

[54] GRINDING MACHINE
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[22] Filed: May 17, 1971
[21] Appl. No.: 143,926
[52] U.S. Cl.....51/165.91
[51] Int. Cl.....B24b 49/04
[58] Field of Search.....51/165 R, 165.78, 165.87, 165.88, 51/165.91, 165.93

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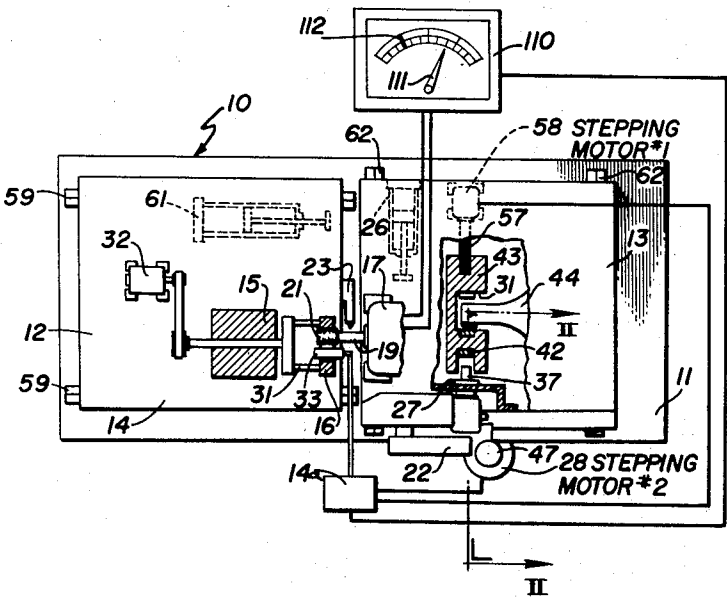
[57] ABSTRACT

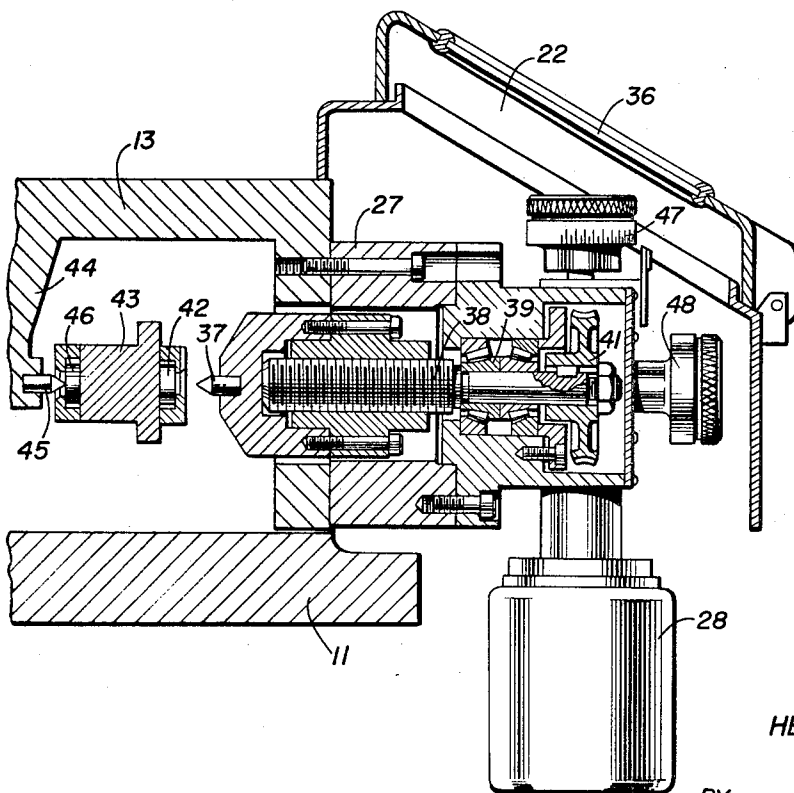
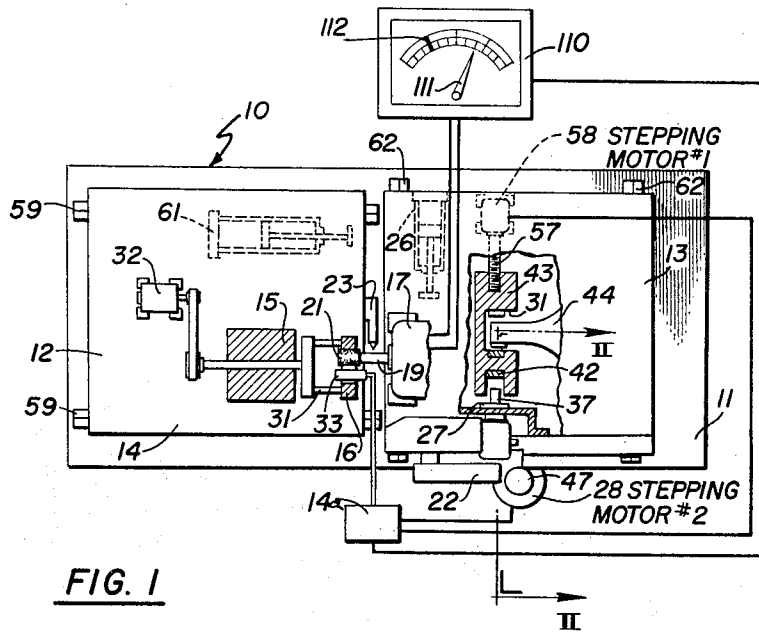
A grinding machine wherein sparkout grinding is carried out with small increments of cross-feed introduced every time the load drops to a predetermined value.

