

June 24, 1969

J. SUNNEN ET AL

3,451,175

HONING MACHINES

Filed Feb. 9, 1966

Sheet 1 of 5

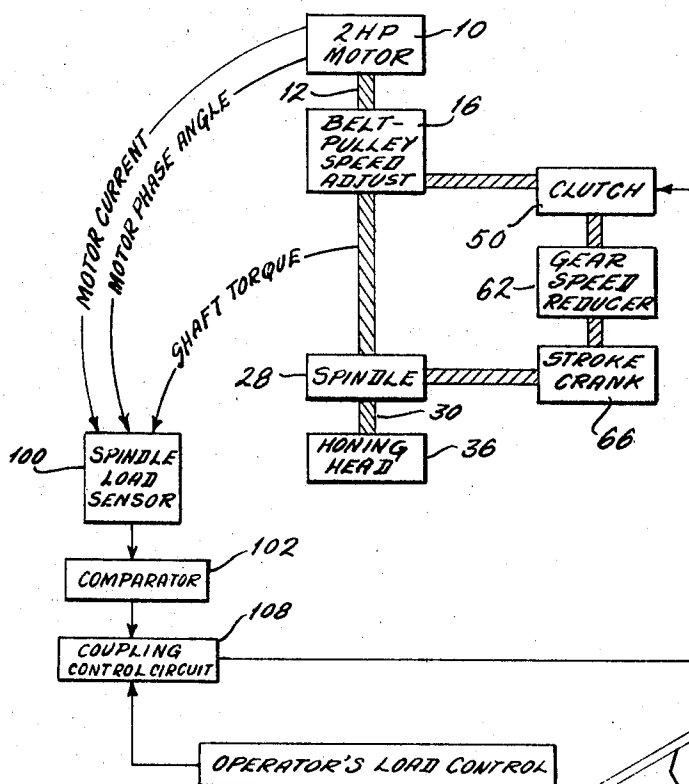


FIG. 1

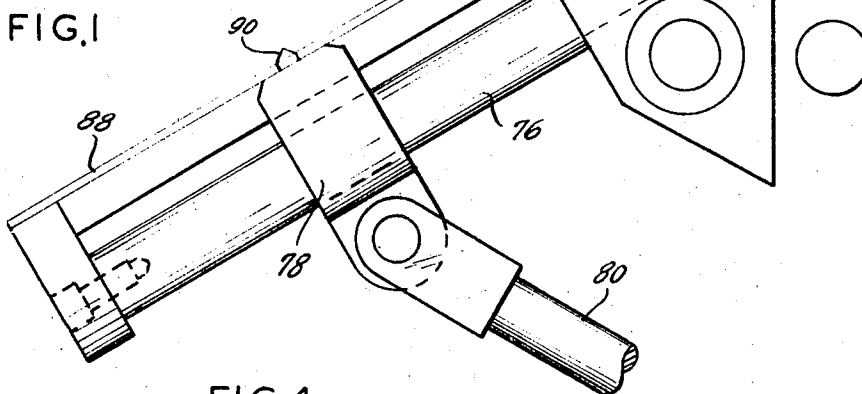


FIG. 4

INVENTORS:
JOSEPH SUNNEN
AUGUST SUNNEN, JR.
BY *Charles B. Haverstock*
ATTORNEY

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J. SUNNEN ETAL
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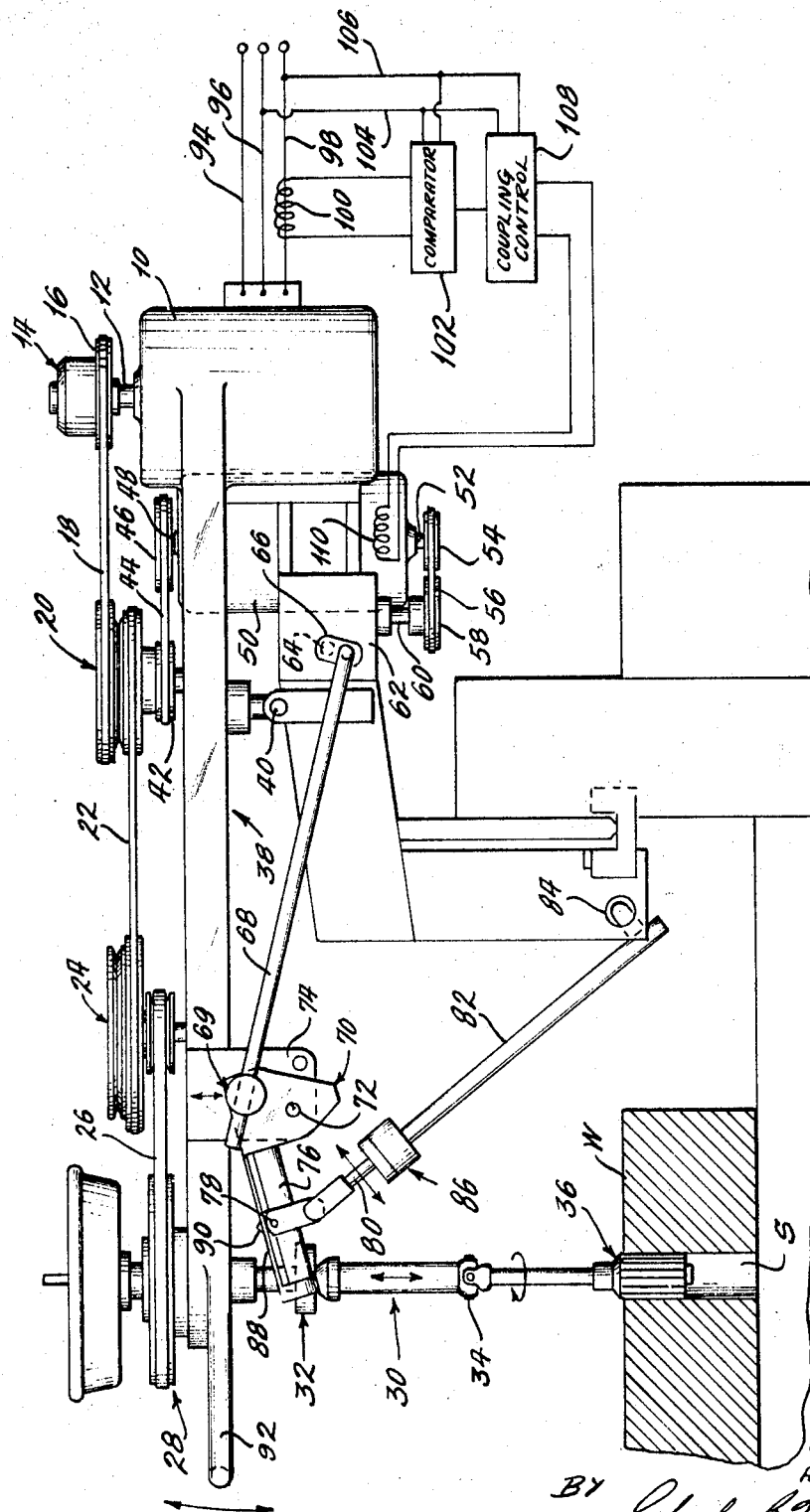


