

Sept. 9, 1958

A. F. TOWNSEND
INTERNAL GRINDING MACHINE

2,850,847

Filed Dec. 7, 1954

4 Sheets-Sheet 1

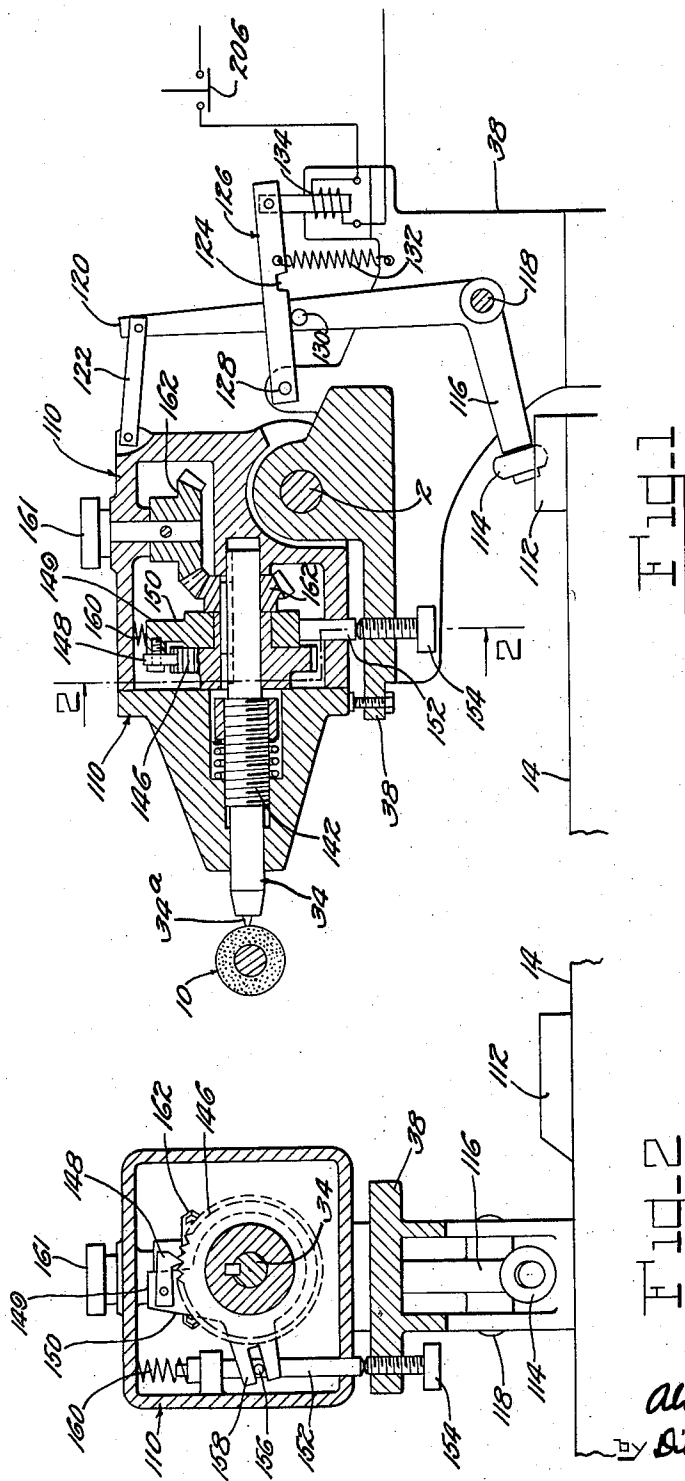


FIG. 1

FIG. 2

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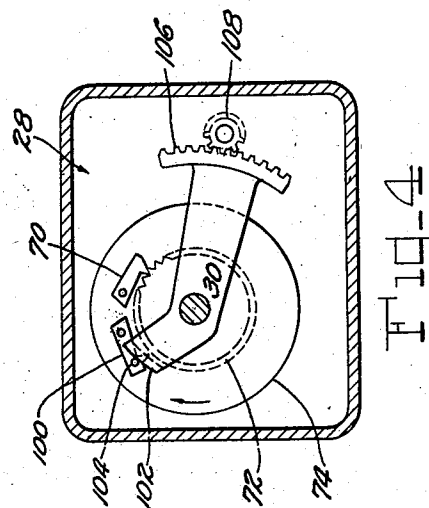
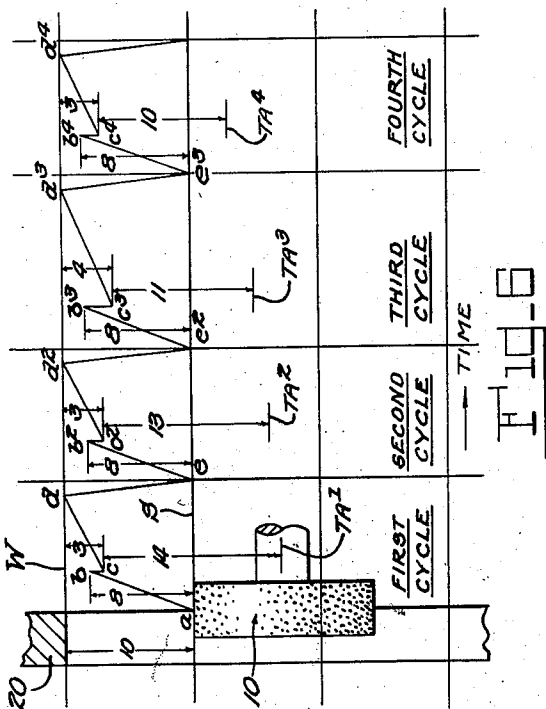
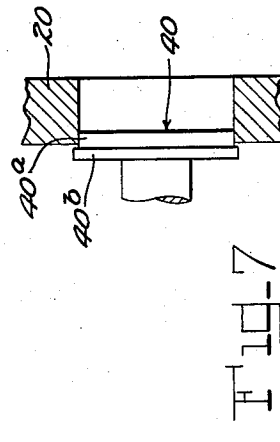
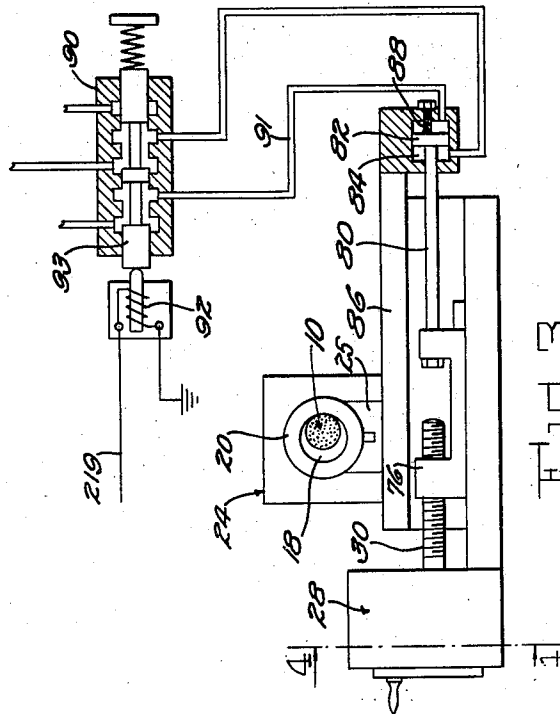
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INTERNAL GRINDING MACHINE

