United States Patent [19]

Robillard et al.

[11] **3,736,704**

[45] **June 5, 1973**

[54] **GRINDING MACHINE**

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[73] Assignee: **Cincinnati Milacron-Heald Corp.,** Worcester, Mass.

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[52] **U.S. Cl.** **51/165.78,** 51/165.87

[51] **Int. Cl.** **B24b 49/10**

[58] **Field of Search** ....51/165 R, 165.78, 51/165.87, 165.88, 165.91, 165.93

[56] **References Cited**

UNITED STATES PATENTS

3,534,509	10/1970	Hatstat et al.	51/165.91
3,403,980	10/1968	Robillard	51/165.87
3,524,285	8/1970	Rutt	51/165 R

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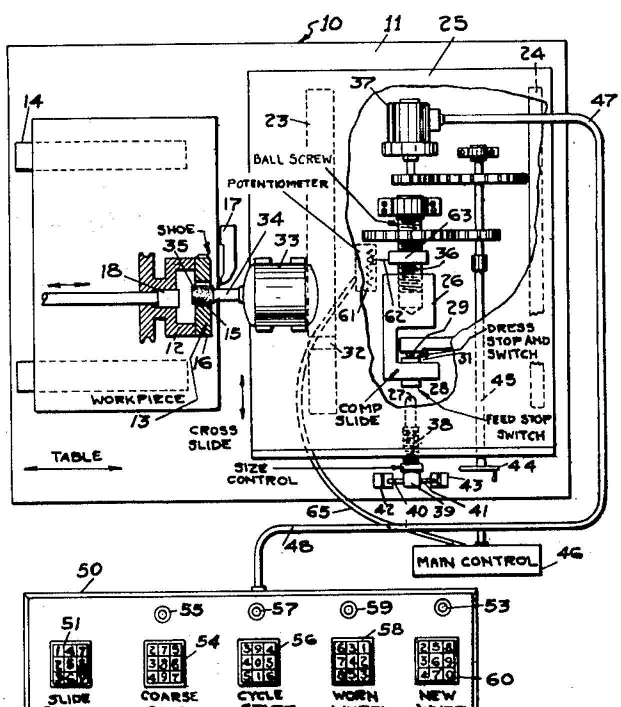
[57] **ABSTRACT**

A grinding machine operative under controlled-force and controlled-rate conditions, wherein the rate of feed is controlled in accordance with the size of the abrasive wheel.