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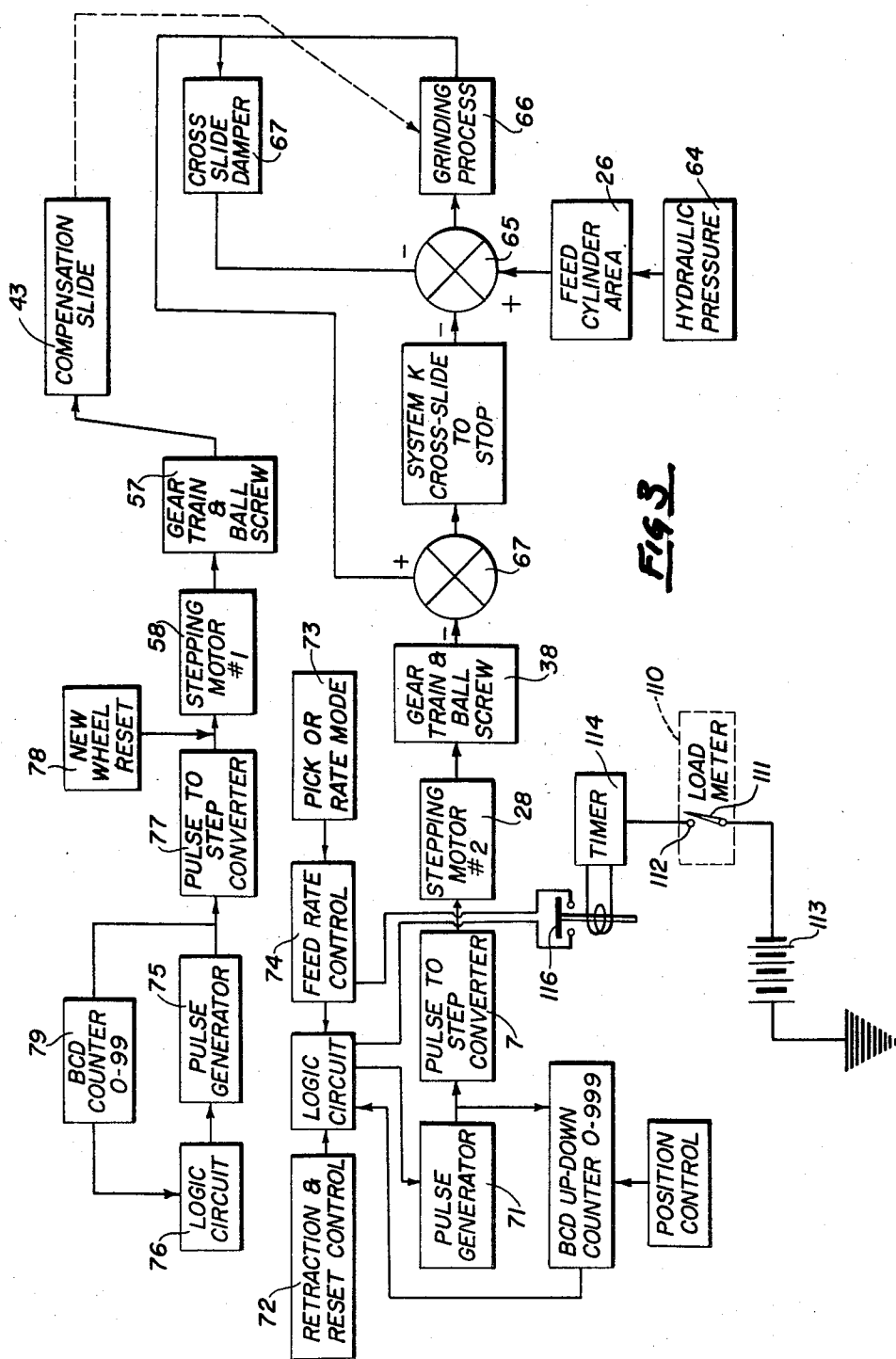
5 Claims, 4 Drawing Figures