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4 Sheets-Sheet 2



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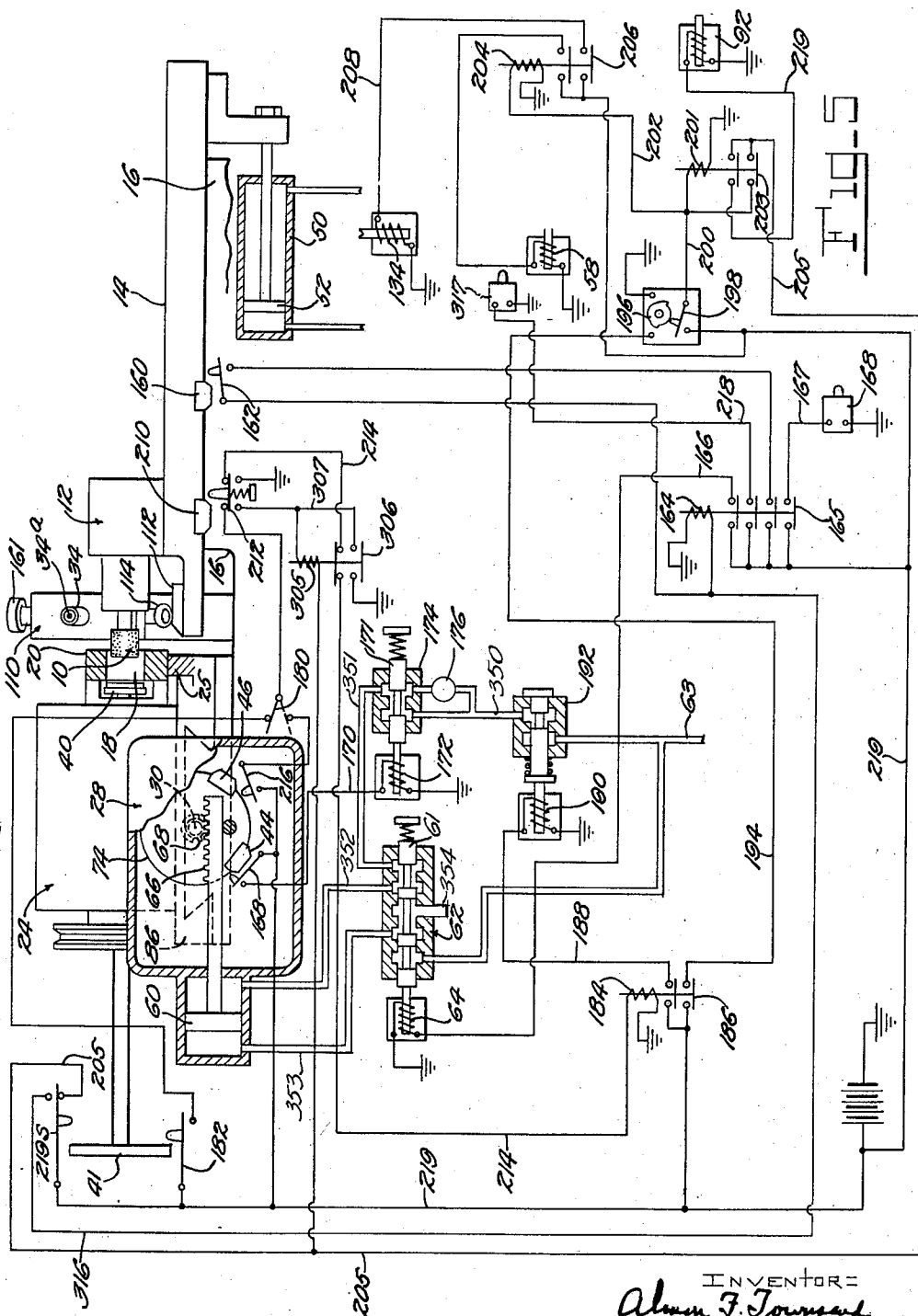
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A. F. TOWNSEND
INTERNAL GRINDING MACHINE

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4 Sheets-Sheet 3



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A. F. TOWNSEND
INTERNAL GRINDING MACHINE

