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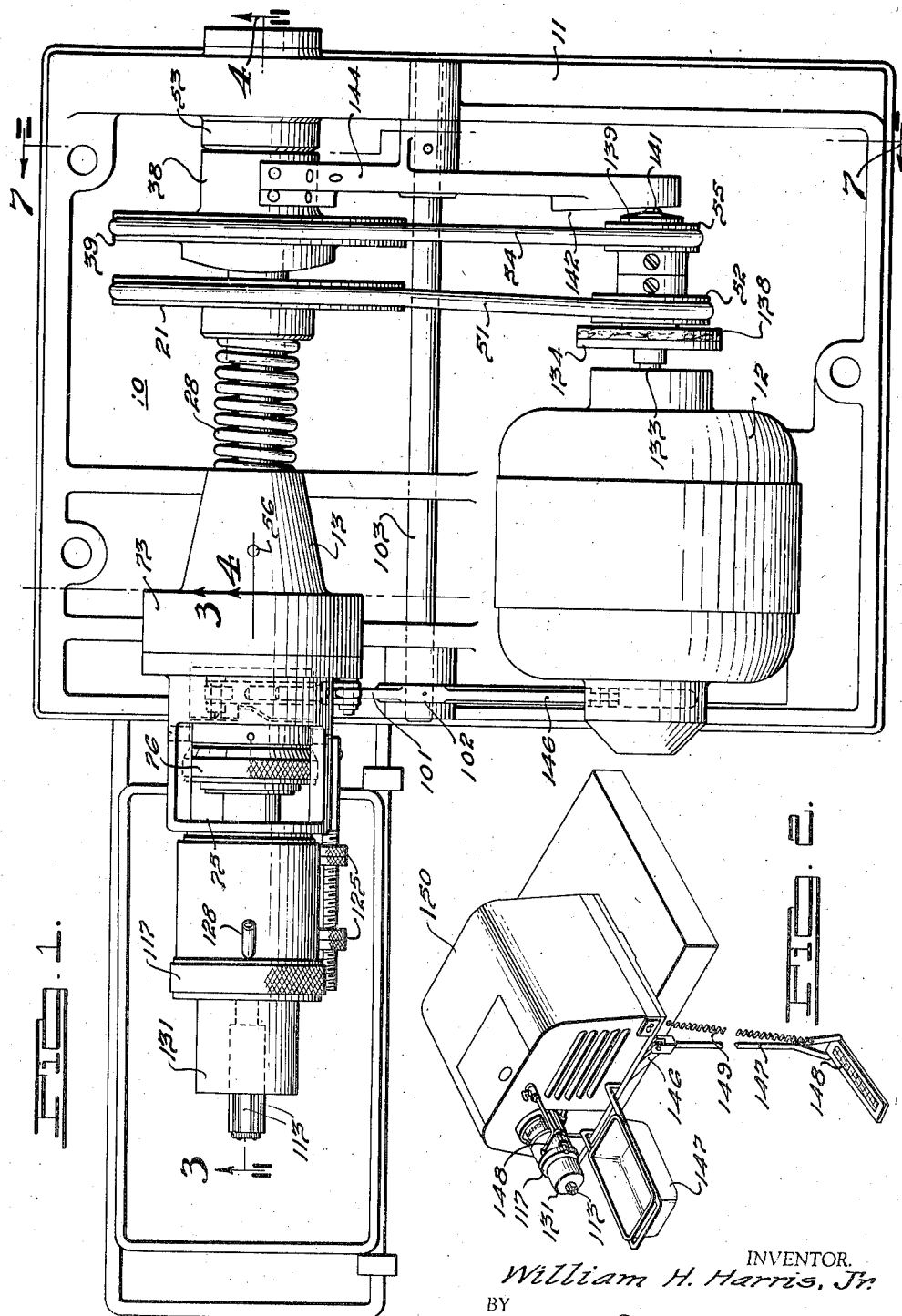
W. H. HARRIS, JR