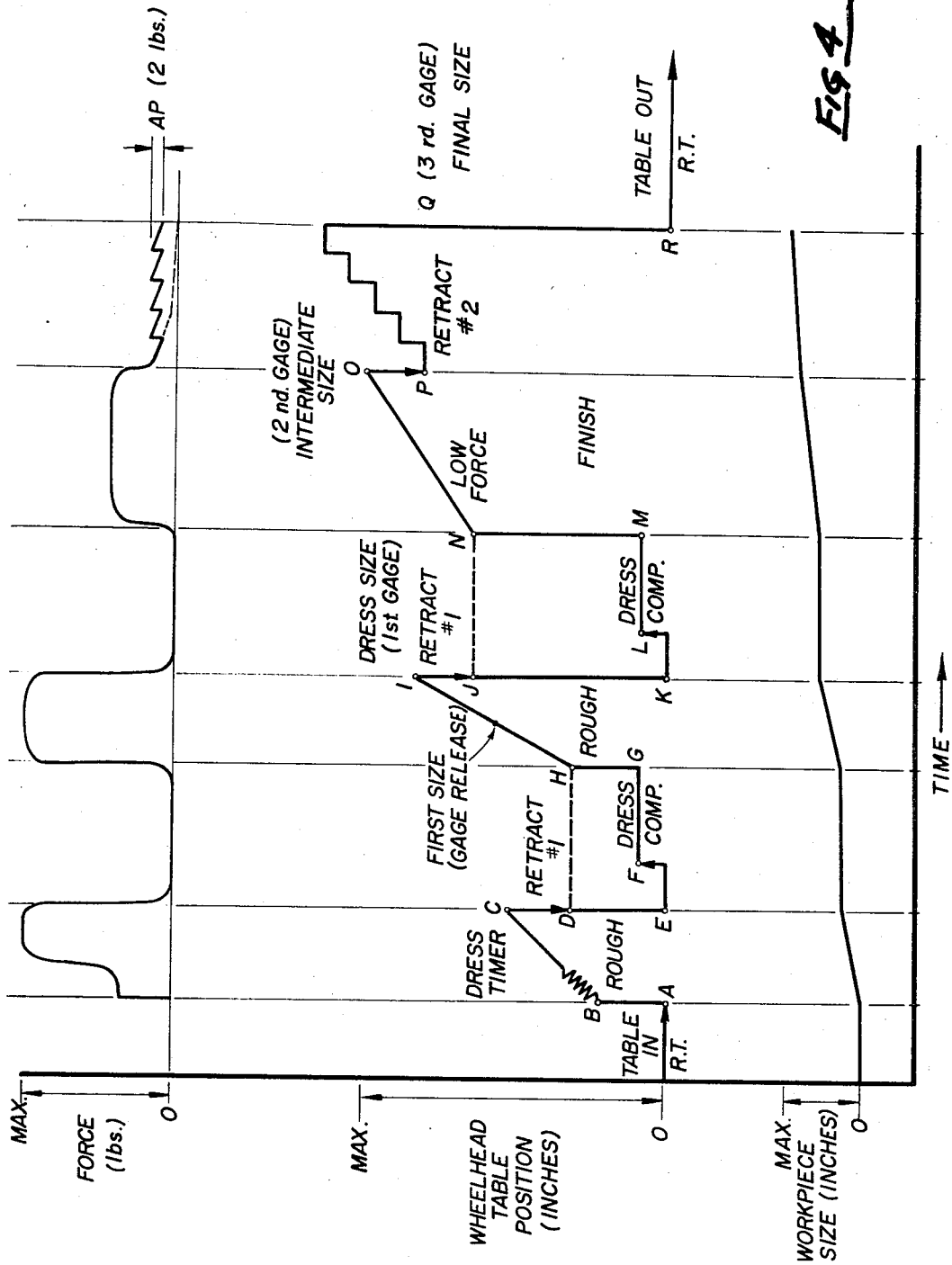




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GRINDING MACHINE

BACKGROUND OF THE INVENTION

It is the usual practice in grinding to provide a "sparkout" period at the end of a grinding cycle. This is accomplished by terminating cross-feed and allowing grinding to take place under the impetus of the deflection of the spindle, which deflection can be appreciable, particularly in an internal grinding machine. Such a sparkout period relieves the workpiece surface of any taper that may be present due to spindle bending or deflection and also provides for a better surface finish because of the light pressure between the wheel and the workpiece. It also allows the final size of the workpiece to be approached gradually, so that more accurate gaging can take place.

As the demands on grinding machines increase for smaller tolerance on taper, size, and finish, the conventional sparkout leaves something to be desired. First of all, final gage size terminates the sparkout. The amount of taper in the workpiece bore (for internal grinding) depends on the amount of deflection left in the spindle at the final size point, and this depends, in turn, on the amount of deflection at the beginning of sparkout. This starting deflection varies from workpiece to workpiece, so that the final taper varies also. If one attempts to overcome this deficiency by allowing the wheel to grind until deflection is entirely removed from the spindle, the grinding cycle becomes very long, and this is unacceptable in the case of an expensive automatic grinding machine, because it increases the amount of labor cost, overhead, and capitalization applicable to each workpiece.

It has been found, furthermore, that the best surface finish is obtained when the finish grinding takes place with an appreciable force between the wheel and workpiece, rather than allowing the force to fall off to a very small value, as is true in the conventional sparkout. Such an appreciable force is, however, substantially less than the amount used in controlled force grinding where the force used is as high as is feasible without destruction of the wheel. Nevertheless, many attempts have been made in the past