FIG. 2

INVENTORS:
JOSEPH SUNNEN
AUGUST SUNNEN, JR.
BY *Charles B. Haverstock*
ATTORNEY.

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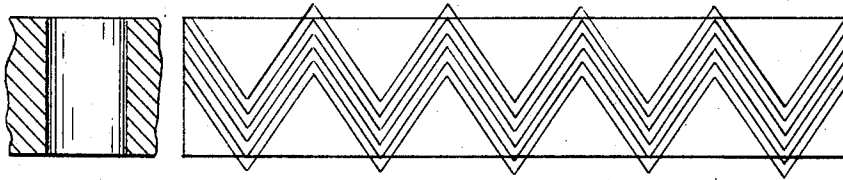


FIG. 3a

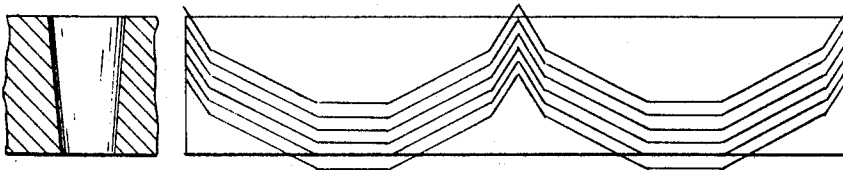


FIG. 3b

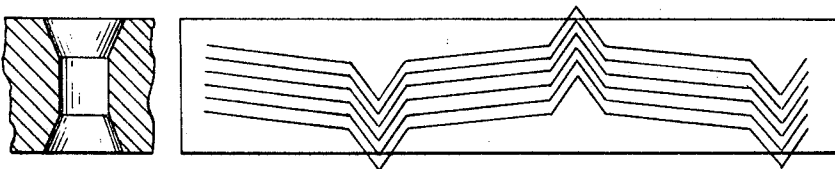


FIG. 3c

INVENTORS:
JOSEPH SUNNEN
AUGUST SUNNEN, JR.
BY *Charles B. Haverstick*
ATTORNEY.

