

[54] **GRINDING MACHINE WITH SIZE CONTROLLED DRESSING MEANS**

[75] Inventors: **Herbert R. Uhtenwoldt**, Worcester;
Diran Deranian, Holden, both of
Mass.

[73] Assignee: **Cincinnati Milacron-Heald**, Wor-
cester, Mass.

[22] Filed: **Feb. 24, 1971**

[21] Appl. No.: **118,317**

[52] U.S. Cl. **51/165.91, 51/165.87**

[51] Int. Cl. **B24b 51/00**

[58] Field of Search..... 51/165.9, 165.91, 165.92,
165.93, 51/165.87

[56]

References Cited

UNITED STATES PATENTS

2,850,847	9/1958	Townsend	51/165.91 X
3,534,509	10/1970	Hatstat	51/165.91
2,387,044	10/1945	Silven	51/165.9
2,984,952	5/1961	Gebel	51/165.9

Primary Examiner—Harold D. Whitehead

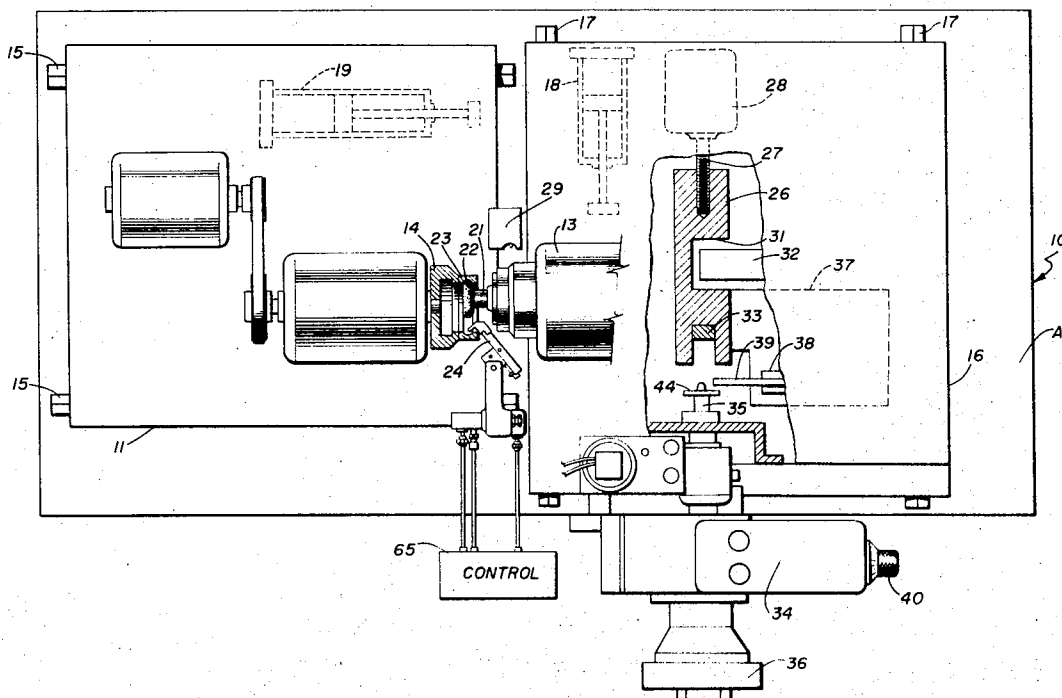
Attorney—Norman S. Blodgett

[57]

ABSTRACT

A grinding machine having a feed means for producing a controlled force between the abrasive wheel and the workpiece and having means for changing the limits of rapid infeed, if dressing takes place during a grinding cycle.