to provide a relatively low, but, nevertheless, appreciable value of force during the finish period of the grinding cycle. Since the controlled force used in the roughing portions of the cycle are produced by using a hydraulic cylinder and controlling the oil pressure and drain restriction for the cylinder, it was natural to try to maintain this low-value force by this means. However, it proved to be unfeasible to hold the forces constant within the required limits, because of the conduits, grinding swarf, guards, etc. It was also suggested that the low-value force could be obtained by swivelling the wheelhead, but experiment proved that the amount of swivel necessary to take care of the deflection difference between finishing with a large wheel and finishing with a small wheel is infinitesimally small, i.e., in the order of magnitude of the deflection resulting from a force change of one pound. Maintaining forces within a 5-pound value has proved to be impossible, especially under shop conditions. 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 sparkout is feasible even under close tolerances of size, taper, and surface finish.

Another object of this invention is the provision of a grinding machine in which substantially constant force is obtainable during finish grinding.

A further object of the present invention is the provision of a grinding machine in which the taper in successive workpieces is maintained at a preselected value.

It is another object of the instant invention to provide a grinding machine in which good repeatability of taper and surface finish is obtainable.

A still further object of the invention is the provision of a grinding machine having means for maintaining low values of controlled force between the abrasive wheel and the workpiece.

It is a further object of the invention to provide a grinding machine wherein short grinding cycles are possible without exceeding selected tolerances on taper and finish.

It is a still further object of the present invention to provide a grinding machine in which surface finish does not change due to the reduction in diameter of the abrasive wheel as it wears and is dressed from the large new wheel to the small worn wheel.

