~~SECRET~~

CONFIDENTIAL

Memo #A-10
25 May 1955

MEMORANDUM FOR: Assistant Chief, TSS for Technical Aids

SUBJECT : German Technical Publication (ULTRASONIC BORING TOOL)

In response to your request, a translation of the subject publication has been made by FDD and is forwarded herewith for your retention.

[redacted] 25X1

Chief, TSS/AUTH/CDS

Attachments
German Technical
Publication w/translation

Distribution:
2 - Addressee
1 - TSS/SRB
2 - TSS/AUTH/CDS

TSS/[redacted] 25X1

008632

DOC 1 REV DATE 22 JULY 80 BY 057447
ORIG COMP 056 OPI 56 TYPE 02
ORIG CLASS S PAGES 12 REV CLASS C
JUST 22 NEXT REV 2010 AUTH: HR 70-2

~~SECRET~~ CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/04/10 : CIA-RDP78-03172A000300050001-4

A New Type of Ultrasonic Boring Tool

For thousands of years holes have been bored in things. For thousands of years boring has been thought of in connection with a rotary motion. The revolutions per minute of the boring tool can be quite varied; they can be less than one revolution per second, or they can be several hundred revolutions per second. The boring tool, in any case, has always rotated. One more thing we take for granted in reference to a boring tool: the tool must be extremely hard, at least much harder than the material thru which the hole is to be bored. Only in the case of the diamond is this rule not applied, for there is no material harder than diamond. For boring thru the hardest materials a boring tool with a diamond point is used. The most common boring tool is made of high-quality steel; with this tool all materials which are softer than the steel can be bored. With all these boring tools the holes bored have always been round. Very often, however, a hole with corners or irregular shape is desired. Here the rotating boring tool cannot be used. It is therefore obvious, that the attempt has been made to design a boring tool which will not rotate but move back and forth on its longitudinal axis. This is only possible, however, when the material to be bored is very soft. The rotating boring tool is a chip cutting tool and thus has a good cutting quality. On the other hand, a boring tool which moves only in its longitudinal direction works like a chisel and cannot be used satisfactorily even for such soft metals as copper and bronze.

A new idea led to the use of longitudinal oscillations of the boring tool. This idea was developed thru the well-known air hammer with which rocks can be broken up (but no holes bored) to the rapidly vibrating boring tool. Higher and higher frequencies of vibration were tried until the surprising fact was discovered, that ultrasound (inaudible oscillations) can be used as a driving power for boring tools.

The boring tool which operates on the principle of ultrasonic vibrations along the longitudinal axis can be improved in operation very much by the use of a pulverized grinding material made of the hardest substances; these small particles themselves are caused to vibrate at ultrasonic speeds, and they, rather than the tool itself, attack the work and produce the boring. The use of this grinding powder has another advantage: if finely divided carbides or diamond powder are used, the very hardest materials can be bored. The tool itself does not have to be made of hard or expensive material, since it does not come into contact with the work. The operation with this boring powder is also an efficient and simple one. The powder can be supplied continuously suspended in water. The cutting is constant, and the water acts as a coolant.

A basic consideration in the design of the oscillating boring tool is the elimination of disturbing noise. Technically, it would be possible to use this type of boring with oscillations of only a few hundred or a few thousand oscillations per second, but such an operation would make the boring tool a source of noise equal to a loudspeaker with several hundred watts output. For this reason, the boring tool had to be designed to operate with more than 20,000 oscillations per second, so that the sound produced would no longer be audible. It was this consideration which led designers into the area of ultrasound.

Except in special cases, the ultrasonic boring tool operates most efficiently with oscillations between 20 and 30 kilocycles. Frequencies below this range would produce a disturbing audible noise, and frequencies above this range would

would not be feasible, since the magnetostrictive efficiency, which is above 70% at 25 kilocycles, decreases approximately inversely with the frequency beyond this point. For example, it is only about 20% at 100 kilocycles. Another disadvantage with higher frequencies would be the fact that the length of the boring tool would have to be decreased as the frequency increases, so that with a frequency of 100 kilocycles the boring tool could only be 3 centimeters long. Only where extremely fine borings with extreme precision are required is it feasible to use frequencies of about 100 kilocycles.

