21 FEBRUARY 1980 (FOUO 2/80) 1 OF 1

JPRS L/8935

21 February 1980

East Europe Report

SCIENTIFIC AFFAIRS

(FOUO 2/80)

FBIS FOREIGN BROADCAST INFORMATION SERVICE

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

For further information on report content call (703) 351-3060.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200050037-4

JPRS L/8935

21 February 1980

EAST EUROPE REPORT

SCIENTIFIC AFFAIRS

(FOUO 2/80)

CONTENTS PAGE

CZECHOSLOVAKIA

RESEARCH ON SOLIDIFICATION OF HEAVY INGOTS BY NUMERICAL PROCESS CONTROL

Prague HUTNICKE LISTY in Czech No 10, 1979 pp 691-698

[Text] Rules for the writing of computer programs designed to monitor the solidification process and temperature ranges of circular section ingots based on the finite-differences method to be used in conjunction with a Hewlett-Packard 9830A calculator and ICL 4-50 computer. How to program temperature range calculations by means of the finite-elements method for octagonal forging ingots on an ICL 2960 computer. The automated cutting of macrosegregations. Key data used to calculate temperature ranges of heavy ingots. A comparison of the measured values of the surface temperatures of molds containing 91-ton ingots with estimated values.

During the past 15 years the demand for very heavy ingots used to produce precision machinery parts has increased. The production of heavy forged pieces means that we must solve complex problems pertaining to the actual technologies used to produce steel, i.e., the degasification and casting of multiple steel batch melts into a single ingot, concerning which strict requirements are levied in terms of its intrinsic purity and homogeneity. In large ingots and castings most elements contained in the iron batch are separated out and, as a result, type A and V segregations are created. Both of these types of macrosegregations are integral parts of the metal solidification process. While porous liquations (V segregations) can be effectively suppressed by selecting a mold with the right back-draft and width-to-thickness dimensions, the problems associated with suppressing A-liquations are more complex; this is why an intensive research effort has been under way in recent years to study the basic mechanisms that generate sheath segregations. We can now say that type A liquations arise only if the speed of the solidification process reaches a certain point, roughly about 1 mm/min. This is why a knowledge of the temperature ranges of large ingots is necessary before we can proceed to make further refinements in their macrostructures. The Vitkovice sectoral enterprise is engaged in the manufacture of heavy forging pieces and it is continuing to focus special attention on technological problems associated with the production and casting of large forging ingots. In line with the findings of foreign researchers the corresponding development of numerical methods for ascertaining the ingot solidification process and also the temperature ranges of forged and rolled pieces is an integral part of metallurgical research on segregation processes in large ingots.

The Use of the Finite-Differences Method

The numerical solution of the Fourier heat conduction equation under variable surface conditions has made it possible, with the aid of computers, to make a very detailed study of the ingot solidification process (see references 1, 2 and 3). Attempts to directly determine the solidification time of heavy forging ingots by measuring the temperature of molten steel have so far failed. From an experimental standpoint it takes far too much time to determine solidification time on the basis of mold temperature readings and the evaluation of the resulting data and the calculation of heat balances is likewise time-consuming. This method was used by A. I. Veynik (see reference 4) to determine a total solidification time of 11 hours for an ingot weighing 110 tons (with a radius R of 935 mm). Using numerical methods A. Kohn and Y. Morillon came up with a solidification time of 12.2 hours for an ingot with approximately the same radial dimensions. At the same time it should be realized that the determination of an ingot's total solidification time based on the heat balance of the mold is an indirect method flawed by a number of measurement errors. The Japanese researchers K. Narita and T. Mori (see reference 6) also have worked out a mathematical model for estimating the solidification time of 20-ton ingots; they estimated a solidification time of 370 minutes for a 20-ton ingot with a radius of 618 mm.

On the basis of preliminary findings involving the application of the finite-differences method at the Vitkovice plant (see references 7 and 8), e.g., to study the heat balance of a killed steel ingot head and also to determine the temperature ranges of a continuously casted salamander (see references 9 and 10), this method was used first of all to write up a computer program a) for the Hewlett-Packard 9830 calculator and b) for the ICL 4/50 computer, the only difference being that in both cases the horizontal octagon ingot section was replaced with a circular cross-section. The actual dimensions of the octagonal horizontal ingot section are shown in fig. 1. It can be seen that the circumference does not conform to that of a true octagon, rather it consists of segments of a circle with two different curvature radii. To determine the solidification time we picked the radius of a circle in place of the original shape of the ingot section as an arithmetic diameter of the circumscribed and inscribed circle for the original area.

Figure 1. Diagram of an octagonal forging ingot mold: D1 - the outside diameter of the mold, D2 - diameter of the ingot, H - height of the ingot.

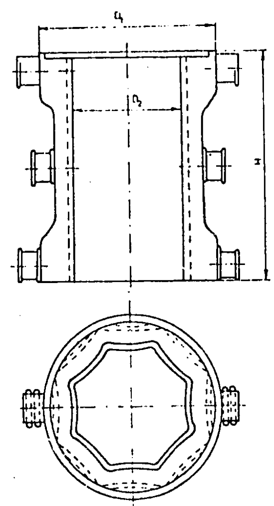
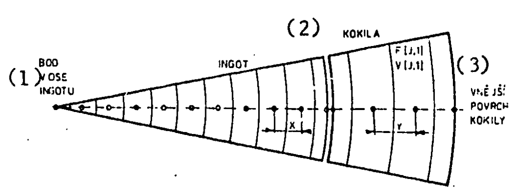


Figure 2. Grid points in a circular cross-section segment of an ingot and mold used to determine heat ranges on the HP 9830A calculator: F [J, 1]--surface of element; V [J, 1]--volume of element 1; X, Y--distance separating grid points in ingot and mold.



Key:
1. Ingot axis point
2. Mold
3. Outer mold surface

a) The program written for the HP 9830A calculator makes its possible on the basis of input data to determine the radial distribution of temperature gradients for the ingot and the mold (see fig. 2). It is assumed that the distribution of temperature gradients is not a function of the central angle, i.e., that the estimated temperature values refer to concentric circles circumscribed from the axis of the ingot. In the case of large ingots this assumption is entirely warranted, since occasional assymetries in heat dissipation, caused by the irregular formation of gaps between the ingot and the mold, are offset by the short duration of the heat resistance effect in the gaps between the ingot and the inside surface of the mold. The duration of this effect is negligible in relation to the total solidification time. For the solution itself the explicit method, which is usually not stable, was used, and the maximum time span is a function of the distance between adjacent grid points, the thermal-physical properties of the steel and cast iron, and the value of the heat transfer coefficient between the ingot and the mold and between the outer surface of the mold and the ambient environment.[11]

For the grid point lying on the outer surface of the mold we determine a maximum time span $\Delta\tau$ from the equations (1) and (2):

$$\Delta\tau = \frac{1}{2a\left[\frac{1}{(\Delta x)^2} + \left(\frac{\alpha}{\lambda}\right)\cdot\frac{1}{\Delta x}\right]} \qquad (1)$$

$$\Delta\tau = \frac{1}{a\cdot\left[\frac{\left(2+\alpha\frac{\Delta x}{\lambda}\right)}{(\Delta x)^2}\right]} \qquad (2)$$

where

1) a součinitel teplotové vodivosti $\lambda/c\rho$
2) λ součinitel tepelné vodivosti
3) c měrné teplo
4) ρ hustota
5) Δx vzdálenost sousedních síťových bodů
6) α součinitel přestupu tepla a povrchu kokily do okolí

Key:
1. thermal conductivity coefficient $\lambda/c\rho$
2. thermal conductivity coefficient
3. specific heat
4. density
5. distance between adjacent grid points
6. coefficient for transfer of heat from mold surface to ambient environment

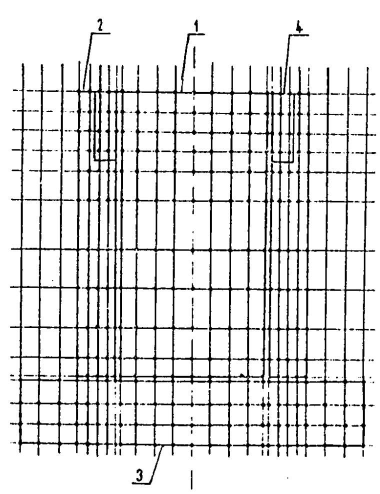
For the grid point lying on the surface of the ingot we estimate the maximum allowable time span for equations (1) and (2) when we substitute for α the coefficient for heat transfer from the surface of the ingot through the gap to the inner wall of the mold. In each time-lapse zone the program sets a minimum time range and estimates new temperatures at all grid time points by $\tau + \Delta \tau$.