2,252,176

MACHINE FOR GRINDING CYLINDRICAL SURFACES

Original Filed Dec. 19, 1936

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

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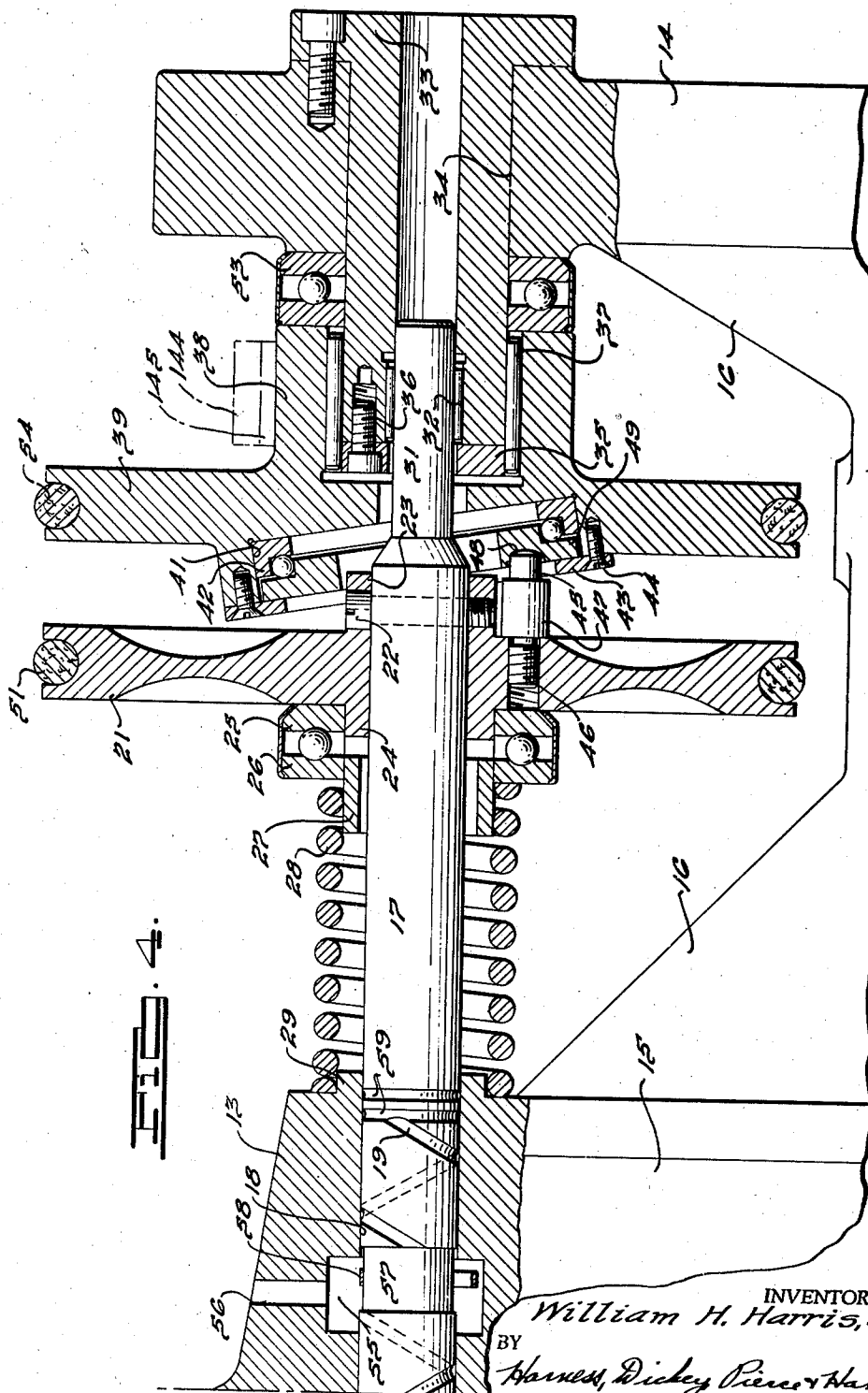
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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