5 Claims, 3 Drawing Figures



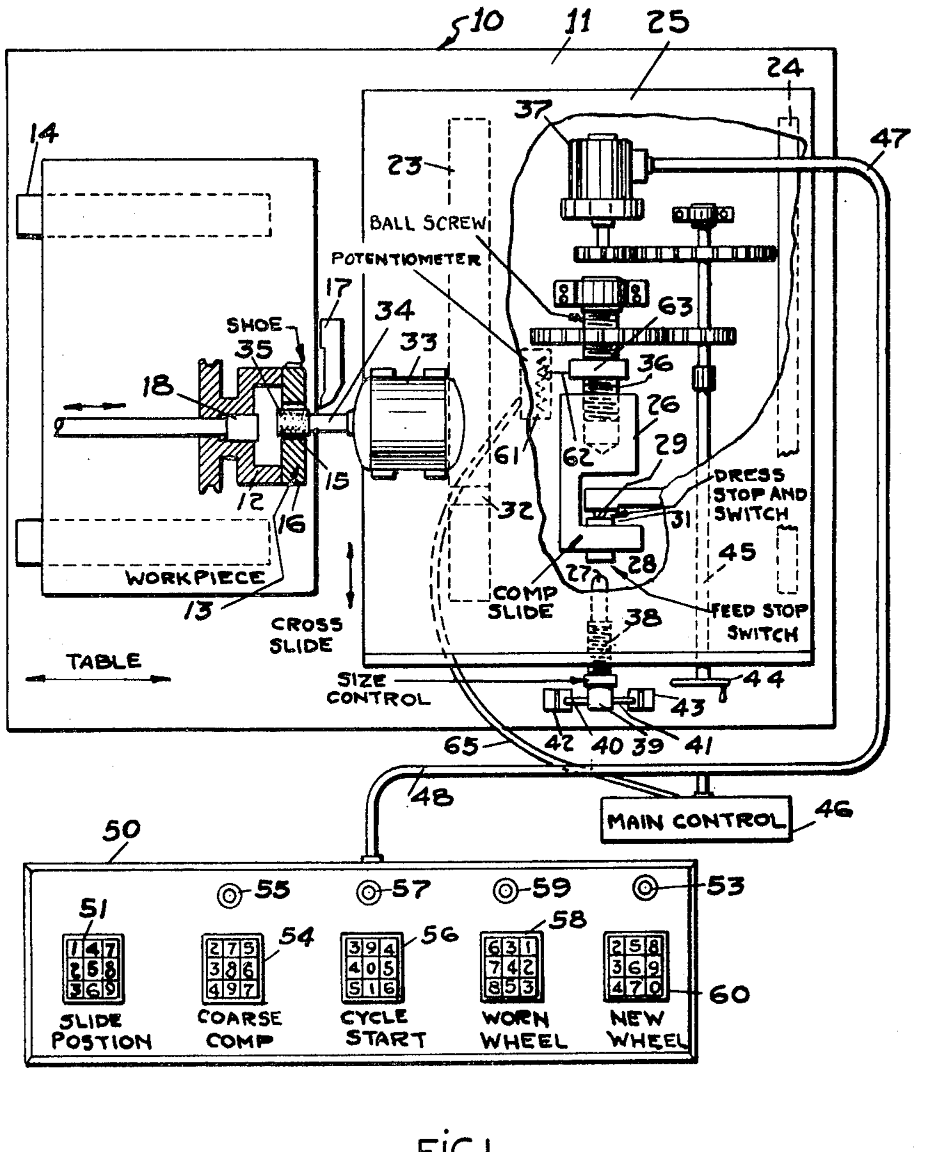


FIG.1.

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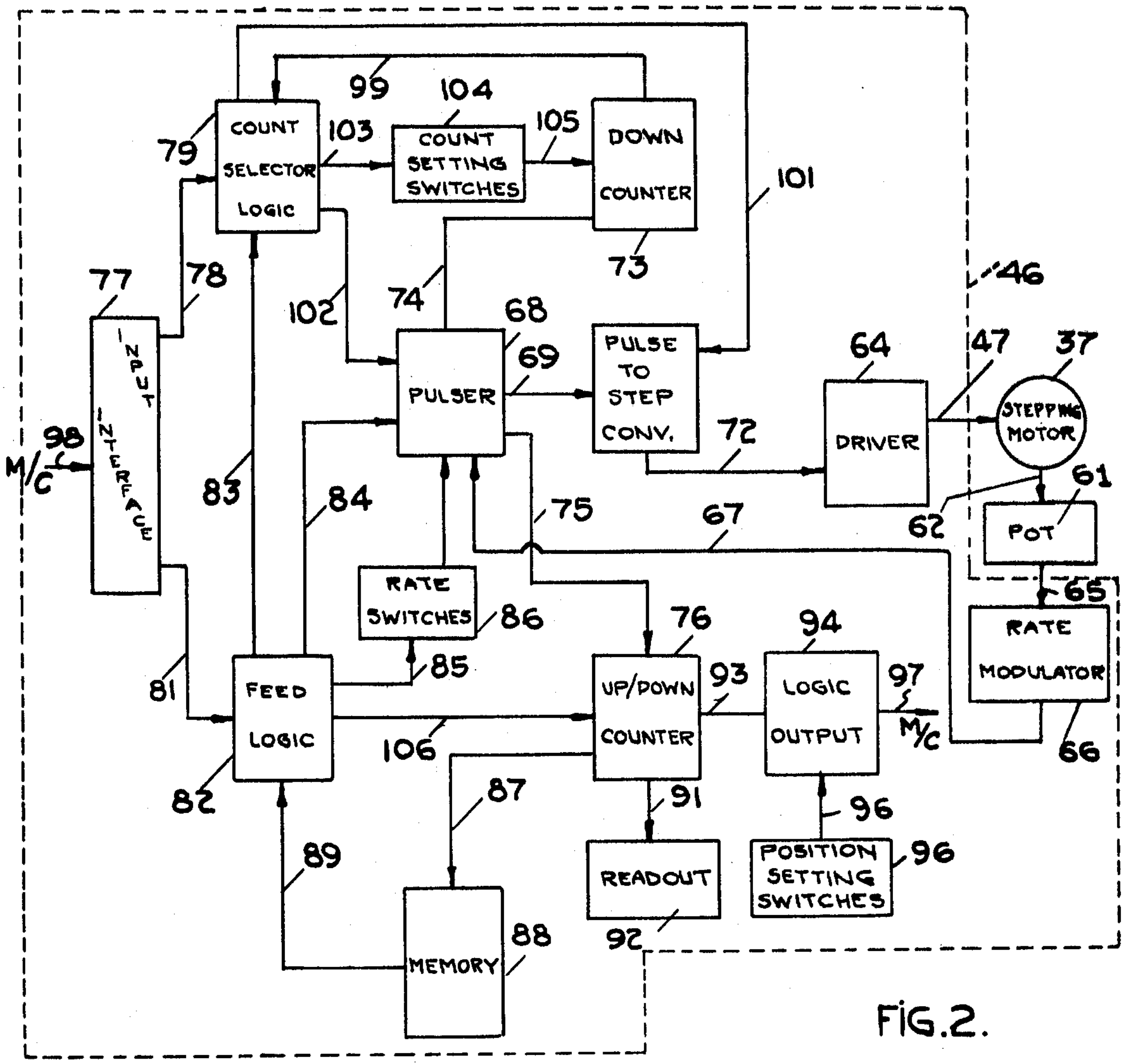
COUNT SELECTOR LOGIC
COUNT SETTING SWITCHES
DOWN COUNTER
PULSER
PULSE TO STEP CONV.
DRIVER
STEPPING MOTOR
POT
RATE MODULATOR
INPUT INTERFACE
M/C
RATE SWITCHES
FEED LOGIC
UP/DOWN COUNTER
LOGIC OUTPUT
READOUT
POSITION SETTING SWITCHES
MEMORY
M/C