10 Claims, 7 Drawing Figures



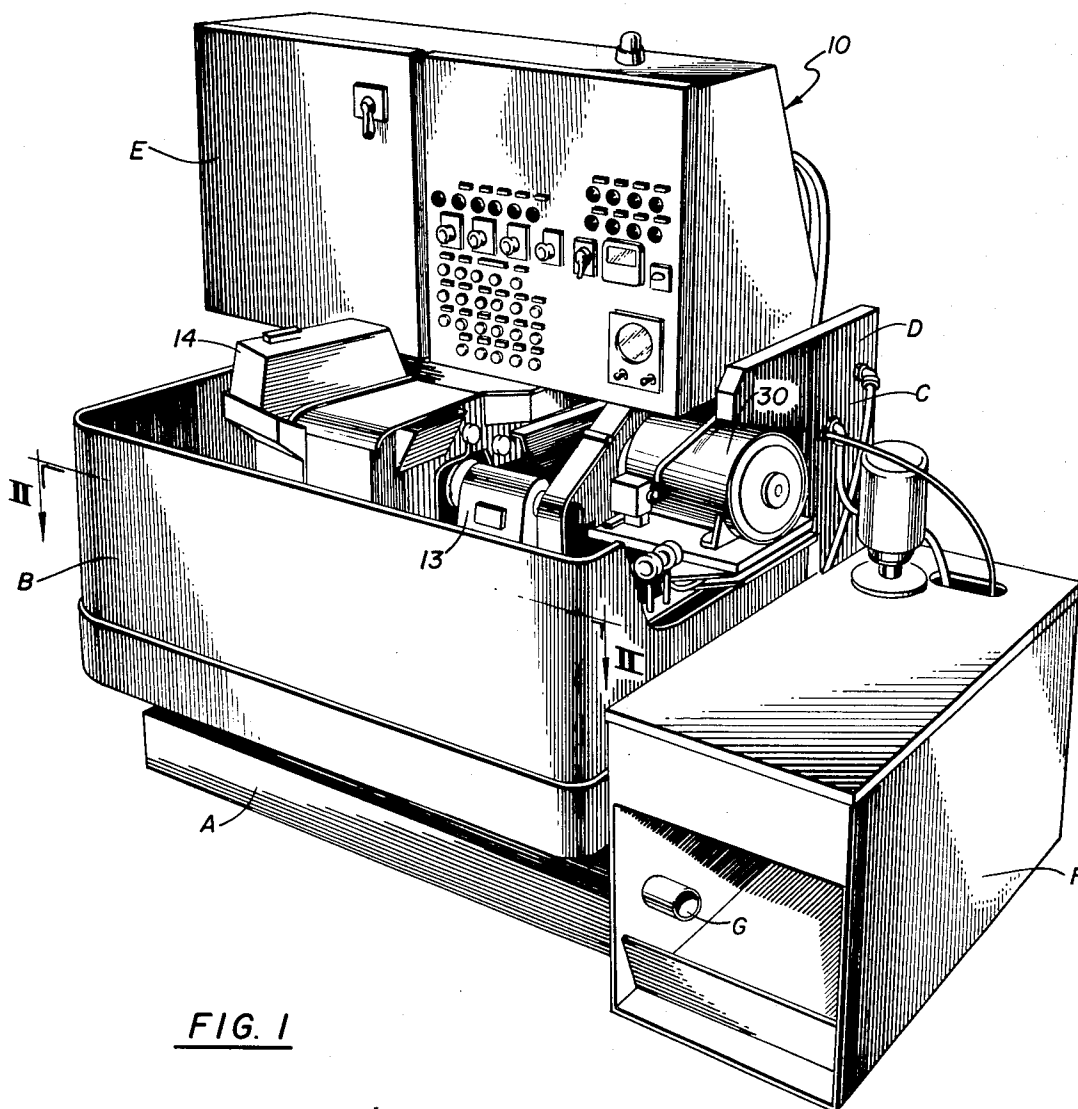


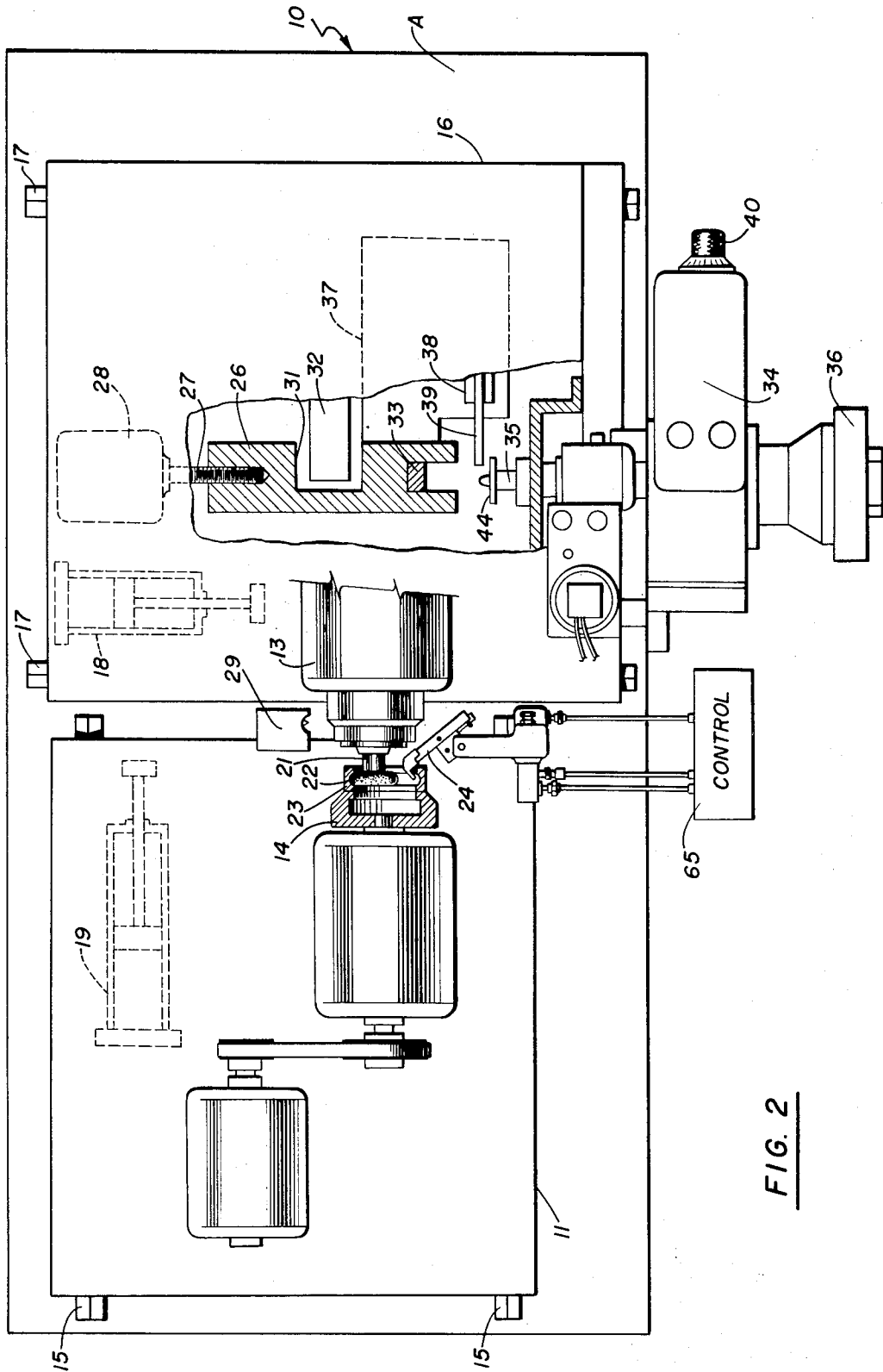
FIG. 1

