June 7, 1960 J. E. KLINE 2,939,250

RESONANT HONING

Filed Jan. 31, 1957 4 Sheets-Sheet 1

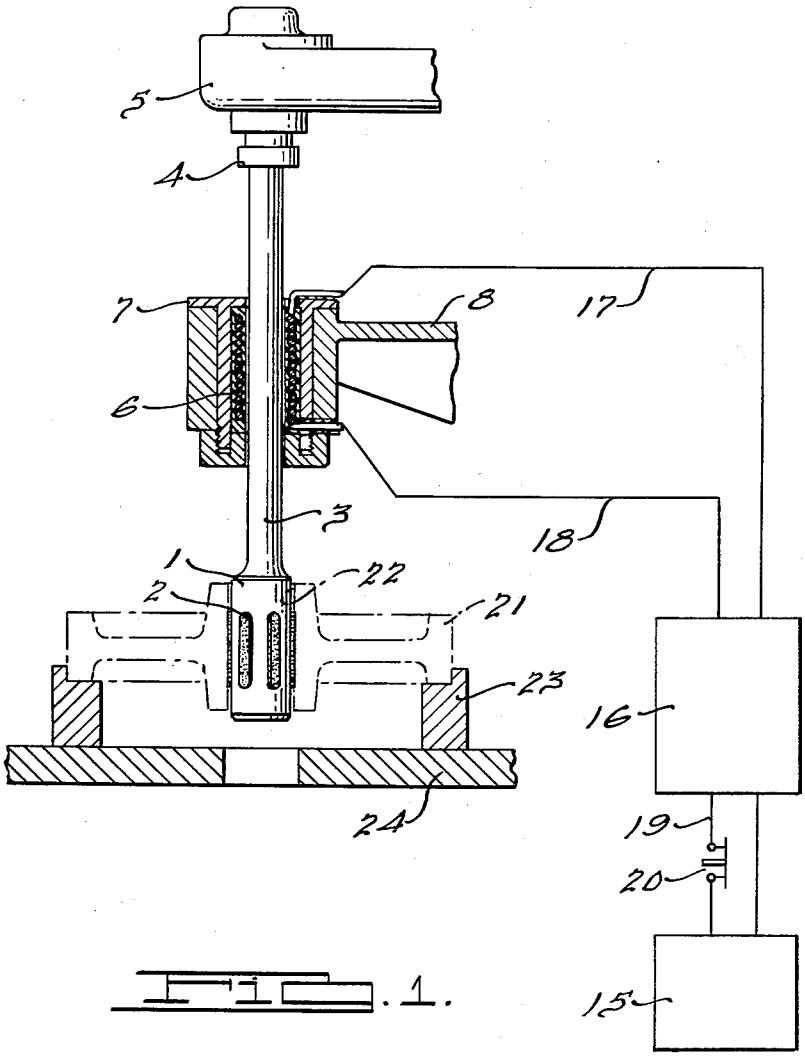


FIG. 1.

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Filed Jan. 31, 1957 4 Sheets-Sheet 2

