April 12, 1960 H. L. BLOOD ET AL 2,932,130

GRINDING MACHINE

Filed March 29, 1957

5 Sheets-Sheet 1

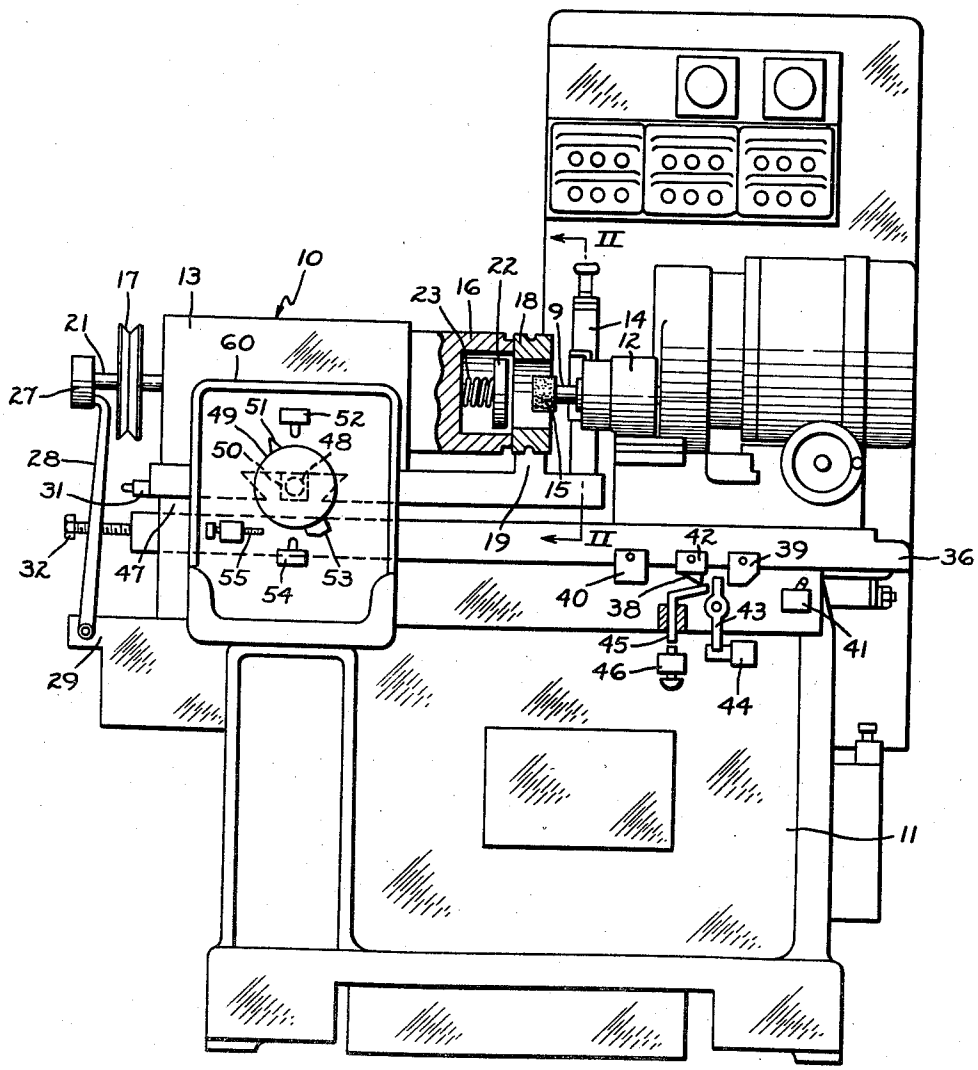


Fig. 1

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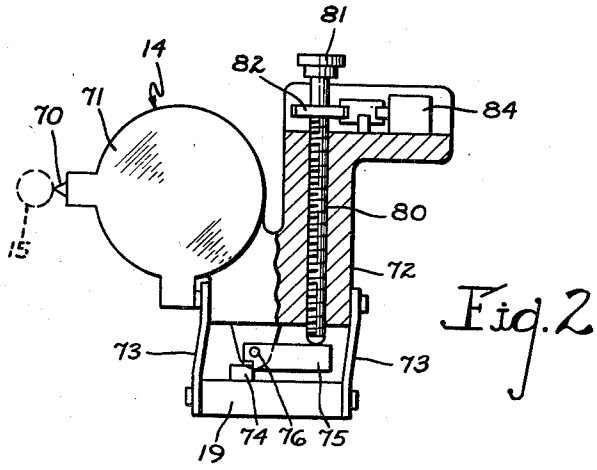