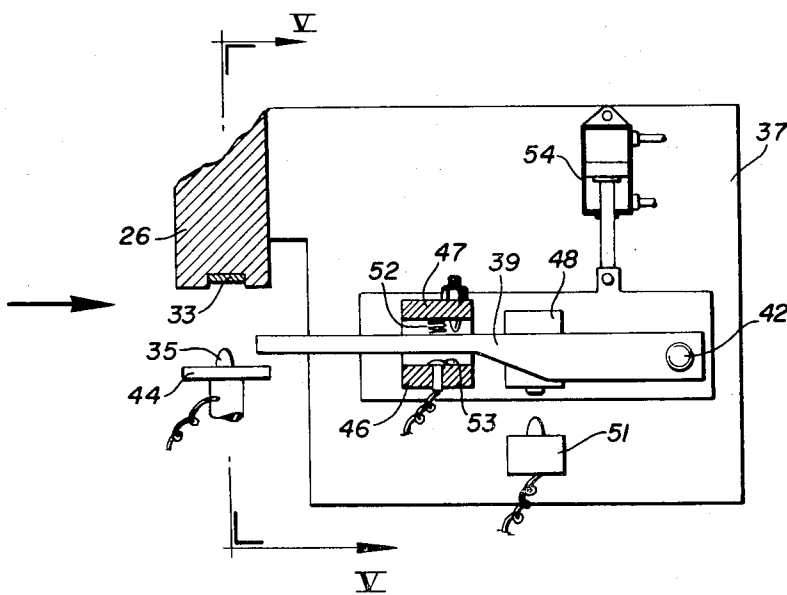
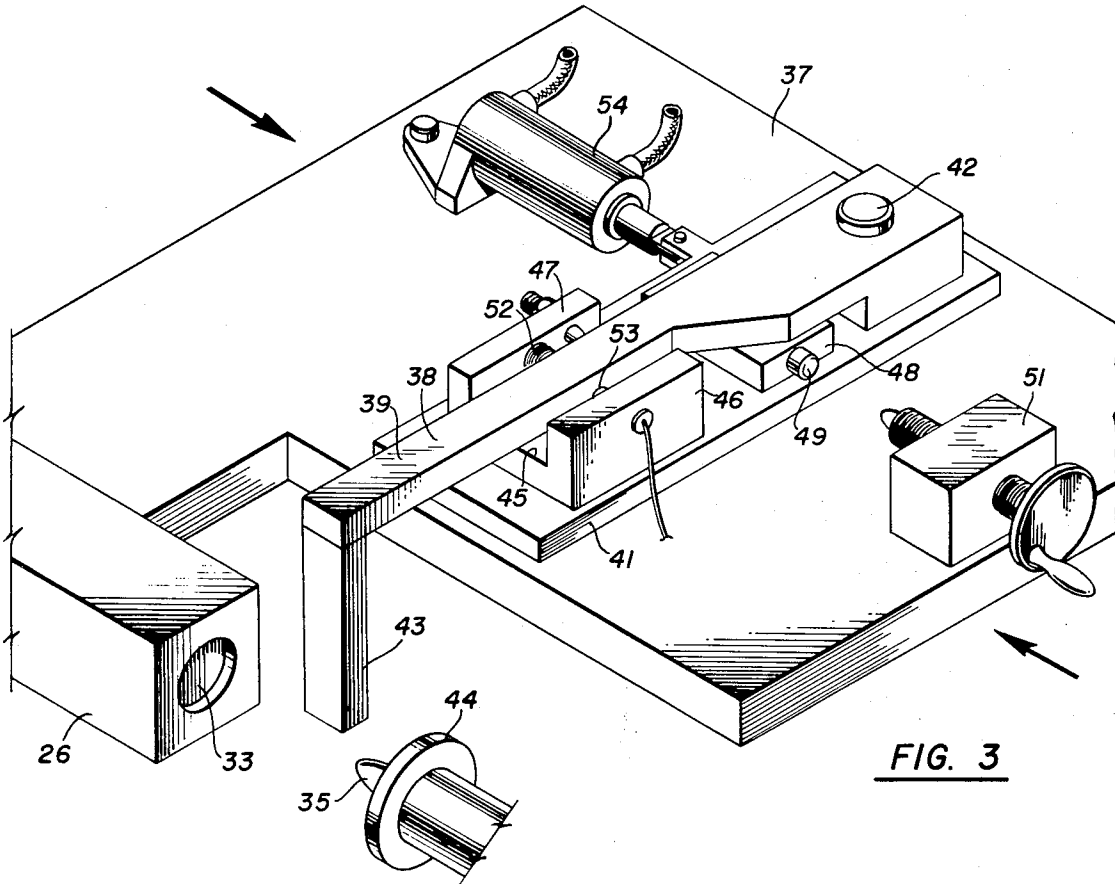
HERBERT R. UHTENWOLDT

DIRAN DERANIAN

INVENTORS.