The input data are: the specific heat of a given steel grade, liquid-state temperature, solid-state temperature, number of mold grid points, number of ingot grid points, ingot diameter, thickness of mold wall, desired time interval for printout of estimated values, ambient environment temperature, temperature of steel when being cast into mold, and mold wall temperature.

The merits of the program developed for this computer consist in the efficiency of the calculations and this makes it possible to measure the effect of various parameters on the ingot solidification process within a relatively short period of time.

b) The program written for the ICL 4/50 computer makes it possible, in comparison with the simplified model described above, to estimate temperatures in radial-tangential and vertical directions.[12] In some sections of the ingot it is also possible to make allowances for the narrowing of grid-point spacing, e.g., in places where two different kinds of material come into contact (fireclay and steel, steel and cast iron, and so on), when we want to obtain a more precise understanding of temperature time ranges in selected sections of the whole unit. In addition, we can monitor the transfer of heat from an ingot with an insulated head section; the grid-points diagram is shown in figure 3.

Figure 3. Grid diagram of a unit consisting of (1) an ingot, (2) insulation lining (2) a mold, (3) insulation lining and (4) a base for estimating a three-dimensional temperature range of a circular cross-section ingot on the ICL 4/50 computer.



APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200050037-4

Figure 4 shows a comparison of temperature flows at various distances from the surface of a 91-ton ingot estimated by the program used in conjunction with options a) and b). It can be said that the results are very similar. Figure 5 shows the vertical solidification process of a 50-ton ingot determined by means of a three-dimensional model per option b).

Figure 4. Distribution of temperatures at certain points in a 91-ton ingot:

1. at a distance of 0.1 R from the ingot surface (HP 9830A)
2. at a distance of 0.48 R from the ingot surface (HP 9830A)
3. at a distance of 0.6 R from the ingot surface (HP 9830A)
4. at the ingot axis point (R = 105 cm), coefficient of relative radiant energy ε_c = 0.53
5. at ingot axis point ε_c = 0.53 (ICL 4/50)
6. at ingot axis point ε_c - 0.23 (HP 9830A).

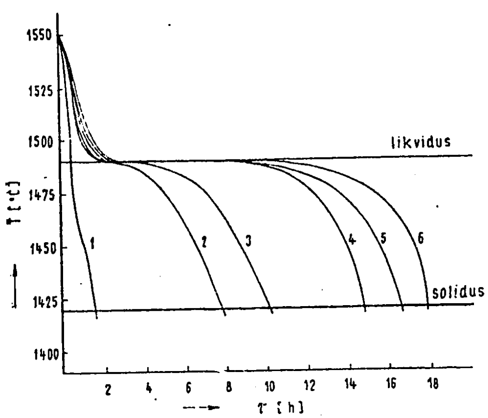
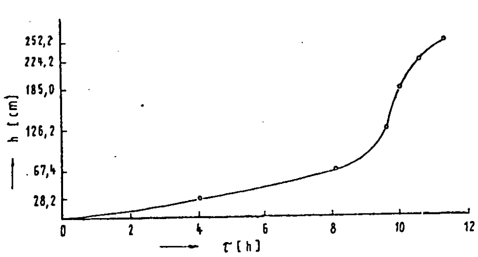


Figure 5. Vertical solidification gradient for a 50-ton ingot (ICL 4/50)



The solution is derived from the Fourier equation for heat conduction in a cylinder:

$$\frac{\partial t}{\partial \tau} c \rho = \frac{1}{r} \frac{\partial}{\partial r}\left(\lambda r \frac{\partial t}{\partial r}\right) + \frac{1}{r^2} \frac{\partial}{\partial \varphi}\left(\lambda \frac{\partial t}{\partial \varphi}\right) + \frac{\partial}{\partial z}\left(\lambda \frac{\partial}{\partial z}\right) \quad (3)$$

where:

1) r poloměr ingotu
2) φ středový úhcl
3) z souřadnici.

Key:
1. ingot radius
2. central angle
3. coordinates

The preceding equation simplifies the horizontal conduction of heat as follows:

$$\frac{\partial t}{\partial \tau} = a\left(\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r} + \frac{1}{r^2}\frac{\partial^2 t}{\partial \varphi^2}\right) \quad (4)$$

When the temperature of a grid point is not a function of the central angle and heat is transferred in a radial direction only, the equation is written as follows:

$$\frac{\partial t}{\partial \tau} = a\left(\frac{\partial^2 t}{\partial r^2} + \frac{1}{r}\frac{\partial t}{\partial r}\right) \quad (5)$$

On the basis of these equations familiar procedures are followed to write a differential equation which is sólved by means of the explicit or implicit methods. In our case we used the explicit method for options a) and b).

The finite-differences method permitted us to obtain a number of data on temperature gradients and solidification rates in very heavy ingots. The choice of a grid for an octagonal ingot posed a number of problems. The substitution of the octagon with a cylinder makes it impossible to determine a temperature range which would come as close as possible to matching real values. Since direct measurement of solidification time in large ingots is not possible, as we proceeded to plot temperature ranges for octagonal (usually polygonal) ingots we used the finite-elements method, which is applicable to surfaces and bodies of any shape. This method was used by A. Grill et al to estimate thermal stresses in continuously casted steel ingots[13].

The Use of the Finite-elements Method

In order to develop an algorithm for solving the two-dimensional and three-dimensional nonlinear problem of heat conduction we turned to the directors of the Computer Laboratory of the VUT [expansion unknown] in Brno. The needed algorithms were developed by the Computer Laboratory during 1977.[14,15] Based on the results of this work the Vitkovice Computer Center then proceeded to write up programs for plotting temperature ranges in polygonal ingots using its newly installed ICL 2960 computer.[16]

The solution of the two-dimensional nonlinear heat conduction problem is based on the primary equation:

$$c\,(t,x,y)\,\rho\,(x,y)\,\frac{\partial t(x,y,\tau)}{\partial \tau} = \frac{\partial}{\partial x}\left[\lambda\,(t,x,y)\,\frac{\partial t}{\partial x}\right] + \frac{\partial}{\partial y}\left[\lambda\,(t,x,y)\,\frac{\partial t}{\partial y}\right] + Q\,(x,y,\tau) \qquad (6)$$

where:

1) $Q\,(x,y,\tau)$ vnitřní zdroj tepla

$[x,y] \in \Omega,\ \tau \in [0,\tau_0]$

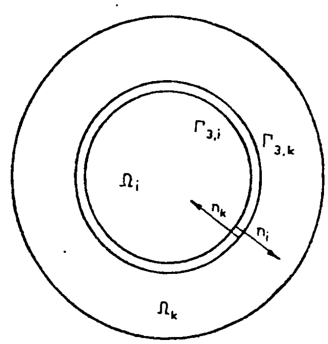
2) Ω rovinnou oblast

τ_0 délku časového kroku, v němž se hledá teplotní pole.

Key:
1. interior heat source
2. two-dimensional area of the length of the time zone in which the temperature range is being sought.

In addition to the usual marginal heat transfer conditions on the outer surface of the mold we also divide the Ω section into two contiguous subsections Ω_i and Ω_k in conjunction with a fixed heat flow intensity (see figure 6).

Figure 6. Diagram of ingot section Ω_i and mold section Ω_k with designation of interior boundary Γ_3 between the ingot and the mold; n_i and n_k represent the outer normal lines of boundary.



There are two interior boundaries between Ω^i and Ω^k. This means that allowances are made for a different temperature on either side of the interior boundary. Every point along the inner boundary Γ_3 corresponds to two temperature values. The heat exchange process along the boundary Γ_3 can be expressed as follows:

$$\lambda (t_i, x, y) \frac{\partial t_i (x, y, \tau)}{\partial n_i} = \beta (t_i - t_k) \qquad (7)$$

$$\text{pro } [x, y] \in \Gamma_{3,i}^{1}, \tau \in [0, \tau_0]$$

$$\lambda (t_k, x, y) \frac{\partial t (x, y, \tau)}{\partial n_k} = \beta (t_k - t_i) \qquad (8)$$

$$\text{pro } [x, y] \in \Gamma_{3,k}, \tau \in [0, \tau_0]$$

β stands for the heat transfer coefficient in the gap between the ingot and the mold.

The Galerkin method was used to perform the two-dimensional breakdown of the heat conduction problem. The boundary Γ, including the inner boundary, is approximately represented by a polygon and duly triangulated. The time breakdown of the problem is accomplished by means of the one-step A-stable linear method.

Figure 7. Diagram of one-eighth section of a 91-ton ingot with numbered macroelements representing the mold segment (1, 2, 3, 4), the ingot sector (5, 6, 7) and intersecting points for estimating the two-dimensional temperature range by means of the finite-elements method.