June 24, 1969

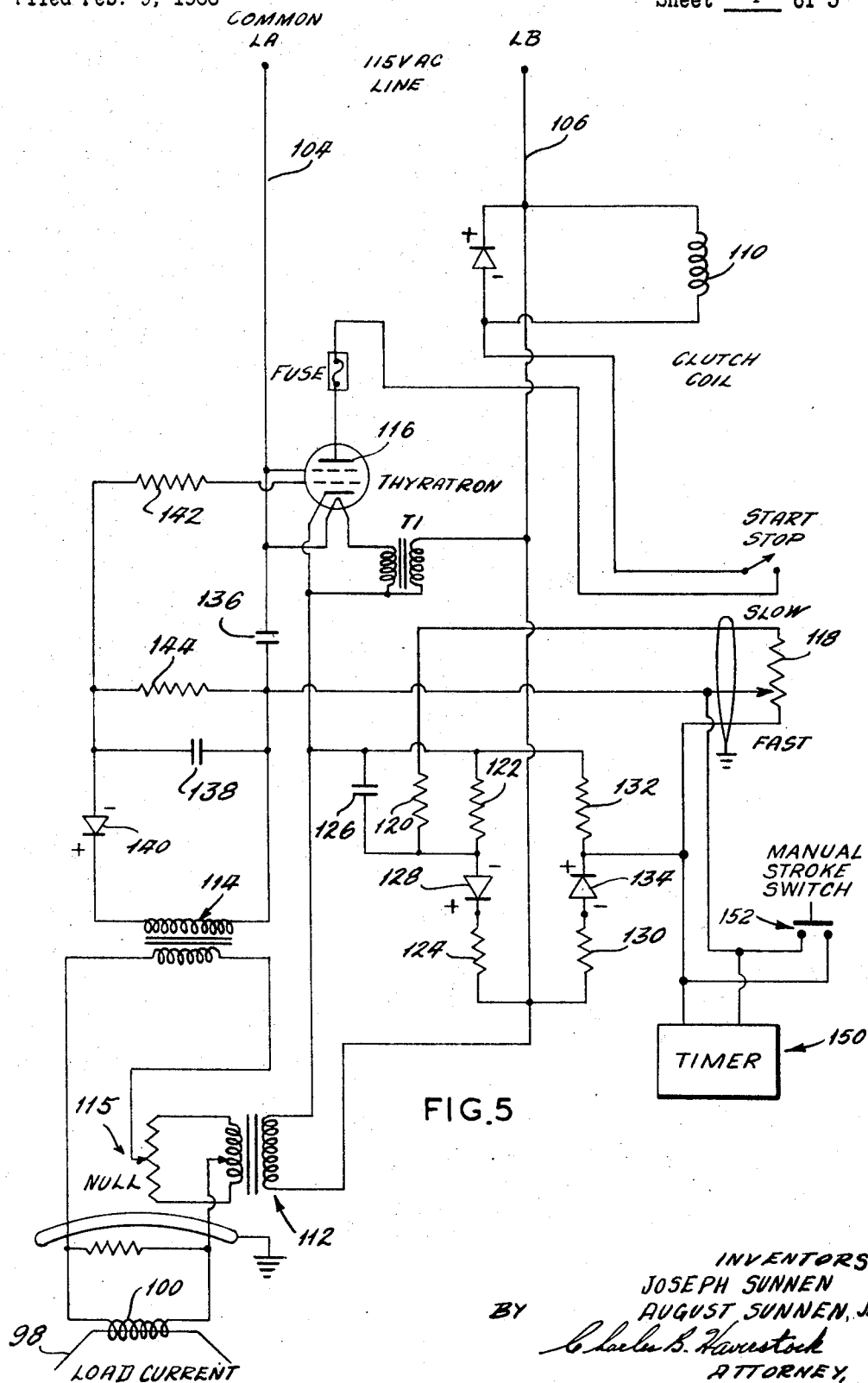
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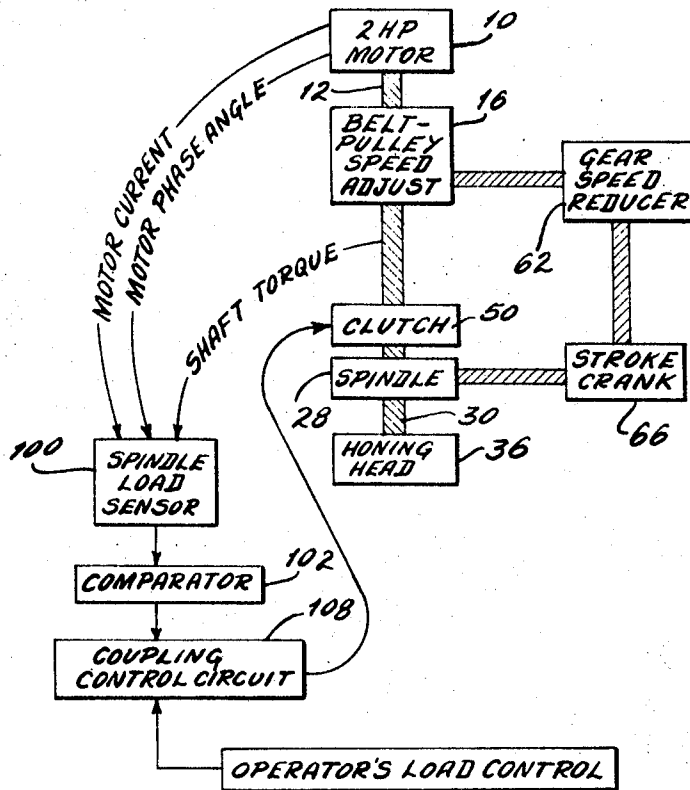