BY
Harold S. Blodgett





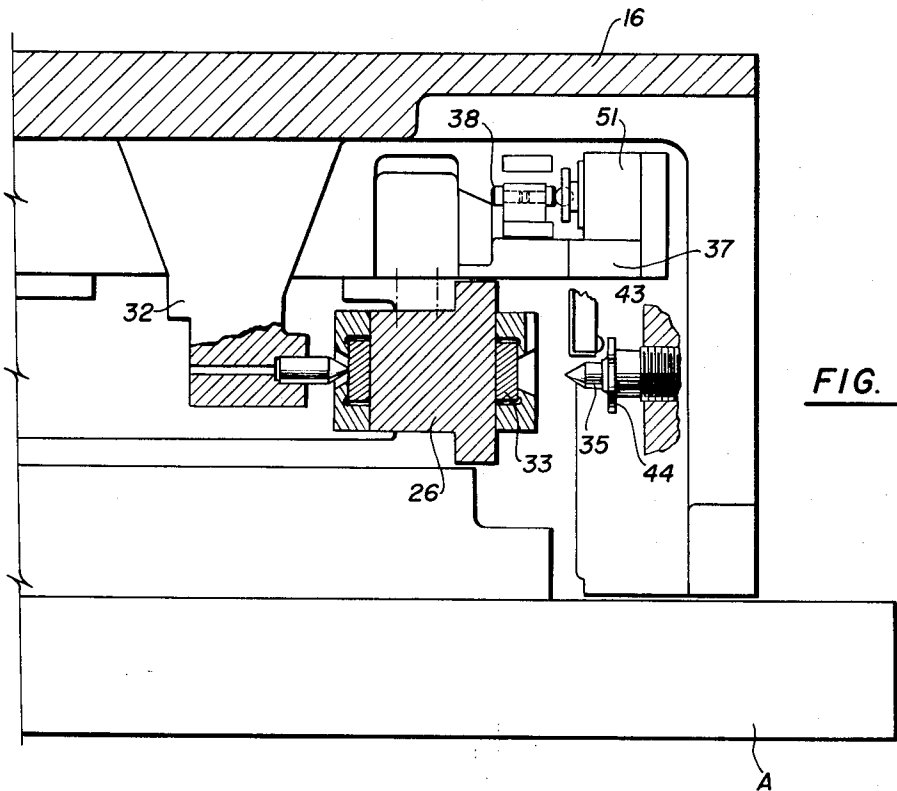


FIG. 5

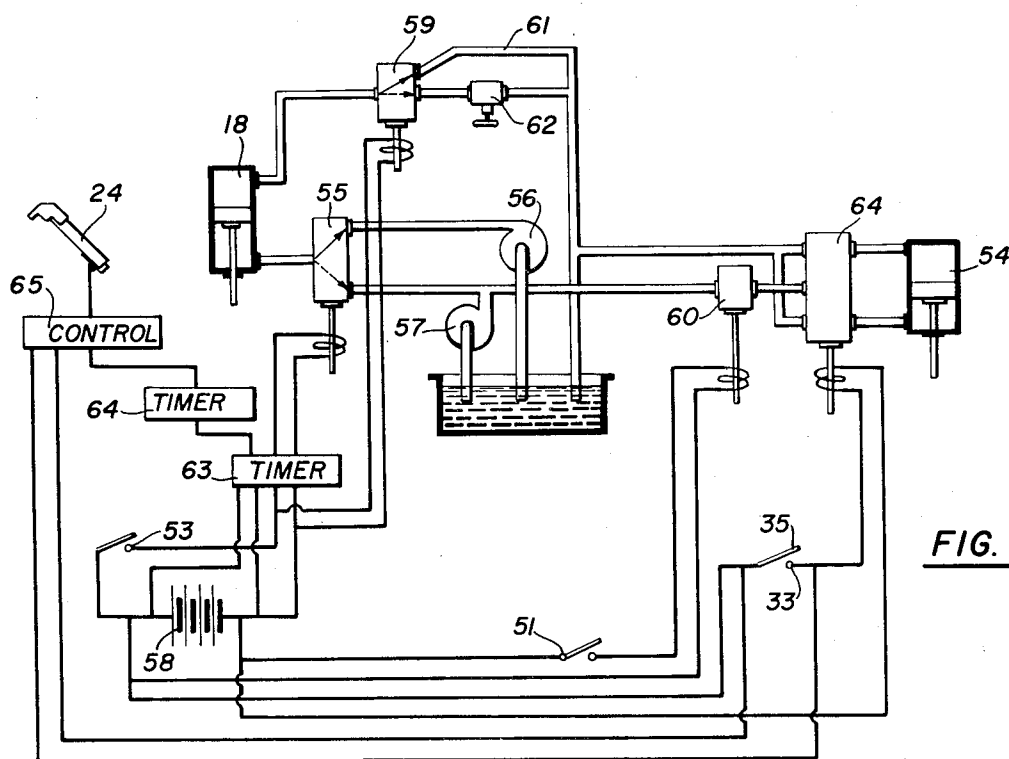


FIG. 6

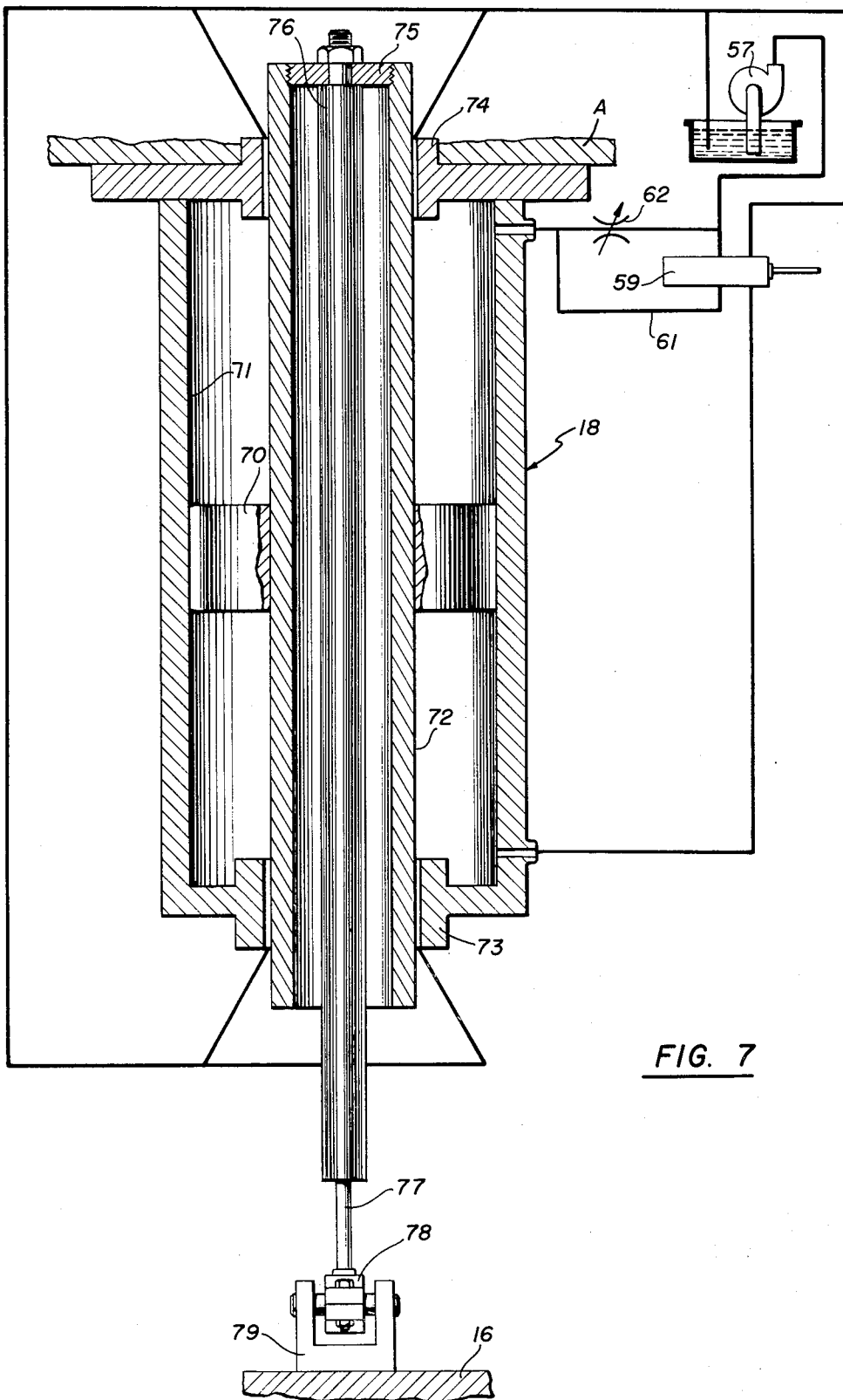


FIG. 7

GRINDING MACHINE WITH SIZE CONTROLLED DRESSING MEANS

BACKGROUND OF THE INVENTION

In the finishing of surfaces by the abrasive method, it is common practice to produce rough grinding by means of a controlled-force feed. When the feed is brought about by the controlled-force method (rather than a controlled-rate method), it is possible to provide the largest possible force between the wheel and the workpiece without destruction of the wheel. The use of such a large force has a number of advantages in addition to providing grinding at the highest rate of stock removal, not the least of which is the greater ability to round up the workpiece. In any case, if a rapid infeed of the wheel is used toward the workpiece, when the initial contact between the wheel and the workpiece takes place at this higher infeed rate, the abrasive wheel is adversely affected, if not actually broken. It is necessary, therefore, to limit the amount of rapid infeed. If a dressing operation is performed during a grinding cycle, the wheel will "cut air" for a considerable period of time. Attempts in the past to introduce the wheel to the workpiece without this non-productive period have not been successful, particularly because of the expensive apparatus required and because the equipment has been complex and easily rendered inoperative. Since a commonly used cycle is one in which the rough grind is interrupted while the wheel is taken out for a dressing operation and then returned to further rough grinding, this is a common problem. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a grinding machine in which grinding takes place at extremely high forces, but the danger of damage to the wheel by collision between the wheel and the workpiece is not present.

Another object of this invention is the provision of a grinding machine capable of repeated rough grind and dress operations during a given cycle on a single workpiece, wherein rapid infeed takes place at the beginning of each roughing grind.

A further object of the present invention is the provision of a grinding machine capable of soft introduction of the abrasive wheel to the workpiece by means of apparatus which is simple in construction, inexpensive to manufacture, and which is capable of a long life of useful service with a minimum of maintenance.

It is another object of the instant invention to provide a grinding machine capable of performing with a grinding cycle in which the abrasive wheel is removed for an intermediate dress whenever the grinding rate is slower than a predetermined amount due to wheel dulling or workpiece hardness.