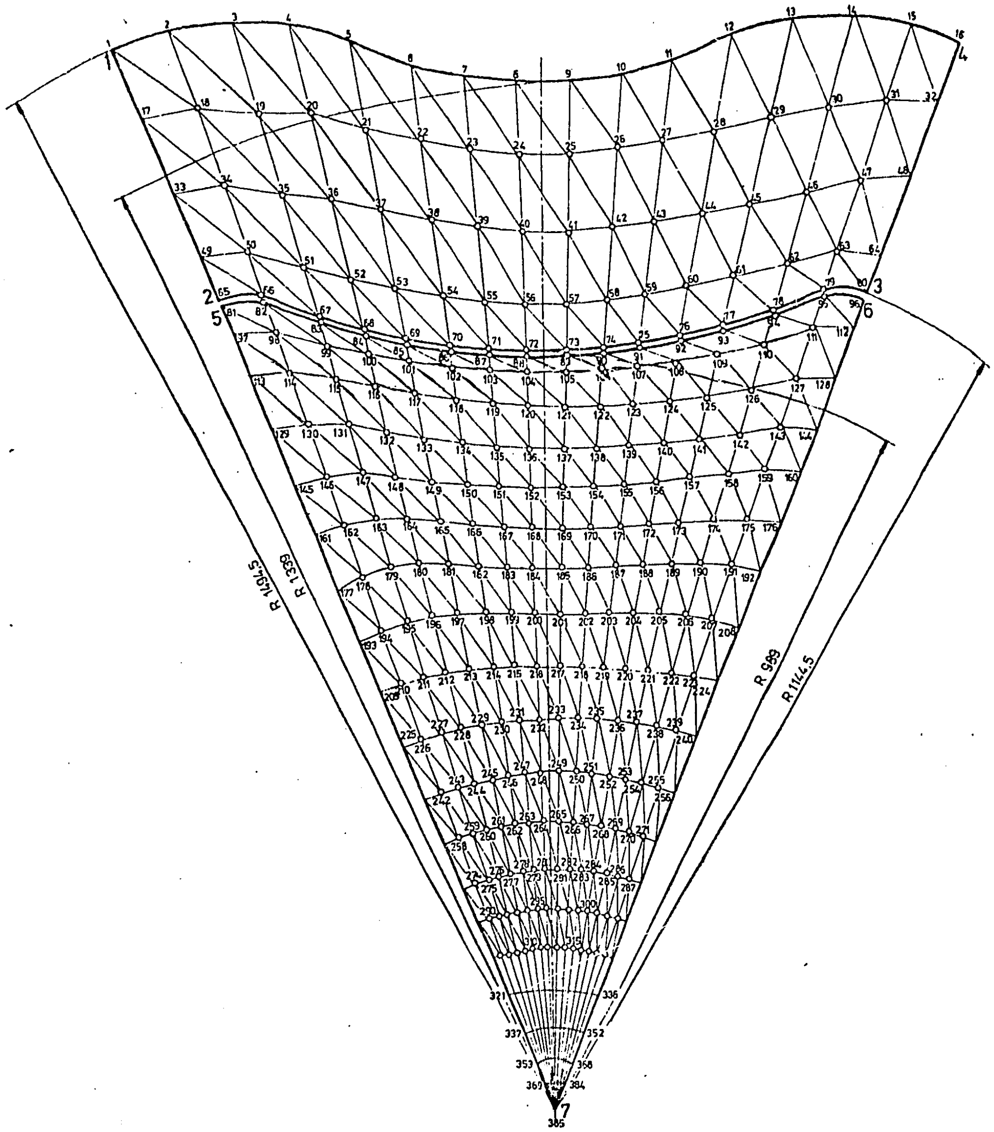


Figure 7 shows a diagram of the macroelements and triangulation for a one-eighth section of a 91-ton forging ingot. The Vitkovice Computer Center subsequently solved as many problems as it could in connection with the automation of the feed of input data while making thorough checks of their accuracy and making provisions for the graphic modeling of input and output data on a visual-display device with an on-line computer hookup.

The newly installed ICL 2960 system, which can very readily integrate various different programs, was used in such a way so as to insure, from the user's standpoint, maximum problem-solving flexibility while making allowances for user-initiated modifications of the operating system and at the same time so as to insure optimum efficiency in the utilization of the computer system.

These efforts led us to the conclusion that we should replace the current technique, which solves problems by means of a single, all-purpose program, with a technique based on the interaction of multiple programs linked by the data base to a disk memory whose operation is controlled by a macro written in the system's communications language (SCL).

Using this technique it is easy, for example, to insure effective control of the accuracy of input data or the accuracy of the automated breakdown of macroelements into primary elements without running the risk of wasting machine time on the running of a program with defective input data.

These programs make it possible to process contiguous and non-continuous areas of diverse materials while also making allowances for various marginal and initial conditions. The entire area can be broken down into any number of macroelements which can have square or triangular shapes with sides or straight or curved circular segments.

Every macroelement can consist of a different kind of material and its angular points can have different initial temperatures, and the program automatically divides them into the desired number of primary elements.

Any side of a macroelement can have an outer or inner boundary. The inner boundary represents a material discontinuity (gap) and the corresponding points on the inner and outer walls of the gap are interrelated by the interior heat transfer function.

There can be two kinds of interior boundaries:

1. They are indicated by the function (polynomials of any series depending on temperature and, transiently, time) governing the boundary temperature.

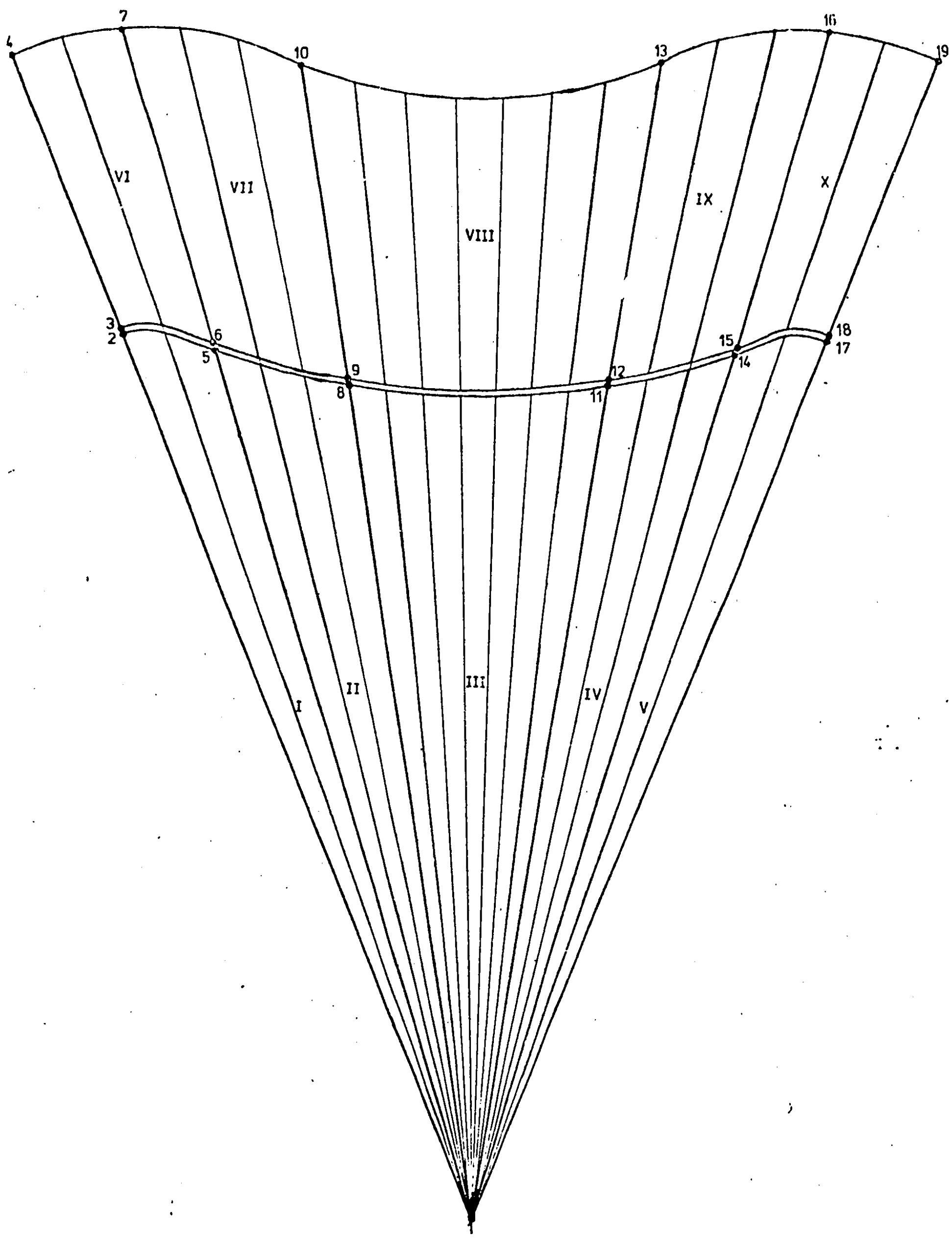
2. It is indicated by the combined transfer of heat by convection and radiation on the boundary where the convection coefficient is again computed from a polynomial of any series depending on temperature and, transiently, on time.