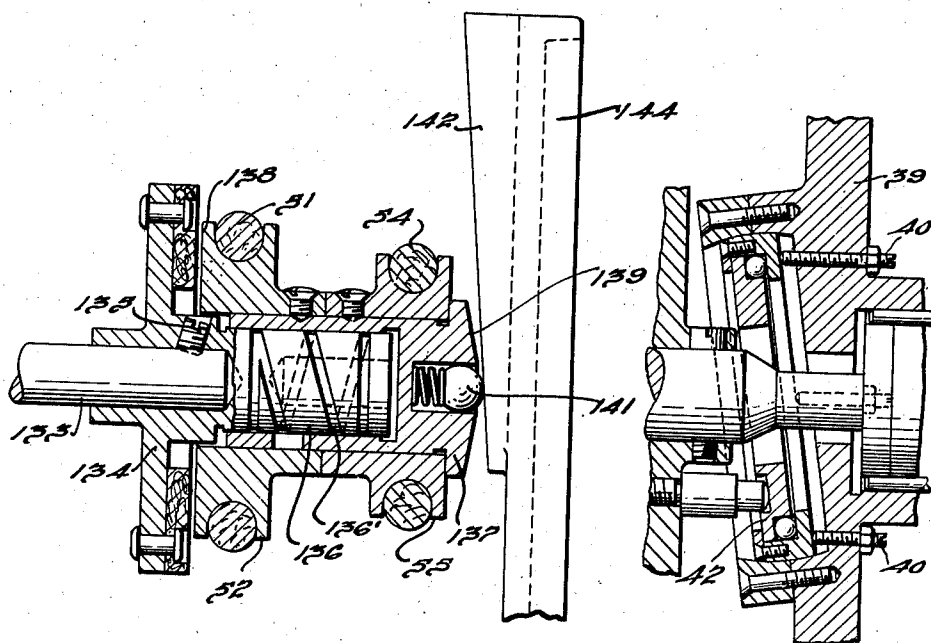
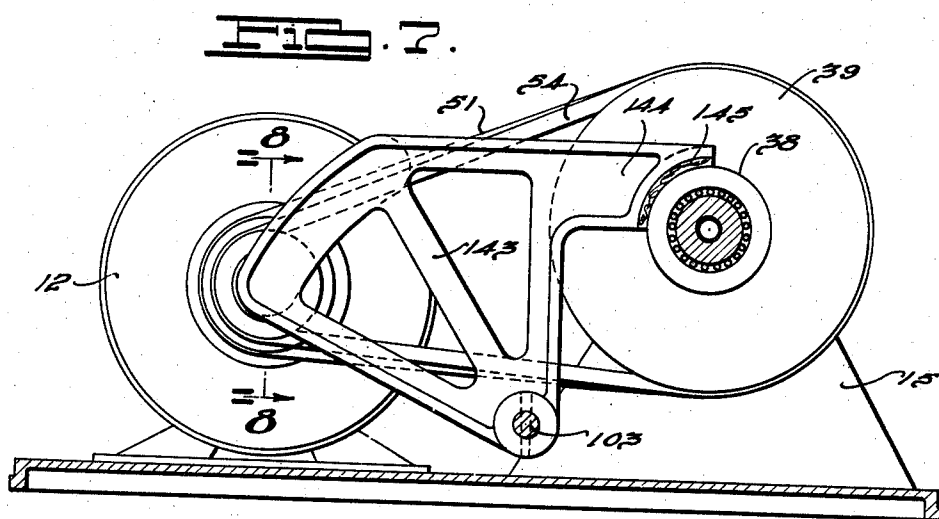


FIG. 8.

FIG. 9.

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UNITED STATES PATENT OFFICE

2,252,176

MACHINE FOR GRINDING CYLINDRICAL SURFACES

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a corporation of Michigan

Application December 19, 1936, Serial No. 116,774
Renewed November 15, 1939

12 Claims. (Cl. 51—34)

My invention relates to grinding and honing devices and methods and particularly to a machine and method for accurately and rapidly finishing the inside surface of a cylinder.

It was the practice heretofore to finish cylinders by a honing method wherein the honing tool was reciprocated during the time it was rotated. The relative speed of reciprocation and rotation varied, depending upon the length of stroke and the peripheral dimension of the tool. The length of stroke varied to conform with the length of the work piece and could be considered as the feed movement between the work and tool. Such a tool is illustrated and described in the F. J. Jeschke Patent No. 1,944,660 which was assigned to the assignee of the present invention.

A method has been evolved for materially improving and standardizing the finishes on the internal surfaces of cylinders by selecting proper ratios between the degree and speed of reciprocation relative to the peripheral speed of rotation of the grinding tool, which ratio may vary, depending upon the type of material which is being operated upon. In addition to these motions in reciprocation and rotation, a relative feed motion is provided between the work and the tool. This method and apparatus for practicing the method is disclosed in the K. W. Connor application for Letters Patent, Serial No. 76,519, filed April 27, 1936, which has become Pat. No. 2,108,029 and assigned to the assignee of the present invention.

In practicing the present invention, I employ principles set forth in the above applications in a honing machine which accurately and rapidly finish the internal surfaces of cylindrical elements to exact size with a very high degree of polish. The machine is provided with an abrading head which is rapidly reciprocated during the time it is rotated. The means for effecting the reciprocation and rotation are adjustable to provide the proper ratio between the peripheral speed and the speed and degree of reciprocation. Means are provided for feeding the work over the abrading head during the time the head is reciprocating and rotating in timed relation.

To permit the insertion and removal of the work piece over and from the abrading head, the machine is provided with a lever for operating a clutch and brake for stopping the rotation of the head and for simultaneously operating means for effecting its collapse. This permits the work to be removed without engaging the abrading elements and a new work piece to be inserted over the honing head.

Unique means are provided for producing the reciprocation of the abrading head which may be varied from substantially zero to extremely high speeds. This is effected by the use of a pair of pulleys which may be driven at different speeds to produce reciprocation through a wobble plate connection therebetween. By varying the speeds of the pulleys, the speed of reciprocation may be varied.