A still further object of the invention is the provision of a grinding machine for high force grinding in which the abrasive wheel is used at its greatest efficiency despite variations in workpiece size and grindability.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

SUMMARY OF THE INVENTION

In general, the grinding machine consists of a base on which is mounted a workhead table for carrying the workpiece and a wheelhead table for carrying an abrasive wheel. Feed means is provided for bringing about relative movement between the tables to cause engagement of the abrasive wheel and the workpiece for a primary grinding operation, the feed means including an actuator for producing selectively a rapid infeed and a slow feed rate between the abrasive wheel and the workpiece. A control means is operative on the actuator to change from the rapid infeed to the slow rate at a preselected point in the said relative movement.

More specifically, means is provided to produce a dressing operation if a predetermined size is not reached in a predetermined interval of grinding at high force, and to produce a further grinding operation at high force after the said dressing operation. Furthermore, the said point in the relative movement at which the change from rapid infeed to slow rate during the said further grinding operation is automatically adjusted, so that the change takes place just before contact is made between the abrasive wheel and the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

FIG. 1 is a perspective view of a grinding machine embodying the principles of the present invention,

FIG. 2 is a horizontal sectional view of the machine taken on the line II—II of FIG. 1,

FIG. 3 is a perspective view of a switch mechanism forming part of the invention,

FIG. 4 is a plan view of the switching mechanism,

FIG. 5 is a vertical sectional view taken on the line V—V of FIG. 4,

FIG. 6 is a diagram of electro-hydraulic circuitry used in the machine, and

FIG. 7 is a sectional view of a main feed cylinder and associated equipment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, it can be seen that the grinding machine, indicated generally by the reference numeral 10, is of the type shown and described in the patent of Hohler et al., U.S. Pat. No. 3,197,921, which issued on Aug. 3, 1965. It is provided with a base A on which is mounted a workhead 14 and a wheelhead 13. Around the front of the base extends a splash guard B which is readily removable. Extending upwardly from the rear of the base A is a superstructure C having two arms similar to the arm D which extend forwardly from the ends of the base. Mounted between the arms is a control cabinet E. At one end of the machine is located a coolant tank F receiving coolant returning from the machine through a pipe G.