The material values of specific heat and thermal conductivity are also computed from polynomials of any series depending on temperature.

An entire area is automatically segregated so that, while the interior points are being established, certain allowances are made for the natural boundaries of the macroelement.

The numbering of all the intersecting points is accomplished in such a way as to insure that the width of the resulting band matrix of the system of linear equations is as narrow as possible, something which will consequently do a very effective job of reducing computation time. Figure 8 shows a diagram of the macroelements and intersecting points of the same segment of a 91-ton ingot as shown in figure 7, that has been automatically segmented by the computer program.

Figure 8. Diagram of a segment (as shown in figure 7) automatically segregated by a program written for the ICL 2960 computer.


4
7
10
13
16
19
VI
VII
VIII
IX
X
3
2
6
5
9
8
12
11
15
14
18
17
I
II
III
IV
V
1

Primary Input Data

In addition to the physical values for the materials of the ingot-mold unit, the results of the numerical process are also contingent upon the heat transfer coefficients, primarily those that apply to the boundary of the outer surface of the mold and the ambient atmosphere and to the gap between the ingot and the mold. A detailed analysis has already been made of all points where heat transfer occurs during the ingot solidification process.[17] When we monitor the cross-sectional solidification process in large ingots we find that heat transfer in the gap and on the surface of the mold is a critical factor.

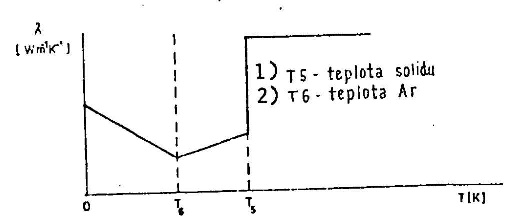
The thermal conductivity coefficient for steel (λ) varies within the range of prescribed temperatures. This variable, as a function of temperature, is described in figure 9. Similarly, figure 10 shows the functional relationship between the specific heat and temperature of steel. Equations developed by E. Mizikar were used for the designated temperature intervals.[18] British standards were used for the mold values.[19] The heat transfer coefficient on the surface of the mold was expressed by the following polynomial:

$$\alpha = 19{,}992 - 1{,}3124 \,.\, 10^{-2} \,.\, t + 1{,}433 \,.\, 10^{-4} \,.\, t^2 \qquad (9)$$

na základě práce A. I. Vejnika[4]).

which is based on work of A. I. Vejnik.[4]

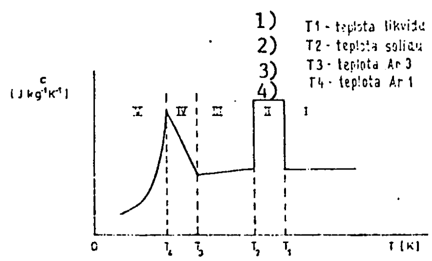
Figure 9. Gradient of steel thermal conductivity coefficient as a function of temperature.



Key:
1. solid-state temperature
2. Ar temperature

Figure 10. Gradient of specific heat value in steel as a function of temperature.

Obr. 9. Průběh součinitele tepelné vodivosti oceli v závislosti na teplotě.



Key:
1. liquid-state temperature
2. solid-state temperature
3. Ar 3 temperature
4. Ar 1 temperature

The atmospheric thermal conductivity coefficient was described by the equation:

$$\lambda_v = 0{,}021159 + 5{,}678 \,.\, 10^{-5} \,.\, t_m - 10^{-8} \,.\, t_m^2 \qquad (10)$$

where:

t_m = the arithmetic diameter of the outer surface of the ingot and the inner surface of the mold.

The width of the gap between the ingot and the mold has no effect on the solidification time of large ingots. Still, during the course of our research work considerable attention was focused on the problem of the development of such a gap. It was found that the conductivity factor of heat transfer within this gap serves to raise the temperature on the outer surface of the mold to higher levels than those detected by direct thermocouple readings. Therefore, in the case of large ingots it suffices to presume that heat is transferred across the gap by radiation only. The use of the gap-width equation (11) derived from Yefimov's measurements[20] of a 6-ton ingot has an important role to play in determining heat transfer in smaller ingots.

$$d = 0{,}5\,D\,\alpha\,t - \frac{n}{4}\cdot\frac{\rho\,H\,D^2}{k\sqrt{\tau}} \qquad (11)$$

where:

1) ρ hustotu tekuté oceli [7000 kg . m^{-3}],
2) n součinitele (0,333 až 0,8) . 10^{-7},
3) k součinitele tuhnutí oceli v kokile (0,015 až 0,018 m . $min^{-0.5}$),
4) τ dobu od odlití ingotu [min],
5) α součinitele objemového smrštění při tuhnutí,
6) t teplotní spád mezi tekutým jádrem ingotu a povrchem ingotu,
7) D průměr ingotu [m],
8) H hloubku horizontální roviny pod hladinou kovu [m].

Key:
1. density of liquid steel (7,000 kg . m^3)
2. coefficients (0.333 to 0.8 . 10^7)
3. coefficients for solidification of steel in mold (0.015 to 0.018 m . $min^{0.5}$)
4. time elapsed since casting of ingot (min)
5. coefficients for volume of contraction during solidification
6. temperature drop between molten ingot core and ingot surface
7. diameter of ingot (m)
8. depth of flat plane beneath metal top (m)

In large ingots the value of the thermal radiation coefficient C, or relative radiant energy, has a critical impact on heat transfer in the gap area. The tabular data values for relative radiant energy for the ingot surface (ε_i = 0.85) and for the surface of the mold (ε_k = 0.7) were used initially. The resulting radiant energy coefficient conforming to the equation:

$$\varepsilon_c = \frac{1}{1/\varepsilon_i + 1/\varepsilon_k - 1} \qquad (12)$$

had a value of 0.62.

Measurements of the Temperature on the Surface of the Mold for a 91-ton Octagonal Ingot and Comparisons with Estimated Values

As we pointed out in the beginning, the taking of direct temperature readings in ingots with long solidification times is for all practical purposes not feasible. We therefore measured surface temperatures at three horizontal levels, namely, 150 mm away from the line separating the ingot head and body, in the center of the ingot and 150 mm away from the base of the ingot as shown in figure 11. Measurement readings were taken over a period of 22 hours. As a result of our evaluation of the measured temperatures it was found that the estimated temperatures were higher, especially during the first few hours after casting, than the actually recorded temperatures. Inasmuch as our measurements of temperatures at the surface of a mold containing a 50-ton ingot produced identical results, it was thus demonstrated that the values for relative radiant energy emitted by the ingot and mold could not be accurate. We had previously determined that the amount of heat transmitted in the gap by conduction has no noticeable effect in the case of large ingots. Likewise, the intensity of the heat flow on the outer surface of the mold, as expressed by the coefficient per equation (9), matched our earlier experimental findings.[9]

Alternatively, the various values of the coefficient for relative radiant energy were also tested using the program written for the HP 9830A calculator. These tests showed that the measured and estimated surface temperatures matched perfectly, displaying a coefficient value of $\varepsilon_c = 0.26$. Figure 12 shows the results of estimated surface temperature values together with the actually measured values. The solidification time of the 91-ton ingot was increased by 0.7 percent in comparison with the coefficient $\varepsilon_c = 0.62$ that was originally used. The temperature gradient, as determined by the finite-difference and finite-element methods, proved to be very similar.

Figure 11. Measurement Points on the surface of a mold containing a 91-ton ingot.