Fig. 2

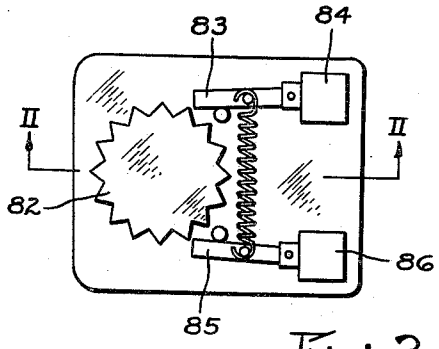


Fig. 3

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GRINDING MACHINE

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5 Sheets-Sheet 3

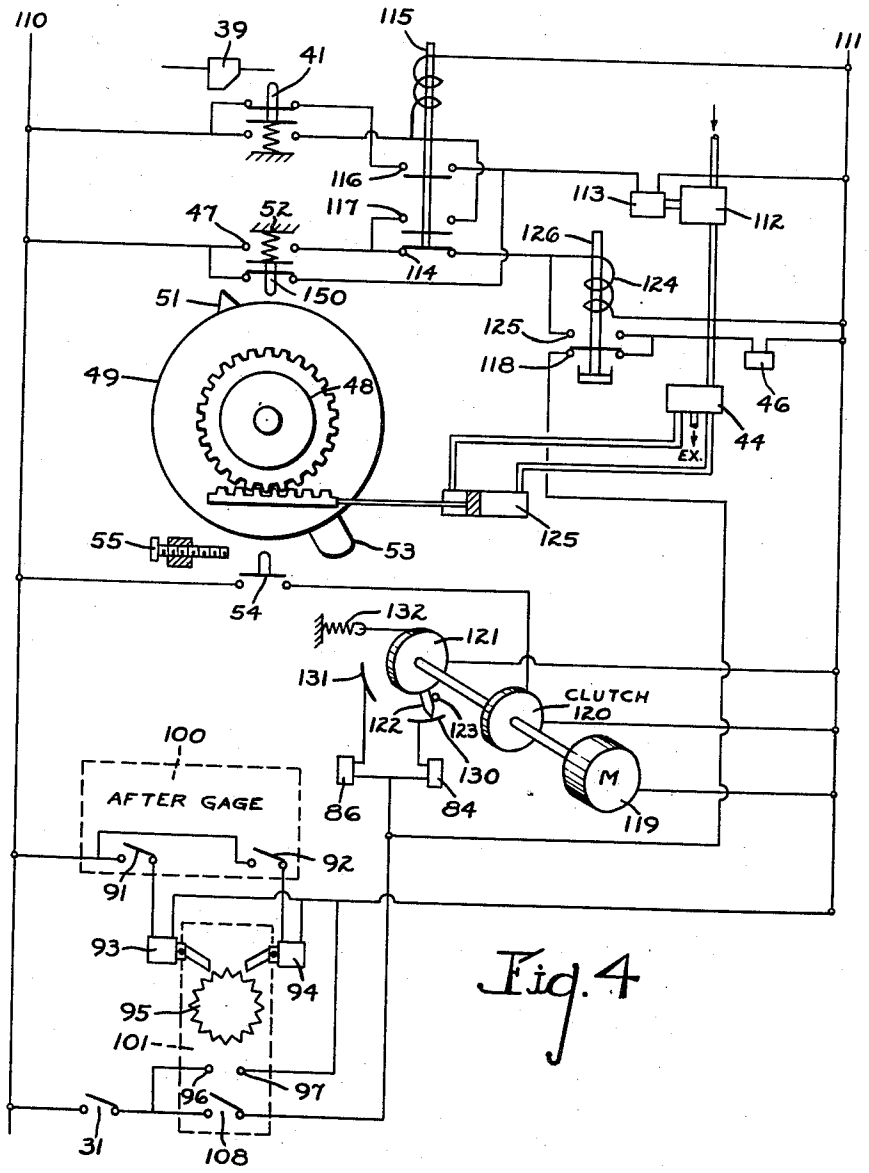


Fig. 4

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GRINDING MACHINE

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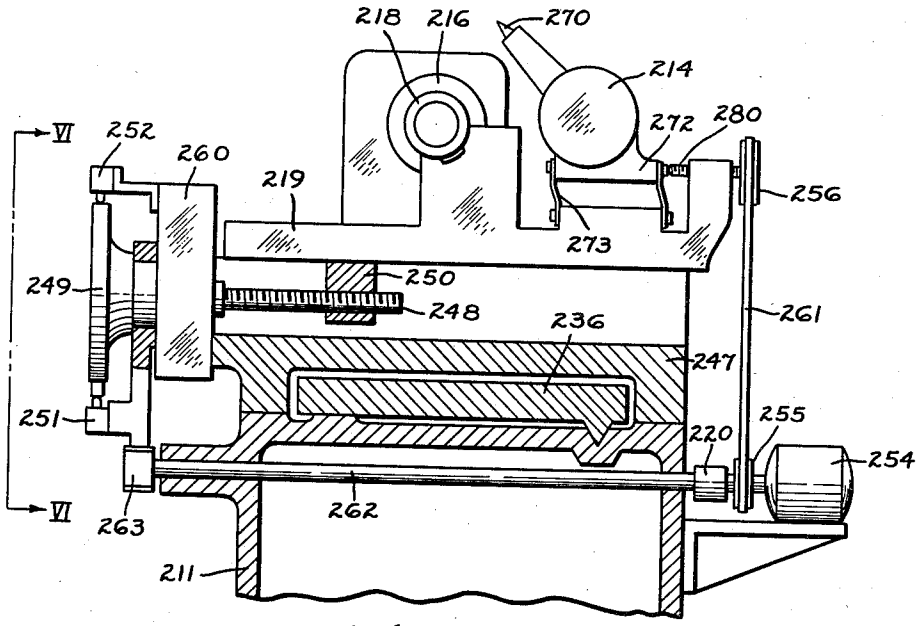