Accordingly, the main objects of my invention are to provide a machine which accurately and rapidly machines a very high polish to the internal surface of a cylinder; to internally finish a cylindrical member by a machine having a reciprocable abrading head which is rotated in timed relation to the speed of reciprocation; to provide a pair of pulleys which are driven at different speeds with a wobble plate connection for producing the reciprocation of the abrading head which may be varied by changing the relative speeds of the pulleys; to provide a means for collapsing the abrading head preferably at the time when the machine is stopped to permit the work piece to be removed and a new work piece to be inserted over the head which is expanded when the machine is again operated; to provide clutches for controlling the operation of the head in rotation and reciprocation and a brake for stopping the rotation of the head immediately upon its disconnection from the driving means; to provide an element in combination with the abrading head which is reciprocable between stops to regulate the degree of relative feed movement between the work piece and the abrading head; and, in general, to provide a machine and method for accurately and rapidly finishing the internal surfaces of a cylindrical element which is rugged in construction, positive in operation, and economical of manufacture.

Other objects and features of novelty of my invention will be either specifically pointed out or will become apparent when referring, for a better understanding of my invention, to the following description taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a plan view of a machine embodying features of my invention, with the cover removed therefrom;

Fig. 2 is a reduced view, in perspective, of the machine illustrated in Fig. 1, with the cover attached thereto;

Fig. 3 is an enlarged sectional view of one-half of the tool illustrated in Fig. 1, taken on the line 3—3 thereof, from the front end to the section

55 line x—x thereof;

Fig. 4 is an enlarged sectional view of the rear half of the tool illustrated in Fig. 1, taken on the line 4-4 thereof from the section line x-x to the rear end of the tool;

Fig. 5 is an enlarged sectional view of the structure illustrated in Fig. 3, taken on the line 5-5 thereof;

Fig. 6 is an enlarged sectional view of the structure illustrated in Fig. 3, taken on the line 6-6 thereof;

Fig. 7 is a sectional view of the structure illustrated in Fig. 1, taken on the line 7-7 thereof;

Fig. 8 is an enlarged broken sectional view of the structure illustrated in Fig. 7, taken on the line 8-8 thereof, and

Fig. 9 is a broken view, in section, similar to that illustrated in Fig. 4, showing a modified form thereof.

In the drawings, a machine 10 is illustrated as being of the table or bench type to be employed for machining work pieces having small internal diameters. It is to be understood that this type of machine is shown for the purpose of illustration and that similar structure and methods of operation may be utilized in larger and heavier machines built on bases which rest directly upon the floor. A base 11 supports a motor 12 and a honing or grinding device 13. The motor 12 is herein illustrated as resting directly upon the base and is bolted or otherwise secured thereto. The tool 13 is herein illustrated as being built on projections extending from and forming part of the base. It is to be understood that the tool itself may be a separate unit to be supported on the base in predetermined relation with the motor.

In the structure illustrated, the base 11 has a pair of bosses 14 and 15 projecting upwardly therefrom in aligned relation. Suitable strengthening webs 16 may be utilized for further strengthening the bosses and the bed. A shaft 17 is disposed through an aperture 18 in the bearing boss 15, the shaft being provided with suitable oil grooves 19 through which the engaging surfaces are lubricated.

The shaft has a pulley 21 secured thereto by a pin 22, or other means well known in the art to be suitable, extending through a frontwardly projecting boss 23 on the pulley. A rearwardly extending boss 24 on the pulley supports a thrust bearing 25, the front race 26 of which carries a sleeve 27 over which a spring 28 is positioned to bear against the race 26 with the opposite end of the spring projecting over a shoulder extension 29 of the bearing boss 15. A thrust is thereby provided to the shaft 19 to the right, as viewed in the figure.

The right hand end of the shaft 19 has a reduced portion 31 which engages needle bearings 32 encased in the end of a sleeve 33 which is provided with an aperture 34 in the bearing boss 14. The needle bearings 32 are retained against axial movement within the recess in the end of the sleeve 33 by an end washer 35 secured thereto by one or a plurality of screws 36. The outer surface of the sleeve 33, diametrically disposed to the inner surface containing the needle bearings 32, forms a race-way for a series of needle bearings 37. The needle bearings 37 are encompassed by the inner surface of a projecting boss 38 on a second pulley 39. The pulley 39 is herein illustrated as being of the same diameter as the pulley 21 but it is to be understood that the diameters may vary relative to each other depending upon the desired speed of reciprocation of the shaft. The

face of the pulley 39, opposite to that from which the boss 38 projects, is provided with a sloping annular recess 41 in which a thrust bearing 42 is secured by a washer 43. The washer 43 is clamped to the face of the wheel 39 by suitable screws 44. The pulley 21 is provided with a finger 45 secured thereto by a threaded extension 46. The projecting end 47 of the finger engages an aperture 48 in the top raceway 49 of the thrust bearing 42.