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 invention has to do with a grinding machine having a feed mechanism for bringing about relative movement between the wheelhead table and the workhead table to cause engagement of the abrasive wheel with the workpiece with controlled force during most of the grinding cycle and to shift to sparkout grinding for the remainder of the cycle. The feed mechanism includes an actuator capable of bringing about the relative movement in an incremental manner during the sparkout grinding. A control is provided, including a device for measuring the load on the wheelhead motor, connected to the actuator to advance the wheel toward the workpiece each time the load drops to a predetermined value.

More specifically, a gage is used to terminate the grinding cycle when a predetermined workpiece size has been reached. The actuator is a stepping motor operative to produce incremental motion in response to the receipt of electrical pulses, and the said device operates a gate at the predetermined load to introduce a preselected number of pulses to the actuator.

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 schematic plan view of a grinding machine embodying the principles of the present invention,

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

FIG. 3 is a schematic view of the controls used in the grinding machine, and

FIG. 4 is a chart showing the relationship of grinding force, wheelhead table position, and workpiece size during a grinding cycle.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, wherein are best shown the general features of the invention, the grinding machine, indicated generally by the reference numeral 10, is shown as consisting of a base 11 on which is mounted a workhead table 12 and a wheelhead table 13. Also mounted on the base 11 is a control cabinet 14. Mounted on the table 12 is a workhead 15 carrying a workpiece 16 which, for the purpose of illustration, is shown as the outer race of a roller bearing whose bore is to be finished. Mounted on the table 13 is a wheelhead 17 driven by an integral motor and carrying a rotatable spindle 19, the outer end of which carries an abrasive wheel 21. At the front of the table 13 is mounted a feed box 22, while mounted on the workhead table 12 is a diamond dressing unit 23 as well as loading mechanism (not shown).

The grinding machine 10 is similar to that shown in the copending patent application of Robillard, Ser. No. 879,785, filed on Nov. 25, 1969. The machine is provided with a cross-feed hydraulic cylinder 26, the front of a retractable stop mechanism 27 operated by a stepping motor 28, and various other controls associated with the machine. The workhead 15 has support shoes (not shown) which engage and support the outer surface of the workpiece 16. One end of the workpiece is engaged and driven by a tubular drive platen 31 which is suitably rotated by a motor 32. Located internally of the workpiece bore is a gage 33 which takes a continuous reading (during certain portions of the grinding cycle) of the size of the bore in the workpiece that is being ground. The other end of the workpiece is engaged by clamping rollers (not shown), in the usual way.

It can be seen that a compensation slide 43 is engaged at the rear by a ball screw 57 operated by a stepping motor 58. In the description that follows, the stepping motor 58 will be spoken of as stepping motor No. 1, while the stepping motor 28 will be considered as stepping motor No. 2. The workhead table 12 is mounted on ways 59 for movement longitudinally of the axis of the workpiece, and this motion is brought about by the operation of a hydraulic cylinder 61. By means of the usual controls, the table can be reciprocated during grinding in the usual way. The wheelhead table 13 is mounted on ways 62 for transverse motion. The gage 33 is shown as being of the pneumatic type having a lead extending outwardly to the control cabinet 14. The motor in the wheelhead 17 is provided with a contact-type load meter 110 having a contact hand 111 and an adjustable contact 112.

FIG. 2 shows the interior of the retractable stop mechanism 27, and it also shows the manner in which the feed box 22 is provided with an observation window 36. The stop mechanism 27 is bolted to the front of the wheelhead table 13 which, in turn, is mounted for transverse sliding motion over the base 11. A contact element 37 is slidably mounted in the housing of the stop and is propelled transversely by rotation of a ball screw 38. The ball screw is, in turn, mounted in bearings 39 and is driven by a worm gear 41.

The contact element is positioned to engage, on occasion, with a hardened element 42 mounted on a forwardly facing surface of a secondary or compensating slide 43. A horn 44 extends downwardly from the wheelhead table 13 and is provided with a contact element 45 adapted on occasion to engage a hardened metal element 46 mounted on a rearwardly directed surface of the compensating slide 43. The worm gear 41 and, therefore, the ball screw 38, is driven by the stepping motor 28 and is manually adjustable by means of a knob 47. A manual compensating knob 48 extends from the front of the machine.