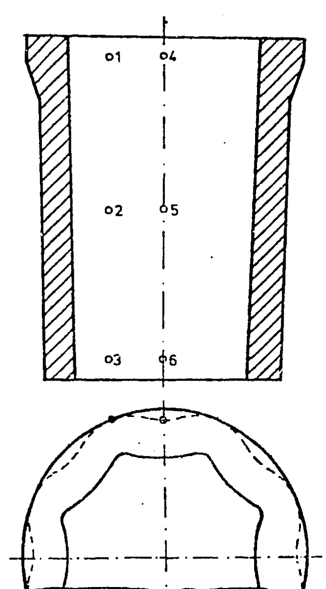
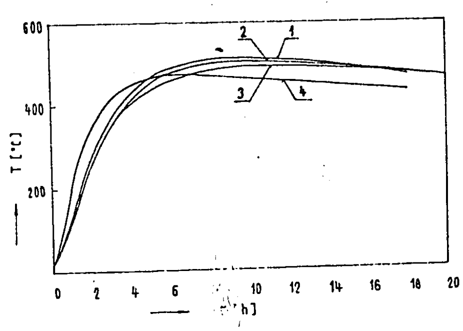


Figure 12. A comparison of measured temperature values with estimated values: 1) estimate made with a HP 9830A calculator (ε_c = 0.28), 2) estimate made with a HP 9830A calculator (ε_c = 0.23), 3) measured gradient at point 2 (per diagram in figure 11), 4) estimate made by means of finite-elements method using the ICL 2960 computer (ε_c = 0.53).



Conclusion

The use of immersed thermocouples to determine the solidification time of large ingots is not yet feasible. A knowledge of temperature ranges makes it possible to enhance the efficiency of foundry operations and to reduce necessary ingot cooling time, which these days are very often processed in vacuum box molds. Due to the long solidification times of large ingots a knowledge of total solidification time could help to improve box-mold utilization and thereby boost the productivity of casting foundries. A knowledge of solidification processes is essential in order to do research on the basic nature of segregations in large ingots and castings and also in order to develop certain new casting techniques.

At the sectoral enterprise Vitkovice, which manufactures heavy forging ingots in steel plant numer 2, computer programs were developed to describe the solidification process and temperature ranges of ingot forging pieces on the basis of the finite-differences method used in conjunction with a Hewlett-Packard 9830A desktop calculator and an ICL 4/50 computer. Based on its collaboration with the VUT [expansion unknown] Computer Laboratory in Brno, which developed an algorithm for the solution of the two- and three-dimensional nonlinear heat conduction problem by means of the finite-elements method, the Vitkovice Computer Center wrote a program for the ICL 2960 computer for the estimation of temperature ranges in octagonal (polygonal) ingots. The program automatically segregates the designated area by triangulation, while at the same time making allowances for the prescribed boundaries of the macroelements. These programs were used to obtain information on temperature gradients in heavy forging ingots. The estimated values were doublechecked by taking long-term temperature readings on the surface of a mold containing a 91-ton ingot. A comparison of estimated and measured values revealed that the accuracy of tabular values for the relative radiant energy of the ingot surface and the working surface of the mold is not reliable. The perfect harmony of experimental and estimated values was achieved by using the coefficient $\varepsilon_{\omega} = 0.26$. The findings obtained thus far show that, in accordance with the finite-elements method, solidification times are approximately 8 percent shorter than those obtained using the finite-differences method. This discrepancy is probably due to the varying basic geometric dimensions of the ingot coupled with the application of two different calculation methods.

BIBLIOGRAPHY

1. Price, P.H. and Slack, M.R., BRITISH JOURNAL OF APPLIED PHYSICS, Vol 3, Dec 1952, pp 379-384.

2. Parmentier, P. and Sevrin, R. REVUE UNIVERSELLE DES MINES, Nov 1959, pp 783-795.

3. Schniewind, J. JISI, July 1963, pp 594-601.

4. Veynik, A. I. "Teploobmen mezhdu slitkom i izlozhnicey" (Heat Exchange Between Ingots and Casting Molds), Moscow, Metallurgizdat, 1959.

5. Kohn, A. and Morillon, Y. REVUE DE METALLURGIE, No 4, 1965, pp 321-338.

6. Narita, K. and Mori, T. ISU TRANSACTIONS, Vol 12, 1972, pp 83-88.

7. Smrha, L. and Fiser, O. HUTNICKE LISTY, No 5, 1974, pp 327-334.

8. Smrha, L. Proceedings of the International Conference on Physicochemical Processes in Steel Manufacturing, Roznov, November 1972.

9. Smrha, L. and Sustek, J. HUTNICKE LISTY, No 9, 1976, pp 623-636.

10. Smrha, L. and Sustek, J. "Sbornik vyzkumnych praci Vyzkumnych Ustavu VITKOVIC 1971-1975" (Collected Research Papers of the Vitkovice Research Institutes 1971-1975), pp 48-50.

11. Ruddle, W. The Solidification of Castings, 2nd ed, London, 1957.

12. Pokuta, P. "Vypocet teplotnich zmen v ingotu kruhoveho prurezu sit'ovou metodou" (Estimating Temperature Changes in Circular Cross-section Ingots by Means of the Network Analysis Method), VITKOVICE, September 1976--a program for the ICL 4/50 computer.

13. Grill, A.; Brinacombe, J.K.; and Weinberg, F. IRONMAKING AND STEELMAKING, No 1, 1976, p 38.

14. Cermak, L. and Zlamal, M. "Reseni rovinne a prostorove rotacne symetricke nelinearni ulohy vedeni tepla" (Solution of the Two- and Three-dimensional Rotation-Symmetric Nonlinear Heat Conduction Problem), VUT Computer Laboratory, Brno; report prepared for the VITKOVICE Research Institutes, March 1977.

15. Cermak, L. and Zlamal, M. "Reseni prostorove nelinearni ulohy vedeni tepla" (Solution of the Three-dimensional Heat Conduction Problem), VUT Computer Laboratory, Brno; report prepared for the VITKOVICE Research Institutes, September 1977.

16. Sustek, J; Rusin, Z.; and Pokuta, P. "Program vypoctu rovinee nelinearni ulohy vedeni tepla pro pocitac ICL 2960" (A Program for Computing Two-dimensional Nonlinear Heat Conduction Problems on the ICL 2960 Computer), VITKOVICE, 1979.

17. Smrha, L. "Tuhnuti oceli v kokilach" (The Solidification of Steel in Molds), report of the VITKOVICE Research Institutes, 1977.

18. Mizikar, E. TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, Vol 239 Nov 1967, pp 1747-1753.

19. Tables of the British Bureau of Standards, 1954.

20. Yefimov, V. A. etal. "Voprosy proizvodstva stali" (Problems of Steel Manufacturing), 7th ed, Kiev, Academy of Sciences of the USSR, 1960, p 135.

11813
CSO: 2402

CZECHOSLOVAKIA

USE OF UNCONVENTIONAL MACHINING METHODS DISCUSSED

Prague STROJIRENSKA VYROBA in Slovak No 10, Oct 79 pp 756-758

[Article by Engr Augustin Herceg, Vah Engineering Works National Enterprise, Povazska Bystrica]

[Text] The article discusses the nonconventional EMO (electrical machining methods) at the Vah Engineering Works, using machines that operate on the principle of EIO (electric-discharge machining) or ECHO (electrochemical machining).

Although the Vah Engineering Works National Enterprise of Povazska Bystrica has been building for many years equipment for electric machining methods that was developed by VUMA [Research Institute of Mechanization and Automation] of Nove Mesto nad Vahom, the enterprise itself uses relatively few such machines.

In terms of use, the machines can be subdivided as follows:

Machines now in use,
Machines prepared for use, and
Machines prepared for eventual use, for example, through 1983.

Significant structural changes have been made in recent years in the product assortment of the Vah Engineering Works. A transmission shop, a forge for semifinished products, a shop for large bearings, etc. are now under construction. For this reason there are growing demands on the tool shop to increase its capacities in special tools for plastics, forging dies for steel and brass, and molds for pressure casting. The output of nonferrous metals is also increasing, and the assortment of rods and shapes is being expanded, for which new tool materials (SK [sintered carbides]) are being introduced that offer longer tool life. For these reasons it is necessary to introduce the production of tools by nonconventional machining methods.

For the past two decades the Vah Engineering Works has already been manufacturing some machines for electric machining methods. Such machines include the following:

1. Machines operating on the principle of electric-discharge machining (EIO). Electric-discharge machining is intended for the fabrication of cavities and holes in materials that are not readily machinable, such as steels of grades 17 and 19, titanium, tungsten or sintered carbide, and also nonreadily machinable materials that involve demanding operations in terms of shape, or microapertures and the cutting of deformable parts.

2. Machines operating by the method of electrochemical machining (ECHO). The application of electrochemical machining is based on the principle of removing metal through its anodic dissolution. There are several modifications of electrochemical machining, and the best-known ones are as follows:

Electrochemical die-sinking,
Electrochemical grinding and sharpening, and
Electrochemical deburring.