FIG. 2.

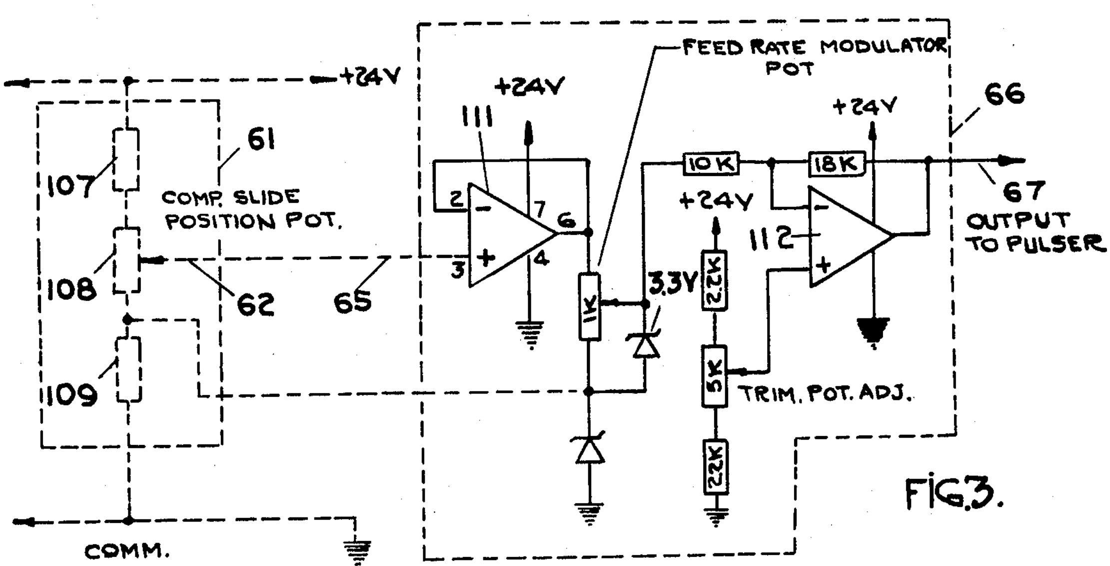
+24V
COMP. SLIDE POSITION POT.
FEED RATE MODULATOR POT
+24V
10K
18K
+24V
+24V
3.3V
1K
2.2K
5K
2.2K
TRIM. POT. ADJ.
OUTPUT TO PULSER
COMM.

FIG. 3.