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4 Sheets-Sheet 4

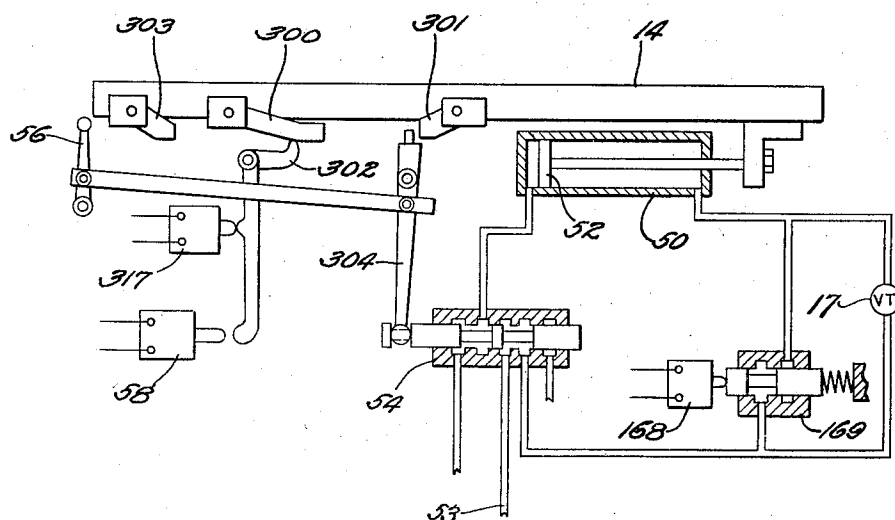


Fig. 8

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2,850,847

INTERNAL GRINDING MACHINE

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23 Claims. (Cl. 51—48)

This invention relates to grinding machines in which the grinding tool is periodically trued by a truing tool for grinding a succession of workpieces to a desired predetermined size, and therefore more particularly to internal grinding machines which inherently have small grinding wheels or tools which because of wheel wear must be constantly re-trued, usually for grinding each workpiece or after a predetermined number of workpieces have been ground.

In previous machines the diamond was initially adjusted to a preset distance from the work, usually from the center or axis of an internal bore or surface of revolution to be ground in the workpiece. Any change in this distance necessarily changed the travel of the wheel relatively from its truing position to its finish size position. If this travel became too short, the wheel might dig into the work and would not have time properly to finish the bore. If too long, time was wasted and the wheel might wear out of shape before the bore was finished. Re-adjustment of the relative position of the truing tool was, therefore, necessary from time to time to compensate for wear of the diamond and for cumulative changes in its relative position due to thermal effects.

In previous machines the feed was slowed after the wheel had been fed a set distance from an initial position. But slow drift or change in the relative position of the diamond while a number of workpieces were being ground disturbed the relation between the feed mechanism and the cutting surface of the wheel, with the result that the feed was slowed too early or too late for best results. For this reason, also, frequent re-adjustment of the diamond was necessary.

One object of this invention is to make re-adjustment of the relative position of the diamond unnecessary. I accomplish this by advancing the diamond relatively toward the wheel a uniform distance for each piece ground, this distance being sufficient for truing the wheel after it has worn, feeding the work relative to the wheel a variable distance depending on the reduction in wheel diameter, and retracting the work a fixed distance in the opposite direction. These motions serve to maintain substantially the desired relation between work and wheel, as will be explained.

Another object is to provide means by which the feed may be slowed when the grinding wheel surface is at a known distance from the finished work surface thereby maintaining a constant optimum condition of final feed.

Another object is to provide a simple automatically operating mechanism to advance the diamond and to turn it slightly, on an axis forming an acute angle with the surface of the wheel, each time the wheel is trued, so that the diamond will wear sharp.

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Another object is to relieve part of the deflection of the wheel spindle and thereby to provide more accurate truing and also grinding by allowing the wheel partially to spark out prior to truing by backing off the wheel slightly relative to the work before it re-enters the work, and by maintaining this backed-off relation during the finish grinding operation if desired.

Other advantages will be apparent from the following description of a preferred example of one of many possible embodiments together with the drawings in which:

Fig. 1 is a side view partly in section of the truing mechanism in operative position,

Fig. 2 is a vertical section taken on the line 2—2 of the mechanism of Fig. 1,

Fig. 3 is a side view of the feed mechanism together with a schematic view of part of its operating mechanism,

Fig. 4 is a section taken on the line 4—4 of Fig. 3,

Fig. 5 is a partial view of operative parts of the machine partly in section and partly broken away together with a schematic view of the operating and control mechanisms,

Fig. 6 is a schematic view illustrating the relative motions of the several operative parts throughout a series of four consecutive grinding cycles or operations, one cycle for each of four successive workpieces, and

Fig. 7 is an enlarged fragmentary detail of the gauge entering the work.

Fig. 8 is an elevation view of the operating mechanism.

Referring to Figs. 1 to 5, the general arrangement of elements in this invention is embodied in an internal grinding machine of the centerless type, the machine illustrated being a so-called shoe type of centerless grinder in which the workpiece is externally supported on one or more arcuately shaped shoes. It includes an internal grinding wheel 10 on a wheel head 12 mounted on a table 14 slidably arranged on the base 16 to run the wheel 10 into and out of the bore 18 of a workpiece 20, a workhead 24, including a suitable work support 25 and associated parts for rotatably supporting each of a succession of workpieces 20, feed mechanism, generally indicated at 28 including a feed screw 30 arranged to feed the workpiece 20 relative to the grinding wheel 10 to apply the wheel to the internal surface of the bore 18 after the wheel 10 has been run into the work and thereafter to retract the work from the wheel, and a truing tool 34, including a cutting diamond 34a and its associated parts, best seen in Figs. 1 and 2, mounted on the base 16 for application to the wheel 10 for truing the wheel when the wheel has been run out of the work during a workpiece grinding cycle.

The diamond 34a is supported on a bracket 38 on the base and, by means to be described, is fed independently and automatically further toward the wheel by a predetermined amount each time it is applied to true the wheel surface.

While the arrangement shown and described is but one of many possibilities for providing the desired relative motion between the three principle elements, the wheel, the work and the truing tool, it is seen that to accomplish the objective of my invention I provide means to feed the work relative to the wheel and independently thereof means to feed the truing tool relative to the wheel co-operating in the manner to be described.

Retraction and run-out of the wheel for a truing operation intermediate of the cycle are controlled by a por-

tion 40a of a plug-type gauge 40, which may be conventionally mounted in the work head 24 on the axis of rotation of the workpiece 20, for insertion in the work when rough size is reached to cause operation of associated control switches to which the cycle is responsive. Alternatively for truing, control means may be selected including a pair of cams 44 and 46 upon a plate 74 to operate associated control switches in the feed mechanism 28, and which thereby controls work size in accordance with depth of relative feed of the wheel and workpiece. Retraction and run-out when finish size is reached is controlled, in the machine illustrated, by a portion 40b of the plug gauge 40 seen in detail in Fig. 7.