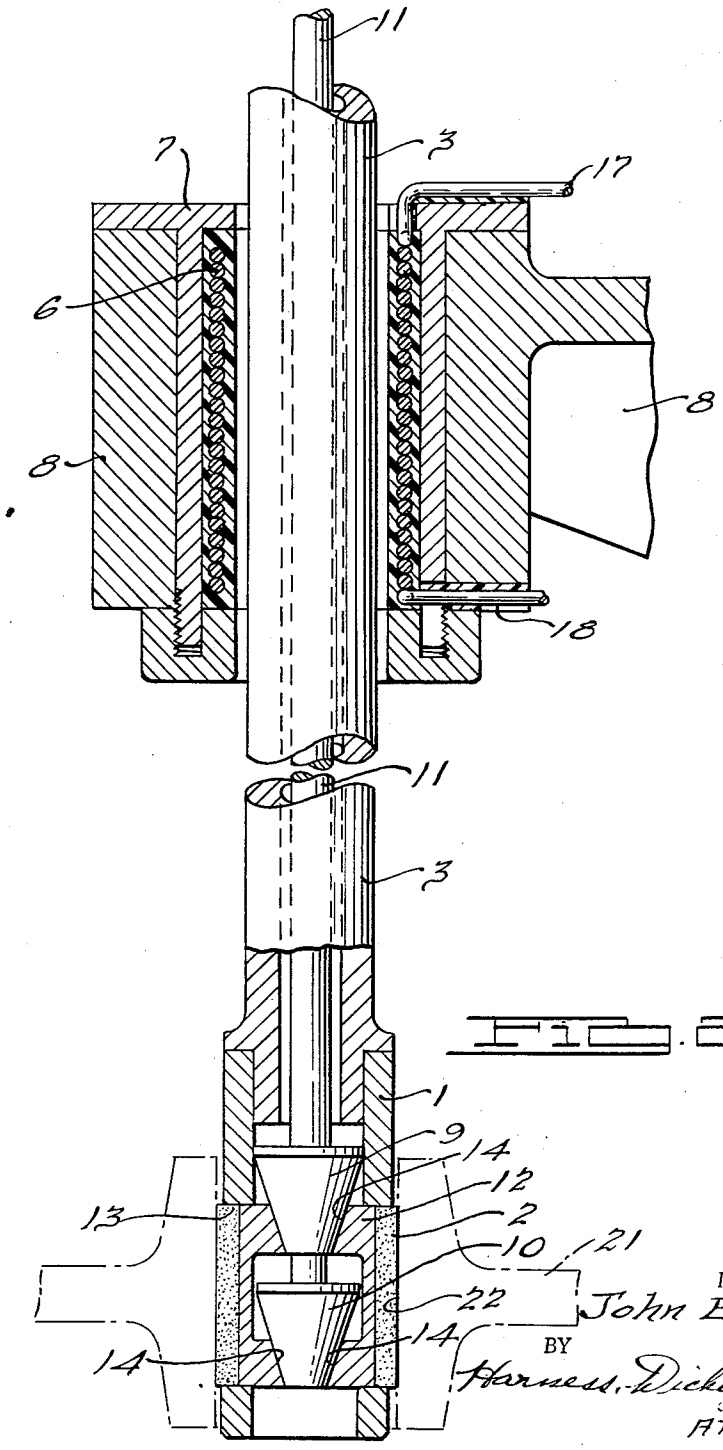


FIG. 2.