FIG. 6

INVENTORS:

JOSEPH SUNNEN
AUGUST SUNNEN JR.

BY

Charles B. Haverstock
ATTORNEY.

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HONING MACHINES

Joseph Sunnen, 400 S. Warson Road, Clayton, Mo. 63105, and August Sunnen, Jr., Ladue, Mo.; said August Sunnen, Jr., assignor to said Joseph Sunnen

Filed Feb. 9, 1966, Ser. No. 526,223

Int. Cl. B24b 49/00, 51/00, 7/00

U.S. Cl. 51—165

10 Claims

ABSTRACT OF THE DISCLOSURE

An improvement for use on honing and other devices and machines which have work engaging members which travel rotationally and axially relative to a work surface such as a cylindrical work surface to bring the work surface to a desired condition including means to continuously sense and respond to the energy required to be applied to the work engaging member during operation thereof, and other means operatively connected to the energy sensitive means to vary the amount of work done on various parts of the work surface by the work engaging member in a way that varies with the energy sensed in order to equalize the energy sensed at all places of the work engaging member on the work surface.

This invention relates generally to improvements in machines of a type that employ work engaging members and more particularly to improvements in honing and grinding machines and devices such as are used for honing and grinding machines and devices such as are used for honing, finishing and grinding cylindrical surfaces.

Many devices are known and available for honing and grinding surfaces which operations are stock removal processes in which a bonded abrasive is rubbed over a surface until the surface has obtained an accurate size and geometry and a smooth and consistent surface finish. and grinding is usually performed by an instrument having one or more abrasive elements or a combination of abrasive elements and guide members. In the honing of cylindrical surfaces the abrasive elements engage the surface being honed and are moved radially as well as axially to continuously bear against the surface and to hone all portions of the surface substantially the same amount. Various means have been developed to control expansion of the abrasive elements during honing and the pressure applied thereby against the work. In the past, however, difficulty has been experienced in correcting surface irregularities such as diameter variations in order to obtain cylindrical accuracy and straightness. The known devices have also required considerable skill and training to operate and considerable operator attention.

The present improved machine overcomes these and other shortcomings and limitations of the known devices by providing means which automatically and continuously sense the load on the operating elements, and means responsive to said load sensing means to modify the machine operation in a way to produce more nearly perfectly straight holes. This equalizes the hole diameter over the length of the hole and has the effect of equalizing the load on the work engaging elements in all operating positions thereof. This is done so that all portions of a surface being operated on or honed will have exactly the same diameter and other characteristics and so that cylindrical surfaces honed by the present device will be more nearly perfectly straight. To this end, the subject invention includes means sensitive to the torque transmitted to a honing or other work engaging device for its rotation, and other means operatively connecting said torque sensitive means which control the relative recipro-

cating motion between the work engaging elements and the work to cause the work engaging elements to operate longer periods of time on areas of the work where greater torque is sensed. By this means the subject device is able to equalize the characteristics of all portions of the work surface to make the work surface have the same diameter and other desired characteristics.

It is therefore a principal object of the present invention to provide means for producing more nearly perfectly cylindrical surfaces.

Another object is to provide improved means for honing and finishing cylindrical surfaces.

Another object is to provide means capable of continuously, accurately and instantaneously sensing the load or torque on a work member.

Another object is to provide means to modify the motion of a work member relative to a work surface in response to the load on the working member.

Another object is to provide means to equalize the load on a working device in all operating positions thereof.

Another object is to provide means in a honing device for automatically eliminating irregularities in cylindrical surfaces.

Another object is to provide means which will enable even relatively unskilled persons to hone extremely accurate cylindrical surfaces.

Another object is to provide relatively simple inexpensive means to improve the operating characteristics and accuracy of honing and like devices.

These and other objects and advantages of the present invention will become apparent after considering the following detailed description of a preferred embodiment of the subject device in conjunction with the accompanying drawings, wherein:

FIG. 1 is a block diagram of control means constructed according to the teachings of the present invention;

FIG. 2 is a side elevational view, partly diagrammatic, of a machine constructed according to the present invention;

FIGS. 3a, 3b, and 3c are diagrammatic representations illustrating in exaggerated form three different operating conditions encountered by the subject machine;

FIG. 4 is an enlarged fragmentary view showing a portion of the operating linkages included in the subject control means;

FIG. 5 is a schematic wiring diagram of a typical circuit for the subject device; and

FIG. 6 is a view similar to FIG. 1 but showing the clutch means in the rotational instead of in the reciprocating drive of the work engaging means.