Here we present information on equipment for electric machining methods that the enterprise

Already uses in production, such as the VJK 2, VJK 5, EBT 2, and Agathos machines;

Is now preparing to use in production in 1979-1980: the ECHO 2 and the EID 5 M machines; and

Is preparing to eventually use in production in 1981-1982: the EIH 8 SM, the ECBT 8 F, and the ECH S3 machines.

Technological Applications of Nonconventional Machining Methods at the Vah Engineering Works

Electrochemical Grinding

The technology of electrochemical grinding is employed on the VUMA machine of the VUMA - EBT 2 series and, among the foreign machines, on the Agathon. The EBT machines use the VUMA method of electrochemical grinding with a loose abrasive, primarily for the form-grinding of sintered-carbide cutting tools. With the help of attachments it is possible to grind also surfaces of rotation. The tool employed is a wheel of material 11 600 that does not undergo wear in the process of grinding.

Achieved results: The metal-removal rate at a grinding surface of 1 cm^2 is approximately 100 mm^3/min. The form-grinding time as a function of the depth is 3 to 7 minutes/workpiece. The attained accuracy V IT 10 is 0.1 to 0.2 mm. The surface roughness R_a is 0.2 to 1.2 μm.

Advantages of electrochemical grinding: In comparison with the mechanical grinding of sintered-carbide tools, electrochemical grinding offers a high metal-removal rate and a very good finish. The ground surface is not affected or damaged.

Technical Characteristics of the EBT 2 Machine

Table's clamping surface	300 x 560 mm
Sliding traverse	320 mm
Surfacing traverse	200 mm
Range of automatic feed	
Traverse feed	To 40 mm/min
Downfeed	To 4 mm/min
Wheel diameter/maximum width	135-240/100 mm
Source	400 A
Operating voltage	5 to 15 V
Capacity of electrolyte tank	10 liters
Spindle's electric drive	2850 rpm

The Swiss-made Agathon machine is likewise used to grind flat surfaces on sintered-carbide tools. The principle of grinding and the electrolyte are the same as above, except the tool is a DIA [aluminum oxide] wheel.

Electrochemical Deburring

Electrochemical deburring is based on the principle of removing through anodic decomposition the burrs on a workpiece after its mechanical machining. Primarily the parts of the workpiece closest to the electrode are removed. The tool electrode is stationary in relation to the workpiece. The parts of the workpiece that are to remain intact must be suitably insulated. Parts are deburred in special fixtures. The technology of electrochemical deburring was successfully designed and tested in deburring large brass separators for spherical roller bearings, on a machine of the VUMA ECHO 2 series (Fig. 1) that operates as an automatic machine.

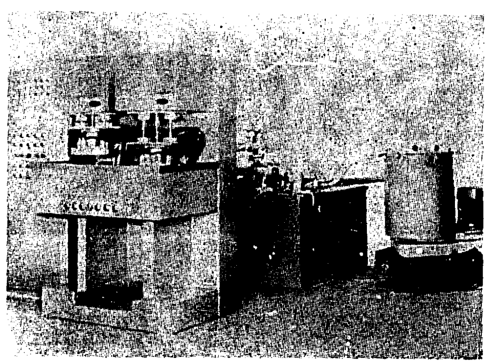


Figure 1. Overall view of the ECHO 2 machine.

Advantages of electrochemical deburring: The quality of deburring is good. The labor intensity is reduced by as much as 50 percent, under better working conditions, and manual labor is eliminated. Here it is possible to automate the process of deburring.

Parameters of Deburring Brass Separators

Operating voltage	6 V
Operating current	450 A
Electrolyte	$NaNO_3$, 15-percent solution
Electrolyte conductivity	0.135 Ω/cm
Electrolyte pressure	1.96 MPa
Deburring time	2 min/workpiece

Technical characteristics of the Echo 2 machine

Number of fixtures	2
Maximum height of fixture	400 mm
Pneumatic cylinder's maximum lift	200 mm
Table's clamping surface	650 x 1050 mm
Source	1200 A
Operating voltage	6-25 V
Capacity of electrolyte tank	1200 liters
Pump output	80 l/min/0.3 MPa

Electrochemical Die-Sinking

In cooperation with VUMA of Nove Mesto nad Vahom, electrochemical die-sinking is used to sink the dies for forging the large brass separators with preforged pockets (Fig. 2) in the single-row roller bearings of types RN 220 MB/P6, N 220 M, and NUP 224. The solution to make the die cavities by electrochemical die-sinking is estimated to reduce the labor intensity as follows:

Machine time in conventional machining	10 standard hours
Machine time in electrochemical machining	1 standard hour
Machine time for finishing the die cavities after electrochemical machining	1.5 standard hours

Dies were made on the VUMA ECH S3 equipment that employs the technology of electrochemical machining with a mixture of air and electrolyte.

Technological Parameters of Electrochemical Die-Sinking on the VUMA ECHS 3 Machine

Principle of metal removal	Electrochemical
Working fluid	2-component $NaNO_3$ electrolyte
Working tool	Tool electrode
Feed	0.4 mm/min
Operating voltage	9 V
Operating current	2000 A

Results attained in electrochemical die-sinking:
Accuracy ±0.05 mm on a machined surface up to 0.5 dm^2
±0.1 mm on a machined surface up to 1.5 dm^2
Roughness R_a = 0.2 to 1.5 μm, depending on the type of material
Machining speed 0.2 to 1 mm/min

Technical Characteristics of the VUMA-ECHS 3 Machine

Source corresponding to machined surface	5000 A
Operating voltage	0-20 V
Total power demand	125 kVA
Spindle lift	250 mm
Quick feed	250 mm/min
Table's clamping surface	500 x 1000 mm
Maximum distance of die block from table level	500 mm

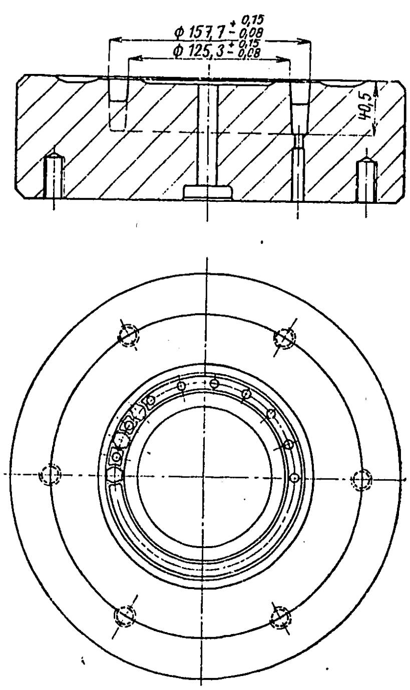


Figure 2. Electrochemically sunk forging die for the brass separator of the RN 220 bearing.

Advantages of electrochemical die-sinking: The metal-removal rate depends on the chemical composition of the material, and not on its mechanical properties. There is no wear of the tool electrode during machining. The faster the machining speed, the better the quality of the machined surface. The surface of the material is not affected by machining.

Electric-Discharge Machining

Among the electric-machining methods, electric-discharge machining is one of the most widespread and industrially most often used methods. It supplements the conventional machining methods. It is intended for machining cavities and holes in materials that are difficult to machine, such as certain types of grade 17 and 19 steels, heat-treated sintered carbides, etc.

The Vah Engineering Works uses at present electric-discharge machines of the VJK series. The older model, VJK 2, is used in the pressing shop to make drawing dies and stamping dies of grade 19 tool steels and sintered carbides. Examples of its application are shown in Fig. 3.

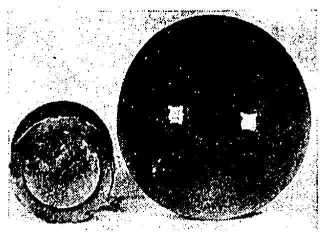


Figure 3. Examples of electric-discharge machining on the VJK 2 machine.

The VJK 5, a newer model, is used in the tool shop to machine punches and apertures of circular or other shapes, in sintered carbides and hardened tool steels (Fig. 4).

Basic Technical and Technological Data of the VJK 5 Machine

With the help of N/C slides, feed can be set with an accuracy of ±0.005 mm.
Minimum roughness of the machined surfaces R_a = 1 μm
Positioning feed of the electric-discharge head up to 150 mm/min
Maximum machined surface 20,000 mm^2
Maximum weight of machined workpiece 250 kg
Maximum dimensions of the machined workpiece 400 x 600 x 300 mm or diameter 600 x 300 mm

Table's clamping surface 400 x 600 mm
Working fluid- industrial kerosene
Tank capacity 160 liters
Machine dimensions (L x W x H) 1200 x 850 x 1900 mm
Machine weight - approximately 1500 kg

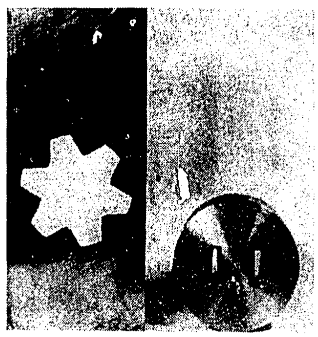


Figure 4. Examples of electric-discharge machining on the VJK 5 machine.