FIG. 3 is helpful in understanding the operation of the invention. Hydraulic pressure originating in a source 64 is passed on to the feed cylinder 26 which operates through a mixer 65 to produce the controlled force grinding process 66. These forces make themselves felt at a mixer 67 which operates through the spring constant, K, of the system (indicated by the box 68) which, in turn, feeds a force signal into the mixer 65. The grinding process also is affected by a cross-slide damper 69 receiving force in the grinding process 66 and entering into the mixer 65. At the same time, a pulse generator 71 operates the stepping motor No. 2, and this is effective through the gear train and ball screw 38 to operate through the mixer 67 on the system spring constant box 68. Retraction and reset control 72 controls the flow of pulses from the pulse generator 71 to the stepping motor No. 2. Similarly, a pick or rate mode selection 73 operates through a feed-rate control 74 to also regulate the flow of pulses from the generator 71 to the stepping motor No. 2. The grinding process 66 is effected by the compensation slide 43 which, in turn, is regulated by the stepping motor No. 1 operating through a gear train and ball screw. A pulse generator 75 is controlled by a logic circuit 76 which, in turn, operates through a pulse-to-step converter 77 in the stepping motor control, a variation in operation being possible by means of the "new wheel" reset control 78. Feedback takes place between the output of the pulse generator 75 and the input of the logic circuit 76 through a binary code decimal counter 79 (BCD counter). The contact hand 111 of the load meter 110 is connected through an electrical source 113 to ground; the contact 112 is connected to a timer 114 having an output relay 115 whose contact 116 is normally open and connected between the feed rate control 74 and the logic circuit. The timer closes the contacts 116 when the hand 111 engages the contact 112 as the load drops. It maintains the contacts closed for a preset interval of time and allows pulses to pass to motor 2 during that interval. It, therefore, acts as a "gate" for stepping motor pulses.

The general operation of the machine can be best understood by examining FIG. 4. The cycle shown and described is one which might be used to grind a bore in a particularly difficult workpiece having a very hard surface to be ground. Referring first to the WHEELHEAD TABLE POSITION graph in the center, it can be seen that the workhead table 12 moves inwardly on rapid traverse to the point A, so that the abrasive wheel 21 lies within the workpiece 16. The hydraulic cross-feed cylinder 26 is energized to cause the wheelhead table 13 to move transversely and to bring the wheel into engagement with the surface to be finished. Engagement of the abrasive wheel 21 with the surface of

the workpiece 16 takes place at the point B, and the workhead table begins reciprocation, while the wheel is advanced laterally into the workpiece under the hydraulic pressure in the cylinder 26 on a controlled force grinding operation. This operation is a rough grind that consists in rounding up the bore in the workpiece and removing substantial amounts of material from the surface. Eventually, a point C is reached, as determined by a dress timer which had started at the point A. A retraction of the wheelhead table rearwardly to the point D takes place to relieve the deflection in the spindle 19 and a further action by means of the cylinder 26 carries the wheelhead forwardly to the point E where the horn 44 engages the rearwardly facing surface of the compensation slide 43. The compensation slide is then moved rearwardly by introducing a suitable number of pulses into the stepping motor No. 1; this also has the effect of carrying the wheelhead table 13 rearwardly a short compensating distance. The workhead table 12 is then operated by the cylinder 61 to cause the diamond dressing unit 23 to move past the wheel 21 to dress the wheel, at which time the point G is reached. The wheelhead 13 is then moved inwardly by the cylinder 26, so that the wheel engages the workpiece at the point H which, because of the retraction from point C to point D that previously took place, means that the wheel begins grinding without "cutting air." Another rough grind takes place to the point I where a second dress timer times out and calls for another dress. Retraction takes place to the point J, which retraction is the same as from the point C to the point D. Then, the wheelhead table 13 is moved back to the point K, compensation takes place to the point L, and a traversing of the workhead table 12 causes a dress to take place to the point M. The wheelhead table moves inwardly again, engaging the workpiece at the point N, and a grind takes place at a low force controlled force process to the point O. The point O is indicated by the gage 33 as having arrived, and a signal takes place, stopping the grinding operation and introducing a retraction movement to the point P. This retraction is considerably less than the retraction from the point C to the point D, or from the point I to the point J because the low force cutting during this finish portion of the cycle has caused a smaller deflection of the spindle 19. After the retraction takes place, the wheel is allowed to "spark out" grind the workpiece to the point Q where the gage indicates that final size is reached. The wheelhead is then backed off to the point R where the workpiece is removed and a new workpiece is inserted during the loading portion of the cycle. During the sparkout portion of the cycle, it can be seen that the wheelhead table 13 is advanced rearwardly in a step-like fashion. This is caused by introducing groups of pulses into the stepping motor 28 to retract the stop 37 toward the front of the machine by small amounts. Since the cylinder 26 keeps the table pressed rearwardly with the stop 37 contacting the button 42 of the compensating slide (see FIG. 2), the effect is to move the wheelhead table rearwardly by the same small amounts.