Fig. 5

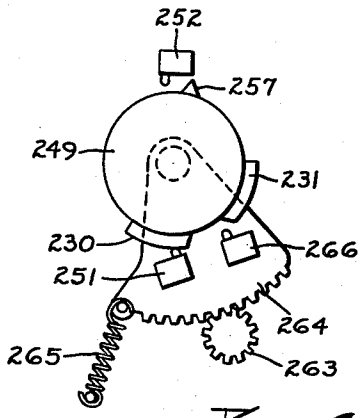


Fig. 6

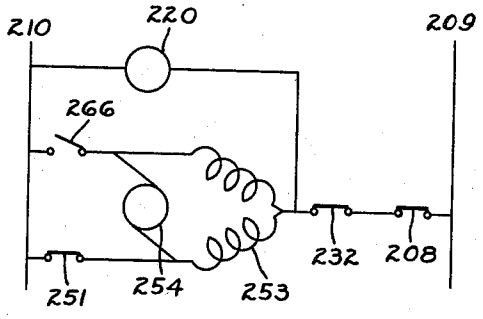


Fig. 7

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GRINDING MACHINE

Filed March 29, 1957 5 Sheets-Sheet 5

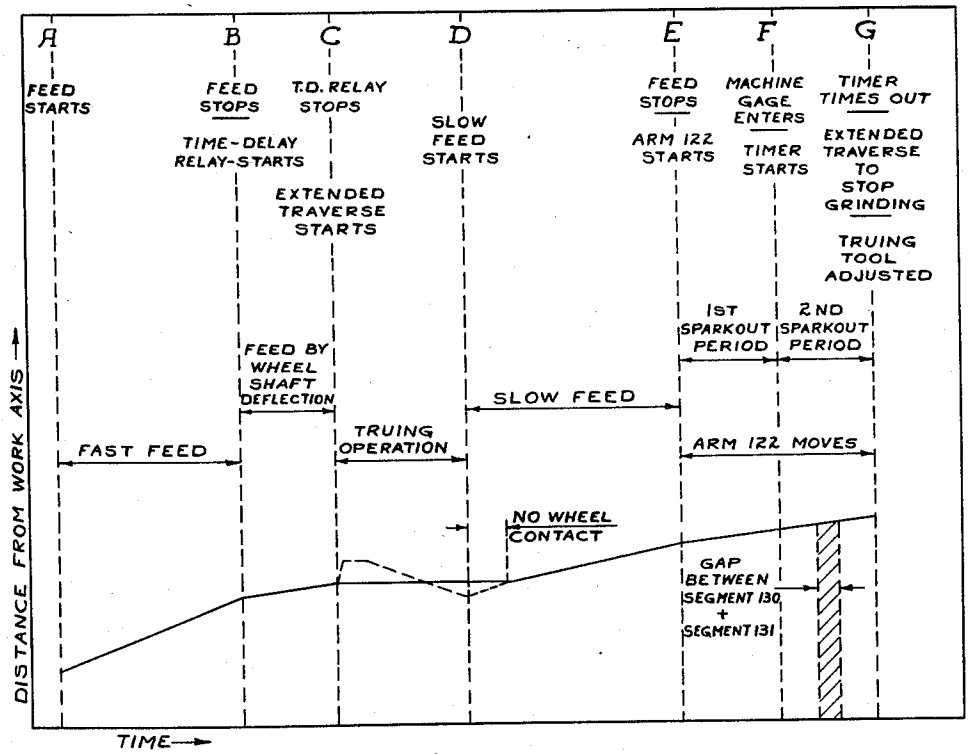


Fig. 8

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2,932,130

GRINDING MACHINE

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Application March 29, 1957, Serial No. 649,406

15 Claims. (Cl. 51—50)

This invention relates to a grinding machine and more particularly to apparatus for removing metal from a workpiece by abrasion with a high degree of accuracy.

It is conventional practice in the art of grinding, particularly when the surface to be abraded is an internal bore or the like, to true the wheel periodically and to feed it relative to the position in which it is trued to a second position at which the feed is reduced or stopped. The grinding operation is then continued by utilizing the deflection of the wheel spindle until the bore has been enlarged to the desired size, as determined by a work-gaging apparatus or by a timing device; this last portion of the grinding cycle is called the "spark-out" period. It will be realized, then, that the size and shape of the bore can be maintained constant at a desired value only if the deflection of the spindle and the length of the spark-out period remain the same for successive workpieces.

In such a machine, if the position of the truing tool changes, the surface of the wheel will not have the desired relation to the work; such changes could occur because of wear or because of thermal drift. If the wheel is too small, excessive time will be required to finish the work; if the wheel is too large, the deflection of the wheel spindle will be excessive and, consequently, the bore will be tapered and the wheel will cut too fast to produce the desired quality of finish.

In the patent of Townsend, Number 2,850,847 and the patent of Blood, No. 2,909,006, suggestions have been made for overcoming these difficulties. In each case, the relative positions of the wheelhead, truing tool, and workhead are re-established at each grinding cycle. However, in these machines the deflection of the wheel spindle is not directly controlled, so that variations in this deflection may effect the time required for the spark-out period and so that tapered bores and the like may result.

In the patent of Townsend, Number 2,826,873, an arrangement is shown wherein a work gage gives a signal after which the spark-out period is continued for a few extra strokes of the machine, the number of such additional strokes being controlled by an after gage. Thus, any change in the work gage, due to wear or thermal effects, is compensated. In this type of machine, also, the errors in taper will be reduced and the cycle time kept to a minimum, if the spindle deflection is kept uniform from piece to piece while the said additional strokes are being made. These and other difficulties experienced with the prior art machines 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 having a cycle of operation of minimum duration and having the ability to form bores having little taper.