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RESONANT HONING

Filed Jan. 31, 1957 4 Sheets-Sheet 3

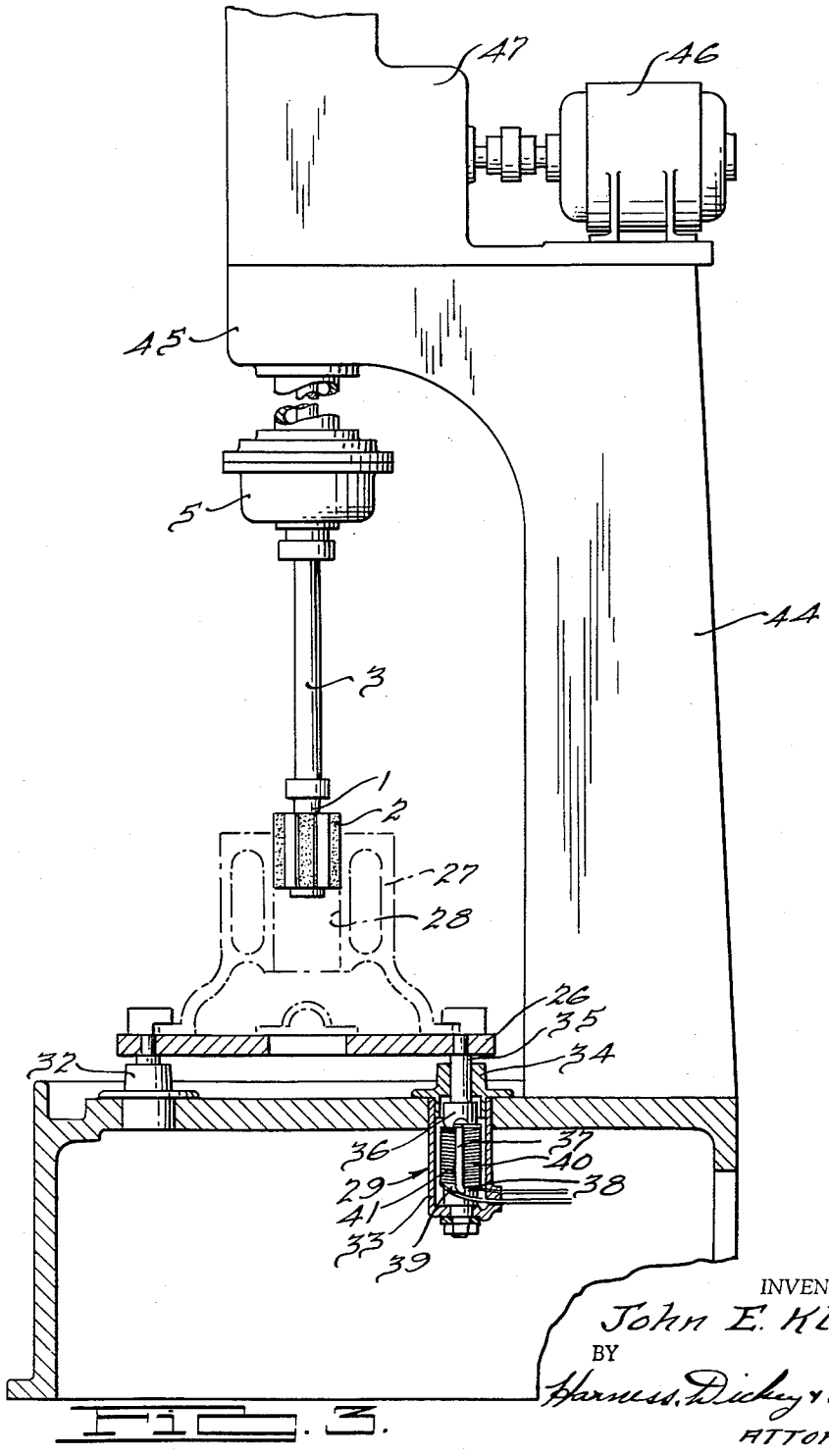


FIG. 3.

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RESONANT HONING

Filed Jan. 31, 1957 4 Sheets-Sheet 4

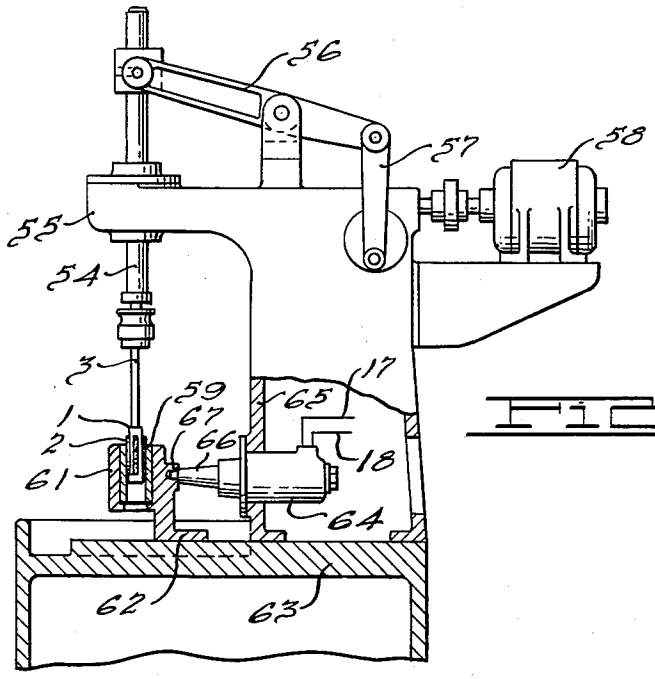


FIG. 3.