Referring to the drawings more particularly by reference numbers, number 10 in FIGS. 1 and 2 refers to a drive motor which has a shaft 12. A clutch assembly 14 including a pulley 16 is mounted on the shaft 12. The pulley 16 is operatively connected by belt 18 to another pulley assembly 20. Another belt 22 engages a different groove on the assembly 20 and extends therefrom for engagement with still another pulley assembly 24. In like manner, power is transmitted from the pulley assembly 24 by another belt 26 to a spindle assembly 28. The spindle assembly 28 is connected to the upper end of a rotating drive tube assembly 30 by means of universal connection means 32. The lower end of the tube assembly 30 is connected to another universal connection 34 which in turn is connected to a honing head assembly 36. Many different forms of honing heads can be used, including, for examples, the heads disclosed in Sunnen Patent No. 3,216,155 and in copending Sunnen application Ser. No. 349,892 now Patent No. 3,378,962, dated Apr. 23, 1968. Expansion of the work engaging elements on the honing head 36 is controlled by feed up and other means in-

cluding the means disclosed in copending Sunnen patent application Ser. No. 466,535 now Patent No. 3,393,472, dated July 23, 1968.

During operation of the subject honing machine the motor 10 imparts rotating motion to the head 36 so that the work engaging elements move on the work surface S of the work W. The device is disclosed in conjunction with means for honing an internal cylindrical surface but is not to be so limited since it can also be used in other operations as well including honing external cylindrical surfaces and so forth.

In addition to the rotary motion imparted to the head 36, the head is also reciprocated axially in order to hone all parts of the surface S to make the surface cylindrical and of a desired diameter. The reciprocating motion is produced by other means also driven by the motor 10 although a second motor could be used for this purpose, if desired. A simplified form of reciprocating motion producing means are shown in FIG. 2 and include a pivotal arm assembly 38 on which the motor 10 and the connections thereto are mounted. The arm assembly 38 is pivotally supported on the base of a honing machine (not shown) by means of shaft 40. During operation of the machine the arm assembly 38 is reciprocated on the shaft 40 and in so doing causes the head 36 to move up and down in the work W.

The reciprocating motion of the arm assembly 38 is produced by means which are driven by the motor 10 including a pulley 42 on the pulley assembly 20, belt 44, and another pulley 46 mounted on an input shaft 48 of an electromagnetic coupling device 50. The opposite end of the coupling device 50 has an output shaft 52 which carries a pulley 54 which cooperates with another belt 56 that extends around another pulley 58. The pulley 58 is mounted on an input shaft 60 to a gear reducer 62, and the gear reducer 62 has an output shaft 64 which rotates a crank 66. One end of a rod 68 is pivotally connected to the crank 66, and the opposite end of the rod 68 is pivotally connected by means of member 69 to a rocker assembly 70. The assembly 70 is in turn pivotally attached to the arm assembly 38 by shaft 72, which shaft is mounted on a plate 74 fixedly attached to the arm assembly 38. When the crank 66 rotates about the shaft 64, the rod 68 moves and causes the rocker assembly 70 to move. In the simplified embodiment shown in FIG. 2 the rocker assembly 70 includes a rod member 76 on which an adjustable slide member 78 is positioned. The slide member 78 can be locked in any desired position on the rod member 76, and the slide member is pivotally connected to one end of another rod 80. The rod 80 telescopes into a tubular member 82, and the lower end of the tubular member 82 is pivotally connected at 84 to the base of the machine. During operation of the subject machine the rod 80 is fixedly connected to the tube 82 by means of a releasable coupling assembly 86. When the coupling assembly 86 is locked as shown in FIG. 2 movements of the rod 68 due to rotating of the crank arm 66 will pivot the rocker assembly 70 on the arm assembly 38 about the shaft 72 and will cause the arm assembly 38 to move up and down a distance determined by the location of the slide 78 on the rod member 76. A scale member 88 is positioned adjacent to the rod member 76 and a pointer 90 attached to the slide 78 may be included to provide means for accurately adjusting the position of the slide 78 and hence preset the distance the arm assembly moves. When the assembly 86 is uncoupled from the rod 80, the arm assembly 38 and the head 36 can be raised to an inoperative position above the work during which the rod 80 telescopes upwardly in the tube 82. Movement of the arm assembly 38 under these conditions is facilitated by means of handle bar 92.