Another object of the instant invention is the provision of a grinding machine in which wheel spindle deflection during the spark-out period is maintained at a uniform value from workpiece to workpiece.

A still further object of this invention is the provision of a grinding machine in which the duration of the spark-out period is controlled by a machine gage and in which the deflection of the wheel spindle is maintained constant during successive cycles to give spark-out periods of constant lengths.

A further object of the present invention is the provision of a grinding machine in which the duration of the spark-out period is determined by a timing device responsive to an after-gage and in which the deflection of the wheel spindle is constant during successive spark-out periods to give equal stock removal on successive workpieces.

Another object of this invention is the provision of a grinding machine in which the spark-out period is composed of two parts, one controlled from a machine gage and the other determined by a timer connected to an after-gage and in which the deflection of the wheel spindle is maintained at a constant value from piece to piece, so that the duration of the said one part and the amount of stock removed during the said other part will not differ from piece to piece.

Another object of the invention is the provision of a grinding machine having a first spark-out period controlled by a machine gage and a second spark-out period controlled from an after-gage, in which machine the sum of the durations of the two spark-out periods is maintained at fixed value, so that the amount of wheel shaft deflection is the same from workpiece to workpiece, thus obviating bell mouth and rough finish in the workpieces.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings in which:

Figure 1 is a front elevational view of a grinding machine embodying the principles of the present invention,

Figure 2 is a view of a portion of the machine taken on the line II—II of Figure 1,

Figure 3 is a plan view of the apparatus shown in Figure 2,

Figure 4 is a diagramamtic view of certain electrical and hydraulic apparatus associated with the machine,

Figure 5 is a transverse sectional view of another grinding machine making use of the invention,

Figure 6 is an elevational view of the machine shown in Figure 5 as seen from the line VI—VI,

Figure 7 is a diagrammatic view of a portion of the electrical apparatus used in the machine of Figure 5, and

Figure 8 is a graphic showing of the operation of the grinding cycle used in the machine of the invention.

Referring first to Figure 1, wherein is best shown the general features of the invention, the grinding machine, designated generally by the reference numeral **10**, is shown as comprising a base **11**, on which are mounted a workhead **13**, a truing device **14**, and a table **36** carrying a motorized wheelhead **12**. From the wheelhead **12** extends a spindle **9** carrying an abrading tool such as a cylindrical abrasive wheel **15**. From the workhead **13** extends a chucking means such as a magnetic platen **16** driven through a pulley **17**; a workpiece **18** is held and rotated by the platen and rests on a supporting member **19**. The machine shown is arranged to finish grind an internal bore in the workpiece. Extending through and

slidably supported by the workhead is a shaft 21 having a gaging head 22 residing in a recess in the platen 16. A coil spring 23 surrounds the shaft 21 and lies under compression between the head 22 and the back wall of the platen.

The end of the shaft 21 opposite that bearing the gage head is provided with a collar 27 the inner side of which contacts one end of a lever 28 which is pivotally connected to a bracket 29 extending from the base 11. A switch 31 is mounted on the workhead 13 in position to be closed by the lever 28 when the gage head 22 enters the workpiece 18. A threaded stop member 32 extends through the intermediate portion of the lever 28 in position to engage one end of a table 36; such engagement will move the lever 28 and the shaft 21 so that the gage head 22 clears the wheel 15. The wheel head 12 is fastened to the table 36 adjacent its other end and the table is mounted for external sliding movement on the base 11.

Extending downwardly from the table 36 is a dog 39 adapted on occasion to engage a switch 41 fixed to the base 11. A dog 42 having a pivoted latch 38 is also mounted on the table for engagement with one end of a lever 43 pivotally mounted on the base; the other end of the lever engages and actuates the plunger of a reversing valve 44. An actuating finger 45 is mounted on the base for vertical sliding to contact, on occasion, and move the latch 38; a solenoid 46 is mounted on the base in a position such that its plunger may contact and raise the finger 45, thus lifting the dog latch 38 and allowing it to run past the lever 43. Another dog 40 extends downwardly from the table.

The workhead 13 is dovetailed to a conventional bridge 47 which straddles the table 36 permitting transverse feed motion of the workhead relative to the base and to the wheelhead. A convenional feed screw 48 is mounted in the bridge and engages a nut 50 fastened to the workhead 13 for bringing about the feeding motion.

Mounted on the screw 48 is a cam wheel 49 which rotates with the screw 48. The screw and cam wheel are rotated clockwise by a conventional feed box 60 similar to that described in the patent of Townsend, Number 2,850,847, to feed the work-piece into the wheel. Extending from the outer periphery of the cam wheel is a dog 51 adapted on occasion to engage a switch 52 fastened to the feed box 60 with its actuating finger in the path of the dog as the wheel rotates. At the other side of the wheel, a cam 53 is mounted to extend outwardly and engage a switch 54 and a stop screw 55, both mounted on the feed box 60.

As shown in Figures 2 and 3, the truing device 14 comprises a truing tool or diamond 70 in a holder 71, which may be swung upward by conventional means, not shown, to move the diamond 70 clear of the wheelhead 12. The holder 71 is carried on a housing 72 attached by means of reeds 73 to the supporting member 19. The housing 72 is forced toward the right, deflecting the reeds 73, by a pin 74 which projects from the supporting member 19 and engages a lever 75 hinged on a pivot pin 76 to the housing 72. The position of the housing 72 relative to the member 19 and, hence, the position of the diamond 70 relative to the wheel 15 is adjusted by means of a screw 80 threaded in the housing 72 and engaged by the lever 75. The screw 80 carries a knob 81 by which the screw may be adjusted manually and the screw also carries a ratchet 82. A pawl 83 is moved by a push solenoid 84 when energized to engage and turn the ratchet 82 to adjust the tool 70 toward the wheel 15. A pawl 85 is moved by a push solenoid 86 to adjust the tool 70 away from the wheel 15.

Referring now to Figure 4, the electrical apparatus is shown connected between power lines 110 and 111. An after-gage 100 is provided of the type shown and described in the patent of Townsend, Number 2,826,873; the after-gage is provided with a normally-open oversize switch 91 which closes when the workpiece being

gauged is larger than a desired value and with a normally-open under-size switch 92 which closes when the workpiece is smaller than desired. The switch 91 is connected on one side to the line 110 and on the other side to the line 111 through the coil of a solenoid 93; the switch 92 is also connected on one side to the line 110 and on the other side to the line 111 through the coil of a solenoid 94. These solenoids are fastened to a timing means such as timer 101 and they act through pawls to turn a ratchet 95 in opposite directions. The timing duration of the timer is adjusted by the turning of the ratchet. An input terminal 96 is connected through the switch 31 to the line 110, while another input terminal 97 is connected to the line 111. The timer 101 is provided with a normally-open switch 108 which closes when the timer times out, i.e., after a predetermined period of time has passed after current is introduced on the input terminals 96 and 97. The switch 108 is connected on one side through the switch 31 to the line 110.

The other side of the switch 108 is connected to one side of each of the coils of the diamond-adjusting solenoids 84 and 86. The other side of the coil of the solenoid 86 is connected to an arcuate segment 131 and the other side of the coil of the solenoid 84 is connected to a similar arcuate segment 130. The segments form part of a timing device 121; the segments have a common center and are slightly separated at their adjacent ends. At the segment center is mounted a contact arm 122 which sweeps over the segments in electrical contact under the driving force of a motor 119 connected to the arm through an electrically-actuated clutch 120 which may be of the electromagnetic friction type. The arm 122 is biased toward the outer end of the segment 130 by a spring 132 and, in that position, it rests against a stop pin 123. The arm 122 is connected electrically at its inner end to the line 111. The motor 119 is connected directly across the lines 110 and 111, so that it operates continuously when the grinding machine is in operation. The clutch 120 contains an actuating coil which is connected on one side through the normally-open switch 54 to the line 110 and on the other side to the line 111.

The said other side of the switch 108 of the timer 101 is also connected to the line 111 through a normally-closed contactor 118 of a time-delay relay 120 and the coil of the solenoid 46 which, it will be recalled, operates the finger 45. A normally open contactor 125 of the relay 126 is also connected on one side through the coil of the solenoid 46 to the line 111; on the other side it is connected to one side of the actuating coil 124 of the relay 126, the other side of which coil is connected to the line 111. The common junction of the contactor 125 and the coil 124 is connected to the line 110 through a normally-closed contactor 114 of a relay 115 and a normally-open contactor 47 of the switch 52. The switch 52 is also provided with a normally-closed contactor 150 which is connected on one side to the line 110 and on the other side to one side of the coil of a solenoid 113, the other side of which coil is connected to the line 111. The solenoid operates the plunger of a feed stop valve 112 which is connected hydraulically through the reversing valve 44 to a hydraulic actuator 125 which is suitably connected to the feed screw 48 and the cam wheel 49. The common junction of the contactor 150 and the coil of the solenoid 113 is connected to the line 110 through a normally-open contactor 116 of the relay 115 and a normally-closed contactor of the switch 41. A normally-open contactor of the switch 41 is connected on one side to the line 110 and on the other side through the actuating coil of the relay 115 to the line 111; the said other side of the contactor is also connected through a normally-open contactor 117 of the relay 115 to a common point between the contactor 114 of the same relay and the contactor 47 of the switch 52.

The operation of the grinding machine will now be readily understood in view of the above description. The

workpiece 18 is placed in the workhead 13 and is rotated by means of the platen 16 driven by the pulley 17. The wheel 15 is rotated by its motor and the wheelhead 12 and the table 36 are subject to longitudinal reciprocation along the base 11 in the usual manner. The workhead 13 bearing the rotating workpiece moves transversely of the base 11 under the action of the feed mechanism. In general, the cycle of operations involves a rough grinding operation, a period of no feed, a truing operation, a slow feed grinding operation, a first spark-out period and a second spark-out period at the end of which the cycle is terminated. During the rough grinding operation the table 36 reciprocates and the feed box 60 receives oil through the valve 112 so that the feed screw 48 is turned clockwise and the cam wheel 49 is turned in a similar manner. Eventually, the cam 51 operates the switch, opening the contactor 50 and de-energizing the solenoid 113; this allows the valve 112 to close, thus stopping the feed motion. At the same time, the contactor 47 is closed, thus completing a circuit through the contactor 114 of the relay 115 and through the coil 124 of the time-delay relay 126; after the relay 126 has timed out, a circuit is completed through the contactors 125 and the solenoid 46, thus raising the finger 45 and the dog latch 38 to allow the table 36 and the wheelhead 12 to run on an extended stroke to the right for a truing stroke. The provision of the timing relay 126 to stop the feed for a period of time between the rough grinding operation and the truing operation makes it possible to feed the workpiece toward the wheel during the rough grinding operation at a faster rate than would otherwise be permissible; this builds up deflection in the wheel spindle 9 and the no-feed period allows the deflection to be reduced before the wheel is withdrawn from the workpiece for truing. The taper of the rough-ground bore is held to a minimum in this way.

As the table moves to the right on the truing traverse, the cam 39 operates the switch 41 opening the normally-closed contactor and closing the normally-open contactor to complete a circuit through the coil of the relay 115; the energization of the coil closes the contactor 116, opens the contactor 114 and completes a holding circuit through the contactor 117 and the contactor 47 of the switch 52. The opening of the contactor 114 allows the relay 126 to be de-energized, thus de-energizing the coil of the solenoid 46 and closing the contactor 118.

The table continues to the right until the dog 40 strikes the lever 43 and reverses the table by means of the valve 44. During the return traverse, the wheel is contacted by the diamond for truing. After the wheel has re-entered the bore in the workpiece, the dog 39 releases the switch 41, thus closing the normally-closed contactor to complete a circuit through the contactor 116 of the relay 115 and through the solenoid 113, starting the slow feed. The cam 51 releases the switch 52, opening its normally-open contactor 47, breaking the holding circuit of the relay 115; at the same time, the contactor 50 is closed completing a circuit through the solenoid 113 which causes the feed to continue.

When the feed has continued for some time, the cam wheel 49 turns to the point where feed will be stopped; the cam 53 strikes the stop screw 55, thus stalling the feed, and at the same time the cam 53 closes the switch 54 completing a circuit through the clutch 120 to couple the motor 119 to the arm 122. The arm is turned clockwise away from the pins 123. Grinding continues under spark-out conditions and, when the bore has been enlarged sufficiently, the gage head 22 enters the workpiece. This allows the switch 31 to be closed and to start the timer 101. Spark-out grinding takes place during the timing period of the timer and, when it times out, the switch 108 is closed. This completes a circuit through the contactor 118 and the solenoid 46, thus permitting the table to traverse to the right away from the workpiece to terminate the grinding cycle. If a relatively short time has

elapsed since the closing of the switch 54, the arm 122 of the timing device 121 will be in contact with the segment 130, thus completing a circuit through the solenoid 84. This adjusts the diamond 70 toward the wheel 15 so that in the next cycle the distance from the surface of the workpiece to the cutting surface of the wheel after truing will be slightly increased. On the other hand, if a relatively long time has elapsed, the arm 122 will have reached the segment 131, completing a circuit through the solenoid 86 which adjusts the diamond 70 away from the wheel. If the elapsed time is of the proper length, the arm 122 will lie between them and no adjustment will be made. The gap between the segments is made large enough so that no adjustment is made unless the difference is large enough to be worthwhile.

At the end of the grinding cycle, the workhead is moved away from the axis of the wheel in the usual way by the feed box 60 and the cam wheel 49 rotates in a counter-clockwise direction. This opens the switch 54 and de-energizes the clutch 120 so that the spring 132 returns the arm 122 to the pin 123.

As the workpiece is discharged from the workhead, it passes through the after-gage 100. If the size of the finished bore differs sufficiently from the desired value, the timer 101 will be adjusted to make the second period of spark-out longer or shorter to compensate for the variation.

In Figures 5, 6 and 7 are illustrated a variation of the invention intended for use where the feed is not absolutely stopped during the "spark-out" period, but progresses at a very slow rate. In such a case it will be possible to use an arrangement associated with the cam wheel in place of the timing device 121 shown in the embodiment of Figure 1. A base 211 has a wheelhead table 236 slidably mounted thereon. Also mounted on the base is a bridge 247 carrying a workhead table 219. A workpiece 218 is rotated by a plate 216. A truing device 214 is resiliently mounted over the table 219 by means of reeds 273 and includes a housing 272 carrying a diamond 270. A screw member 260 is mounted in the table 219 and is adapted to engage the housing 272 to adjust the diamond toward and away from the wheelhead table 236. A pulley 256 is keyed to the screw member and is driven through a belt 261 from a pulley 255. The pulley is mounted on the shaft of a motor 254 mounted on the base 211. The motor also drives a shaft 262 through a clutch 220 of the electromagnetic type. A feed box 280 mounted on the bridge 247 rotates a feed screw 248 which engages a nut 250 extending dwonwardly from the workhead table 219. A cam wheel 249 is also rotated in synchronization with the feed screw. A cam 251 extends from the cam wheel in position to engage, on occasion, a switch 252 fastened to the feed box. Extending from the cam wheel diametrically opposite the cam 251 are segmental cams 230 and 231 positioned to engage, on occasion, a normally-closed switch 251 and a normally-open switch 266 mounted on a gear segment 264. The gear segment is pivotally mounted on the same axis as the cam wheel, but is movable independently thereof. The outer end of the gear segment is formed with teeth positioned to engage a small gear 263 mounted at the end of the shaft 262 opposite the motor 254. A coil spring 265 connects the gear segment to the base 211 and serves to return it to an initial position at the end of every grinding cycle. In the electrical circuit associated with this embodiment of the invention, the actuating coil of the clutch 220 is connected on one end to a power line 210 and on the other end to a power line 209 through a machine gage switch 232 and a timer switch 208, these switches corresponding, respectively, to the switches 31 and 108 of the first-described embodiment. The switch 266 is connected on one side to the line 210 and on the other side through a field coil 253 of the motor 254, the switch 232, and the switch 208 to the line 209. The switch 251 is also connected at one side

to the line 210 and on the other side through another coil 253 of the motor 254, the switch 232 and the switch 208 to the line 209. The ends of the motor coils away from the switches 266 and 251 are joined in a common junction, while the armature of the motor 254 is connected between the other ends.