The ultrasonic boring tool "Datron" (see Figure 1) is made of several parts. An electric high-frequency generator, generally a two-stage electron tube oscillator, produces the necessary high-frequency output (about 600 watts in the illustrated model), which can be regulated by a special knob. This output is led to the so-called sound-head, which converts the electrical oscillations into mechanical oscillations (see Figure 2). The main part is a specially shaped rod of a high-quality nickel alloy surrounded by a coil thru which a high-frequency electric current passes. This rod is immersed in oil, which is cooled by water passing thru a surrounding copper coil. This cooling is necessary, since the oscillator, with only 70% efficiency (30% of the high-frequency output is converted into heat), would heat up too much without it. The actual boring tool, discussed below, is screwed on to the nickel rod.

The sound-head is attached to a mechanical precision mounting, which in turn is mounted on a drill stand. This precision mounting, as in the case of the conventional boring machine, has two functions: it must position the tool with the greatest possible accuracy in a vertical position to the surface of the work and must supply an adjustable spring force against the work corresponding to the size of the boring. With the ultrasonic machine, these two mechanical functions have considerably greater requirements than in the case of the conventional boring machine. The design of the drill stand varies according to the use and precision requirements. The stand illustrated in Figure 1 has a high-precision horizontal table to provide for accurate boring of several holes in a single piece of work. Finally, there is a pump to supply a steady stream of abrasive material to the oscillating tool. This material, boron carbide in water suspension, is supplied near the top of the tool to provide cooling over a large area of the tool surface. The abrasive material flows down the outside of the tool and provides a constant supply at the boring spot.

This design has a maximum efficiency when the tool itself is tuned as close as possible to the resonant frequency corresponding to the natural frequency of the magnetostrictive oscillator, and when the electrical high frequency has the same resonant frequency. The sound-head and the tool form a coupled oscillating system. Such a system oscillates with maximum amplitude when the natural frequencies of the individual oscillators are the same, and when the oscillating impetus is produced at the same frequency. The oscillations of the generator and the tool are purely longitudinal. If the tool were struck with a hammer in the axial direction, it would produce attenuated longitudinal oscillations at its natural frequency. Since it is not struck a single blow by a hammer, but is oscillated continuously by a high-frequency generator, its oscillations are not damped, i.e., it oscillates with a time-constant amplitude. This amplitude is naturally at a maximum when the oscillation is equal to the natural frequency of the tool. Since sonic velocity in steel is equal to about 6000 meters per second, the wavelength of the longitudinal wave in steel at 25 kilocycles is 6/25 m or 24 centimeters. The natural frequency of a rod is computed from the rule that the wavelength is twice ~~that of the~~ its length. Consequently, the correctly tuned tool of an ultrasonic boring machine for 25-kilocycle operation must be 12 centimeters long. Correspondingly, as mentioned above, a tool for 100-kilocycle operation would have to be 3 centimeters long.

These specifications apply strictly only when the oscillating tool has a constant cross section over its entire length. Such a shape is used for the tools of an ultrasonic drilling machine only in very rare cases. Actually, the tool of such a machine almost invariably has a conical shape (see Figure 3). This shape is used because the tool, which transmits the oscillation energy from the sound-head to the working point, must at the same time be a mechanical matching transformer. The oscillator in this case has a constant radiating surface of about 10 square centimeters. The amplitude is distributed uniformly over this surface and, at a given frequency, depends only on the supplied electrical high-frequency. The effective area of the boring tip, however, is in most cases smaller than 10 square centimeters and varies according to the size of the hole to be bored. The total oscillation energy must be transmitted from the large radiating surface to the much smaller surface of the boring tip. If this occurs without loss, the oscillation amplitudes behave in a manner opposite to that of the surfaces. Since this is the case, a definite conical shape is necessary for the tool. Because of its shape, it will be referred to as the "boring snout" in the following discussion. It thus performs at the same time the function of a mechanical matching transformer similar to that of an electrical transformer. The optimal form of the boring snout can be computed. For this reason, each ultrasonic boring machine is supplied with characteristic tables from which the optimal form for the boring snout can be read off for any desired purpose.