When the adjustable slide member 78 is positioned near the right end of the rod member 76 (FIGS. 2 and 4) relatively short reciprocating strokes will be imparted to the arm assembly 38 because the distance between the

pivot 72 and the slide 78 is relatively short. Therefore the head 36 will move correspondingly short distances during stroking. On the other hand, when the slide 78 is located near the left end of the rod 76 the same regular displacement of the assembly 70 will act over a much longer lever arm and the stroke movements will be relatively long.

One of the main features of the present device has to do with the construction and operation of the coupling device 50 connected between the output of the drive motor 10 and the input to the gear reducer 62. The coupling device 50 is preferably an electromagnetic device such as an eddy current coupling device, and includes means by which the speed of its output shaft 52 can be made to vary relative to the speed of its input shaft 48. The means for changing the speed of the output shaft 52 includes means which respond to the load or torque on the head 36. In the preferred form of the subject device the load on the head 36 is sensed by means which sense the input power or current required to drive the motor 10. The input current thus sensed is fed to a control circuit such as the circuit shown in FIG. 5 and an output is produced which is applied to a control winding 110 in the coupling 50 to vary the speed of the output shaft 52. The coupling device 50 can be energized to produce a substantially 1 to 1 ratio between the input and output shafts 48 and 52, or it can be energized to produce slippage whereby the output shaft 52 is driven at a slower speed than the input shaft or made to almost stop. Furthermore, the changes that take place in the speed of the output shaft 52 must take place relatively rapidly so that the stroking motion of the head 36 is modified to correct irregularities at the time they are sensed. This means that when the torque on the head increases the speed of the coupling output shaft 52 must be substantially instantaneously reduced so that the speed of the gear reducer 62 and the crank 66 is also reduced to cause the stroking motion to slow down. This is manifested by a reduction in the speed of the up-down motion of the arm assembly 38 and the head 36. The rotational speed of the head 36, however, will remain substantially constant. On the other hand, if the work surface S is substantially cylindrical as illustrated in FIG. 3a, the load on the head will remain relatively constant in all operating positions and the head will be stroked at a substantially uniform rate. This is also illustrated in FIG. 3a.

If a surface S being honed has a shape like that illustrated in exaggerated form in FIG. 3b, the head 36 will be under greater load when honing the smaller diameter lower end than when it is honing the larger diameter upper end. Under these conditions greater load will be sensed by the sensing means when honing the lower end than when honing the upper end. The increased load sensed in the lower head position will therefore be used to reduce the exciting current of the eddy current coupling device 50 in a manner to slow down the stroking motion so that the head 36 will hone for a longer time at the lower end of its stroke. This will cause the lower end of the hole to be enlarged more than the upper end and will equalize the hole diameter over the length of the surface S. The modified stroke pattern is illustrated graphically in FIG. 3b.

FIG. 3c shows a third possible hole condition in which the center portion of the hole has a smaller diameter than the end portions. In this condition, the head 36 will be caused to be slowed while moving in the mid range of its stroking motions.

Various means can be used to sense the instantaneous load on the head 36 and to control the coupling device 50. The particular means disclosed include current or wattage sensing means connected or coupled to leads 94, 96 and 98 which supply power to the motor 10. In the disclosed embodiment a transformer winding 100 is coupled to the input lead 98 and is also connected to a comparator circuit 102. The comparator 102 is also connected

by other leads **104** and **106** across the input leads **96** and **98**. The leads **104** and **106** are also connected to the input of a coupling control circuit **108** which is connected to the comparator **102** and has its output connected to a control winding **110** in the eddy current coupling **50**. When the input power (current) to the motor **10** increases the current on the control winding **110** decreases and this slows down the speed of movement of the head **36**.

It can therefore be seen that the subject coupling **50** is provided to cause the head **36** to stall or to move more slowly when in portions of the surface **S** having smaller diameters to equalize the diameter in all portions thereof. This is done automatically and continuously during a honing operation to correct for any irregularity and to straighten the surface being honed. The subject device is preferably very fast acting and can be made as sensitive as desired.

Factors other than surface irregularities can also effect the torque required to rotate the head **36** and these are likewise taken into account by the subject control. Examples of other factors which may effect the torque include the torque required to rotate the head **36** and these are work and the construction of the work, the finish of the work surface, whether the work has different hardness portions, and the type of lubricant that is used. The type of feed up mechanism employed to maintain the stones engaged with the work may also cause changes in the torque. It would also be possible to modify the subject device so as to vary the speed of rotation of the head **36** as illustrated in FIG. 6 rather than the stroking speed to correct for errors although it is usually more desirable to vary the stroking and maintain the rotational speed relatively constant. FIG. 6 shows a structure that is substantially the same as the structure of FIG. 1 except that it is modified to cover the situation just described in which the rotational speed instead of the stroking motion is made to vary in a controlled way. The components in FIG. 6 are identified by the same numbers as the corresponding components in FIG. 1. The difference between the structures of FIGS. 1 and 6 is that in the structure of FIG. 6 the clutch is positioned between the drive motor **10** and the spindle **28** rather than being in the drive that produces the stroking motion. It is also possible to use mechanical load sensing devices instead of electrical means as disclosed. Many such devices are known in the art. For economy and accuracy, however, it is usually preferred to employ current detecting means. Current detecting means such as are shown in FIG. 2, for example, can also be made to operate with single phase or multiple phase systems.