In the structure thus far described, the shaft 17 is supported for rotation in the aperture 18 of the bearing boss 15 with its rear end supported by the needle bearings 41 within the sleeve 43. The rotation of the shaft is produced through the operation of the motor 12 driving a belt 51 through a pulley 52 mounted on the motor shaft. The pulley 39 which is rotatably supported on the needle bearings 37, is supported against axial movement by a thrust bearing 53 which is disposed between the bearing boss 14 and the boss 38 of the pulley. The pulley 39 is driven in rotation by a belt 54 from a pulley 55 which is herein illustrated as being of less diameter than the pulley 52 which drives the pulley 21. As a result, the pulleys 21 and 39 are rotated at different speeds causing a relative movement to occur between the finger 45 and the pulley 39. As a result of the relative travel between the finger and pulley, the pulleys will be moved apart against the tension of the spring 28 as the finger 45 moves from one position of the tilted race 49 to another position thereof. It will thus be seen that the relative driving speeds of the pulleys 21 and 39 is very important in producing the proper speed of reciprocation to the shaft 28. If the pulley 21 is rotated ten times while the pulley 39 is retained stationary, the shaft would be reciprocated ten times. If, however, the pulley 21 is rotated ten times, while the pulley 39 is rotated once, the shaft 38 will be reciprocated nine times. If the pulley 21 is rotated ten times while the pulley 39 is rotated five times, the shaft will reciprocate five times.

By mounting the bearing 42 in the pulley 39 in such a manner that it may be tilted at various angles relative to the face thereof as illustrated in Fig. 9, the degree of reciprocation may likewise be varied at will. The adjustment is effected through the manipulation of the screws 40.

The bearing boss 15 has a reservoir 55 disposed in aligned relation with the aperture 18 communicating with a filling passage 56. A recess 57 is provided on the shaft over which a ring 58 extends to provide lubrication to the oil grooves in a well known manner. Annular grooves 59 are provided at each end of the shaft within the confines of the aperture 18 to seal the surface of the shaft against the egress of lubricant.

The left-hand end of the shaft 17, as viewed in Fig. 3, has a collar 61 threaded thereon and retained in position by a locking nut 62. The collar abuts against a hollow spindle 63 having an enlarged end 64, the outer surface of which is threaded. A tool spindle 65 is slidably disposed within the spindle 63 and extends forwardly a considerable distance from its front end. A pin 67 is carried by the tool spindle 65 projecting through a slot 66 in the wall of the spindle 63. The pin 67 engages and supports a sleeve 68 which is slidably disposed in engagement with the outer surface of the spindle 63. A spring 69 is disposed between the enlarged end 64 of the spindle 63 and a shoulder on the end of sleeve 68. Encompassing the spindle 63 at its front end is

a housing 71 of annular shape having projecting extensions 72 in cylindrical alignment with the front end, which projections are joined to an annular flange which mates with a flanged extension 73 of the bearing boss 15 and secured thereto by a plurality of screws 74. The openings 75 between the projecting extensions 72 permit access to an adjusting sleeve 76 on the tool.

The collar 61 on the end of the shaft 17 forms a portion of a roller thrust bearing with an element 78 which is provided with a collar 77 having a plurality of cam surfaces 79 thereon. The rear end of the spindle 63 carries a slidable sleeve 81 having a shoulder 82 at its forward end and a thread on the outer surface of its opposite end. A threaded sleeve 83 encompasses the sleeve 81 and forms therewith a double ball race which is assembled by means of a nut 84 retained by a locking nut 85 disposed on the threads of the sleeve 82. The outer surface of the sleeve 83 is provided with threads over which the adjusting nut 76 is threaded. A plurality of recesses 85 are disposed in the end face of a collar 87 having complementary cam faces in engagement with the cam faces 79 on the collar 78. A spring pressed ball 88 carried by the nut 76, engages one of the plurality of the recesses to lock the nut relative to the collar 87 while permitting its adjustment relative thereto. A split spring locking element 86 prevents the movement of the adjusting nut 76 beyond a predetermined point. The sleeve 81 has a pin 89 projecting therethrough and through slots 91 in the sleeve 83. The pin engages a nut 92 screwed on the end of a plunger 93 having a head 94 on its forward end. A suitable locking nut 95 secures the nut 92 in fixed adjusted position on the plunger 93. A sleeve 96 has sliding engagement with the plunger 93 and has a flanged end 97 in engagement with the end of the tool spindle 65. A spring 98 encompasses the plunger 93 and sleeve 96 and extends between the flange 97 and the locking nut 95. Through the adjustment of the hand nut 76, the position of the tool spindle 65 relative to the spindle 63 is determined. Such adjustment moves the sleeve 81 and the pin 89. The change in the position of the pin 89 adjusts the plunger 93 and positions the spindle 65 through the sleeve 96.