GRINDING MACHINE

BACKGROUND OF THE INVENTION

In the operation of grinding machines, one of the problems that often arises is that, as the diameter of the abrasive wheel becomes smaller, it tends to cut faster. While fast stock removal is desirable in some parts of a grinding cycle, it is often undesirable particularly at the finish. This is particularly true in the case of internal grinding where the diameter of the wheel is very close in size to the diameter of the bore; this means that a change in the diameter of the wheel due to wear and to the dressing operations brings about a much greater disparity in relative diameters of wheel and bore than would be true in the case of external grinding where a very large grinding wheel is used. More rapid stock removal results in a number of effects, the most important of which is that the finish of the surface deteriorates. Other factors that come about because of this faster cutting rate (due to the smaller size of the wheel) have to do with the amount of taper in the bore due to deflection of the spindles and with the size of the bore. Attempts to reduce the feed rate in accordance with reduction of the diameter of the abrasive wheel have been made in the past, but the apparatus for doing this in an automatic grinding machine has been complicated and expensive and easily changed so that adjustment is lost. 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 the finish of the ground surface does not change from workpiece to workpiece as the abrasive wheel is reduced in diameter.

Another object of this invention is the provision of a grinding machine having automatic means for reducing the rate of feed in accordance with wear and with dressing of the wheel.

A further object of the present invention is the provision of a grinding machine for carrying out a combined controlled-force and controlled-rate grinding cycle, wherein the characteristics of the finished surface do not deteriorate with reduction of wheel diameter.

It is another object of the instant invention to provide a grinding machine having an automatic wheel size feed rate control, which is simple and inexpensive and which is capable of a long life of useful service with a minimum of maintenance.

A still further object of the invention is the provision of an automatic grinding machine in which feed rate is adjusted very accurately in accordance with reduction of wheel diameter.

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 consists of a grinding machine for generating a surface of revolution on a wheel piece, having a base, a workhead table mounted on the base, having a support for carrying the workpiece, and a wheelhead table mounted on the base having a rotatable spindle on which an abrasive wheel is mounted. Feed means is provided for bringing about relative motion between the workhead table and the wheelhead table transversely of the axis of the surface of revolution, the feed means including an actuator for producing a rough grind with controlled-force conditions and a motor for producing a finish grind with controlled-rate conditions. Control means is provided for adjusting the rate of feed during the said finish grind in accordance with the size of the abrasive wheel.

More specifically, the said motor is an electrical stepping motor. The feed means is operative on the wheelhead table to bring about the said relative movement, a compensation slide lies between the wheelhead table and the base, and the said motor is operative to move the compensation slide by an incremental amount every time a dressing operation takes place. A potentiometer is connected to the compensation slide to partake of the same incremental amount of movement. The potentiometer produces an electrical signal indicative of the compensation slide position and of wheel size, and this electrical signal is fed into a pulser to control the rate of pulses fed to the motor during the finish grind.

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

FIG. 2 is a diagram showing the various integrated circuits used in controlling the grinding machine, and

FIG. 3 is an electrical schematic diagram of a portion of the apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. **1**, which best shows the general features of the invention, the grinding machine, indicated generally by the reference numeral **10**, is of the general type shown and described in the patent of Robillard, U.S. Pat. No. 3,403,480, dated Oct. 1, 1968, and the patent of Robillard, U.S. Pat. No. 3,503,158, dated Mar. 31, 1970. The grinding machine **10** consists of a base **11** on which is mounted a workhead **12** carried on a workhead table **13**, which is capable of sliding motion on ways **14** extending parallel to the axis of a surface of revolution **15** of a workpiece **16** which is to be finished. Also mounted on the workhead table **13** is a dressing apparatus **17** having a diamond. Extending through the workhead **12** for engagement with the workpiece bore (surface of revolution **15**) is a pneumatic gage **18** of the type shown and described in the patent of Schmidt et al. U.S. Pat. No. 2,771,714 of Nov. 27, 1956. This gage is suitably connected to pressure switches (not shown) capable of indicating when the size of the bore has reached an intermediate size at which the finish grind is to be terminated, and indicating when the size of the bore has reached the final size.

Also mounted on the base **11** is a wheelhead table **25** which is slidable on ways **23** and **24** to move transversely of the axis of the surface of revolution **15.** Both the table **13** and the table **25** are movable under the impetus of hydraulic linear actuators to produce their respective motions. Lying on the base **11** and slidable over its surface is a compensation slide **26.** Extending from the wheelhead table **25** is a finger **27** aligned to engage a forwardly-facing feed stop **28** which is located on the forward face of the compensation slide. The finger 27 and the feed stop 28 are also arranged as an electrical switch for placing the pneumatic gage 18 in operative condition on occasion, as is well known.