In the circuit diagram of FIG. 5 current transformer **100** is coupled to the input phase lead **98** and is connected into a circuit which includes other transformers **112** and **114**. This circuit is balanced by means of a nulling potentiometer **115** which is used to establish a particular operating relationship between the signal produced in the winding **100** and the reference on the secondary of transformer **112**. This adjustment also minimizes the no-load current so that essentially only load current signals greater than no-load are available at the control circuit input. The output of the load current circuit is taken from the secondary of the transformer **114** which couples the control signal to the grid circuit of a thyatron tube **116**. When the thyatron fires current flows through the clutch coil **110** of the eddy current coupling **50**. A control potentiometer **118** with an adjustable contact is connected in the grid circuit of the thyatron **116**. One side of the potentiometer **118**, marked "slow," is supplied with half-wave rectified negative voltage from a circuit which includes resistors **120**, **122** and **124**, capacitor **126** and a rectified **128**, and the other side of the potentiometer **118**, marked "fast," is supplied with half-wave rectified positive voltage from a circuit which includes resistors **130** and **132** and rectifier **134**. The grid circuit of the thyatron **116** is also provided with a circuit which includes ca-

pacitors **136** and **138**, rectifier **140**, and resistors **142** and **144**.

Under normal operating conditions the potentiometer **118** is adjusted to produce a positive potential on the grid which is somewhat greater than the minimum necessary for conductivity of the thyatron. Thereafter, when a load increase is detected by the current transformer **100**, an increasing negative potential is produced by the sensor circuit. The magnitude of the current surge that is produced and the setting of the control potentiometer **118** establishes the degree of conductivity or non-conductivity and hence the power delivered to the clutch winding **110** of the eddy current device **50**. The eddy current coupling device **50** receives input power from its belt connection with the drive motor **10** and it delivers controlled output torque to the gear reducer **62** depending on the field excitation applied to the clutch control winding **110**. The output of the coupling **50** can be varied from a normal pre-established stroking rate to a condition wherein the stroke rate is very slow or almost stopped.

When the motor input current rises as a result of the head **36** moving into a small diameter portion of a hole, a negative signal will be applied to the grid of the thyatron **116** to throttle its plate current and in turn reduce the clutch field strength and ultimately the stroke rate. With the reduced stroke rate, the head, which rotates at a constant speed, will be slowed so as to remain for a longer period in the area of reduced diameter. This will cause the reduced diameter portion of the hole to be honed more than other portions to bring it up to substantially the same diameter as the rest of the hole. As the smaller diameter portions of the hole are enlarged the load on the head will reduce and the stroke speed will increase. The operation continues repeatedly and automatically until all the tight spots have been removed and the surface has a uniform straight diameter throughout.

It is possible with the present control that the desired final hole diameter will be reached at a time when the clutch is operating so as to produce a very slow stroke motion. Under these conditions it may be desirable to end the operation by producing a normal stroke pattern for a predetermined time. This can be done by changing the load adjustment control or by providing a finish cycle at the conclusion of the honing operation. This can be done regardless of the motor current by providing full clutch excitation for a predetermined time just before the honing operation is over. It is also possible to introduce cycles of short duration of full excitation between periods of controlled honing for the purpose of truing or dressign the stone. These are optional features which can be accomplished by means of simple conventional mechanical and/or electrical timer and/or switch means such as the optional timer means **150** and the switch means **152** shown in FIG. 5. Numerous other variations are also possible with the subject control.

It is also possible to sense load by means other than the motor current or power sensing means disclosed herein. For example, known and available mechanical sensors could be used to sense the motor torque, as well as known mechanical or electrical transducers or strain detectors could be used, known means could be used to sense the tension on one or more of the drive belts as an indication of torque, and known bore sensing means such as fingers or other devices which move on the surface being honed could also be used without changing the nature of the invention. Other means could also be used to correct a surface irregularity when one is sensed in place of slowing down the stroking movement. These include the possibility of changing the speed of rotation of the head as described above and shown in FIG. 6, moving the work relative to the head instead of vice versa and so on. Any one of these corrective measures can be controlled by sensing means of the types described above. Over stroking of a portion of the hole which is also well known in the honing art can also be used, and it is possible to include means for making corrections

in steps particularly in cases where the work is constructed of several different hardness materials.