The operation of this embodiment of the invention takes advantage of the fact that the feed mechanism continues to move during the final finishing or "spark-out" operation. The cam wheel 249 continues to move until the grinding is completed and the cam 251 may strike the switch 252 to cause the feed rate to change from the slow feed to a very much slower speed; at this slower speed, the wheel shaft deflection will enter appreciably into the grinding effect. In the condition shown in Figures 6 and 7, the machine gage switch 232 is closed and so is the timer switch 208, thus completing a circuit to energize the clutch 220. The cam wheel 249 has not turned clockwise far enough for the cam segment 230 to run off the switch 251, so that switch is closed; therefore, a circuit exists through the armature and field coils 253 of the motor 254. The motor, thus, drives the screw 260 to move the diamond toward the grinding wheel axis. The motor also drives the shaft 262, thus turning the gear segment 264. The segment carries the switch 251 counterclockwise until it runs off the cam segment 230, thus stopping the motor 254. Upon completion of the grinding cycle, the machine gage head is retracted, as is conventional, and the switch 232 is opened, releasing the clutch 250 and allowing the spring 265 to return the gear segment 264 to the position shown. As is evident, the switch 266 is operated by the cam segment 231 if the cam wheel 249 turns clockwise more than a predetermined distance, causing the motor 254 to turn in the direction to adjust the diamond away from the axes of the work and the wheel. This embodiment, in which the amount of each diamond correction is determined by the amount of error, is especially useful when the error is large, as would be the case when the machine has been idle for some time or when it has been set up for a new job. It is only necessary for the operator to locate the truing device approximately; the machine will make finer adjustments automatically.

An understanding of the advantages of the invention will be best obtained from an examination of the chart shown in Figure 8. In the chart, which represents the operation of the machine shown in Figure 1, the abscissa represents time, while the ordinate represents the distance of the wheel surface from the work axis; the lines divide the entire cycle time into periods whose lengths are approximately as shown. At time A, the fast feed starts and continues to the time B. At time B, the feed stops entirely and the time-delay relay 120 starts; during the period from time B to time C, grinding takes place due to wheel shaft deflection only. At time C, the time-delay relay times out and extended transverse for truing starts. During the time from time C to time D the wheel is trued on its extended traverse; the dotted line represents the average wheel surface, while the solid line indicates the surface of the workpiece. At the point C, the wheel springs forward as it leaves the workpiece and then remains at that new position for a short while before its traverse motion brings it into contact with the diamond. At the end of the truing period, the wheel surface may be separated from that of the workpiece. A short infeed or compensation for truing takes place at the point D, this being a conventional motion built into all such machines. At time D, the wheel is again within the bore in the workpiece and slow feed begins. At time E the feed stops and the arm 122 starts its passage over the segments 130 and 131. Grinding proceeds under spark-out conditions until time F, at which time the machine gage head enters the bore in the workpiece and the timer 101 starts. Grinding continues under spark-out conditions until the time G is reached; at that time the timer 101 ends the cycle and the diamond is adjusted, if need be.

Consideration of this cycle shows a number of factors that effect the quality of work, but which work against one another if care is not exercised. The duration of the so-called "second spark-out period" is adjusted by the after-gage to compensate principally for changes in the machine gage due to thermal drift. The machine gage determines the duration of the so-called "first spark-out period" so that the bore in the workpiece is of a desired size, despite differences in the bore sizes of successive pieces at the time E, the start of the spark-out. The adjustment of the diamond assures that the sizes of successive pieces will not differ, despite changes in the distance between the diamond and the work head. While these compensations are being made, it must be remembered that the accuracy of the finished bore depends also on (1) the wheel spindle deflection at the start of the spark-out period being the same and (2) the duration of the spark-out period being he same during successive cycles. With regard to wheel spindle deflection, this can be accomplished by maintaining constant the period of "no wheel contact" at the beginning of the slow feed period; when this is done, the cutting rate during the productive part of the slow feed period is the same from cycle to cycle, so that the wheel spindle deflection at time E remains the same. The period of no wheel contact is dependent on the amount of stock removed from the wheel during the truing operation, so the adjustment of the diamond provided for in the present invention takes care of this factor. It should be noted that it is common practice in grinding machines to advance or "compensate" the wheel rapidly toward the work after the truing operation, otherwise, of course, the "no wheel contact" period would grow progressively larger with each cycle. The mechanism for doing this is not shown or described in connection with the invention lest the description become unduly complicated. The jog in the dotted line at time D indicates this compensation.

With regard to the second factor, i.e., constant spark-out time, the spark-out time in the present case is made up of a first period, determined by the machine gage, and a second period determined by the after-gage. The first period will remain constant from cycle to cycle if the size of the bore and the deflection of the wheel spindle remain the same at time E; these two factors remain the same from cycle to cycle if the "no wheel contact" period remains the same; therefore, indirectly, proper adjustment of the diamond assures constant duration of the first spark-out period. Presumably, the second spark-out period should remain at constant duration and only change to compensate for machine gage changes, since the gage is the last criterion of the size of the bore at time F and the second spark-out period is used to make small changes necessary by machine gage variations. As a practical matter, however, the after-gage is the final standard of comparison, so it naturally tries, by changing the spark-out period, to compensate for changes in bore caused by any part of the machine. Changes in the duration of the period from time E to time G are compensated for by the timing device 121 causing diamond adjustment, since diamond adjustment adjusts the first spark-out period. These factors require a careful selection of the increments of adjustment provided by these controls.

While certain novel features of the invention have been shown and described and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes in the forms and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention.

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 base member, a table member, a work holder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of said members, a rotating wheel on the wheel head, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means determining a spark-out period during which no feeding movement takes place between the workholder and the wheelhead, means comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the predetermined period and controlling the direction of the adjusting movement in accordance with the difference between the said periods.

2. A grinding machine comprising a base member, a table member, a workholder to rotate a workpiece on an axis, a wheelhead supported by one of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, said workholder and said truing device being supported by the other of said members, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including a machine gage operating on the workpiece during grinding for determining a fine feed period during which the feeding movement between the workholder and the wheelhead is at a substantially decreased rate, means comparing the length of the said fine feed period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the fine feed period differs from the length of the said predetermined period.

3. A grinding machine, comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including an after-gage for measuring the workpiece after the grinding is finished and for determining a period during which the feeding movement between the workholder and the wheelhead is decreased substantially, means comparing the length of the said period with a predetermined length of time, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the period differs from the said predetermined length of time.

4. A grinding machine, comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means determining a spark-out period during which the feeding movement between the workholder and the wheelhead is obtained mainly from deflection in the machine, means including a motor which operates during the spark-out period for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

5. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means determining a spark-out period during which the feeding movement between the workholder and the wheelhead is decreased substantially, means including a motor operating after the spark-out period is finished for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

6. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, gage means determining a spark-out period during which the feeding movement between the workholder and the wheelhead is decreased substantially, the said gage means including a machine gage engaging the workpiece during grinding and an after-gage engaging the workpiece after the grinding is finished, means comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

7. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including a machine gage operating on the workpiece during grinding for determining a spark-out period during which the feeding movement between the workholder and the wheelhead is stopped, means including a motor which operates during the spark-out period for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

8. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including a machine gage operating on the workpiece during grinding for determining a spark-out period during which the feeding movement between the workholder and the wheelhead is decreased substantially, means including a motor which operates after the spark-out period is finished for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-

out period differs from the length of the said predetermined period and controlling the direction and extent of the adjusting movement in accordance with the difference between said periods.

9. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including an after-gage operating on the workpiece after the grinding is finished for determining a spark-out period during which the feeding movement between the workholder and the wheelhead is stopped, means including a motor which operates during the spark-out period for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

10. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, means including an after-gage operating on the workpiece after the grinding is finished for determining a spark-out period during which the feeding movement between the workholder and the wheelhead is decreased substantially, means including a motor which operates after the spark-out period is finished for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

11. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, gage means including a machine gage operating on the workpiece during grinding and an after-gage which operates on the workpiece after the grinding is finished, the said gage means determining a spark-out period during which the feeding movement between the workholder and the wheelhead is stopped, means including a motor which operates during the spark-out period for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

12. A grinding machine comprising a base member, a table member, a workholder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of the said members, a rotating wheel on the wheelhead, a truing device for the wheel, means for producing relative feeding movement between the workholder and the wheelhead, means for producing relative adjusting movement between the truing device and the wheelhead, gage means including a machine gage operating on the workpiece during grinding and an after-gage which operates on the workpiece after the grinding is finished, the said gage means determining a spark-out period during which the feeding movement between the workholder and the wheelhead is decreased substantially, means including a motor which operates after the spark-out period is finished for comparing the length of the said spark-out period with the length of a predetermined period, and means bringing about the said adjusting movement between the truing device and the wheelhead when the length of the spark-out period differs from the length of the said predetermined period.

13. A machine for performing a grinding operation, a work support, an abrading tool, a truing device, a feed mechanism, means including a first timing means responsive to the feed mechanism to interrupt the grinding operation and to move the abrading tool across the truing device, a machine gage adapted to engage a workpiece in the work support, a second timing means started by the machine gage and operating at the end of a time interval thereafter to terminate the grinding operation, an after-gage operative thereafter to measure a finished workpiece, means responsive to the after-gage to adjust the second timing means, and a third timing means started by the feed mechanism and operative upon termination of the grinding operation to adjust the truing device.

14. A grinding machine comprising a base member, a table member, a work holder supported by one of said members to rotate a workpiece on an axis, a wheelhead supported by the other of said members, a rotating wheel on the wheelhead, an adjustable truing device for the wheel, machine gage means, timing means, cross feed means to feed the wheel relatively against a workpiece in the work holder, means to reduce the feed, means to start the timing means, and means responsive to the machine gage to adjust the truing device in a direction determined by the position of a part of the timing means.

15. In a grinding machine, a work support, a tool support, an abrading tool mounted on the tool support, feed means to move one of said supports to bring about contact between the tool and a workpiece in the work support for a grinding operation, work engaging means, a device for truing the abrading tool, a first and a second timing means, means responsive to the position of a part of the feed means to stop the feed and to start the first timing means, means effective when the first timing means times out to interrupt the grinding operation and to produce a truing operation, means operative after the resumption of feed to stop the feed and to start the second timing means, and means responsive to the second timing means and to the work gage means to adjust the position of the truing device relative to the work support.

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