The table 14 is moved in and out by a conventional fluid pressure operated cylinder 50 and piston 52 controlled by a valve 54, shown in Fig. 8, which may be manually operated by a handle 56 or else automatically operated by conventional dogs 300, 301 on the table to reciprocate the wheel 10 across the face of the work, and also to run the wheel out of the work by a solenoid 58, which actuates a rock arm 302 holding the dog 300 in an upward inoperative position to allow the table to run out. The dog 303 runs the table back in by reversing the valve 54, but is held inoperative at the end of the cycle by the rock arm 302.

The feed mechanism 28 is actuated by a fluid pressure operated piston 60 controlled by a valve 62, which is operated by a solenoid 64. The piston 60 moves a rack 66 and pinion 68 to which the plate 74 is fixed. The plate 74 carries a pawl 70, see Fig. 4, which turns a ratchet 72 attached to the feed screw 30 in a clockwise direction to feed the workpiece toward the wheel. Rotation of the feed screw 30 moves a nut 76 to which is attached a piston rod 80 and a back-off piston 82 in a cylinder 84 attached to the slide 86 upon which the work head 24 is mounted, as seen in Fig. 3. When the left side of the back-off cylinder 84 is filled with fluid, the back-off piston 82 is held rigidly against an adjustable stop 88, locking the piston rod 80 and the slide 86 together so that movement of the feed screw 30 moves the workpiece 20 to the left and into the wheel 10. The position of the back-off piston 82 and its cylinder 84 is controlled by fluid passing through a valve 90 which in turn is controlled by a solenoid 92.

The workpiece is retracted from the wheel surface by a predetermined fixed amount after the grinding of each workpiece by a pawl 100 acting on the ratchet 72 to move it in a counterclockwise direction. The pawl 100 is controlled to operate the ratchet 72 through an angle equivalent to a predetermined number of notches by an adjustable cam 102 upon which rides a pin 104 on the pawl 100 during an inoperative portion of its movement. The position of the cam 102 is adjusted by a rack 106 and pinion 108 and a hand wheel, not shown, attached to the pinion 108 so that the pawl 100 becomes operative to turn the ratchet 72 through the desired angle which is equivalent to the desired amount of retraction of the wheel from the work.

Referring to Figs. 1 and 2, the truing tool 34 is supported in a head 110 which is pivoted at 2 to raise the tool 34 to an inactive position and to lower it to an operative position to true the wheel by means of a cam 112 on the table 14 which raises and lowers a cam follower 114 on an arm 116 pivoted at 118 on the bracket 38 and connected at its upper end 120 by a link 122 to the pivoting head 110. After the truing tool 34 has been raised to its inactive position by the cam 112, it is retained by a notch 124 in a latch 126 pivoted at 123 and held downwardly over a pin 130 on the arm 116 by a spring 132. The latch 126 is raised to release the truing tool by a solenoid 134. The truing tool 34 is externally threaded at 142 in the support head 110 so that when the truing tool 34 is turned it is moved toward the center of the wheel 10. Secured to the rotatable truing tool 34 is a ratchet 146 operated as seen in Fig. 2 by a pawl 148 on

the arm 149 of a plate 150. When the truing tool 34 and its supporting head 110 are lowered, a plunger 152 strikes an adjusting screw 154, raising the plunger 152 by an amount determined by the position of the screw 154. A pin 156 on the plunger 152 engages a fork 158 on the plate 150 to move the plate 150, the pawl 148 and the ratchet 146, which turns the truing tool 34 and moves the truing tool 34 toward the center of the wheel by an amount determined by the position of the adjusting screw 154. Turning of the truing tool provides a means to index it so that it presents a new cutting edge when it is advanced toward the wheel. When the truing tool is raised out of operative position by the cam 112, a spring 160 returns the plunger 152 and the plate 150 to their initial positions ready for a subsequent operation. A knurled handle 161 connected through a pair of bevelled gears 162 to the truing tool provides initial adjustment of the position of the truing tool 34.

The machine and its operation may be better understood by reference to the successive relationships of its principal elements through several grinding cycles on successive workpieces, one for each cycle as schematically illustrated in Fig. 6, in which the line W represents the position of the finished work surface of each of the several successive workpieces 20 being ground, the line S represents the relative retracted position of the grinding surface of the grinding tool 10 throughout four grinding operations on four successive workpieces, and the lines TA¹, TA², TA³ and TA⁴ represent four successive relative retracted positions of the axis of rotation of the grinding tool 10, the distances between these four successive tool axis positions and the line S representing the diminishing radius of the grinding tool 10 resulting from truing the wheel 10 during each of the grinding operations or cycles, all of the dimensions in Fig. 6 being exaggerated for illustrative purposes.

At the beginning of the first grinding cycle, the workpiece 20 is located so that after it has been ground its finished work surface will lie on the line W and the grinding wheel 10 is located with its axis at TA¹, a distance of seventeen units from the line W, and its grinding surface at *a* on the line S, a distance of ten units from the line W.

The wheel 10 and the work 20 are fed relatively toward each other from *a* to *b*, a distance of eight units, during the latter part of which the wheel is rough grinding the workpiece. For simplification, it is assumed in the description of Fig. 6 that the workpieces are not backed off from the wheel 10 by operation of the back-off piston 82, but that the wheel is run straight out of the workpiece and across the truing tool after rough grinding. At the completion of rough grinding, the wheel surface is at the point *b*, two units from the line W, the wheel is run out of the work and passes across the truing tool, the point of which is at *c*, which is three units from the line W and fourteen units from the initial position TA¹ of the wheel axis, so that after truing, the wheel cutting surface is also at *c*, whereupon the wheel is again run into the work and is fed at a reduced rate relative to the work a distance of three units from *c* to *d* for finish grinding, after which the wheel is relatively retracted so that its surface moves back from the work a distance of ten units from *d* to *e*. Since the wheel has been trued and thereby reduced in radius by one unit, its axis now lies at TA² with its cutting surface still initially on the line S. In other words, the diamond has been advanced relative to the axis a distance of one unit and the wheel and the work have been fed toward each other a total distance of eleven units, i. e. from *a* to *b* and *c* to *d* and retracted a fixed distance of ten units from *d* to *e*. The advance of the diamond relative to the wheel axis is represented by the movement of the initial position of the wheel axis TA¹ to TA², so that the diamond is now thirteen units from the axis of the wheel.