The collar 77 is provided with a lug 98 to which an adjustable link 99 is pivoted. The link is connected to arm 101 on a bell crank 102 which is pinned to a shaft 103, as illustrated more clearly in Fig. 1. When the bell crank is rotated clockwise to move the link 99 toward the bottom of the drawing as viewed in Fig. 1, the collar 78 rotates in counter-clockwise direction causing the cam surfaces 79 thereof operating on the cam surfaces on the collar 87 to force the collar 87 toward the front of the tool. This will move the sleeve 81 and pin 89 frontwardly to move the plunger 93 along therewith. This movement of the plunger releases the support of the head 94 from the sleeve 97 which will then load the tool spindle 64 because of the presence of the tension in the spring 98. The bias thus provided to the spindle 65 will cause the spindle to move forwardly, which movement is opposed by the weaker spring 69 operating on the sleeve 68 to which the pin 67, carried by the spindle 65, is secured. Suitable means, such as a split annular spring, a garter spring or the like 104, may be employed to retain the pin 67 in position relative to the sleeve 68.

The front end of the spindle 65 is herein illustrated as being provided with a plurality of T

slots 105, the sides of which slope toward the bottom to merge therewith and form rectangular slots as illustrated in Fig. 5. Slides 106 are disposed in the slots having similar sloping faces 107 which engage the sloping faces on the slots 105. The sloping surfaces are utilized for the purpose of adjusting the abrading head in expansion and retraction. The front portions of the slide 106 form stone carriers 108, while the rear end has projections 109 which are secured to the end of the spindle 63 by an end cap 111 secured to the enlarged end 64 thereof. A split annular or garter spring 112 may be employed to retain the end projections in position.

In operation, the carriers 108 are retained against longitudinal movement while the tool spindle 65 is moved axially which, in view of the sloping surfaces, moves the carrier outwardly to expand the tool when the spindle 65 is moved to the left as viewed in the figure. When the spindle is moved to the opposite direction, the action of the sloping surfaces permits the carriers to move radially inwardly to thereby reduce the diameter of the honing head.

Suitable abrading elements 113 are secured to the carriers 108, the ends of which are drawn radially inward by a garter spring 114 projecting over hooked lugs 115 provided on the ends of the carriers.

Slidably disposed over the housing 71 is a sleeve 116 having an end cap 117 threaded on its front end. A sleeve 118 is also secured to and carried by the cap 117 disposed internally of the housing 71. A shoulder 119 is provided on the sleeve 118 against which a spring 121 abuts, the other end of the spring contacting a flange 122 on the housing 71. The spring tends to move the two sleeves 116 and 118 forwardly along with the cap 117. For regulating the degree of movement and to position such movement relative to the tool head, I have provided a gauge comprising a thread stem 123 bolted or otherwise secured to the projection portion 72 of the housing 71 by screws 124. Two sets of thumb nuts 125 are disposed on the stem 123, each pair being spaced from each other an amount equal to the desired limit of reciprocation of the cap 117. The nuts may be adjusted, when regulating the degree of reciprocation, to position the point where the reciprocation of the cap 117 occurs relative to the abrading tool. A stud 126 projects from the sleeve 116 directly adjacent to the stem 123 between the nuts 125. The stud 126 acting between the nuts 125 limits the degree of reciprocation to the cap 117. A slot 127 is provided in the sleeve 116 and also in the end of the housing 71. A tube 128 is carried by the sleeve 116 projecting into the slot 127.

A coolant is delivered through the tube 128 directly adjacent to the cap 116 and a central aperture 130 provided therein through which the spindle 65 extends. The purpose of the cap 117 is to provide a means for assisting the operator in holding and feeding the work piece over the abrading head. The adjustable stop prevents the movement of the work piece out of contact with the abrading elements 113 during the machining operation. Such movement provides even wear on the abrading elements 113 by distributing the honing operation over the entire length of the elements.

The work piece 131, illustrated in Fig. 3, is an annular collar, the inner surface of which is to be polished and machined to very accurate size. In the position shown, the collar is moved to the

right over the abrading elements 113 limited by the engagement of the stud 126 with the right hand pair of nuts 125. The operator releases the pressure on the work piece to permit the spring 121 to force the work piece in the opposite direction limited by the engagement of the stud 126 against the left hand pair of nuts 125. In this manner, the feeding of the work piece over the elements 113 is very accurately adjusted.