Referring next to FIG. 2, it can be seen that the base A is provided with a flat horizontal upper surface on which are mounted the workhead 14 and the wheelhead 13. The workhead 14 is carried on a workhead table 11 which is mounted for longitudinal motion on

the base by means of ways 15. Similarly, the wheelhead 13 is carried on a wheelhead table 16 which is mounted for transverse sliding motion on the base A by means of ways 17. Extending between the workhead table 16 and the base A is a feed cylinder 18 which is suitably provided with fluid pressure to bring about movement of the table 16 transversely of the base. Similarly, the hydraulic cylinder 19 connects the table 11 to the base A and brings about longitudinal movement of the table 11 over the ways 15. Extending from the wheelhead 13 is a rotatable spindle 21 carrying on its outer end an abrasive wheel 22. Carried by the workhead 14 and rotated thereby is a workpiece 23; for the purpose of illustration, this workpiece is shown as the outer race of a ball bearing whose inner groove is being ground by the abrasive wheel 22. The workpiece is supported on its outer cylindrical surface by shoes, in the usual way, and rotatably driven by the workhead 14. Residing in the bore of the workpiece during the grinding operation is a pneumatic air gate 24.

Slidable on the upper surface of the base A is a compensation slide 26 which, at its rearward end, is threadedly attached to a threaded shaft 27 which, in turn, is driven by a motor 28 fastened to the base A. This motor is of the type capable of small discrete rotary increments in response to pulses received from an electrical control, i.e., a stepping motor. By regulating the number and nature of the pulses from the electrical control, it is possible to rotate the motor quickly or slowly in exact amounts to make the compensating slide 26 move transversely over the surface of the base A. This motor is used to produce a compensation after dress and to provide for a retraction of the wheel at a suitable time in the grinding cycle, as is well known. A dressing apparatus 29 is mounted on the workhead table 11 in position to engage the wheel 22 at a suitable time in the grinding cycle.

The compensating slide 26 is provided with a transverse slot 31 and, in this slot resides a horn 32 extending downwardly from the undersurface of the wheelhead table 16. The front of the compensating slide is provided with a hardened metal insert 33. Mounted on the front portion of the wheelhead table 16 is a retractable stop 34 having a contact rod 35 extending toward the compensating slide 26 and toward the metal insert 33. Mounted at the front of the retractable stop is a feedback gear 36 and an adjusting knob 40. Extending laterally from the compensating slide 26 is a shelf 37 having an upper horizontal surface on which is mounted a switching mechanism 38.

In FIG. 3 it can be seen that the shelf 37 has a flat horizontal upper surface on which the switching mechanism 38 is mounted. The switching mechanism comprises an upper lever 39 and a lower lever 41 which are mounted for horizontal swinging action about a common pivot shaft 42. The upper lever 39 has a downwardly-dependent finger 43 which slides into position to be engaged by an outwardly-extending flange 44 formed on the contact rod 35. Mounted on the upper surface of the lower lever 41 is a block 44 having a notch 45, having a bottom surface on which the undersurface of the upper lever 39 is slidable. The notch defines two abutments 46 and 47 which serve to limit the swinging action of the upper lever 39 relative to the lower lever 41. Mounted on the upper surface of

the lower lever 41 under the upper lever 39 is a contact block 48 having a forwardly directed button 49 in position to engage on occasion with a switch element 51 mounted on the upper surface of the shelf 37.

In FIG. 4 it can be seen that a coil spring 52 lies between the upper lever 39 and the abutment 47. It can also be seen that the inner surface of the abutment 46 is provided with a contact button 53 in position to be engaged by the corresponding facing side of the upper lever 39 on occasion. Mounted on the upper surface of the shelf 37 is a hydraulic cylinder 54 operative to press the lower lever 41 in a forward direction on occasion.

FIG. 5 is useful in visualizing the relationships of the parts in the vertical plane. The switching mechanism 38 is carried on the shelf 37 in a recess under the table 16 where it does not engage the table except, of course, through the offices of the contact rod 35. The compensation slide 26, is, of course, slidable over the upper surface of the base A and is contacted on occasion by the horn 32 extending downwardly from the underside of the table 16.

Referring to FIG. 6, it can be seen that the controls associated with the grinding machine 10 are different in some respects than a conventional grinding machine. Generally speaking, the controls in the present grinding machine incorporate all of the hydraulic and electrical controls of machines of the type shown in the patent application of Uhtenwoldt et al., Ser. No. 879,038, filed Nov. 24, 1969. The main feed cylinder 18 is connected through a selector valve 55 to a pump 56 issuing low pressure fluid and a pump 57 issuing high pressure fluid. The valve 55 is connected electrically to a switch formed in a timer 63 which, in turn, is connected to the contactor 53 in series with a source 58 of electrical power. The other end of the cylinder 18 is connected to a selector valve 59 allowing fluid to return to the sump through an unrestricted conduit 61 or through a restrictor 62. The restrictor 62 and the cylinder 18 make up the combination shown and described in the patent application of Uhtenwoldt et al., Ser. No. 840,324, filed July 9, 1969, wherein the restrictor presents viscous restriction to the flow of fluid out of the cylinder during the cross-feed operation. The selector valve 59 is electrically connected to the contactor 53 which is opened. The high pressure pump 57 is connected through a reversing valve 64 to the cylinder 54 and through a stop valve 60 operated by the contactor 51. The machine contains the controls as shown in the patent of Hatstat et al., U.S. Pat. No. 3,534,509, which issued on Oct. 20, 1970, and is capable of performing a finishing operation by means of a retractable stop in the manner suggested in that patent.

FIG. 7 shows the details of construction of the cylinder 18. The piston 70 slides in the bore 71 of the cylinder connected to the base A and is provided with a piston rod 72 which extends from each side of the piston. At one end it passes through a hub 73 which is suitably bored to act as a hydrodynamic bearing with the outer surface of the rod; at the other end it passes through a similar hub 74. The operating fluid in the cylinder is allowed to pass out of the cylinder around the outer rod surface through the bores in the hubs. This fluid is collected and returned to sump.