The wheelhead table 25 is also provided with a downwardly-extending finger 29 which is in position to engage a rearwardly-directed dress stop 31 formed on the compensation slide 26. There is a considerably greater distance between this finger 27 and the finger 29 than there is between the feed stop 28 and the dress stop 31, so that the table 25 is capable of a wide range of operative movement between these two portions, such motion being brought about by a suitable hydraulic cylinder 32. This cylinder is arranged with the usual servo valves and so on to produce very quick action in moving the wheelhead table 25 from a first position where the finger 27 engages the feed stop 28 to the second position at which the finger 29 engages the dress stop 31. Mounted on the table 25 is a wheelhead 33 carrying a rotatable spindle 34, the outer end of which carries an abrasive wheel 35. The cylinder 32 is provided with hydraulic fluid at a carefully regulated pressure, so that it is possible to pre-determine the force produceable by the cylinder and use that force for engagement of the abrasive wheel 35 with the workpiece 16 according to the well-known "controlled-force" grinding principle. The back end of the compensation slide 26 is threadedly engaged with a ball screw 36 which is driven through suitable gearing by a stepping motor 37. The stepping motor, the screw 36, and the compensation slide 26 operate to give a readily-selected accurate compensation at the time of dress, in accordance with the teachings set forth in the Robillard U.S. Pat. No. 3,403,480 mentioned above. The finger 27 is engaged with the front of the cross-slide or wheelhead table 25 through a screw 38 to provide a certain degree of adjustment. This adjustment takes place by a ratchet 39 mounted on the front of the screw 38 and operated in opposite direction by pawls 40 and 41 slidable back and forth by means of cylinders 42 and 43. A handwheel 44 operates through a rod 45 to permit manual operation of the screw 36 to provide for minor adjustments of the compensation slide 26.

A main control 46 feeds a pattern of electrical pulses through a cable 47 to the main stepping motor 37 and, at the same time, through the cable 48 to a control panel 50. At one side of the panel is located a visual slide position indicator 51 which shows the cross-slide position at any given time. Also mounted on the panel is a NEW WHEEL lamp 53, a COARSE-COMPENSATION device 54 and corresponding lamp 55, a CYCLE START device 56 and a corresponding lamp 57, and a WORN WHEEL device 58 and its lamp 59, as well as a NEW WHEEL DEVICE 60 associated with the lamp 53. The panel 50 is constructed in accordance with the patent application of Robillard, Ser. No. 720,912, filed Apr. 12, 1968.

Mounted on the base 11 beside the compensation slide 26 is a potentiometer 61 having a movable arm 62 which is connected to a nut 63 engaged by the ball screw 36. The nut is moved back and forth when the screw rotates. In other words, the movement of the arm 62 is in synchronization with the compensation slide 26.

Referring now to FIG. 2, it can be seen that the stepping motor 37 receives its driving pulses through the cable 47 from a driver 64, forming part of the main control 46. The stepping motor, of course, serves directly to move the arm 62 of the potentiometer 61 which is connected by a cable 65 to the main control 46 and, particularly, to a rate modulator 66. The rate modulator is connected by a line 67 to a pulser 68. The pulser output passes through a line 69 to a pulse-to-stop converter 71. This output, in turn, passes through a line 72 to the driver 64 for the stepping motor. The output of the pulser also passes through a down-counter 73 through a line 74. Similarly, the output of the pulser also passes through a line 75 to an up/down counter 76. An input interface 77 passes a signal through a line 78 to a count selector logic 79; it is also connected through a line 81 to a feed logic 82. The output of the feed logic goes to the count selector logic 79 by way of a line 83. Another output of the feed logic 82 is connected to the pulser 68 by means of a line 84 and also to the pulser by way of a line 85 and rate switches 86. The up/down counter 76 has an output which is connected by a line 87 to a memory 88 which, in turn, is connected by a line 89 to the input side of the feed logic 82. The up/down counter 76 has an output connected through a line 91 to a readout 92, which also has an output connected through a line 93 to a logic output 94, the logic output also receiving signals from position-setting switches 95 by a line 96. The logic output 94 is also connected by a line 97 to the conventional machine controls. The input interface 77 is similarly connected by a line 98 to the conventional machine controls in the well-known manner.

The count selector logic 79 receives a signal from the down counter 73 through a line 99. It has an output signal which passes through a line 101 to the pulse two-step converter 71. Another output passes through a line 102 to the input side of the pulser 68. Another output of the count selector logic 79 passes through a line 103 to count setting switches 104 whose output passes through a line 105 to the down counter 73. Finally, the feed logic 82 is connected by a line 106 to the up/down counter 76.