The circuit shown in FIG. 5 is included for illustrative purposes to illustrate one of many possible ways to construct the subject device. Many other forms of control circuits can also be used without departing from the novel concept of the invention including other forms of tube circuits, solid state circuits and magnetic circuits. The coupling device can also be of several different constructions including being an eddy current coupling device, a magnetic particle type clutch, an hydraulic coupling device or any other variable slip electrical or mechanical device.

Thus there has been shown and described novel means for producing more nearly perfect honed surfaces which means fulfill all of the objects and advantages sought therefor. Many changes, variations, modifications, and other uses and applications of the subject device will, however, become apparent to those skilled in the art after consideration of this disclosure in conjunction with the accompanying drawings. All such changes, alterations, modifications and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. In a machine of a type having a tool portion contacting a cylindrical surface on a work piece comprising means for rotating the tool portion relative to the cylindrical surface, other means simultaneously moving the tool portion parallel to the axis of the cylindrical surface, means sensitive to the instantaneous torque required to rotate the tool relative to the work piece, and means controlled by the torque sensing means to increase the amount of honing done by the tool on the cylindrical surface in areas of the cylindrical surface where increased torque is sensed.

2. In the machine defined in claim 1 said means controlled by the torque sensitive means includes means for reducing the speed of movement of the tool portion parallel to the axis of the cylindrical surface in response to increases in torque sensed by the torque sensing means.

3. In the machine defined in claim 1 said means for moving the tool portion parallel to the axis of the cylindrical surface include means for imparting reciprocating motion to the tool portion relative to the cylindrical work piece surface, said means controlled by the torque sensing means including means to reduce the rate of the reciprocating motion in response to increased torque.

4. In the machine defined in claim 1 said torque sensitive means include means for sensing the energy required to rotate the tool portion, and means responsive thereto to vary the speed of rotation of the tool portion.

5. In the machine defined in claim 1 said means controlled by the torque sensitive means include an electromagnetic coupling device having an input, an output, and means responsive to the torque sensitive means for varying the electromagnetic coupling between the input and output.

6. In the machine defined in claim 1 said means controlled by the torque sensitive means includes an eddy current coupling device having a control winding operatively connected to the torque sensitive means.

7. In a machine of the type having a tool for contacting a cylindrical surface of a work piece including means for rotating said tool about the axis of said surface,

means for reciprocating said tool along said axis, the improvement comprising means sensitive to the torque transmitted to said tool for said rotation thereof, and means operatively connecting said torque sensitive means to said reciprocating means including means to reduce the speed of reciprocation of said reciprocating means in response to the sensing of increasing torque by the torque sensitive means.

8. In a machine of the type having a tool for contacting a cylindrical surface of a work piece including motor means for rotating said tool about the axis of said surface, and other means for reciprocating said tool along said axis, the improvement comprising means sensitive to the current drawn by the motor means, variable coupling means connected between said motor means to said reciprocating means, and means connecting said current sensitive means to said coupling means to control the speed of reciprocation of the tool inversely relative to the current drawn by the motor means.

9. A honing machine comprising a honing tool for contacting a cylindrical surface of a work piece, motor means operatively connected to the honing tool for rotating the honing tool relative to the cylindrical surface, other means for moving the honing tool parallel to the axis of the cylindrical surface during rotation thereof, said last named means including an electromagnetic coupling device having an input operatively connected to the motor means, and an output operatively connected to the honing tool, and means for controlling the speed ratio between the input and output of the coupling device including a coupling control winding, and means connected to said control winding including means sensitive to the current drawn by the motor means.

10. A honing machine for honing cylindrical surfaces on work pieces comprising work engaging means including at least one honing element engageable with a cylindrical surface to be honed, motor means operatively connected to the work engaging means for rotating said work engaging means during a honing operation, means movably supporting the work engaging means during a honing operation including means for producing relative axial movement between the work engaging means and the cylindrical surface being honed, said movable support means including the motor means and means operatively connecting the motor means and the support means, said last named means including an electromagnetic coupling device having an input operatively connected to the motor means and an output operatively connected to the movable support means, and means for varying the speed ratio between the input and output including means sensitive to the torque required to rotate the work engaging means.

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LESTER M. SWINGLE, *Primary Examiner.*

U.S. Cl. X.R.

51—34

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,451,175

June 24, 1969

Joseph Sunnen et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 31, cancel "and grinding machines and devices such as are used"; line 32, cancel "for honing"; line 37, "suface" should read -- surface --; line 39, "and" should read -- The honing and --. Column 4, line 71, "wettage" should read -- wattage --. Column 5, line 22, "torque required to rotate the head 36 and these are" should read -- the condition of the stones, the kind of material in the --; line 71, "rectified" should read -- rectifier --. Column 6, line 6, "loan" should read -- load --; line 49, "dressnig" should read -- dressing --.

Signed and sealed this 21st day of April 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents