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Kurimoto et al.

[54] **GRINDING MACHINE**

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[51] **Int. Cl.** **B24b 5/42**

[58] **Field of Search** .... 51/165 R, 165.77, 51/165.83, 165.91, 105 SP

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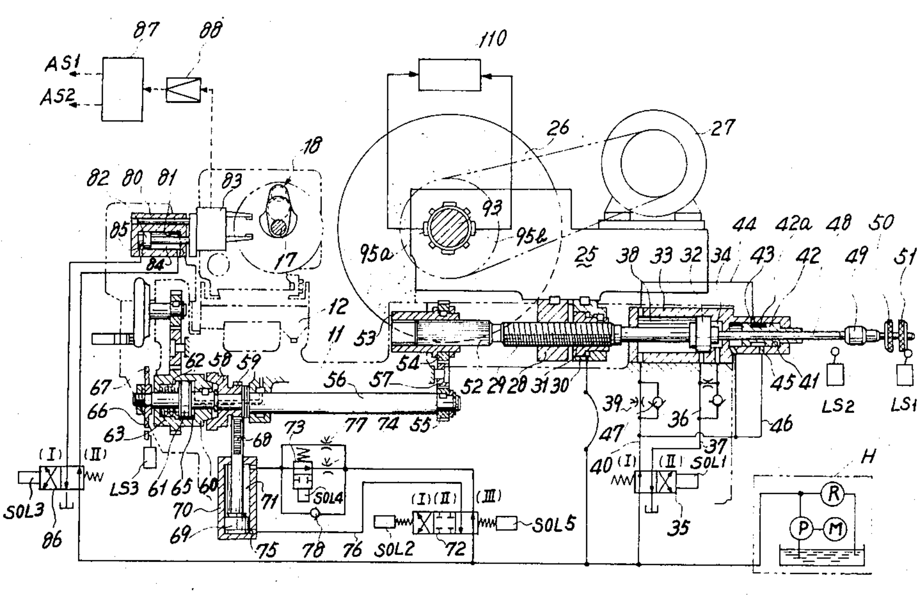
Attorney—Norman F. Oblon et al.

[57] **ABSTRACT**

A grinding machine comprises a feed means for effecting movement of a grinding wheel towards and away from a workpiece. A sizing device generates a sizing signal in response to the diameter of the workpiece for stopping the feed movement at an appropriate time in order to effect a spark out operation. A detector detects the grinding resistance applied on the grinding wheel. A timer is energized during the movement of the grinding wheel towards the workpiece and is timed out after a predetermined time period. If the grinding resistance becomes substantially of a zero value before the timer is timed out, then the grinding wheel is caused to be retracted from the workpiece and a succeeding grinding operation is rendered operative.

9 Claims, 8 Drawing Figures



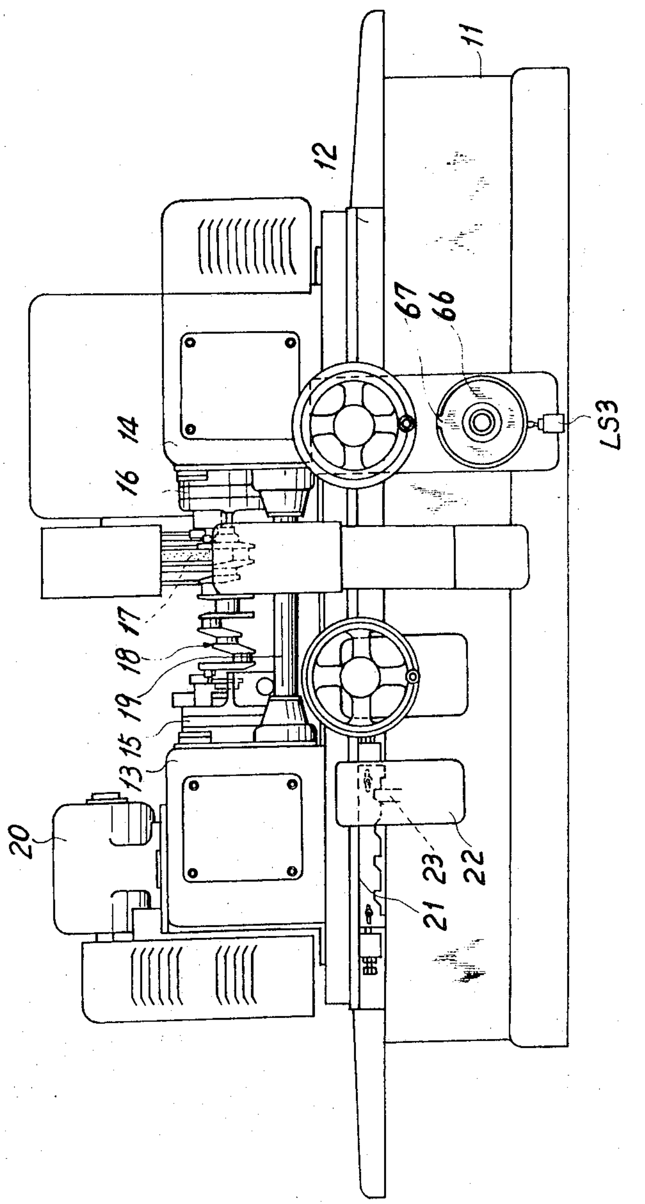


Fig 1

Fig. 2

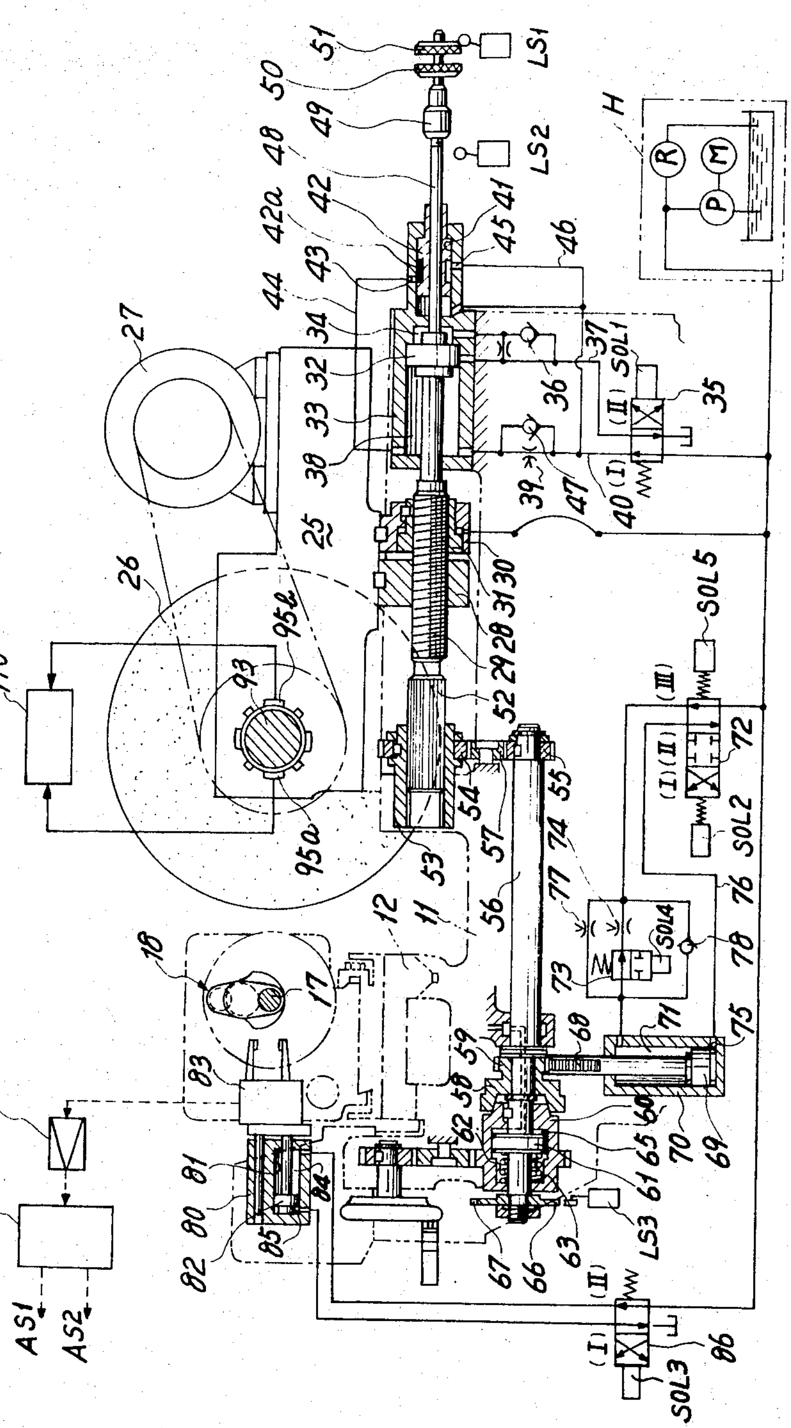
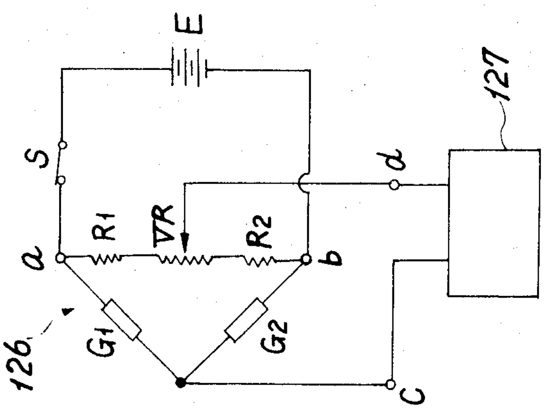


Fig. 4


E
S
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b
c
d
R1
VR
R2
G1
G2
126
127

Fig. 3

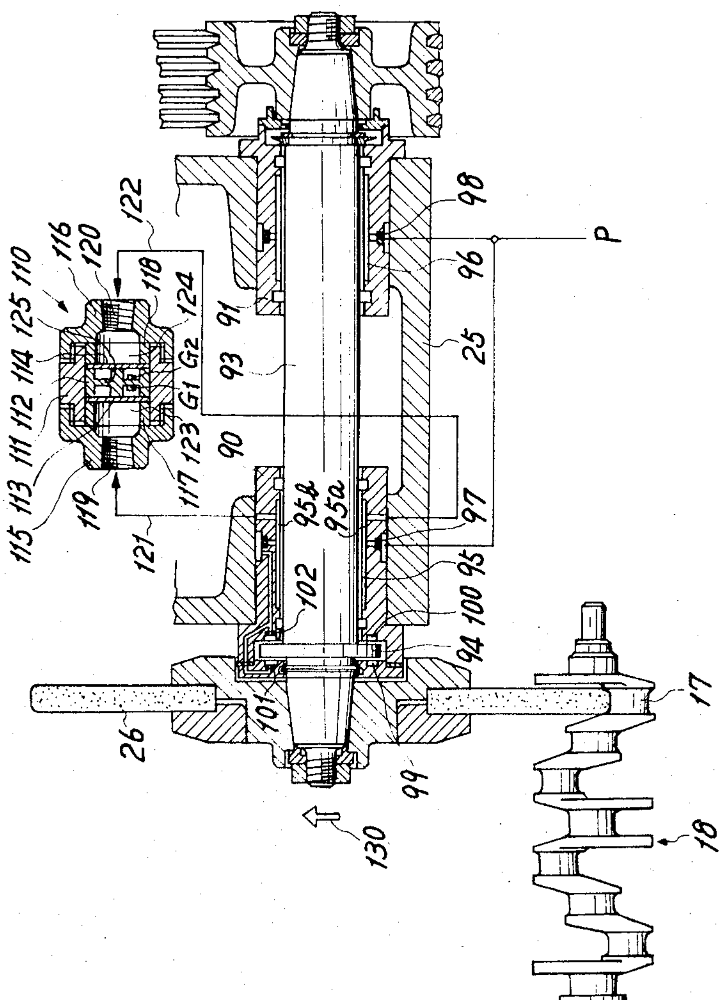
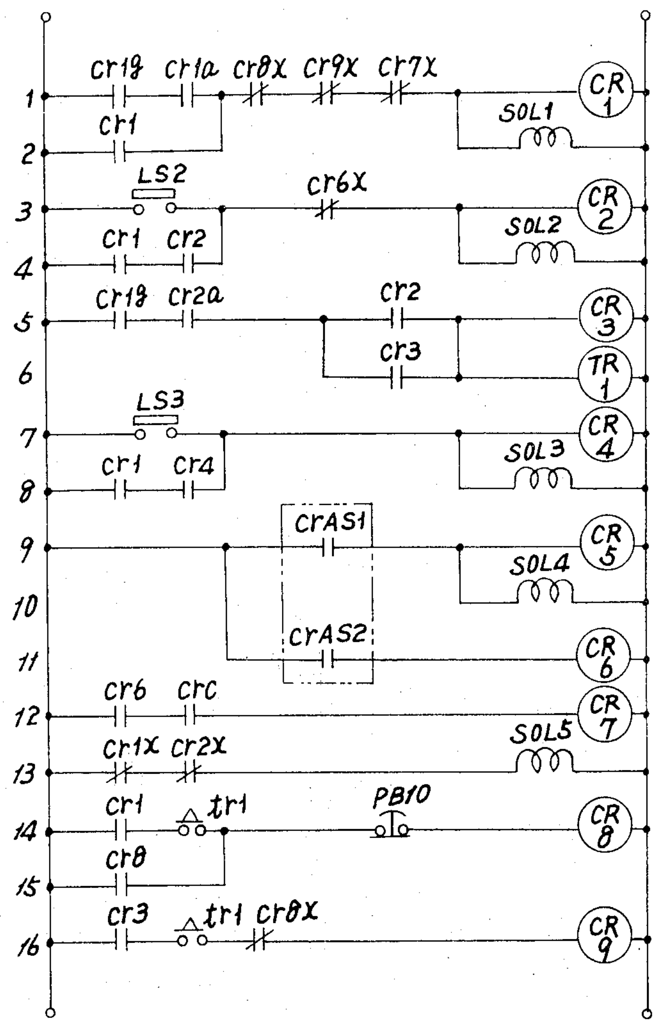

115 113 111 112 114 125 110
116
120
122
118
124
G2
G1
123
117
119
121
90
93
91
96
98
25
P
95b
95a
97
95
100
94
102
101
99
26
17
18
130

Fig. 5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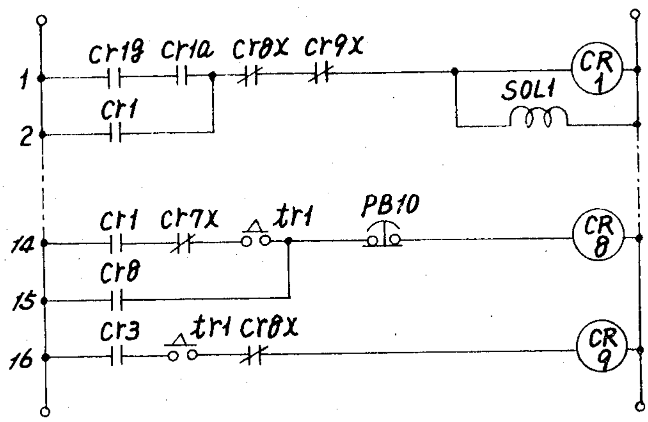
cr1a
cr8x
cr9x
cr7x
cr1
CR 1
SOL1
LS2
cr6x
cr1
cr2
CR 2
SOL2
cr1g
cr2a
cr2
cr3
CR 3
TR 1
LS3
cr1
cr4
CR 4
SOL3
crAS1
CR 5
SOL4
crAS2
CR 6
cr6
crc
CR 7
cr1x
cr2x
SOL5
cr1
tr1
PB10
cr8
CR 8
cr3
tr1
cr8x
CR 9
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Fig. 6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cr1a
cr8x
cr9x
CR 1
SOL1
cr1
1
2
cr1
cr7x
tr1
PB10
CR 8
cr8
14
15
cr3
tr1
cr8x
CR 9
16

Fig 7

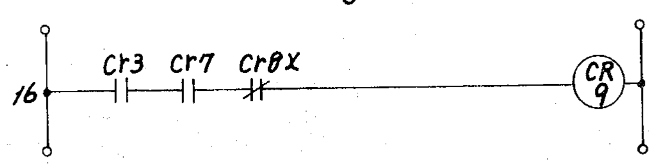
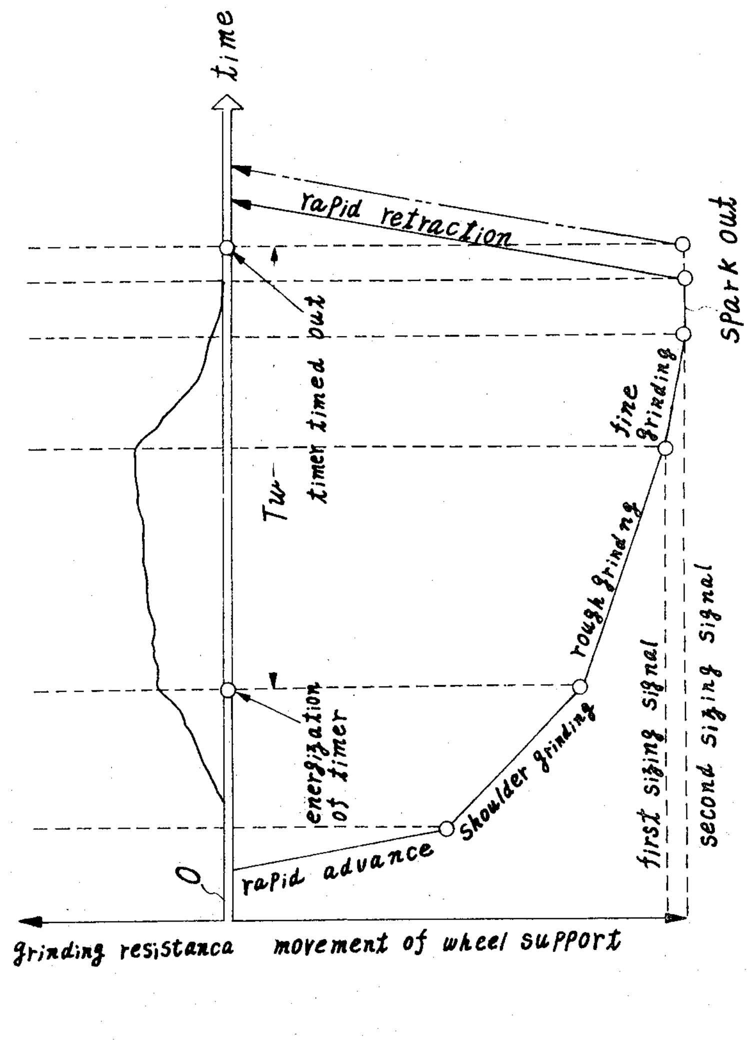

cr3
cr7
cr8x
CR 9
16

Fig. 8


time
rapid retraction
spark out
fine grinding
rough grinding
shoulder grinding
rapid advance
Tw
timer timed out
energization of timer
first sizing signal
second sizing signal
0
grinding resistanca
movement of wheel support

GRINDING MACHINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a grinding machine wherein a spark out operation is provided until the detected grinding resistance applied on a grinding wheel thereof becomes substantially of a zero value.

2. Description of the Prior Art:

In a conventional automatic grinding machine, the feed movement of a grinding wheel towards a workpiece was stopped in response to a sizing signal generated from a sizing device which was engaged with the workpiece during a grinding operation. Upon the stopping of the workpiece in response to the sizing signal a spark out operation would be performed for a predetermined time period as set by a timer. After the predetermined time period of the spark out operation, the grinding wheel was retracted away from the workpiece. Since, in accordance with the above, it is seen that the final finished dimension of the workpiece was therefore controlled only by the sizing device, it was found that the grinding efficiency would often be lowered and also the workpiece would often be ground, with a lower accuracy, due to chattering marks and seizure thereon, when the actual grinding speed was eventually lowered far from an optimum grinding speed because of some problems in the hydraulic control system or because the grinding wheel was loaded with metal or dirt particles. Moreover, some occasional problems would often occur in the sizing device itself and result in too much feeding of the grinding wheel towards the workpiece, which in turn would often damage some parts of the machine as well as the grinding wheel and the workpiece. These problems have had a particularly bad effect on the full type automatic grinding machine which was used for automatically performing the loading and unloading of the workpiece.

In addition, in the past the time period set by the timer for a spark out operation was usually set as short as possible in order to eliminate unnecessary time consumption. As a result thereof, the workpiece would often be ground to a finished size during a deflection thereof. Thus, the workpiece size accuracy would often be dispersed and good surface roughness could not always be expected, even though the final finished dimension of the workpiece was controlled by the sizing device.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a new and improved unique grinding machine which is capable of eliminating any inefficient grinding operation when the actual grinding speed thereof is lowered far from the optimum grinding speed.

Another object of the present invention is to provide a new and improved unique grinding machine which is capable of controlling a spark out operation in response to the grinding resistance applied on the grinding wheel without any deflection of the workpiece.

Still another object of the present invention is to provide a new and improved unique grinding machine which is capable of performing a predetermined succeeding grinding operation after the previous grinding operation has been performed within a proper time period and with the workpiece being ground to a high accuracy without any deflection thereof.

Briefly, the foregoing and other objects are, in one aspect attained in accordance with the present invention by the provision a grinding machine which includes a work support for supporting a workpiece, a wheel support for supporting a grinding wheel and a feed means for effecting movement of the wheel support towards and away from the work support. A sizing means is provided and is adapted to be engaged with the workpiece in order to generate a sizing signal in response to the diameter thereof. Means are provided for detecting the grinding resistance of the grinding wheel during a grinding operation. A timer means which is energized during the movement of the wheel support towards the work support is provided and the same is timed out after a predetermined time period. A control means which is responsive to the sizing signal is provided for stopping the movement of the wheel support in order to effect a spark out operation before the timer means is timed out. The control means is operable such that when the timer means is timed out before the grinding resistance becomes a predetermined value in accordance with the spark out operation, the wheel support will be retracted from the work support and a succeeding grinding operation will be rendered inoperative, and when the grinding resistance becomes a predetermined value before the timer means is timed out, the wheel support will be retracted from the work support and the succeeding grinding operation will be rendered operative.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. **1** is a front view of a grinding machine according to the present invention;

FIG. **2** is a schematic hydraulic circuit diagram of the present invention;

FIG. **3** is a sectional view of a wheel support, showing a bearing structure for a grinding wheel spindle;

FIG. **4** is a schematic circuit diagram for detecting a grinding resistance applied on a grinding wheel;

FIG. **5** is an electric circuit diagram for controlling the grinding cycle;

FIG. **6** shows another modification of the electric circuit diagram shown in FIG. **5**;

FIG. **7** shows still another modification of the electric circuit diagrams shown in FIGS. **5** and **6**; and,

FIG. **8** shows a feed cycle diagram of the grinding wheel and the change in grinding resistance according to the feed movement of the grinding wheel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the Drawings, wherein like reference numerals designate identical, or corresponding parts throughout the several views, and more particularly to FIG. **1** thereof, wherein a grinding machine according to the present invention is shown as including a bed **11** on which a table **12** is slidably mounted for a longitudinal movement. Fixedly mounted on the table **12** are opposed head stocks **13** and **14** which rotatably support respective pot chucks **15** and **16**. The pot chucks **15** and **16** are provided for clamping the opposite ends of a crankshaft **18** with the axis of a pin portion 17 thereof which is to be finished and which is in alignment with the common axis of the pot chucks 15 and 16. The pot chucks 15 and 16 are synchronously rotated through a driving shaft 19 by a motor 20 in order to rotate the crankshaft 18. An index plate 21 is secured to the underside of the table 12 and is provided with spaced notches which correspond to pin portions of the crankshaft 18. A locating device 22 secured to the front of the bed 11 includes a locating pin 23 to be inserted into one of the notches of the index plate 21 for longitudinally indexing the table 12 in accordance with the pin portion of the crankshaft 18 to be finished. Before being clamped by the pot chucks 15 and 16, the crankshaft 18 is angularly indexed by an index device, not shown, which is arranged in the head stock 13 for alignment of the pin portion to be finished with the common axis of the pot chucks 15 and 16. The crankshaft is then moved axially a small amount by a positioning device, not shown, which is arranged on the bed 11 so that the pin portion to be finished may be precisely aligned with a grinding wheel 26.

As shown in FIG. 2, a wheel support 25 is slidably mounted on the bed 11 for movement transversely to the table 12 and rotatably carries the grinding wheel 26. The grinding wheel 26 is driven by an electric motor 27 which is mounted on the wheel support 25. Referring still to FIG. 2, it is seen that the wheel support 25 is provided at its underside with a feed nut 28 which is threadedly engaged with a feed screw shaft 29. The feed screw shaft 29 is also engaged with a sub-nut 31 which is slidably keyed in a nut case 30 secured to the underside of the wheel support 25. A supply of pressurized fluid is inserted into a chamber formed between the nut case 30 and the sub-nut 31 and serves to eliminate any backlash between the feed nut 28 and the feed screw shaft 29. The feed screw shaft 29 has a piston 32 integrally formed at its right end and the same is slidably received in a cylinder 33 provided on the bed 11 for enabling a rapid feed movement of the wheel support 25 and the grinding wheel 26. A right chamber 34 is formed at the right side of the piston 32 and is connected to a change-over valve 35 through a check valve 36 and a conduit 37, while a left chamber 38 is connected thereto through a throttle 39 and a conduit 40. A valve chamber 41 is provided adjacent to the right end of the cylinder 33 and receives a slidable hollow spool valve 42 having a recess 42a at an intermediate portion thereof. A port 43 is provided at an intermediate point of the valve chamber 41 and is connected to the left chamber 38 of the cylinder 33 through a conduit 44, while a port 45 is connected to the change-over valve 35 through a conduit 46. A check valve 47 is provided in parallel with the throttle 39. A shaft 48 is connected to the right side of the piston 32 and extends through the spool valve 42 and carries at its right end dogs 49, 50 and 51 which are operatively associated with the right end of the spool valve 42 and limit switches LS2 and LS1, respectively.

A spline shaft 52 is formed at the left end of the feed screw shaft 29 and is engaged with an internal spline member 53 rotatably received in the bed 11 for enabling an axial sliding movement. A gear 54 is secured on the outer peripheral surface of the spline member 53 and engages a gear 55 which is secured on a right end of a feed shaft 56 which is rotatably journaled in the bed 11 through an intermediate gear 57. A clutch member 58 having a gear 59 integrally formed therewith is rotatably mounted on an intermediate portion of the feed shaft 56. Another clutch member 60 is axially slidably keyed on the feed shaft 56. A piston 61 is provided at the left end of the feed shaft 56 and is slidably received in a cylinder 62 formed in the clutch member 60. A spring 63 is interposed into a left chamber 64 of the cylinder 62 for enabling the frictional engagement between the clutch members 58 and 60 to be released. It should be understood that when a pressurized fluid is normally introduced into a right chamber 65 of the cylinder 62, the clutch member 60 will be held in frictional engagement with the clutch member 58. On the left end of the feed shaft 56, a plate 66 having a dog 67 is angularly and adjustably secured, as shown in FIG. 1. The plate 66 is operatively associated with a limit switch LS3 mounted on the front of the bed 11. The gear 59 of the clutch member 58 engages a rack shaft 68 which is connected to a piston 69 which is slidably received in a cylinder 70.

An upper chamber 71 of the cylinder 70 is connected to a change-over valve 72 through a change-over valve 73 and a throttle 74, while a lower chamber 75 of the cylinder 70 is connected thereto through a conduit 76. A throttle 77 and a check valve 78 are provided in parallel with the change-over valve 73 and the throttle 74.

Mounted on the bed 11 is a bracket 80 having a cylinder 81 therein which slidably receives a piston 82 which is connected to a sizing device 83 for enabling its movement transversely to the table 12. Right and left chambers 84 and 85 of the cylinder 81 are connected to a change-over valve 86. The sizing device 83 has a pair of feelers which are adapted to embrace the pin portion 17 of the crankshaft 18 and the same will generate a signal responsive to the diameter of the pin portion and be applied to a Schmitt circuit 87 through an amplifier 88. The Schmitt circuit 87 generates first and second sizing signals AS1 and AS2 in response to the diameter of the pin portion, as described hereinafter.

Referring to FIG. 3, there is shown a bearing apparatus for rotatably supporting the grinding wheel 26. At the opposite ends of the wheel support 25, there are secured bearing members 90 and 91 in which a grinding wheel spindle 93 is rotatably received with a small radial clearance therebetween. The grinding wheel spindle 93 is provided with a radial enlargement 94 which faces the side surfaces of the bearing member 90, and provides small axial clearances therebetween. A plurality of bearing pockets 95 and 96 are circumferentially formed in the respective inner periphery of the bearing members 90 and 91 in equally spaced relation with each other. A supply of pressurized fluid is applied in the bearing pockets 95 and 96 through respective resistors 97 and 98 and creates hydrostatic pressures in the bearing pockets 95 and 96 which serve to radially support the grinding wheel spindle 93. The side surfaces of the bearing member 90 are provided with respective annular grooves 99 and 100, facing the radial enlargement 94 of the wheel spindle 93. A supply of pressurized fluid is applied to the annular grooves 99 and 100 through respective restrictors 101 and 102 and creates hydrostatic pressures in the annular grooves 99 and 100, which serve to axially support the wheel spindle 93. A pair of horizontally arranged pockets of the bearing pockets 95, as shown in FIG. 2, are referred to as front and rear bearing pockets 95*a* and 95*b*.

Referring to FIGS. 3 and 4, there is shown a device for detecting grinding resistance applied on the grinding wheel 26.

A pressure differentiator 110 comprises a hollow housing in which a pair of flexible disc diaphragms 113 and 114 are received in a separate relation through a flexible member 112. A pair of caps 115 and 116 are screwed into the opposite ends of the housing to clamp the outer peripheral portions of the diaphragms 113 and 114 in position through a pair of space collars 117 and 118. The cap 115 is provided with a port 119 which is connected with the rear bearing pocket 95*b* of the bearing member 90 through a conduit 121, while the other cap 116 is provided with a port 120 which is connected with the front bearing pocket 95*a* of the bearing member 90 through a conduit 122. Between the cap 115 and the diaphragm 113, and between the cap 116 and the diaphragm 114, there are formed pressure chambers 123 and 124, respectively, into which the hydrostatic pressures created into the bearing pockets 95*b* and 95*a* are applied through conduits 121 and 122. The flexible member 112 has a flexible portion 125 which is deflected in response to the pressure differential between the fluid pressures applied into the pressure chambers 123 and 124. Strain-gauge elements G1 and G2, of a semiconductor material, are bonded on opposite sides of the flexible portion 125 for detecting the deflection thereof.