In FIG. 3 it can be seen that the potentiometer 61 actually contains three resistors 107, 108, and 109 connected from a common ground to a 24-volt supply line. The central resistor 108 is the actual potentiometer resistor contacted by the arm 62, which is connected by the line 65 to the rate modulator 66 which, in turn, is connected by the line 67 to the pulser 71. Circuitry in the rate modulator 66 makes use of two operational amplifiers 111 and 112 with suitable connections and resistors in the usual way to amplify the signal from the potentiometer 61 and pass it to the pulser.

The operation of the machine will now be readily understood in view of the above description. The grinding cycle takes place in the usual way, i.e., a new wheel is placed on the spindle 34, the raw wheel is dressed down to a standard size, and the regular grinding cycles are started on a succession of workpieces. The cycles continue with occasional dressing until the wheel diameter is reduced to the worn wheel size, at which time a new wheel is mounted on the spindle. As the negative and positive pulses are introduced to the main stepping motor 37 to move the wheelhead table 25 back and forth during the successive grinding cycles, this is indicated on the control panel 50. Furthermore, the arm 62 is moving in synchronization with the compensation slide 26, so that the voltage appearing on the arm and transmitted to the rate modulator 66 is indicative at all times with the position of the compensation slide 26.

As the successive workpieces are ground and the machine passes from the new wheel position to the worn wheel position, the compensation slide moves rearwardly across the base **11** in the usual way. When the cycle starts out with a roughing grind under controlled-force conditions under the impetus of the cylinder **32** and finishes with the controlled-rate conditions under the control of the motor **37**, the signal emanating from the potentiometer **61** decreases or becomes lower and lower as the wheel becomes smaller. This means that the voltage passing through the rate modulator **66** and, eventually, passing through the line **67** to the pulser **68** becomes smaller and smaller. The pulser passes pulses to the main motor **67** at a slower rate, thus reducing the rate at which the table **25** is moved transversely during the finish portion of the grinding cycle to a lower quantity. This compensates for the fact that, as the wheel becomes worn, its diameter is smaller, its radius of curvature is smaller, and, therefore, it cuts at a faster rate. Thus, by reducing the rate of feed as the wheel becomes smaller, it is possible to maintain the finish on the workpiece at a predetermined quality while, at the same time, maintaining the size and the taper equally at a preset value. It should be noted that all of the circuits shown in FIG. **2** are integrated circuits and as such are readily replaceable for repair of the machine. They are also relatively indestructible and more or less standard in manufacture. At the same time, because the rate of feed is maintained at a constant value, there is a tendency to maintain the deflection of the spindle at a constant value, which tends to keep the force between the abrasive wheel and the workpiece at a constant value, all of which tends to maintain the finish on the surface of revolution at a fixed amount as the wheel wears from the new wheel to the 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 for generating a surface of revolution on a workpiece, comprising

a. a base,

b. a workhead table mounted on the base and having a support for carrying the workpiece,

c. a wheelhead table mounted on the base and having a rotatable spindle carrying an abrasive wheel,

d. feed means for bringing about relative motion between the workhead table and the wheelhead table transversely of the axis of the surface of revolution, the feed means including an actuator for producing a rough grind with controlled-force conditions and a motor for producing a finish grind with controlled-rate conditions, and

e. control means for adjusting the rate of feed during the said finish grind in accordance with the size of the abrasive wheel.

2. A grinding machine as recited in claim **1**, wherein the said motor is an electrical stepping motor.

3. A grinding machine as recited in claim **1**, wherein the feed means is operative in the wheelhead table to bring about the said relative movement, wherein a compensation slide lies between the wheelhead table and the base, wherein the said motor is operative to move the compensation slide by an incremental amount every time a dressing operation takes place, and wherein a potentiometer is connected to the compensation slide to partake of the same incremental amount of movement.

4. A grinding machine as recited in claim **3**, wherein the motor is connected to the compensating slide by a ball screw, and wherein the rotation of the screw produces a corresponding movement of a contactor in the potentiometer.

5. A grinding machine as recited in claim **4**, wherein the potentiometer produces an electrical signal indicative of the compensation slide position and of wheel size, and wherein this electrical signal is fed into a pulser to control the rate of pulses fed to the motor during the finish grind.

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