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In the second cycle or grinding operation on the second workpiece, the wheel and the work are fed eight units toward each other from e to b^2 , the wheel is trued, reducing its radius by one unit, and its cutting surface is fed in a finishing operation from c^2 to d^2 , or a total feed of eleven units, and then it is retracted ten units from d^2 to e^2 . The diamond is again advanced one unit toward the wheel.

Now, assuming that in addition to the one-unit normal advance of the diamond, thermal changes have advanced the diamond an additional unit nearer the wheel so that the distance from the diamond at c^3 to the wheel axis at TA^3 is now eleven units.

In the third cycle for the third workpiece the wheel surface advances relative to the workpiece surface W for rough grinding eight units from e^2 to b^3 , but it is reduced two units in radius by truing so that at the commencement of the finishing operation the cutting surface lies at c^3 and it advances four units from c^3 to d^3 , or a total feed in the third cycle of twelve units instead of eleven units. It is retracted ten units from d^3 to e^3 .

During the fourth cycle for the fourth workpiece the wheel surface advances eight units for rough feeding from e^3 to b^4 whereupon the diamond having been advanced one unit relative to the wheel axis removes one unit from the radius of the wheel and the wheel then goes into the work from c^4 to d^4 for a finishing operation over a distance of the original three units, the total feed being eleven units from e^3 to b^4 to c^4 to d^4 , after which the cycle is repeated. The operation of the mechanisms including the cams 44 and 46 and the gauge 40 for producing the above described relative motions is hereinafter more particularly described.

It will be understood that in the particular machine described and illustrated these relative motions are produced by holding the wheel axis in a fixed position and moving the work and also the truing tool each with a motion independent of the other.

It is thus seen that in spite of the error introduced into the relative position of the diamond and the workpiece during the third cycle by the additional relative movement of one unit due to thermal changes, this error was removed in the subsequent cycle with the result that the desired total distance of feed between the wheel and the work, and also the distance of the feed of the wheel for finish grinding after the wheel has been dressed, was re-established and the error due to change of position of the truing tool was washed out. Also, the errors in the amount by which the wheel is reduced in one cycle are corrected in the next cycle. This is the essential difference between the machine of the invention and prior machines in which such changes in relative position of the truing tool and the finished work surface produced errors which accumulated to such an extent that they caused either a waste of time during the feeding cycle or else damage to the wheel or work, and had to be eliminated by repeated adjustment of the position of the truing tool with respect to the work.

Referring now to Figs. 5 and 8, the details of the machine may be further understood by a description of its operation throughout the cycle during which a workpiece is finished.

A workpiece 20 is loaded on the support 25 in the work head 24 and the wheel 10 is run into the bore 18 of the work by movement of the handle 56 connected to the valve 54, which admits fluid from the pressure line 53 to the right-hand side of the piston 52 in the cylinder 50. When the table 14 moves to the left, at rapid traverse speed, a cam 160 under the table allows a switch 162 to open, de-energizing the circuit in the coil 164 of a contactor switch 165. This breaks a circuit 167 to de-energize a rapid traverse solenoid 168, which closes a valve 169 and causes the fluid to flow through a throttle valve 17, thus slowing the table from

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a rapid to a grinding speed. The table 14 now reciprocates to move the wheel relatively back and forth across the face of the work under the action of the table dogs 300 and 301 in the system shown in Fig. 8, while the wheel is grinding the work. This also breaks a circuit 166 and thereby de-energizes the feed control valve solenoid 64, allowing the plunger 61 in the feed control valve 62 to move to the left and admitting fluid from a pressure line 63 through the valve 192, the line 350, the valve 174 and the lines 351 and 352 to the right side of the feed piston 60, moving the latter to the left, thereby feeding the work head 24 toward the wheel 10 to the left, as viewed in Fig. 3. The fluid on the left side of the piston 60 is exhausted through the line 353, the valve 62 and the exhaust line 354 from which it returns to the sump. The work head feeds in rapidly to approach the wheel until the cam 44 on the plate 74 closes its associated switch 168 to energize a circuit 170 and a solenoid 172 which shifts the plunger 171 of the valve 174 to the right, causing fluid to the piston 60 to be metered through a throttle valve 176, slowing the rate of feed to a grinding rate. The wheel is now rough grinding.

A selector switch 180 may be set in its condition as shown in Fig. 5 to use the portion 40a of the gauge means 40 (see Fig. 7) to stop the rough grinding part of the cycle or it may be set alternatively downward as shown by dotted line to utilize the cam 46 on the plate 74 to stop the roughing feed at a preset amount of in-feed.

When the selector switch 180 is in the condition shown, a switch 182 is closed by a rear end element 41 of the gauge 40 when the portion 40a of the gauge enters the work, and this through a circuit 214 energizes the coil 184 of the contactor switch 186, closing the switch 186, which energizes a circuit 188 and a solenoid 190 which thereupon closes a stop valve 192, shutting off fluid to the feed piston 60 and stopping feed. Closing of the switch 186 also energizes a circuit 194 to a timer 196, starting the timer. After a preset time, depending upon the setting of the timer, the latter closes a switch 198, energizing through a circuit 200 the coil 201 of a contactor switch 203 which closes the switch 203 and energizes a solenoid 92 through circuits 205 and 219.

The solenoid 92 reverses the plunger 93 of the back-off valve 90 (see Fig. 3). During the period of the operation of the timer 196 the wheel is allowed to spark out at the end of the rough grinding portion of the cycle. When the back-off valve 90 is reversed, fluid under pressure is introduced into the line 91 to the right-hand side of the back-off piston 82, thus moving the workhead 24 and the work 20 slightly to the right and away from the wheel 10 relative to the piston 82 and feed mechanism, as seen in Fig. 3, backing the work away from the wheel.