The rod 72 is tubular with a cap 75 at one end in which is mounted one end of a relatively slender rod

76. This rod extends coaxially through the tubular rod 72 and emerges from it at the other end. At that end, it is provided with a reduced portion 77 by which it is connected through a universal joint 78 to a block 79 mounted on the underside of the wheelhead table 16.

The operation of the invention will now be readily understood in view of the above description. Referring to FIGS. 1 and 2 and assuming that the workpiece 23 is in place and is being rotated by the workhead 14 and that the abrasive wheel 22 is being rotated by the wheelhead 13, let us also assume the conditions at the start of operation before the wheel 22 makes contact with the surface of the workpiece 23. At that time, the cylinder 18 is connected to the low pressure pump 56 and the table 16 begins advance transversely. At the same time that the abrasive wheel 22 makes contact with the workpiece 23, the flange 44 on the retractable stop 34 contacts the finger 43 of the upper lever 39 of the switching mechanism 38. Further rearward movement of the table 16 brings about contact of the wheel 23 with the workpiece and also carries the lever 39 rearwardly. In a very short time, the lever leaves the contactor 53 formed on the abutment 46. As soon as the lever leaves the contactor 53, electrical power from the source 58 no longer actuates the valve 59 and the valve is changed to cause the fluid leaving the cylinder 18 to pass through the restrictor 62 instead of through the unrestricted conduit 61. This causes the movement of the table 16 to be inhibited and to permit rounding up of the workpiece without the table being cammed back and forth by eccentricities and irregularities in the workpiece surface. The force is still a low force, however, and the wheel 22 engages the workpiece 23 very softly and without damage to the wheel. At the same time that the contactor 53 was opened, the timer 63 began operation and, after a preset time, the timer 63 times out and electrical power is removed from the valve 55. The valve reverses and connects the cylinder 18 to the high pressure pump 57, so that grinding begins under high force.

Grinding proceeds now on a roughing grind with controlled-force at a high level of force. Eventually, the table 16 moves rearwardly and the wheel 22 feeds into the workpiece 23 far enough so that the contact rod 35 strikes the button 33 on the compensation slide 26 and indicates that a certain point has been reached in the cross-feed movement. At that time, the workpiece should have been ground to a certain size, assuming that the wheel 22 is adequately sharpened and that the workpiece 23 is of a given grindability. The gage 24 measures the size of the workpiece and determines when the size has been reached which has been predetermined as the end of rough grinding. If the gage indicates the end of rough grinding before the contact is made between the contact rod 35 and the button 33, the grinding machine moves the wheel out on a dressing cycle and then returns it for a finish grind. If, however, the contact is made between the contact rod 35 and the button 33 before the gage indicates that rough size has been reached, the wheel is moved out on a dressing cycle, but this time is returned for a roughing grind in the same manner as has been described before.

Now, when the flange 44 made engagement with the upper lever 39 and continued pressing it rearwardly during the feeding of the table 16, the upper lever 39,

eventually, struck the abutment 47, despite the bias presented by the coil spring 52, and began to carry the lower lever 41 across the upper surface of the shelf 37 with it. When the table 16 is moved forwardly again to remove the abrasive wheel 22 from the surface of the workpiece and to carry it out for a dressing cycle with the dressing apparatus 29, the lower lever 41 remains where it was last moved during the feeding operation. Furthermore, the upper lever 39 is allowed to move forwardly away from the abutment 47 under the impetus of the coil spring 52 but, in a short while, strikes the contactor 53 and closes it. This has the first effect of returning the condition of the cylinder 18 to the original situation where the valve 55 selected low pressure oil from the pump 56 and allowed the oil to leave the cylinder through the unrestricted conduit 61, as determined by the valve 59. The second effect, of course, is that the upper lever 39 remains with the lower lever 41, aside from some slight motion between the abutments 47 and 46. In FIG. 4, the distance between the abutments and the surfaces of the lever are greatly exaggerated for purposes of description but, in the practical embodiment, only a few thousandths in gap is provided. When the grinding machine returns to a normal roughing operation after dress, it finds that the upper lever 39 is located a considerable distance rearwardly from what it was at the beginning of the grinding cycle. This means that the table 16 is pushed rearwardly under low power fluid (without restriction) and is connected to drain through the unrestricted conduit for a longer period of time. Eventually, however, it reaches the upper lever 39 and its flange 44 starts to press the lever rearwardly, thus opening the switch formed by the contactor 53 and switching to low pressure fluid but with the damper 62 in operation. At a preselected time later, the timer 63 switches the cylinder to high pressure oil and the rough grind continues. This cycle of rough grind and dress may continue repeatedly until, eventually, the gage 24 will indicate that the workpiece size has been enlarged to a preselected end of rough grind size, at which time the wheel will be taken out for dress but, when it returns, continues on with the rest of the cycle, which may involve a finish grind and a sparkout, in the well-known manner. It is interesting to note, however, that, every time the roughing grind is repeated, because of a dulled wheel or a very hard workpiece, the lower lever 41 is moved slightly further in the rearward direction, so that the table 16 moves even further at the low pressure before the restrictor 62 is placed in operation. The switching mechanism 38, therefore, acts as a "memory" and remembers the point to which the wheel must be returned after the dressing operation.

It can be seen, then, that the present invention provides not only for introducing the abrasive wheel 22 to the surface of the workpiece 23 at a low force to prevent damage to the wheel and to prevent the introduction of undesirable vibratory disturbances into the grinding machine operation. It also provides that this soft introduction of the wheel to the workpiece take place, even though the beginning of the roughing grind be changed in cross-feed position when a repeated rough grind dressing operation cycle be carried on in a difficult situation. The mechanism is simple and inexpensive and yet carries out the function adequately.