Every time the abrasive wheel removes enough material from the workpiece during sparkout to lower the load enough so that the hand 111 on the load meter 110 strikes the contact 112, the timer 114 closes the

contact 116 of the relay 115 for a short period of time and allows a selected number of pulses to pass to stepping motor No. 2.

In the top part of the chart shown in FIG. 4, the force used from point B to point C is shown as at an intermediate value. After dress takes place, grinding occurs from point H to point I at a high force rate. Then, from point N to point O, the force is at a low value. These force values are selected by supplying the cylinder 26 with fluid at different values in the manner shown and described in the patent of Ware et al., U.S. Pat. No. 3,535,828 which issued on Oct. 27, 1970. If the wheel permitted to sparkout in the conventional manner, the force would drop off in the manner indicated by the broken line. However, because the wheelhead table is advanced every so often, the force drops off only slightly and is then raised upwardly. This alternate raising and dropping of the force is shown by the solid line from point P to point Q. Although the scale is exaggerated in the drawing, it will be understood that the sawtooth pattern is actually a mere ripple and, so, the force is maintained at a substantially constant value. The net effect is controlled force grinding at a very low value of force. Because the stepping motor is capable of very small increments of motion, it is possible to advance the wheelhead table by very small amounts; in a practical embodiment of the machine, the stop 37 was advanced in increments of 0.0000050 inch. It was found that the surface finish was excellent and consistent from one workpiece to another, because the wheel had finished the bore at a substantially constant load, thus compensating for variations due to:

1. Cutting conditions on the wheel,
2. Dressing, and
3. The increase of unit pressure because of a smaller worn wheel.

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, comprising
 - a. a base,
 - b. a workpiece support mounted on the base,
 - c. a wheelhead support mounted on the base,
 - d. a wheelhead including a spindle and an abrasive wheel and a motor therefor mounted on the wheelhead support,
 - e. a feed mechanism for bringing about relative movement between the wheelhead support and the workpiece support to cause engagement of the wheel with the workpiece with a controlled force for most of the grinding cycle and shifting to sparkout grinding for the remainder of the cycle, the feed mechanism including an actuator capable of bringing about the said relative movement in an incremental manner during sparkout grinding,
 - f. a control, including a device for measuring the force on the said wheelhead spindle, connected to the actuator to advance the wheel toward the workpiece each time the force drops to a predetermined value, and

7

g. a gage connected to the feed mechanism to terminate the grinding cycle when a predetermined workpiece size has been reached.

2. A grinding machine as recited in claim 1, wherein the feed mechanism includes a hydraulic cylinder for producing the controlled force.

3. A grinding machine as recited in claim 2, wherein the said actuator is a stepping motor operative to produce incremental motion in response to the receipt of electrical pulses, and wherein the said device operates a gate at the predetermined load to introduce a preselected number of pulses to the actuator.

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4. A grinding machine as recited in claim 3, wherein the controlled force portion of the grinding cycle is brought about by engagement of the wheelhead support with a stop mounted on the base, wherein the stepping motor operates to retract the stop and allow the hydraulic cylinder to press the wheelhead support rearwardly.

5. A grinding machine as recited in claim 4, wherein the said device is a load meter having an adjustable contact operable as a switch to operate the gate.

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