Referring to Figs. 1, 7 and 8, I have illustrated the clutch and brake mechanism which controls the starting and stopping of the tool. The motor 12 is provided with a shaft 133 upon the end of which a clutch plate 134 is secured, preferably by a set screw 135. The front end of the plate is provided with a hub 136 having oil grooves 136' therein and over which a cylinder 137 is disposed. The pulleys 51 and 52 are secured to the cylinder 137 with the end face 138 of the pulley 52 slightly spaced from the clutch plate 134. The cylinder 137 is provided with a head 139 carrying a spring pressed ball 141 in its end. The ball is disposed to contact a sloping surface 142 provided on a cam lever 143 which is pinned to the shaft 103.

The cam plate 143 has a projection 144 which is disposed adjacent to the hub 38 of the pulley 39. The projection 144 is provided with a brake material 145 to form a brake shoe of a contour to engage the outer surface of the hub 38. An arm 146 of the bell crank 102 is connected to a link 147 which is secured to a foot treadle 148 for controlling the operation of the shaft 103.

When the treadle is moved down toward the floor, the bell crank is moved in clockwise direction rotating the collar 78 in counter-clockwise direction to produce the extension of the collar 87 and, therefore, the tool spindle 65 which effects the expansion of the elements 113. The movement of the bell crank in this manner causes the shaft 103 to also move in a clockwise direction moving the brake shoe 145 out of contact with the hub 38 and the cam surface 142 into engagement with the ball 141 on the head 139. The engagement of the surface 142 with the ball 141 moves the cylinder 137 and pulleys 51 and 52 to the left, as viewed in Fig. 8, causing the surface 138 to frictionally engage the clutch plate 134. This produces a driving connection between the shaft 133 of the motor and the pulleys.

Upon releasing the foot treadle 148, the link 147 will be raised by the spring 149 moving the bell crank in a counter-clockwise direction and the collar 78 in clockwise direction. This moves the collar 87 and spindle 65 to the right, thereby collapsing the abrading head by permitting the elements 113 to move radially inwardly. The counter-clockwise movement of the bell crank 102, the shaft 103 and cam plate 143, moves the cam surface 142 out of engagement with the ball 141 and permits the cam surface 138 to disengage the cam plate 134. Further movement of the cam plate 143 causes the brake shoe 145 to engage the hub 38. The abrading head will cease rotation instantly and, since the abrading head has been collapsed, the work may be removed without contacting the abrading elements 113. A new work piece may then be inserted over the abrading elements and the abrading head operated in rotation and reciprocation through the movement of the foot treadle 148.

As the abrading elements 113 wear, because of repeated abrading operations, they may be adjusted radially through the operation of the adjusting nut 76 which moves the pin 89 relative to the camming surface 79 to thereby regulate the

position of the flange 97 relative to the spindle 65. When the collar 77 is rotated, the cam surfaces 79 move the collar 87 to the left, as viewed in Fig. 3, which movement causes a similar movement of the pin 89 and the plunger 93 and places a direct bias of the spring 98 against the spindle 65 and the retrieving spring 69. The adjustment may be such that the abrading elements will engage the inner surface of the work piece 131 while the flange 97 is slightly spaced from the head 94 of the plunger 93 to permit a feed movement of the elements 113 outwardly until the flange 97 engages the head 94. A proper diameter should then be provided to the work piece. The diameter may be changed in this manner and may be corrected as the elements 113 wear.

A coolant is delivered through the tube 128 directly adjacent to the point of contact between the abrading elements 113 and the work piece 131.

A receptacle 147 is provided below the abrading head of the tool to receive the coolant. The coolant may be delivered to a suitable reservoir from which it may be pumped through a conduit 148 to the tube 128. The conduit is flexible to permit the movement of the tube with the cap 117.

In Fig. 2, I have illustrated a cover 149 which encloses the motor and the rear portion of the tool. It is to be understood that the machine thus described is utilized for machining small work pieces. Such work pieces may be grasped in the fingers of an operator and moved over the abrading head while engaging the cap 117 and slowly feed back and forth during the time the abrading head is rapidly reciprocating and rotating.

On similar machines or machines for operating on large work pieces, a mechanical feeding device may be employed which may be automatic. A receptacle may be employed for receiving the work piece and moving it along the abrading head between predetermined limits. After a predetermined number of cycles of movement, the machine may be automatically stopped, at which time the work piece can be removed. It is also within the purview of my invention to employ automatically operating means for contracting the abrading elements after the machine operation which functions upon the insertion of a new work piece in the feeding device to expand the abrading elements and start the machining operation.