When the timer switch 198 is closed, a circuit 202 and a coil 204 of a contactor switch 206 are also energized, closing the switch 206 and energizing the truing run-out solenoid 58, operating the trip lever 302 far enough to trip the reverse dog 300, causing the table 14 and the wheel 10 to run out to the right and away from the work.

Closing of the timer switch 198 and the contactor switch 206 also energizes a circuit 208 and the truing mechanism solenoid 134 (see also Fig. 1), raising the truing tool release latch 126 and allowing the truing tool 34 to drop into operative position and at the same time advancing the truing tool with respect to the grinding wheel. When the latch 126 is raised, the cam follower 114 follows the cam 112, allowing the truing tool 34 to drop down into truing position.

When the truing reverse dog 303 strikes the reverse lever 304 the table runs in and the cam 112 raises the truing tool 34 to its inoperative position to clear the

wheel head where it is held by the latch 126. A cam plate 210 on the table moves the switch 212 to its downward position, momentarily energizing a coil 305 of a contactor switch 306, breaking the circuit 214 to the coil 184 of the contactor switch 186, breaking the circuit 188 and de-energizing the feed stop solenoid 190, allowing the feed valve 192 to open to resume feed. Opening of switch 186 breaks circuit 194 allowing the timer to reset. Timer switch 198 is opened, de-energizing the back-off solenoid 92, reversing the back-off control valve 90 and resetting the back-off piston 82 against the stop 88. The contactor switch 206 is also de-energized, breaking the circuit 208 to the truing control solenoid 134, de-energizing the latter and allowing the latch 126 to lock the truing tool 34 in retracted position. The truing run-out solenoid 58 is also de-energized to allow the wheel to reciprocate when it re-enters the work. A holding circuit 307 on switch 306 holds the switch energized and the circuit 214 open until after a gauge operated switch 219S resets it.

The feed valve 192 being open, feed resumes for a finishing operation as the wheel 10 enters the work 20.

When the bore 18 reaches finished size, the larger part 40b of the gauge 40 (see Fig. 7) enters the bore, the gauge element 41 moves a switch 219S to energize a circuit 316 and the coil 164 of the contactor switch 165, thereby energizing a circuit 218 and the run-out solenoid 317, which trips the dog 300 and also the dog 303 (see Fig. 8) causing the table 14 to run out to and remain at its extreme right-hand position. When the contactor switch 165 closes, the rapid traverse solenoid 168 is energized, opening the valve 169 allowing the fluid to by-pass the throttle valve 17 causing the table to move at rapid traverse speed. Closing of the contactor switch 165 also energizes the circuit 166 and the feed valve solenoid 64, reversing the feed valve 62 to retract the work head relative to the wheel by moving the feed piston 60 to the right. With the table 14 at final run-out position, the switch 162 is closed, forming a holding circuit for the contactor switch 165, maintaining the latter closed and the feed retracted.

As the feed plate 74 retracts counter-clockwise, and as new work is loaded, the cam 46 permits the switch 216 to open and the loading of new work moves the gauge element 41, dropping the switch 219S, breaking the holding circuit on contactor coil 305 and resetting it for the next cycle.

As the plate 74 turns counter-clockwise, it does not move the ratchet 72 (see Fig. 4) until the pin 104 on the pawl 190 drops off the cam 102, allowing the pawl 100 to turn the ratchet 72 and retract the feed a predetermined angle. The retraction of feed stops when the feed piston 60 reaches the right end of its stroke and is a uniform predetermined amount to the nearest ratchet tooth regardless of how far the ratchet 72 has turned while feeding. Retraction is less than the previous feed motion, resulting in an advance of the work head relative to the axis of the wheel at each cycle. This advance is known as compensation for wheel wear and truing and may be obtained by other known means. It will be seen that the advance corresponds to the amount by which the radius of the wheel has been reduced since the last cycle, which in turn depends upon the position of the truing tool and, to an extent which is usually negligible, on the wear of the wheel during the finishing operation.

With the feed mechanism retracted and the table 14 run out to the right, the machine is ready for loading of a new workpiece 20.

Automatic means may be incorporated with the machine for feeding and ejecting a succession of workpieces from the work support 25, and which operate in connection with other suitable means for automatic repetition of the grinding cycles.

In practice the machine should be so adjusted that the

truing tool reduces the wheel by a minimum amount. The truing tool may even fail occasionally to touch the wheel. Provision may be made, if desired, to omit the truing operation except after a number of cycles, in which case the compensating mechanism described will compensate for wheel wear, and for truing when it occurs.

It is seen that in the machine of the invention, the position of the grinding surface of the wheel is corrected and maintained at a known distance from the finished surface of the work. This in turn allows the slow feed after truing to be maintained at a predetermined optimum length which is long enough to prevent digging of the wheel into the work and consequent damage and inaccuracy, and short enough to prevent loss of time through too long a finish grinding operation.

I claim:

1. In a grinding machine including a grinding wheel, a support for the wheel, a work support and a truing tool, said machine having a grinding cycle, and in combination, means to pass the truing tool relatively across the face of the wheel, means operated in timed relation with the machine cycle to advance the truing tool relatively closer to the wheel axis each time the truing tool is passed across the wheel face, feed means to move the work support relatively toward the wheel for a grinding operation upon a workpiece in the work support, said means to advance the truing tool operating independently of the relative movement of the work support and the wheel produced by the feed means and means to stop the feed when the work reaches a predetermined size, said feed means including compensating means operating to retract the work support to successive positions which are equidistant from the cutting surface of the wheel.