The strain-gauge elements G1 and G2 are connected as a part of a bridge circuit 126, as shown in FIG. 4. More particularly, lead wires extending from one end of the strain-gauge elements G1 and G2 are connected to terminals *a* and *b*, respectively. The other ends of the strain-gauge elements G1 and G2 are connected to a common terminal c. Resistors R1 and R2 and a shunted adjustable resistor VR are arranged in series between the terminals *a* and *b*, in parallel with an electric current source E and a contact S which are arranged in series. The slider of the shunted adjustable resistance VR is connected to a terminal *d*. The terminals *c* and *d* which constitute an output from the bridge circuit are connected to a Schmitt circuit 127 so that an output voltage responsive to the pressure differential between the fluid pressures supplied into the pressure chambers 123 and 124 is impressed thereon. The Schmitt circuit 127 is set to be actuated only when the output voltage becomes substantially of a zero value, that is, when the fluid pressures supplied into the pressure chambers 123 and 124 are substantially equal because no grinding resistance is applied on the grinding wheel 26.

The operation of the grinding machine according to the present invention will now be described with reference to FIGS. 5 and 8. The grinding wheel 26 is shown in its original position in FIG. 2. When an automatic cycle start button, not shown, is pressed, a contact cr1g in line 1 in FIG. 5 is closed. When the crankshaft 18 is thereafter clamped by the pot chucks 15 and 16, a contact cr1a in line 1 is closed. In accordance therewith, a relay CR1 in line 1 and a solenoid SOL1 in line 2 for the change-over valve 95 are energized by means of the closed contacts cr1g and cr1a and normally closed contacts cr8x, cr9x and cr7x. Upon energization of the relay CR1, a contact cr1 thereof in line 2 is closed so that the relay CR1 and the solenoid SOL1 are held energized.

Upon energization of the solenoid SOL1, the change-over valve is changed to its position (II) so that the pressurized fluid from a supply source H is supplied into the right chamber 34 of the cylinder 33 through the conduit 37 and the check valve 36, and the fluid in the left chamber 38 is exhausted through the conduit 44, the port 43, the annular groove 42*a* of the spool valve 42, the port 45, the conduit 46 and the change-over valve 35. The piston 32 is therefore moved to the left, as viewed in FIG. 2, to thereby rapidly advance the grinding wheel 26 towards the crankshaft 18. When the dog 49 which is moved with the piston 32 is brought into contact with the spool valve 42, the spool valve 42 is moved to the left to close the fluid communication between the ports 43 and 45. The fluid in the left chamber 38 is therefore exhausted through the throttle 39, the conduit 40 and change-over valve 35, so that the rapid feed movement of the grinding wheel 26 is changed to a shoulder feed movement for grinding the shoulder portion of the crankshaft 18.

When the grinding wheel 26 begins to grind the shoulder portion of the crankshaft 18, a grinding resistance in the direction of an arrow 130 in FIG. 3 is applied on the grinding wheel 26 to thereby shift the grinding wheel spindle 93 through a small amount in the same direction, so that the hydrostatic pressure in the rear bearing pocket 95*b* becomes higher than that in the front bearing pocket 95*a*. The pressure differential thereby created in response to the grinding resistance is changed into an electrical signal by the pressure differentiator 110, and is then applied to the Schmitt circuit 127. Since the Schmitt circuit 127 is set so as to be actuated only when a substantially zero voltage is impressed thereon, the Schmitt circuit is rendered inoperative in response to the output from the pressure differentiator 110, to thereby open its contact crc in line 12 in FIG. 5.

When the dog 50 actuates the limit switch LS2 during the shoulder grinding operation, a relay CR2 in line 3 and a solenoid SOL 2 in line 4 in FIG. 5 are energized through a normally closed circuit cr6x and at the same time are held energized by means of closed contacts cr1 and cr2 in line 4. Upon energization of the solenoid SOL 2, the change-over valve 72 is changed to its position (I) so that the pressurized fluid is introduced into the lower chamber 75 of the cylinder 70 through the conduit 76, while the fluid in the upper chamber 71 is exhausted through the change-over valve 73, the throttle 74 and the change-over valve 72. The piston 69 of the cylinder 70 is thus moved upward at a predetermined speed set by the throttle 74 so that the feed shaft 56 is rotated by means of a rack and pinion mechanism 68 and 59. Rotation of the feed shaft 56 is transmitted to the feed screw shaft 29 through the gears 55, 57 and 54, the spline member 53 and the spline shaft 52 so that the grinding wheel 26 is moved toward the crankshaft 18 at a rough grinding speed.

There is provided a timer TR1 in line 6 in FIG. 5 for inspecting whether or not the rough grinding operation and the succeeding fine grinding operation are performed within a predetermined time period so as to detect an unusual grinding operation. The timer TR1 and a relay CR3 in line 5 are energized by energization of the relay CR2 through previously closed contact cr1g and cr2a for confirmation of insertion of the locating pin 23 into the index plate 21 and are held energized by the contact cr3. The timer TR1 is set to be timed out after a predetermined time period TW, as shown in FIG. 8, such that the timer TR1 is usually or normally timed out a short time after the grinding resistance applied on the grinding wheel has become substantially of a zero value.

The limit switch LS3 is actuated by the dog **67** of the plate **66,** while the rough grinding operation is proceeding. Upon actuation of the limit switch LS3, a relay CR4 in line **7** and a solenoid SOL3 in line **8** for the change-over valve **86** are energized and at the same time are held energized by the contacts cr1 and cr4. Upon energization of the solenoid SOL3, the change-over valve **86** is changed to its position (I) so that the sizing device **83** is advanced toward the crankshaft in order to embrace the same.

When the pin portion **17** of the crankshaft **18** is ground to a predetermined size with a certain amount of finish allowance being left, the Schmitt circuit **87** for the sizing device **83** generates the first sizing signal AS1 to energize a relay CR5 in line **9** and a solenoid SOL4 in line **10** for the change-over valve **73** in FIG. **5.** Upon energization of the solenoid SOL4, the change-over valve **73** is shut off so that the fluid in the upper chamber **71** of the cylinder **70** is exhausted through the throttle **77.** The rough grinding speed of the grinding wheel **26** is thus changed to a fine grinding speed set by the throttle **77** for a fine grinding operation. In accordance therewith; the grinding resistance applied on the grinding wheel **26** is gradually decreased, as shown in FIG. **8.**

When the pin portion **17** of the crankshaft **18** is ground to a finished size, the Schmitt circuit generates the second sizing signal AS2 to energize a relay CR6 in line **11.** Upon energization of the relay CR6, its normally closed contact cr6x in line **3** opens to de-energize the relay CR2 and the solenoid SOL2. Upon de-energization of the solenoid SOL2, the change-over valve **72** is changed to its position (II) so that the movement of the grinding wheel **26** is stopped in order to perform a spark out operation.

It should be noted that one of the features of the present invention is that the spark out operation is controlled in response to the grinding resistance applied on the grinding wheel. More particularly, when the feed movement of the grinding wheel **26** is stopped, the grinding resistance is still applied on the grinding wheel **26,** as shown in FIG. **8,** since the crankshaft has been deflected. The grinding resistance is gradually decreased in accordance with the proceeding of the spark out operation. When the grinding resistance becomes substantially of a zero value, the Schmitt circuit **127** is actuated to close the contact crc in line **12** in FIG. **5,** to thereby energize a relay CR7 through the closed contact cr**6.** Upon energization of the relay, CR7, its normally closed contact cr7 in line **1** opens to de-energize the relay CR1 and the solenoid SOL1. Therefore, the grinding wheel **26** is returned back to its original position at a rapid speed to thereby complete the spark out operation. By controlling the time of the spark out operation in response to the grinding resistance applied on the grinding wheel each pin portion **17** is enabled to be finally finished without any deflection of the crankshaft **18,** which assures high accuracy of finishing including surface roughness and roundness.

The de-energization of the relay CR1 causes energization of a solenoid SOL5 in line **13** through normally closed contacts cr1x and cr2x to change the change-over valve **72** to its position (III), to thereby enable the downward movement of the piston **69** of the cylinder **70.** The de-energization of the relay CR1 also causes de-energization of the relay CR4 and the solenoid SOL3 to change the change-over valve **86** to its position (II) to thereby move the sizing device **83** away from the pin portion **17** of the crankshaft **18.** In accordance therewith, the relays CR5, CR6 and CR7 and the solenoid SOL4 are all de-energized, whereby one grinding cycle of one pin portion of the crankshaft is completed.

It should be noted that another feature of the present invention is to enable discrimination as to whether the total time required for the rough grinding, fine grinding and spark out operations is within a predetermined time period by using the timer TR1 to thereby eliminate unusual or inefficient grinding operations. More particularly, when the grinding operation is normally performed such that the grinding wheel **26** is retracted away from the crankshaft **18** before the timer TR1 is timed out, the contact cr1 in line **14** opens before the timer contact tr1 in line **14** is closed, so that a relay CR8 in line **14** is not energized, even though the timer TR1 is thereafter timed out. Therefore, a relay CR9 in line **16** used for the preparation of a succeeding grinding cycle is energized through the contacts cr3 and tr1 and the normally closed contact cr**8**x when the timer TR1 is timed out after the retraction of the grinding wheel **26** away from the crankshaft **18.** The succeeding grinding cycle will be started under an AND condition of energization of the relay CR9 and actuation of the limit switch LS1 which is effected when the grinding wheel is returned back to its original position.

On the other hand, when the grinding operation is unusually or inefficiently performed suth that the timer TR1 is timed out before the grinding wheel **26** is retracted away from the crankshaft **18,** then the relay CR8 is energized through the contacts cr1 and tr1 when the timer TR1 is timed out and is held energized by its contact cr8 in line **15.** In accordance therewith, the relay CR1 and the solenoid SOL1 are de-energized through the normally closed contact cr8x so that the grinding wheel is immediately caused to be retracted. In accordance therewith, an alarm buzzer, not shown, is actuated to inform an operator of the abnormality. Therefore, an inefficient grinding operation caused by trouble in the hydraulic control system or by the grinding wheel being loaded with metal or dirt particles may be immediately eliminated, thereby providing a great advantage to a full automatic grinding machine. When the relay CR8 is energized, its normally closed contact cr8x in line **16** opens, whereby the relay CR9 is not energized and thus the succeeding operation is not performed. The relay CR3 in line **5** and the timer TR1 in line **6** in FIG. **5** are deenergized when the locating pin **23** of the locating device **22** in FIG. **1** is disengaged from the index plate **21.**

Referring to FIG. **6,** there is shown another modification of a control circuit for the present invention wherein only the portions in lines **1, 2, 14, 15** and **16** which are different from those in FIG. **5** are illustrated. When the grinding operation is normally performed such that the relay CR7 in line **12** is energized to open its normally closed contact cr7x in line **14** before the timer TR1 is timed out, the relay CR8 in line **14** is not energized even though the timer TR1 is thereafter timed out. Therefore, at the same time that the timer TR1 is timed out, the relay CR9 in line **16** is energized through the contacts cr3 and tr1 and the normally closed contact cr8x. Upon energization of the relay CR9, the relay CR1 in line 1 and the solenoid SOL1 in line 2 are de-energized by means of the normally closed contact cr9x to thereby retract the grinding wheel 26 away from the crankshaft 18. The predetermined succeeding grinding cycle will be started under an AND condition of energization of the relay CR9 and actuation of the limit switch LS1.

On the other hand, when the grinding operation is unusually or inefficiently performed such that the timer TR1 is timed out before the relay CR7 is energized, the relay CR8 is energized through the contact cr1, the normally closed contact cr7x and the timer contact tr1 when the timer TR1 is timed out, and at the same time is held energized by its contact cr8 in line 15. Upon energization of the relay CR8, the relay CR1 and the solenoid SOL1 are de-energized through the normally closed contact cr8x in line 1 so that the grinding wheel is immediately caused to be retracted. When the relay CR8 is energized, it normally closed contact cr8x in line 16 opens, whereby the relay CR9 is not energized and thus the succeeding operation is not performed.

Referring to FIG. 7, there is shown still another modification of a control circuit wherein only the portions in line 16 different from those in FIGS. 5 and 6 are illustrated. In this circuit, the relay CR9 inenergized through the contacts cr3 and cr7 and the normally closed contact cr8x in response to the energization of the relay CR7 when the normally closed contact cr8x of the relay cr8 does not open so that the predetermined succeeding grinding cycle is to be performed.

While the invention has been described by means of specific embodiments, it should be understood that the novel and unobvious characteristics thereof may be incorporated into other structural forms without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed as new and desired to be secured by letters patent of the United States is:

1. A grinding machine comprising:
a work support for supporting a workpiece;
a wheel support for supporting a grinding wheel;
feed means for effecting movement of said wheel support towards and away from said support;
sizing means adapted to be engaged with said workpiece to generate a sizing signal in response to the diameter thereof;
means for detecting grinding resistance applied on said grinding wheel during a grinding operation;
timer means energized during the movement of said wheel support towards said work support which is timed out after a predetermined time period;
control means responsive to the sizing signal for stopping the movement of said wheel support against said work support in order to effect a spark out operation before said timer means is timed out;
control means operable, when said timer means is timed out before the grinding resistance becomes a predetermined value in accordance with the spark out operation, to cause retraction of said wheel support from said work support and to render a succeeding grinding operation inoperative; and,
control means operable, when the grinding resistance becomes a predetermined value before said timer means is timed out, to cause retraction of said wheel support from said work support and to render the succeeding grinding operation operative.

2. A grinding machine comprising:
a work support for supporting a workpiece;
a wheel support for supporting a grinding wheel;
feed means for effecting movement of said wheel support towards and away from said work support;
sizing means adapted to be engaged with said workpiece to generate a sizing signal in response to the diameter thereof;
means for detecting grinding resistance applied on said grinding wheel during a grinding operation;
timer means energized during the movement of said wheel support towards said work support which is timed out after a predetermined time period;
first control means responsive to the sizing signal for stopping the movement of said wheel support against said work support in order to effect a spark out operation before said timer means is timed out;
second control means energized when the grinding resistance becomes substantially of a zero value in accordance with the spark out operation, said second control means being operable, when energized before said timer means is timed out, to cause retraction of said wheel support from said work support;
third control means operable, when said timer means is timed out after said second control means is energized, to render a succeeding grinding operation operative; and,
fourth control means operable, when said timer means is timed out before said second control means is energized, to cause retraction of said wheel support from said work support and to cause said third control means to become inoperative to thereby render the succeeding grinding operation inoperative.

3. A grinding machine as set forth in claim 2, wherein said second control means is operable, when energized before said timer means is timed out, to render said fourth control means inoperative.

4. A grinding machine comprising:
a work support for supporting a workpiece;
a wheel support for supporting a grinding wheel;
feed means for effecting movement of said wheel support towards and away from said work support;
sizing means adapted to be engaged with said workpiece to generate a sizing signal in response to the diameter thereof;
means for detecting grinding resistance applied on said grinding wheel during a grinding operation;
timer means energized during the movement of said wheel support towards said work support which is timed out after a predetermined time period;
first control means responsive to the sizing signal for stopping the movement of said wheel support against said work support in order to effect a spark out operation before said timer means is timed out;
second control means energized when the grinding resistance becomes substantially of a zero value in accordance with the spark out operation;
third control means operable, when said timer means is timed out after said second control means is energized, to cause retraction of said wheel support from said work support and to render a succeeding grinding operation operative; and,

fourth control means operable, when said timer means is timed out before said second control means is energized, to cause retraction of said wheel support from said work support and to cause said third control means to become inoperative to thereby render the succeeding grinding operation inoperative.

5. A grinding machine as set forth in claim **4,** wherein said second control means is operable, when energized before said timer means is timed out; to render said fourth control means inoperative.

6. A grinding machine comprising:

a work support for supporting a workpiece;

a wheel support for supporting a grinding wheel;

feed means for effecting movement of said wheel support towards and away from said work support;

sizing means adapted to be engaged with said workpiece to generate a sizing signal in response to the diameter thereof;

means for detecting grinding resistance applied on said grinding wheel during a grinding operation;

timer means energized during the movement of said wheel support towards said work support which is timed out after a predetermined time period;

first control means responsive to the sizing signal for stopping the movement of said wheel support against said work support in order to effect a spark out operation before said timer means is timed out;

second control means energized when the grinding resistance becomes substantially of a zero value in accordance with the spark out operation, said second control means being operable, when energized before said timer means is timed out, to cause retraction of said wheel support from said work support;

third control means operable, when said second control means is energized before said timer means is timed out, to render a succeeding grinding operation operative; and,

fourth control means operable, when said timer means is timed out before said second control means is energized, to cause retraction of said wheel support from said work support and to cause said third control means to become inoperative to thereby render the succeeding grinding operation inoperative.

7. A grinding machine as set forth in claim **6,** wherein said second control means is operable, when energized before said timer means is timed out, to render said fourth control means inoperative.

8. A grinding machine comprising:

a work support for supporting a workpiece;

a wheel support for supporting a grinding wheel;

feed means for effecting movement of said wheel support towards and away from said work support;

sizing means adapted to be engaged with said workpiece to generate a sizing signal in response to the diameter thereof;

means for detecting grinding resistance applied on said grinding wheel during a grinding operation;

timer means energized during the movement of said wheel support towards said work support which is timed out after a predetermined time period;

first control means responsive to the sizing signal for stopping the movement of said wheel support against said work support to effect a spark out operation before said timer means is timed out;

second control means energized when the grinding resistance becomes substantially of a zero value in accordance with the spark out operation;

thrid control means operable, when said second control means is energized before said timer means is timed out, to cause retraction of said wheel support from said work support and to render a succeeding grinding operation operative, and,

fourth control means operable, when said timer means is timed out before said second control means is energized, to cause retraction of said wheel support from said work support and to cause said third control means to become inoperative to thereby render the succeeding grinding operation inoperative.

9. A grinding machine as set forth in claim **8,** wherein said second control means is operable, when energized before said timer means is timed out, to render said fourth control means inoperative.

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