Other machines planned for future use at the Vah Engineering Works include the following:

EID 5 M, a coordinate electric-discharge perforating machine, will be used to make contoured and rotational precision tools of small dimensions, such as forging, stamping and drawing dies, and tools of a similar nature.

ECBT-8F, an electrochemical milling machine, is intended for the electrochemical milling of sintered-carbide tools, by the method of an abrasive diffused in the electrolyte.

1014
CSO: 2402

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200050037-4

CZECHOSLOVAKIA

EXPERIENCE WITH INTRODUCTION OF N/C MACHINES TOLD

Prague STROJIRENSKA VYROBA in Slovak No 10, Oct 79 pp 762-765

[Article by Engr Imrich Biescar of the Vah Engineering Works National Enterprise, Povazska Bystrica]

[Text] Experience with introducing N/C machines in the production of machine tools, large bearings, and transmissions for tractors and for construction and road machinery. Changes in the organization of management and their economic effect. Production of N/C machines. Ways of further utilizing N/C machines. Automation of programming. Sets of N/C machines. Innovation of the production of N/C machines.

The Vah Engineering Works is making extensive structural changes in its production programs, and in conjunction with this the enterprise is also undergoing extensive capital construction that will double its fixed capital as compared with the situation before the start of capital construction. In accordance with these changes, innovation is taking place of the technological processes of machining, through the introduction of numerically controlled machine tools, machining centers, and IVU [integrated production sections]. We now have in operation or startup 49 N/C machines on which 451 parts are processed. The introduction of these machines at our enterprise will result in relative savings of manpower, floor space and electric power, and in shorter production time. In the final outcome, this will produce a 2.5-fold rise in labor productivity as compared with the previous technology, and annual savings of nearly 2.0 million korunas.

In view of the wide assortment of our products, we set as our objective not only to automate series production with the help of special-purpose machines, but also to introduce the most advanced technology, with the maximum degree of automation, to recurring custom and small-series production in lots of 10 to 300 a month.

After a detailed analysis of our parts base, we selected the N/C machines and machining centers, both domestic and foreign. In conjunction with the selection of the machines we worked out a project for assigning sets of N/C machines to the individual manufactures, so as to achieve the greatest possible gains in labor productivity in comparison with the conventional technology. Today our enterprise has in operation or startup 49 N/C machines, machining centers and integrated production sections. Sets of N/C machines have been introduced in the plants of our enterprise as follows:

In the production of machine tools we have six N/C machines and one ITU 200. On these N/C machines we machine 263 parts;

In the production of large bearings, 108 parts are machined on 13 N/C machines and four machining centers;

In the production of transmissions we have 23 N/C machines and three machining centers, on which we machine 80 parts.

Parallel with the gradual introduction of N/C machines in production, we are training our workers, at the manufacturer, in programming and in electrical and mechanical maintenance of the machines.

So far as the writing of programs is concerned, we decided to provide control systems for all our N/C machines in a single code, namely EIA-RS 244. This saves us a programming automaton for the IOS code.

At present the programs for all our N/C machines are being written manually, with the help of a Consul 251 programming automaton.

Production of N/C Machines

The first N/C machines that we introduced in our production of machine tools were of Czechoslovak make, namely the SPN 12 lathe and the WHN 9A horizontol boring machine. Even before these N/C machines were delivered, and after our programmers were trained in programming at the manufacturers, we wrote programs for about 50 percent of the parts. The programs for the SPN 12 lathe were debugged at the Malenovice plant of ZPS [Precision Machine Plants) of Gottwaldov. Here we simultaneously tested automatic programming on a computer, using AUTOPROG. This was done in cooperation with VUOSO [Machine Tools Research Institute] of Prague, which wrote these programs for us.

Production of Large Bearings

In the production of large spherical roller bearings we introduced for the production of 6 TPRM bearings two NDM 22/90 lathes equipped with the Sinumerik 521 K continuous control system. The machines are arranged in a line and are served by an automatically programmable loader (Fig. 1). The entire line was supplied by the Georg Fischer Company of Switzerland.

According to the technology originally proposed by Georg Fischer, the bearing rings were to be machined on this line from forgings, including the finishing operations. After the delivery and testing of this line, the production plan for bearings doubled, and for this reason the line with its originally proposed programmed technology would have been unable to ensure the capacity necessary for this production. In order to meet the increased production plan for bearings, we were forced to raise the productivity of the line by including two roughing operations on SU 80 machines.

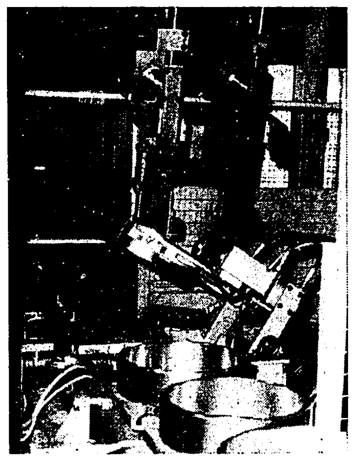


Figure 1. Programmable loader serving two NDM 22/90 machines arranged in a line.

We revised the operational plans so that all internal and external rings could be machined with the same set of renewable-tip tools. Six tools are needed to machine the internal ring, but only two for the external ring. To utilize the maximum feed while maintaining the prescribed machining accuracy of 3.2 μm, we selected a fillet radius of 1.6 mm for the cutting edge. Economic use of these machines was feasible only by increasing the cutting parameters: the cutting speed, the feed, and the metal-removal rate. Because the renewable tips manufactured in Czechoslovakia did not meet these requirements, we tested foreign renewable tips made by the Sandvik, Kennametal, Carboloy and Seco companies. On the basis of these tests, in which representatives of the individual companies participated, it was found that Kennametal renewable tips were suitable for our conditions of machining at that time, namely type KC 810 with a chip-former, and VNM 6 with a rake angle $\varepsilon = 35°$. On materials whose hardness ranged from 174 to 257 Brinell, we achieved suitable speeds for the following types of cuts: rough cuts, v = 120 m/min; finishing cuts, v = 140 to 150 meters per minute. At a cut depth of 2 to 5 mm and a feed of 0.25 to 0.9 millimeters per revolution, tool life was 30 to 40 minutes.

A further opportunity to raise productivity has emerged at present, by using Sandvik tips RCMX 16 06 00 GC 015. In tests with cutting material GC 015 we attained a cutting speed of 200 m/min; here the line's cycle dropped from 5 to 3 minutes on the inner race of bearing 23234 B, but the 0.75 minute for changing the workpiece cannot be shortened.

By optimizing the conditions of machining and by introducing high-speed cutting materials, we have achieved a fivefold rise in productivity as compared with the conventional production technology on ordinary machines, and annual savings of more than 400,000 korunas on this line. This total corresponds to partial savings of 13,500 standard hours of machine time, 50,000 kWh of electricity, and 220,000 korunas of savings on tool costs, as compared with the proposal submitted by the supplier.

For the finishing operations of grinding the raceways and faces of the special large bearings equipped with gear rings (Fig. 2), we introduced nine VGM single- and double-spindle turret-type grinders (Fig. 3) made by the Berthiez Company of France, on which we machine twenty-four TPRM large bearings ranging from 500 to 3000 mm in diameter. These high-capacity machines represent a sort of transition between conventional and N/C machines, because the program is entered manually into the Sinumerik 56 S control system. These are machines of very rigid design, which permits full use of the optimal machining parameters with a highly efficient abrasive. In the final outcome this corresponds to a 40-percent reduction of labor intensity as compared with the original technology.

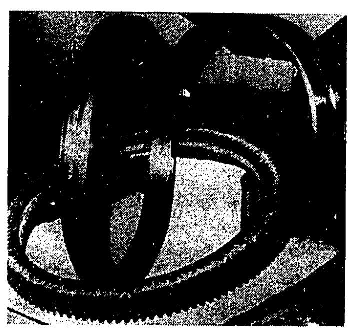


Figure 2. Typical parts of the large bearings, machined on the VGM machines.