2. In a grinding machine including a grinding wheel, a support for the wheel, a work support and a truing tool, said machine having a grinding cycle, and in combination, means to pass the truing tool relatively across the face of the wheel, means operated in timed relation with the machine cycle to advance the truing tool relatively closer to the wheel axis each time the truing tool is passed across the wheel face, feed means to move the work support relatively toward the wheel for a grinding operation upon a workpiece in the work support, said means to advance the truing tool operating independently of the relative movement of the work support and the wheel produced by the feed means said feed means operating to slow the feed when the work support has moved a predetermined distance toward the wheel, and means to stop the feed when the work reaches a predetermined size, said feed means including compensating means operating to retract the work support to successive positions which are equidistant from the cutting surface of the wheel.

3. In a grinding machine including a grinding wheel, a support for the wheel, a work support and a truing tool, said machine having a grinding cycle, and in combination, feed means to feed and retract the work support relatively toward and from the grinding wheel, a gauge to stop the feed when the work reaches a predetermined size, a truing tool, means operated in timed relation to the machine cycle to move the truing tool to and from a truing position, means operated independently of said feed means and in timed relation to the said movement of the truing tool to advance the truing tool relatively to a truing position closer than a previous truing position to the wheel axis, and means to pass the truing tool across the grinding wheel for a truing operation, said machine including compensating means operating successively and independently of the said means to advance the truing tool and in timed relation to the machine cycle to advance the retracted position of the work support relatively variably toward the grinding wheel axis in accordance with the reduction of the radius of the grinding wheel.

4. In a grinding machine including a grinding wheel, a support for the wheel, a work support, a truing tool and

a work gauge, said machine having a grinding cycle, and in combination, feed means operable to feed the work support relatively toward the wheel to a predetermined first position, means operated independently of said feed means and in response to the machine cycle to advance the truing tool relatively to a new truing position closer than a previous truing position to the wheel axis, means to pass the wheel across the truing tool when the work support is in said first position and the truing tool is in said new position, and means controlled by the gauge relatively to feed the work support from said first position to a final position and then to retract the work support variably to a position determined by its distance from the cutting surface of the wheel.

5. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece and a truing tool for the wheel, said machine having a grinding cycle, and in combination, feed means initially to feed the support relatively toward the wheel a predetermined distance from an initial position relative to the wheel axis and then to stop the feed, means operated independently of the feed means operated in timed relation to the machine cycle to advance the truing tool relatively to a truing position closer than a previous truing position to the axis of the wheel, means operating thereafter to pass the wheel across the truing tool and means operating thereafter to continue the feed of the support to a position determined by a predetermined distance between the trued wheel surface and the workpiece support and then to retract the support to a point in advance of its previous said initial position and at a predetermined distance from the cutting surface of the wheel.

6. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece and a truing tool for the wheel, said machine having a grinding cycle, and in combination, feed means to feed the support relatively toward the wheel from an initial position, means to change the rate of feed during said movement, means independent of the feed means operated in timed relation to the machine cycle to advance the truing tool relatively to a position closer than a previous truing position to the axis of the wheel, means to pass the wheel across the truing tool, and means responsive to the feed means relatively to retract the support from the wheel to a variable point in advance of its said initial position and in accordance with its distance from the cutting surface of the wheel.

7. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece and a truing tool for the wheel, said machine having a grinding cycle, and in combination, feed means initially to feed the support relatively toward the wheel by a predetermined amount from an initial position and then to stop the feed, back-off means in addition to the feed means to separate wheel and support, means independent of the feed means operated in timed relation to the machine cycle to advance the truing tool relatively to a truing position closer than a previous truing position to the axis of the wheel, means to pass the wheel across the truing tool while wheel and support are in backed-off condition, and means operating thereafter to continue the feed of the support and wheel while in backed-off condition to finish the work and then to retract the support to a variable point relatively in advance of said initial position and in accordance with its distance from the cutting surface of the wheel.

8. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of the workpiece and a truing tool for the wheel and in combination, feed means initially to feed the support relatively toward the wheel from an initial position and then to stop the feed, timed control means responsive to said feed means, means independent of the feed means operating in response to said timed control means to advance the truing tool relatively to a truing position

closer than a previous truing position to the axis of the wheel, means also responsive to said timed control means to pass the wheel across the truing tool, and means operating thereafter to continue the feed to a finished work size and then to retract the support to a variable point in advance of its said initial position and in accordance with its distance from the cutting surface of the wheel.

9. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece and a truing tool for the wheel, said machine having a grinding cycle, and in combination, feed means initially to feed the support relatively toward the wheel from an initial position and then to stop the feed, timed control means responsive to said feed means, back-off means in addition to the feed means operating in response to said timed control means to separate wheel and support, means independent of the feed means responsive to the machine cycle to advance the truing tool relatively to a truing position closer than a previous truing position to the axis of the wheel, means to pass the wheel across the truing tool while the support is in backed-off condition, and means operating thereafter to continue the feed of the support and wheel while in backed-off condition to finish the work and then to retract the support to a predetermined distance from the cutting surface of the wheel.

10. A grinding machine including a support for a workpiece, a grinding wheel applicable to a surface of the workpiece, a truing tool for the wheel movable to and from a truing position which is variable in relation to the support, a work gauge, feeding means controlled by the gauge for moving the support relatively toward the wheel for a grinding operation, and means also controlled by the gauge and independent of the extent of feeding movement to advance the truing tool a predetermined distance for a truing operation.

11. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece, a slidable table to support the grinding wheel, and a truing tool for the wheel and in combination, feed means to feed the support relatively toward the wheel from an initial position and then to stop it at a predetermined point, means responsive to the feed means but operating independently thereof to move the truing tool from an inoperative position to an operative position relative to the wheel and then automatically to move said truing tool from a previous operative position further toward the wheel axis, said table being operatively responsive to the feed means to run the wheel out of the work across the truing tool and back into the work, and means responsive to the movement of the table to continue the feed of the support to a finished work surface position and then to retract the support to a predetermined position relative to the cutting surface of the grinding wheel.

12. In a grinding machine including a support for a rotating workpiece, a grinding wheel applicable to a surface of the workpiece and a truing tool for the wheel and in combination, a rotatable screw supporting the truing tool, means for bodily moving the screw and tool from an inoperative position in which the tool clears the wheel to an operative position in which the tool may engage the wheel, and rotating means for turning the screw, said rotating means being actuated by said bodily movement of the screw into operative position thereby advancing the truing tool by a substantially predetermined increment and causing it to present a new aspect to the wheel.