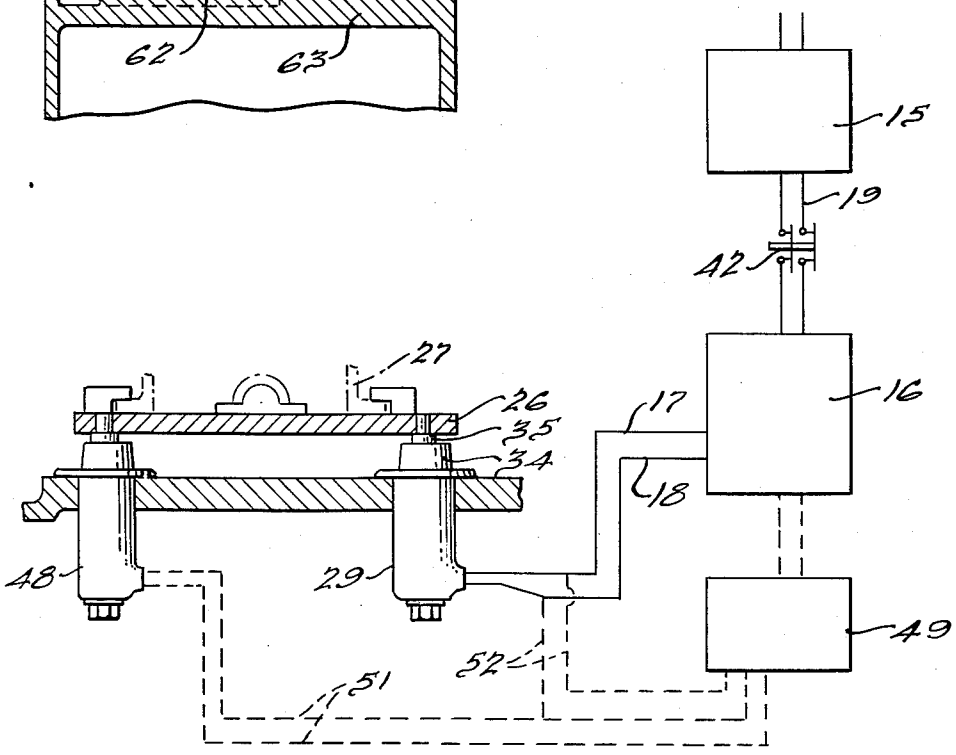


FIG. 4.

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United States Patent Office

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2,939,250

RESONANT HONING

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Filed Jan. 31, 1957, Ser. No. 637,486

7 Claims. (Cl. 51—34)

This invention relates to honing devices, and particularly to a honing device employing a high order of vibration for producing rapid and continuous honing.

The invention pertains to a new and useful application of wave-energy to supplement the present honing, superfinishing, polishing and similar operations performed by abrasives of the rigidly bonded types, in contast with those employing loose grit or abrasive slurries. It has heretofore been the practice in the honing art to cause the bonded abrasive honing stones to bear against the workpiece surface with a force sufficient to obtain penetration of the abrasive grain into the work surface while relatively rotating and reciprocating the workpiece and the abrasive stones. So long as such penetration and motions obtain, the abrasive particles may shear the work material and thereby hone the work surface. But, abrasive grains, like all other cutting tools, become dull due to attritional or solid solubility wear, and hence, their outward surface areas become too large or too smooth to permit continued penetration. It is then termed in a "glazed" condition. Thus, the condition of the work-contacting face of the abrasive stone is an important function of its ability to perform efficiently as an abrasive rather than as an excellent bearing surface which it becomes when "glazed."

The grains employed to make hone abrasive stones are brittle and usually of silicon carbide or fused alumina with the bonding material a vitrescent substance. The latter may have many physical properties similar to those of the grain, but are of very much lower "hardness" predicated upon their relative ability to indent or scratch other materials. When this indentation exists and the grain is subjected to sufficient tangential force, it must either scratch the surface or it or its bond must fracture and thereby be re-sharpened.

A high ratio of grit to bond, in the order of 90% to 10% or less, is employed in the formulation of hone abrasive stones to make them competent of self-dressing under reasonably normal conditions of operation. As additional assurance of this, abrasive bonds of soft grades are deliberately chosen which are overly self-dressing to avoid the imponderable problem of periodically re-dressing them, with the result of inefficient abrasive life. The ideal rate of "self-dressing" of the abrasive is that which enables the greatest amount of material displaced from the workpiece per unit abrasive expended per unit time. Disintegration is the best form of "self-dressing" as it produces a sharpening effect on the abrasive stone face by fracture of dulled abrasive grains to thereby create new cutting edges, or by fracture of the bond to dislodge the grains and expose new grains to the workpiece surface. The use of a high order of vibratory motion, in the form of wave-energy, when applied at a proper frequency and amplitude, not only prevents the glazing of the rigidly bonded honing stones but reduces the amount of power and pressure required to perform the honing operation. In the present invention, the motion induced by the wave energy is supplementary to the

