599, 1601, 1602, 1603, 1604, 1605, 1606, 1607, 1608, 1610, 1611, 1614, 1615, 1616, 1617, 1619, 1620, 1621, 1622, 1623, 1624, 1628, 1629, 1633, 1634, 1636, 1637, 1638, 1639, 1640, 1643, 1644, 1649, 1650, 1653, 1654, 1657, 1658, 1659, 1660, 1661, 1663, 1664, 1666, 1667, 1668, 1676, 1678, 1680, 1681, 1682, 1684, 1688, 1689, 1692. 1693, 1694, 1695, 1697, 1702, 1703, 1704, 1705, 1706, 1707, 1708, 1709, 1710, 1711, 1712, 1713, 1714, 1716, 1717, 1719, 1720, 1721, 1722, 1726, 1727, 1728, 1729, 1730, 1736, 1737, 1738, 1739, 1740, 1741, 1742, 1744, 1745, 1747, 1753, 1754, 1762, 1763, 1764, 1765, 1767, 1775, 1776.

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