13. In a grinding machine, including a support for a workpiece, a grinding wheel applicable to a surface of a said workpiece and a truing tool for the wheel and in combination, feed means to feed the support relatively toward the wheel from an initial position relative to said wheel, means independently of the feed means relatively to advance the truing tool from a previous operative position further toward the axis of the wheel, means to

pass the wheel across the truing tool, and retracting means responsive to the operation of the feed means to retract the support from the wheel to a position relatively in advance of its said initial position, said retracting means operating independently of said means to advance the truing tool and comprising a reversing ratchet associated with the feed means and a cam operating to render said ratchet inoperative during part of the retraction of the support.

14. In a grinding machine, a work support, a grinding wheel, a support for the grinding wheel, a truing tool mounted independently of said supports, one of said supports being movable relative to the other to produce a traverse motion between the wheel and the work support and to pass the wheel across the truing tool, feeding means for moving the work support toward the wheel for a grinding operation, and means operated independently of the feeding means and in time with said traverse motion to advance the truing tool from a previous operative position further toward the axis of the wheel to true the wheel when the wheel is passed across said truing tool.

15. In a grinding machine including a support for a workpiece, a grinding wheel applicable to a surface of the workpiece and a truing tool for the wheel and in combination, a rotatable screw supporting the truing tool, means for swinging the screw and truing tool into and out of an operative position in which the truing tool may engage the wheel, and adjustable ratchet means for rotating the screw and tool, said ratchet means being actuated by said movement of the screw and tool into and out of operative position thereby advancing the truing tool by a preadjusted increment and causing the tool to present a new aspect to the wheel.

16. A grinding machine comprising in combination a grinding wheel applicable to a surface of a workpiece, a work support arranged to support a said workpiece and relatively movable from variable relative initial positions toward the wheel for successive grinding operations, a truing tool for the wheel, tool advancing means independent of but timed with said movement of the work support incrementally to move the truing tool progressively closer toward the wheel axis for successive truing operations upon the wheel surface, and means operating in response to the reduction of the size of the grinding wheel and independently of the tool advancing means for progressively varying the successive relative initial positions of the work support and the wheel axis to compensate for the said reduction in size of the grinding wheel.

17. In a grinding machine including a work support, a grinding wheel, a support for the wheel, a truing tool, and power operating mechanism to effect a cyclic operation of the machine, and in combination, feed means to feed and retract the supports relatively toward and away from each other, means independent of the work support to effect advance of the truing tool relatively toward the wheel support from a previous operative position, and means operated independently of said advance of the truing tool and in response to the reduction of the size of the wheel to move one of said supports to a position relative to the other in which the reduced wheel surface is at a predetermined distance from the work support, each of said means being actuated in timed relation by said power operating mechanism.

18. In a grinding machine including a work support, a grinding wheel, a support for the wheel, a truing tool and power operating mechanism to effect a cyclic operation of the machine for grinding a succession of workpieces, and in combination, feed means to effect feeding and retraction of the supports relatively toward and away from each other, means independent of the feed means and responsive to the power operating mechanism to effect advance of the truing tool relatively toward the wheel support from a previous operative position, con-

trol means for the feed means to stop the feeding and to cause retraction of the supports when a workpiece has reached a predetermined size, and variably operable means responsive to the difference between the extent of feeding and retraction of the supports in a grinding cycle to effect a relative movement of the supports toward each other to compensate for reduction of the wheel prior to the subsequent grinding cycle.

19. In a grinding machine including a work support, a grinding wheel, a support for the wheel, a truing tool and power operating mechanism to effect a cyclic operation of the machine for grinding a succession of workpieces, and in combination, feed means to effect feeding and retraction of the supports relatively toward and away from each other, means independent of the feed means and responsive to the power operating mechanism to effect advance of the truing tool relatively toward the wheel support from a previous operative position, control means for the feed means to stop the feeding and to cause retraction of the supports when a workpiece has reached a predetermined size, and means responsive to the extent of feeding of the supports in a grinding cycle operating to control the extent of retraction of the supports at the end of said cycle to compensate for wheel wear prior to the subsequent grinding cycle.

20. In a grinding machine including a work support, a grinding wheel, a support for the wheel, and a truing tool, said truing tool being mounted separately from and independently movable relative to said supports, and in combination, power operating means to effect a cyclic operation of the machine for grinding a succession of workpieces, and means actuated by and in timed relation with said power operating means to effect feed of the supports relatively to each other and advance of the truing tool relative to the grinding wheel respectively to grind workpieces and to true the wheel, said feed and advance motions being effected independently of each other said means including a control mechanism which operates to vary the said feed in relation to the said truing tool advance in response to the progressive reduction in the size of the grinding wheel.

21. In a grinding machine for machining a succession of workpieces to a predetermined size including a work support, a grinding wheel, a support for the wheel and a truing tool movable relatively across the face of the wheel, said truing tool being mounted to move independently relative to both of said supports, and in combination, feed means operable to effect feeding and retraction motions of the work support relative to the wheel, means independent of the feed means operated in time with the feed means to advance the truing tool relatively toward the wheel support from a previous operative position, and control means for the feed means to interrupt the feeding motion and to move the truing tool relatively across the face of the wheel to true the wheel, said feed means including mechanism selectively to advance or retard said feed control means into a predetermined relation with the cutting surface of the wheel in response to the position of the wheel support relative to the work support when a said workpiece reaches a predetermined size.

22. In the combination set forth in claim 21, said control means being operative to slow the feed motion after the truing tool has trued the wheel.

23. In a grinding machine including a work support, a grinding wheel and a truing tool, said machine having an operative cycle, and in combination, means operable to feed and retract the work support relative to the wheel, said means including mechanism which operates to retract the work support relatively from the grinding surface of the wheel in successively equal predetermined increments from cycle to cycle, means to pass the truing tool across the face of the wheel, and means mounted independently of the feed means and which operates incrementally in response to the operation of said last

named means to move the truing tool relatively toward the wheel.

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