The concept of interrupting the grinding cycle for a dressing operation if a fixed switch is contacted by the wheelhead table before a pneumatic gage indicates that the proper workpiece size has been reached is shown and described in the patent of Lockwood, U.S. Pat. No. 3,327,432 and the apparatus shown in that patent for accomplishing that function is used in connection with the present invention.

The operation of the machine, therefore, involves a plunge-grind at low force with no damper until the wheel arrives at the workpiece. Then, the operation is switched to low force but with the viscous restrictor in the line. Also, a timer is begun and when the timer times out, the force is switched to high force while retaining the viscous damper in place. The steps of the cycle can be described as follows:

1. Low force, no damper.
2. Strike switching mechanism, start timer, and throw in damper (still low force).
3. Timer times out and high force presented.
4. Grind at high force. Either
 - a. the machine reaches the rough size before the switch is reached; the normal dressing operation takes place and the cycle is continued to the finish of the grinding cycle, or
 - b. The machine reaches the switch before the gage indicates rough size; a dress takes place and then the wheel is returned to the workpiece for a further rough grind.

If (a) occurs, the ordinary machine cycle continues from that point, but, if (b) occurs, the rough grind is repeated once more. Eventually, of course, the rough grind size will be reached and the grinding cycle will be continued to the finish size.

It should be noted that, as soon as the grinding cycle is finished, the contact between the elements 33 and 35 actuates the valve 64 and causes the cylinder 54 to return the switching mechanism to its original condition. When the lower lever 41 is returned to its original position, it makes contact with the switch 51 which cuts out power to the cylinder until it is needed again. The cylinder 54, therefore, is operated only when it is used to return the levers to their front position.

In an alternate method of operation, a timer 64 may be used in connection with a control 65 to determine whether the dressing and rough grind operation need to be repeated in connection with a particular workpiece. The timer 64 is started in operation at the same time as the timer 63 starts the high pressure high force operation. If the timer 64 times out before the control 65 indicates that the rough size has been reached, the control 65 acts also to repeat the dressing and rough grind cycle.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. A grinding machine for generating a surface of revolution on a workpiece, comprising
 - a. a base,

- b. a workhead table mounted on the base and adapted to carry the workpiece and rotate it about the axis of the surface of revolution,
- c. a wheelhead table mounted on the base and adapted to carry a wheelhead in which is rotatably mounted a spindle having an abrasive wheel mounted thereon,
- d. a hydraulic cylinder connecting the base to one of the tables to produce relative movement between the tables to cause engagement of the abrasive wheel and the workpiece for a grinding operation, the cylinder being connected selectively to sources of low pressure and high pressure fluid, the cylinder being connected for discharge selectively through a restrictor and through an unrestricted conduit to drain, the unrestricted conduit being operative and the cylinder being connected to the source of low pressure fluid as the wheel approaches the workpiece and before engagement therewith,
- e. a switch operable during the said relative movement to make the restrictor operative with the cylinder at approximately the same time that the wheel makes engagement with the workpiece, and
- f. a timer which is started by the switch and which, after a predetermined interval of time, changes the connection of the cylinder from the source of low pressure fluid to the source of high pressure fluid.

2. A grinding machine as recited in claim 1 wherein the switch consists of two levers mounted for hinged movement about the same axis, the levers lying face-to-face for sliding movement relative to one another, wherein one of the levers is engaged on occasion by the said one of the tables and is moved thereby relative to the other lever to produce a switching motion, further movement of the said one of the levers in this way causing the other lever to move with it.

3. A grinding machine as recited in claim 2, wherein the other lever is provided with two spaced abutments, the said one of the levers lying on the said other lever and capable of swinging movement relative thereto only between the two abutments, one of the abutments acting as a switching contact and the other acting as a mechanical stop.

4. A grinding machine as recited in claim 3, wherein a hydraulic cylinder is provided to return the two levers to an initial position after a grinding cycle has been completed, a spring lying between the said other abutment and the said one of the levers to maintain it normally in contact with the said one of the abutments.

5. A grinding machine as recited in claim 4, wherein the said other of the levers rests on a broad surface with substantial friction to maintain it in a given position to which it has been moved during a particular grinding cycle.

6. A grinding machine as recited in claim 1, wherein the cylinder is provided with a piston having a tubular piston rod, a solid rod extends coaxially through the tubular piston rod and is connected to it at one end only, the other end of the solid rod extending outwardly of the tubular piston rod and is attached to the wheelhead table.

7. A grinding machine as recited in claim 6, wherein the solid rod is provided with a substantially reduced portion adjacent the point of attachment to the wheelhead table.

8. A grinding machine as recited in claim 6, wherein the tubular rod passes through a bore in a hub located at each end of the cylinder, the space between the tubular rod and the surfaces of the bores being provided with fluid from the interior of the cylinder to form hydrodynamic bearings. 5

9. A grinding machine, comprising:

- a. a base,
- b. a workhead table for carrying a workpiece mounted on the base,
- c. a wheelhead table for carrying an abrasive wheel mounted on the base,
- d. feed means bringing about relative movement between the tables to cause engagement of the abrasive wheel and the workpiece for a primary grinding operation, the feed means including an actuator for producing selectively a high speed and a low speed movement between the abrasive wheel and the workpiece, 15
- e. control means operative on the actuator to change from the high speed to the low speed at a 20

preselected point in the said relative movement, the said point in the relative movement at which the change from high speed to low speed during the said further grinding operation is automatically adjusted, so that the change takes place almost immediately before contact is made between the abrasive wheel and the workpiece, and

- f. means to produce a dressing operation if a predetermined size is not reached in a predetermined interval of grinding at high force and to produce a further grinding operation at high force after the said dressing operation.

10. A grinding machine as recited in claim 9, wherein the said change from high speed to low speed takes place a predetermined time interval before contact between the abrasive wheel and the workpiece, the predetermined time interval being the same in the primary grinding operation and the further grinding operation.

* * * * *

25

30

35

40

45

50

55

60

65