principal machining forces which are derived from the rotary and translatory motions presently employed. The highly cyclical wave motion produces an entirely different action than the similar but slower superimposed motion disclosed in the patent to Peden, No. 2,350,527, issued June 6, 1944, and assigned to the assignee of the present invention. It is axiomatic that currently-used abrasive honing stones are of harder grades for operation upon soft or low tensile strength materials than those normally used for hard or high tensile strength materials. The latter is contrary to the best interest of abrasive life, but is necessary to enable a self-dressing action on the face of the honing stone sufficient to sustain cutting on hard materials.

The use of wave energy during the honing operation does not directly produce the cutting action on the workpiece but functions to condition the working surface of the abrasive stones to any desired state of effectiveness. In this process, the workpiece surface being honed literally performs as the "tool" for conditioning the abrasive stones. At resonance a system absorbs and dissipates energy at a maximum rate. The locale of such dissipation occurs principally at the point of the weakest couple which is at the abrasive-to-workpiece points of contact. Numerous tests of the principles of this invention have shown that hone abrasive stones with the hardest bonding materials are readily dressed in use by the influence of wave energy employed as herein described. If the workpiece is "soft" or of low tensile strength, intermittent use of said energy during the operation may suffice. Alternatively, a continuous application of wave energy may be necessary throughout the heavy stock removal phase of the honing operation in the case of "hard" or high tensile strength materials.

It is an object of this invention to make possible the use of hard-grain, long-life bonding materials for abrasive honing stones.

It is a further object of this invention to induce vibration at the interface of the work surface and the abrasive honing stones to supplement and thereby reduce the pressure required therebetween for effecting ready penetration of said surface by the abrasive grain of the stones.

Another object of this invention is to induce in a workpiece surface and an abrading tool carrying rigidly bonded abrasive stones in contact therewith, an energy wave approximating the frequency of resonance of either said workpiece or said tool or a harmonic thereof and thus create a high-frequency, high-velocity impact therebetween to cause percussive attribution of the surface of said abrasive stones which sharpens and conditions the working faces thereof for maintaining continuous and efficient abrasion of the workpiece surface.

Still another object of the invention is to provide means for employing wave energy to improve the efficiency and range of application of honing operations in which rigidly bonded abrasive stones are used as the cutting medium.

Other objects and features of novelty of the invention will be specifically pointed out or will become apparent when referring, for a better understanding of the invention, to the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic view, with parts in section and parts in elevation, illustrating one embodiment of this invention in which the tool is vibrated;

Fig. 2 is an enlarged broken sectional view of a portion of the structure illustrated in Fig. 1;

Fig. 3 is a view of structure, similar to that illustrated in Fig. 1 showing the workpiece being vibrated;

Fig. 4 is a view of structure, similar to that illustrated in Fig. 3 showing the vibration of the workpiece normal to the direction of reciprocation between the tool and workpiece, and

Fig. 5 is a broken view of the structure illustrated in Fig. 3, showing the addition of a second vibratory element thereto.

In Figs. 1 and 2, a hone body 1 is illustrated in which rigidly bonded abrasive stones 2 are mounted and radially expanded after the manner shown in the patent to J. E. Kline, No. 2,315,062, which was assigned to the assignee of the present invention. The hollow drive shaft 3 which supports the body 1 is made of Monel metal or other nickel-bearing material having magnetostrictive properties. The drive shaft 3 drives the body 1 in rotation and reciprocation by forces applied through a spindle 4 and a head 5 of a conventional honing machine. It is to be understood that the body 1 may be rotated and the workpiece supporting table may be reciprocated, as is also the conventional practice in the art. The drive shaft 3 passes through an electromagnetic coil 6 and forms the core thereof. The coil 6 is housed in a casing 7 which is secured to the frame 8 of the machine or work-holding fixture.

The body 1 of the honing tool has a pair of conical camming elements 9 and 10 on a vertically movable adjusting rod 11 mounted within the drive shaft 3. The bonded abrasive honing stones 2, along with their related cone-engaging elements 12, are mounted in radial slots 13 in the body 1, with the sloping surface 14 of the elements 12 in engagement with the cones 9 and 10. The axial movement of the rod 11 and the cones 9 and 10 with respect to the body 1 produces the radial adjustment of the abrasive honing stones 2. The adjusting rod 11 is engaged by a feed mechanism (not shown) within the head 5 which adjusts the rod axially to cause radial expansion or retraction of the abrasive honing stones 2.

Due to their magnetic properties, ferrous metals containing more than 6% and less than 79% of nickel elongate and those having 81% or more of nickel shorten when subjected to a magnetic field. The degree of this respective lengthening and shortening is a function of the field strength to which they are subjected and varies for different materials. It is therefore preferable, for the potential of maximum amplitude, that the drive shaft 3 and the adjustable rod 11 be composed of materials having these opposite properties. Thus, when an alternating or pulsing current is impressed through coil 6 of the device shown in Figs. 1 and 2, the resulting lengthening of the adjusting rod 11 and the shortening of the drive shaft 3 causes greater relative axial movement between cones 9 and 10 and the cone-engaging elements 12 with a consequent radial movement of the abrasive honing stones with respect to the workpiece surface.

Normal radial expansion or feed pressure of the abrasives is produced by devices such as shown in the United States patents above mentioned. The additional radial pulsating movement resulting from the above described magnetostrictive effect creates forces at the interface between the abrasive stones and the workpiece surfaces, not possible by pressure alone, which dress the abrasive surface. Thus, penetration of the abrasive grain into the material of the workpiece readily occurs wherever the former is harder than the latter and the frequency of impact between them approaches, or is some multiple of, the natural vibrating frequency of either of them. At the point of resonance, the interface between the abrasive stones and the workpiece surfaces absorbs and dissipates energy at a maximum rate. The period of resonance of the tool body, the abrasive stones or the workpiece, or a multiple thereof, may be employed so long as the total energy (mass $\times$ velocity) is sufficient to cause the desired disintegrating impact on the cutting faces of the abrasive stones.

The source of current, as shown in Fig. 1, may initiate from an adjustable frequency oscillator 15 of either the Hartley or the balanced reactance type and be controlled by a magnetostrictive or a tuned circuit primary oscillator. The voltage output of the oscillator 15 is amplified through a variable amplifier 16 whose output is conducted to the coil 6 through leads 17 and 18, the oscillator being connected to the amplifier through a circuit 19 having a switch 20 therein.

A workpiece 21 represents a typical part having a large mass and a disproportionately small bore surface 22. The workpiece is mounted on a work-holding fixture 23 on which it is secured against rotation in a suitable manner, not herein illustrated. A table 24 supports the fixture and may be mounted in fixed position. The head 5 and tool 1 are moved relative to the table in reciprocation. In the present arrangement, the casing 7 is retained in fixed relation and the table 24 is moved upwardly to have the tool 1 inserted within the aperture 27 of the workpiece, and thereafter the tool 1 is moved in reciprocation to stroke the workpiece. In this particular arrangement, the hone body 1 is rotated and reciprocated when the workpiece and body are in the position illustrated in Figs. 1 and 2. Pressure is applied to the upper end of the adjusting rod 11 to have the cones 9 and 10 apply an outward pressure to the engaging elements 12 which force the abrasive stones 2 outwardly against the surface of the bore 22 with a predetermined pressure. This will produce the normal honing action on the surface 22 of the bore and to this action the superimposed high order of vibration is added through the energization of the coil 6. The oscillator is adjusted to produce resonance between the faces of the abrasive stones 2 and the surface 22 which results in the minute breaking down of the engaged surfaces of the grains of the stone faces with the surface, to thereby maintain sharp points on the grains which produces the continuous rapid cutting without any glazing. In the particular arrangement, a lengthening and shortening of the drive shaft 3 and adjusting element 11 produce a minute amount of reaction and advancement of the cones 9 and 10, which thereby alternately relieves and applies pressure to the stones. This maintains a cutting relationship between the grains and surface as glazing is prevented by the constant breaking down of the grains and the bonding material.

Referring to Fig. 3, another form of the invention is illustrated, that wherein the wave energy pulse is applied to the work-holding fixture 26. The wave energy pulse is applied directly to the fixture and workpiece which is herein illustrated as a cylinder block 27. A resonant vibration is produced between the surface 28 of a bore of the engine block and the stones 2 of the hone body 1 by a transducer 29 which is supported upon a bed 31 of the machine and secured to a corner of the fixture 26. An opposite corner of the fixture is secured to the bed by suitable means, herein illustrated as by a shoulder element 32 which is similar to the supporting portion 34 of the transducer 29, permitting movement at the corner. This is desirable so that the element 32 may be removed and a second transducer applied to the bed 31 for vibrating a second corner of the fixture 26. The transducer 29 has a housing 33 supported in the portion 34 through which an armature 35 extends and connects to a corner of the fixture 26. The armature is brazed or otherwise secured to a laminated core 36 of sheets of nickel having a slot 37 therein providing two branches 38 and 39 about which coils 40 and 41 are wound and disposed in series relation to each other. The leads 17 and 18 of the coils 40 and 41 are connected to a variable amplifier 16 which amplifies the signal from the oscillator 15. A circuit 19 interconnects the oscillator to the amplifier through a disconnecting switch 42. Pulsating current from the amplifier energizes the coils 40 and 41 and produces a high order of vibration to the armature 35. This will cause the plate 26 to rapidly move upwardly and downwardly a minute amount, to thereby superimpose a vibration between the surface 28 of the bore of the block 27 and the faces of the stones 22. This causes the breakdown of the engaging points of the abrasive grains to produce new and sharp points thereon which

thereby maintains maximum efficiency in the abrading of the surface 28 of the bore.

In the present arrangement, a standard 44 extends upwardly from the base 31 from which a portion 45 projects frontwardly for supporting the head 5 in position to maintain the drive spindle 4 in operating relation thereon. A motor 46 is mounted on top of the standard for driving mechanism within a casing 47 which drives the spindle 4 in rotation and reciprocation in a conventional manner. A normal operation in rotation and reciprocation is performed upon the surface 28 of the bore by the honing body 1. Superimposed upon this normal operation is the vibratory motion applied to the engine block 27, resulting in a vibrating motion occurring between the surface 28 and the faces of the stone 2 which, as pointed out hereinabove, produces the continuous sharpening of the stones, resulting in a maximum efficiency in the performance of the abrasive operation.

Fig. 4 illustrates a similar construction to that of Fig. 3, with the exception that a second transducer 48 is applied to another corner of the fixture 26, and it is to be understood that a transducer may be employed at all four corners of the fixture 26 which is desirable when extremely heavy workpieces are supported thereon. When two or more of the transducers are employed, they are actuated 180° out of phase on opposite sides of the fixture. A self-balancing phase inverter 49 may be employed for this purpose, connected with the amplifier 16 and directly to the transducer 48 through a circuit 51 and parallel to the circuits 17 and 18 through a circuit 52. A pulsating current 180° out of phase is then supplied alternately to the transducers 29 and 48, thereby superimposing the desired order of frequency of movement to the fixture 26 and engine block 27 which superimpose the vibratory motion between the surfaces of the block bore and the honing stones.

In Fig. 5 a still further form of the invention is illustrated, that wherein the tool spindle 3 is supported upon the machine spindle 54 which is driven in rotation through the gears in the head 55 and reciprocated through the action of the rocker bar 56 driven by the pitman 57 from a motor 58. The workpiece, herein illustrated as a cylinder 59, is mounted in a fixture 61 having a supporting leg 62 attached to the base 63. A transducer 64, similar to the transducer 29 above referred to, is mounted on a vertical wall 65 of the machine, with the armature 66 disposed horizontally and attached to one side of the fixture 61 at 67. The conductors 17 and 18 from the transducer 64 is connected to the oscillating and amplifying mechanisms 15 and 16 in the same manner as illustrated in Fig. 1. Pulsations are produced to the armature 66 at low magnitude and high frequency, to thereby apply a vibration between the surface of the workpiece 59 and the stones 2 in a direction lateral to the direction of reciprocation of the tool. In Figs. 1 and 2, the vibration was produced in the tool itself, and in the structure illustrated in Figs. 3 and 4 the vibration was applied through the fixture, and in all four instances the vibration was parallel to the engaged surfaces of the stones and the wall of the workpiece. In the structure of Fig. 5 the vibration is produced in the workpiece laterally of the movement in reciprocation between the surfaces of the stones and the bore. This movement produces the breaking down of the grains of the honing stones and the most efficient and rapid abrasive action on the bore surface in time and cost.

With the use of the transducer or transducers, the roughing operation is rapidly performed to increase the diameter of the bore to desired size and when size is approximately reached the transducers are interrupted, preferably through the operation of the switches 20 and 42, and the operation of the honing tool is continued for a short time for producing a desired finish on the honed surface. Not only is an extremely accurate and rapid abrasive operation performed on the bore, but without shifting the work to a second machine or changing to a tool with finer grain stones, the finishing operation is performed. Through the use of a mechanism for superimposing a high order of vibration on the normal abrasive movements employed between the stone faces and bore surface, many benefits are obtained. A more accurate bore diameter is machined in a much shorter time with an increase of stone life. The destructive breakdown to the stone face, heretofore found necessary after the grains became glazed, is eliminated, making it possible to employ abrasive stones having much harder bonds. Finally, in performing the finishing operation without removing the work and transferring it to a second machine or changing the stones in the tool, further time and cost are saved.

What is claimed is:

1. In a honing device, a honing tool having an abrading stone and means within the tool for moving the stone outwardly to increase the tool diameter, means for operating said tool in rotation, a support for a workpiece, means for relatively advancing a workpiece and the stone of the tool into working relationship to each other, means for relatively reciprocating said tool and workpiece, and means for producing a relative vibration radially between the workpiece and stone in a high order of reciprocation for dressing the stone face during the honing operation.

2. In a honing device, a honing tool having abrading stones and means within the tool for moving the stones outwardly to increase the tool diameter, means for operating said tool in rotation, a support for a workpiece, means for relatively advancing a workpiece and the stones of the tool into working relationship to each other, means for relatively reciprocating said tool and workpiece, and an electrically operated transducer for producing a high cyclical vibration laterally of said reciprocation between the stone faces and the wall of the workpiece.

3. In a honing device, a honing tool having abrading stones and means within the tool for moving the stones outwardly to increase the tool diameter, means for operating said tool in rotation, a support for a workpiece, means for relatively advancing a workpiece and the stones of the tool into working relationship to each other, means for relatively reciprocating said tool and workpiece, and an electrically operated transducer for producing a high cyclical vibration laterally of the movement in reciprocation between the stone faces and the wall of the workpiece, said vibration occurring transversely of the stone faces.

4. In a honing device, a honing tool having an abrading stone and means for adjusting the stone radially, a support for a workpiece, means for relatively advancing the support and tool to have the stone advance into engagement with the surface of the workpiece to be honed, means for relatively reciprocating the tool and workpiece and for relatively rotating the same, transducer means on opposite portions of said support, and means for energizing said transducer means in one portion 180° out of phase with the other portion.

5. In a honing device, a honing tool having an abrading stone, an adjusting rod within the tool for moving the stone radially, a driving spindle supporting said tool and through which said rod extends, said rod and spindle being made from materials having coefficients of magnetic expansion and contraction different from each other, a coil about said spindle, and pulsating current means for energizing said coil which produces a high cycle of relative longitudinal movement between the rod and spindle for changing the pressure exerted between the abrasive stone face and the surface of the workpiece in an extremely rapid manner.

6. In a honing device, a honing tool having abrasive stones, a spindle for supporting and driving said tool, an adjusting rod through the center of said spindle for applying pressure to the abrasive stones, said rod and spin-

dle being constructed of material having different coefficients of expansion when subjected to a magnetic field, and means for subjecting said spindle and rod to a vibratory magnetic field for producing a high cycle of relative longitudinal movement between said rod and spindle.

7. In a honing device, a honing tool having an abrading stone and means within the tool for moving the stone outwardly to increase the tool diameter, means for operating said tool in rotation, a support for a workpiece, means for relatively advancing a workpiece and the stone of the tool into working relationship to each other, means for relatively reciprocating said tool and workpiece, and means for producing a high order of vibration to the support and workpiece laterally of the movement in reciprocation between the stone and workpiece for dressing the stone face during the honing operation.

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