While I have illustrated and described but a single embodiment of my invention, it will be apparent to those skilled in the art that various changes, additions, omissions and substitutions may be made therein without departing from the spirit and scope of my invention as set forth in the accompanying claims.

I claim as my invention:

1. A grinding machine including, in combination, a base, a spindle rotatable thereon, means for rotating and reciprocating said spindle in timed relation, an abrading head carried by said spindle, abrading elements in said head, means for adjusting said abrading elements to a desired diameter, means for expanding and retracting said abrading elements in said head, and means for retracting said abrading elements and for simultaneously stopping the rotation of said spindle.

2. A grinding machine including, in combination, a base, a spindle rotatable thereon, means for rotating and reciprocating said spindle in timed relation, an abrading head carried by said spindle, abrading elements in said head, means for adjusting said abrading elements to a desired

diameter, means for expanding and retracting said abrading elements in said head, and means for retracting said abrading elements and for simultaneously stopping the rotation of said spindle, said means being effective to expand said abrading element and simultaneously produce the driving of said spindle in rotation and reciprocation.

3. A machine for grinding a work piece including, in combination, a spindle, means for rotating and reciprocating said spindle, an abrading head carried by said spindle, means for controlling the feed of the work piece relative to said abrading head during the time it is reciprocating and rotating, and means for delivering a coolant to said abrading head carried by said feed control means which encompasses the end of said delivery means.

4. A machine for grinding a work piece including, in combination, a spindle, means for rotating and reciprocating said spindle, an abrading head carried thereby, means for expanding and contracting said abrasive head, means providing a limited feed movement to said abrading head to permit its expansion during the time it is reciprocating and rotating and means encompassing said spindle for controlling the feed of a work piece over said abrading head during the time it is reciprocated and rotated.

5. A grinding machine including, in combination, a rotatable spindle, a plurality of tapered slots in said spindle, carriers in said slots having tapered surfaces mated with those of said slots, means for retaining said carriers against longitudinal movement, and means for moving said spindle longitudinally to effect the contraction and expansion of said carriers.

6. A machine tool including, in combination, a rotatable spindle provided with a plurality of slots having sloping surfaces, a plurality of stoneholders having sloping surfaces mateable with those in said slots, means for retaining said holders against longitudinal movement, means for biasing said holders into said slots, and means for moving said spindle longitudinally to effect the contraction and expansion of said holders.

7. A machine tool including, in combination, a rotatable spindle, a driving pulley secured to said spindle, an additional pulley mounted adjacent to said first pulley and rotatable independently thereof, a swash plate carried by one of said pulleys, projecting means carried by said other pulley contacting said swash plate, a spring urging said contacting means toward said swash plate and means for driving said pulleys at relative speeds for effecting the rotation and reciprocation of said spindle.

8. A machine tool including, in combination, a rotatable spindle, a driving pulley secured to said

spindle, an additional pulley mounted adjacent to said first pulley and rotatable independent thereof, a swash plate carried by one of said pulleys, projecting means carried by said other pulley contacting said swash plate, a spring urging said contacting means toward said swash plate and means for driving said pulleys at relative speeds for effecting the rotation and reciprocation of said spindle, a grinding head carried by said spindle, and means for controlling the feeding of a work piece relative to said grinding head for limiting its degree of movement.

9. A grinding machine including, in combination, an abrading head, a spindle for rotating and reciprocating said head, means for expanding and contracting said abrading head, and a control lever for stopping the rotation of the spindle and for collapsing said head when moved in one direction and for expanding said head and starting the rotation of the spindle when moved in an opposite direction.

10. A grinding machine including, in combination, a base, a rotatable spindle, means for rotating and reciprocating said spindle, an abrading head carried by said spindle, means for expanding and contracting said abrading head, a clutch in said driving means, a brake for said spindle, and control means for contracting said head, for disconnecting said clutch and applying said brake to said spindle.

11. A grinding machine, including, in combination, a base, a spindle rotatable thereon and mounted for axial movement, an abrading element on said spindle, a pulley having a swash plate disposed on one face and having its axis aligned with that of said spindle, a pulley on said spindle, a projection on said shaft pulley engaging said swash plate, and a spring for urging said spindle towards said swash plate.

12. A machine tool including, in combination, a rotatable element mounted for axial movement, a pulley in driving relation to said element, an additional pulley mounted adjacent to said first pulley and rotatable independently thereof, a swash plate, connection between said swash plate and one of said pulleys, means providing connection between said swash plate and said rotatable element such that the element is moved in reciprocation following the slope of the swash plate, means for driving said pulleys at relative speeds for effecting rotation and reciprocation of said rotatable element, an abrading element actuated by said rotatable element in rotation and reciprocation, and means for adjusting the slope of said swash plate to vary the length of the movement of said element in reciprocation.

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