Production of Transmissions for Tractors, and Construction and Road Machinery

At our enterprise we will gradually produce four types of transmissions, in 14 variations, for road and construction machinery. These transmissions

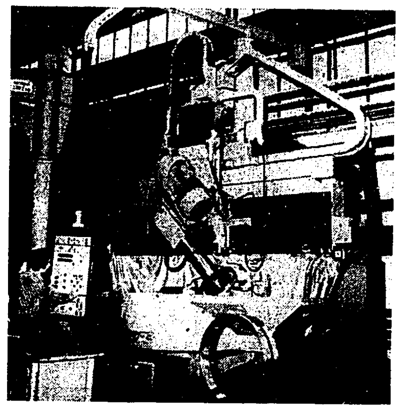


Figure 3. The VGM 120 numerically controlled turret-type grinder.

will be machined on two CU 9 machining centers (Fig. 4), built in Hungary under a licensing arrangement with Forest of France. At present we are using these centers to machine the housing and auxiliary housing (Fig. 5) of the Z 16045 transmission for tractors. Once full series production is attained, this transmission will be built on automatic lines. The housing, on a line supplied by Pavesi of Italy; and the auxiliary housing, on a line supplied by TOS [Machine Tool Works] of Kurim. The lines will comprise special single-purpose machines.

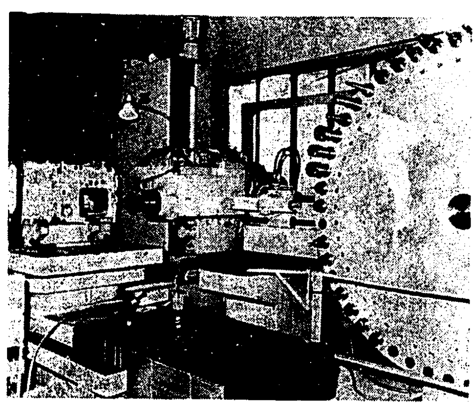


Figure 4. The CU-9 numerically controlled machining center machining the Z 16045 tractor transmission's housing.

The housing measures 775 x 480 x 400 mm, and its machining involves the following operations:

Milling 12 surfaces,
Reaming 16 holes,
Boring 11 holes 30 to 140 mm in diameter,
Cutting: a. Nineteen M 8 threads, and
b. Eight M 14 threads.

The magazine holds 37 different tools, and the time required for the mentioned operations is 574 minutes.

The auxiliary housing measures 530 x 520 x 310 mm, and its machining involves:

Milling 9 surfaces,
Drilling 63 holes,
Reaming eight holes,
Boring nine holes,
Cutting: a. Thirty M 8 threads,
b. Twenty-four M 14 threads,
c. One M 16 x 1.5 thread, and
d. One M 42 x 1.5 thread.

For these operations the magazine stores 35 different tools. The machining of one auxiliary housing takes 720 minutes.

The total number of tools required for machining the housing and auxiliary housing is 72. Their composition, in terms of the cutting material, is as follows:

RO [high-speed steel] - 54 percent, i.e., 39 of the tools;
Sintered carbide - 46 percent, i.e., 33 of the tools, includind three made of VD [vanadium].

Through the suitable layout of the consecutive technological operations and the utilization of maximum cutting conditions in machining, with due consideration for the rigidity of the machine and optimal tool life, the introduction of these two CU 9 machining centers raised productivity by as much as sixfold, as compared with the original technology. In spite of these favorable results, we will continue to optimize the programs so as to replace the tools made of high-speed steel -- on the boring and milling machines -- with sintered-carbide tools.

Changes in the Organization of Management, Economic Gains

The optimal and smooth operation of the machines at our enterprise required the following:

Changes in work organization,
Regular deliveries,

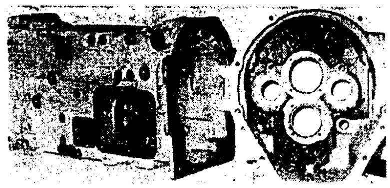


Figure 5. The Z 16045 tractor transmission's housing and auxiliary housing, machined on the CU-9 machining center.

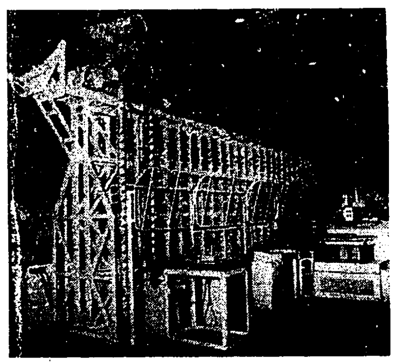


Figure 6. Layout of the IVU 200 integrated production section's basic module. 1 - in-process storage rack with stacking crane; 2 - OCV-1 machining center; 3 - OCH-1 machining center; 4 - vertical milling machine; 5 - initial processing station, entry and exit of materials; 6 - IMS-1 coordinate measuring machine; 7 - EUC DIA ultrasonic washer; 8 - toolroom, issuance of tools; 9 - carts for transporting the laid-out tools to the OCV-1 and OCH-1 machining centers; 10 - supplies; 11 - dispatcher; 12 - maintenance station.

Adequate supply of spare parts,
Regular diagnostic inspections of the machines' electrical and mechanical parts,
Optimization of the programming documentation, with possibilities for using advanced cutting materials so as to save machine time,
Regular monitoring and evaluation of the N/C machines' operation so as to flexibly eliminate the recurring organizational and technological shortcomings.

The gradual introduction of all 49 N/C machines at our enterprise will result in the following annual savings: 92,000 standard hours in labor intensity, 120,000 kWh of electricity, 200,000 korunas' worth of floor space, 184,000 korunas of social overhead, and 350,000 korunas of tools.

Production of N/C Machines

Our enterprise not only uses N/C machines but also actively participates in their production. The functional model of the IVU 200 integrated production section, designed within the framework of the state program by VUSTE [Engineering Technology and Economy Research Institute] of Prague, was built at our enterprise. In cooperation with VUSTE, we prepared the technology and the programming documentation, and tested the programs for the OCV-1 and OCH-1 numerically controlled machining centers of the third developmental stage. At present the integrated production section is undergoing operation tests. In two-shift operation we are machining 92 parts, and the number of parts is being increased systematically. Simultaneously we are testing a project for production scheduling with a TESLA 200 computer, in conjunction with the entire conventional production of machine tools. Once they are brought to the planned capacity, we expect productivity to double.

The IVU 200 integrated production section is intended for machining flat and box-shaped parts, to the size of a cube whose sides measure 200 mm. The parts intended for machining may be steel, aluminum of alloy castings.

The basic module of the IVU 200 integrated production center produced at our enterprise (Fig. 6) occupies a floor space of 272 m^2. It consists of an in-process storage rack 10.2 m long, with a travelling stacker crane. The in-process storage rack divides the workplace into two parts. The machine tools are located to the left of the in-process storage rack.

To the right of the rack are the following: The initial-processing station; from here the part moves on a transport or technological pallet to the storage rack, and from there to the designated OCV-1 or OCH-1 machining center; the IMS-1 control measuring machine for checking the machined parts; an ultrasonic washer for degreasing the parts and removing the impurities that remain after machining.

The entire workplace is managed through a dispatcher. All the technological work stations are interconnected with the in-process storage rack by means of an automatic pallet conveyor.

Ways for the Further Utilization of N/C Machines

Our worker collective has gained considerable experience in both the operation and production of N/C machines. In the future we wish to focus attention on the following three basic areas: gradual automation of programming; use of N/C machines only in sets; and innovation of the production of N/C machines.

Automation of Programming

The basic prerequisites for the gradual automation of writing the programs for N/C machines are ensured, since our enterprise has its own TESLA 200 computer and an EC 1033 computer. By optimizing the programs with the help of a computer, in cooperation with VST [Institute of Technology] in Kosice, we wish to speed up the entire preparation of the programs and to raise the productivity of the N/C machines.

Use of N/C Machines in Sets

We are aware that the form in which N/C machines are introduced at our enterprise decisively influences also the utilization of the capabilities and advantages that N/C technology unquestionably offers for the production process. For us it seems the most advantageous to introduce N/C machines exclusively in sets of the specified optimal number, so that we may avail ourselves of the relationship that exists between the special equipment and the manpower required for N/C technology. By introducing N/C machines in sets we wish to fully integrate the technical preparation of production, planning, the preparation and planning of production with production proper; furthermore, to interconnect the workplace system, the system of in-process transportation and handling, and the system of managing the production process itself, in such a way that the flow of materials and the flow of information may be the most favorable, the most simple, and as fully automated as possible, or at least to permit such automation, up to the integrated production section.

Innovation of the Production of N/C Machines

In the production of N/C machines we wish to continue with the production of the OCH-2 and OCV-2 improved machining centers. These machining centers are of modular design, and this advanced design ensures wide application in all areas of engineering production, in the machining of small flat or box-shaped parts.

1014
CSO: 2402

END