It is naturally not necessary to use a different size boring snout for every square-millimeter change in the size of the hole to be bored. In general, an assortment of from 3 to 6 boring snouts, each for a certain range of hole diameters, can be used. If an energy loss of a few percent occurs, it makes no difference, since the loss can be compensated by the high-frequency generator. Any losses which occur lead to additional heating of either the oscillator or of the boring snout. This heating, however, is kept low by the above-mentioned cooling systems.

The oscillator (Figure 2) is capable of radiating almost 500 watts of ultrasonic power on a surface of 10 square centimeters. This means that the maximum surface load is 50 w/cm^2. Such a load requires a high tensile strength for the oscillator material, since we are dealing with longitudinal oscillations. Special alloys had to be developed, which have high tensile strength and magnetostrictive effect and the lowest possible losses. The losses are the customary electrical eddy currents, hysteresis, and other magnetic losses, which we shall not discuss further here. The boring snout must have even greater tensile strength and higher elastic qualities than the tool itself, since there is a concentration of energy on the smaller cross section of the snout. If such a boring snout were diminished in cross section from 10 square centimeters to 1 square centimeter, the specific surface load at the tip would be tenfold, or a maximum of 500 watts per square centimeter. Such a density of energy cannot be supported by even the highest grade steels. The forces of tension and compression occuring in the ultrasonic range at 500 watts per square centimeter would far exceed the elastic limits and cause an intense heating of the material, followed ultimately by fatigue break.

Thus, if the diameter of the hole to be bored is small, the ultrasonic boring machine cannot be opprated with full power. It must be remembered that a boring snout tapered down to a few sqare centimeters, when operated with 500 watts ultrasonic power, can be brought to a red glow in a very short time.

Special alloys of copper and nickel with elastic limits 2 to 3 factors higher than those of high-grade steel are available on the market. With a boring snout made of such an alloy (for exampel, of monel metal) the boring speed can be increased for small holes, since this material can stand a higher ultrasonic stress than steel. The price of such alloys, however, makes their use feasible only in very rare cases.

There are very many uses to which the "Diatron" can be put. We have already mentioned that the shape of the oscillating tool or the hard tip [redacted] does not have to be round, but can be used in any shape. Thus, holes with the most varied shapes can be bored (see Figure 4). Another advantage is that any hard material can be drilled as long as the abrasive used is harder than the work. The most welcome area of application is the working of cemented carbides for the production of stamping dies. Up until now, punches and dies for precision parts such as those produced in the watchmaking industries have been made of tempered steel; now they can be made better and cheaper out of cemented carbides with the aid of the ultrasonic boring machine.

By adhering to a few important rules in the operation of the "Diatron" accuracies of within a few thousandths of a millimeter and surface roughnesses of less than one-thousandth of a millimeter can be obtained. The working process at the tip of the boring tool is actually made up of two processes: The granules of abrasive material, dancing to and fro at ultrasonic frequencies between tool and work, act like microscopically small chisels and perform the actual boring process; some granules of the abrasive material move parallel to the tip of the boring tool as soon as it moves down into the work and thus polish the sides of the hole. Even though the tool oscillates in a purely longitudinal direction, this polishing effect produces a slightly conical shape to the hole, since the polishing continues for a slightly longer period of time at the end where the tool enters the work.

If a single boring is made with high precision in a 5-millimeter thick plate of cemented carbide, the diameter of the back end of the hole will be about 1/10 millimeter larger than the diameter of the front end. Such a stamping die can be put to good use, since a slightly conical shape is desirable. In such a case, only the side of the boring which was underneath during the operation should be used as a cutting edge for the die. If such a plate were to be polished several times, as is usually necessary in mass production, the boring would become perceptibly larger, because of its conical shape. This can be overcome by using two or three boring tips of slightly varying size. With the first tool, the hole can be cut 2/10 millimeter undersize, the second tool can be 18/100 millimeter thicker, and the last tool can be the exact size desired. It is also well to use different grades of powdered abrasive material. The boring speed with coarse ~~granuled~~ abrasive (granulation 5 to 10 μ) is much greater than with the finest abrasive powder (about 1 μ granulation). Thus, the first section of the boring will be made with coarser abrasive. Nevertheless, the time necessary for the first boring will be ten to one hundred times longer than that necessary for the subsequent borings, since the first boring removes most of the material. Thus, the undesired polishing effect at the back end of the boring, which produces the conical shape of the hole, is also strongest during this initial boring operation.

The boring time for the second and third tools is much shorter, because these tools do not have to wear away very much material. Correspondingly, their polishing time and tendency to produce a conical hole are reduced. The accuracy of any certain procedure depends, naturally, on the type of boring, length, shape, and material worked. Of course, the number of different sized tools used in a single operation can be greatly increased in order to obtain greater precision. In any case, only a small amount of additional work with polishing paste is necessary in order to give the borings a surface quality required for punches and dies.

If larger holes are to be produced, the core can be punched out or removed with an electric-arc cutting tool before the ultrasonic boring is applied. Electric-arc cutting is much cheaper, but has nowhere near the accuracy and surface-quality results of the ultrasonic method. Electric-arc cutting is also limited in application to metals and materials which are electrically conductive. The ultrasonic method, on the other hand, can be used on any material, including porcellain, sintered boron carbide, precious stones and semiprecious stones.

The tip of the tool of the ultrasonic boring machine wears down during the boring process. It gradually becomes rounded. This is not serious in the case where holes with parallel sides are driven thru the work. With blind holes, or holes with sides which are not parallel, a frequent sharpening or exchanging of the tip is necessary. The tips, which are brazed to the snout, can be exchanged in about a minute with a small appurtenant high-frequency induction-heating unit.

The more brittle the work is, the easier it is to work with the ultrasonic method. On the other hand, the boring capacity is lower, the more ductile the work is.

The tool tip should be made of the toughest steel, so that the wear of the tip will be much less than the wear of the work. It must be remembered that the ultrasonic method is not advisable when the work is a ductile material. Heat-treated steel is easier to work, the deeper its penetration hardening is. In no case should the ultrasonic method be used on work which has only a surface hardening. With such material, the first stage of boring thru the hardened outer surface goes very rapidly, but then the speed of boring decreases considerably, and it is possible that a continuation thru the work could produce a greater wear of the cutting tip of the tool than in the work. The limits for the use of the "Diatron" should always be kept in mind, since it is designed for use on only the hardest and brittlest materials. It should be remembered that the "Diatron" can produce punches and dies of cemented carbides in a much shorter time than that required to make them out of tempered steel. In view of this new process it is therefore strongly recommended that cemented carbide tools be used in those areas where they heretofore have not been able to be put to use because of their poor machineability.

The production of stamping dies has been consciously emphasized in the application of the ultrasonic boring machine. There are, however, countless other possible applications. We might mention the production and machining of spraying nozzles or pressed shapes for the plastics industry, the boring and polishing of jewel bearings, the machining of small precision dies, and work in the jewelry industry. It must be remembered, however, that in the production of holes with sides which are not parallel, the cutting tips must be retooled more often than in the drilling of straight-thru holes. The ultrasonic method can also be used variously in the machining of hard industrial porcelain, quartz crystals and quartz plates. For the production of round holes in such materials, however, the use of the more expensive rotary diamond drills is actually more economical than the use of the ultrasonic method. In all other cases (where the holes to be bored are not round) the ultrasonic method is preferable. The same applies for boring round holes also, whenever the number of holes to be bored is too small to justify the purchase of a precision diamond drill, and the cost of an ultrasonic drill is extremely low.

Wilhelm Lehfeldt, Heppenheim (Hessen)

- End -