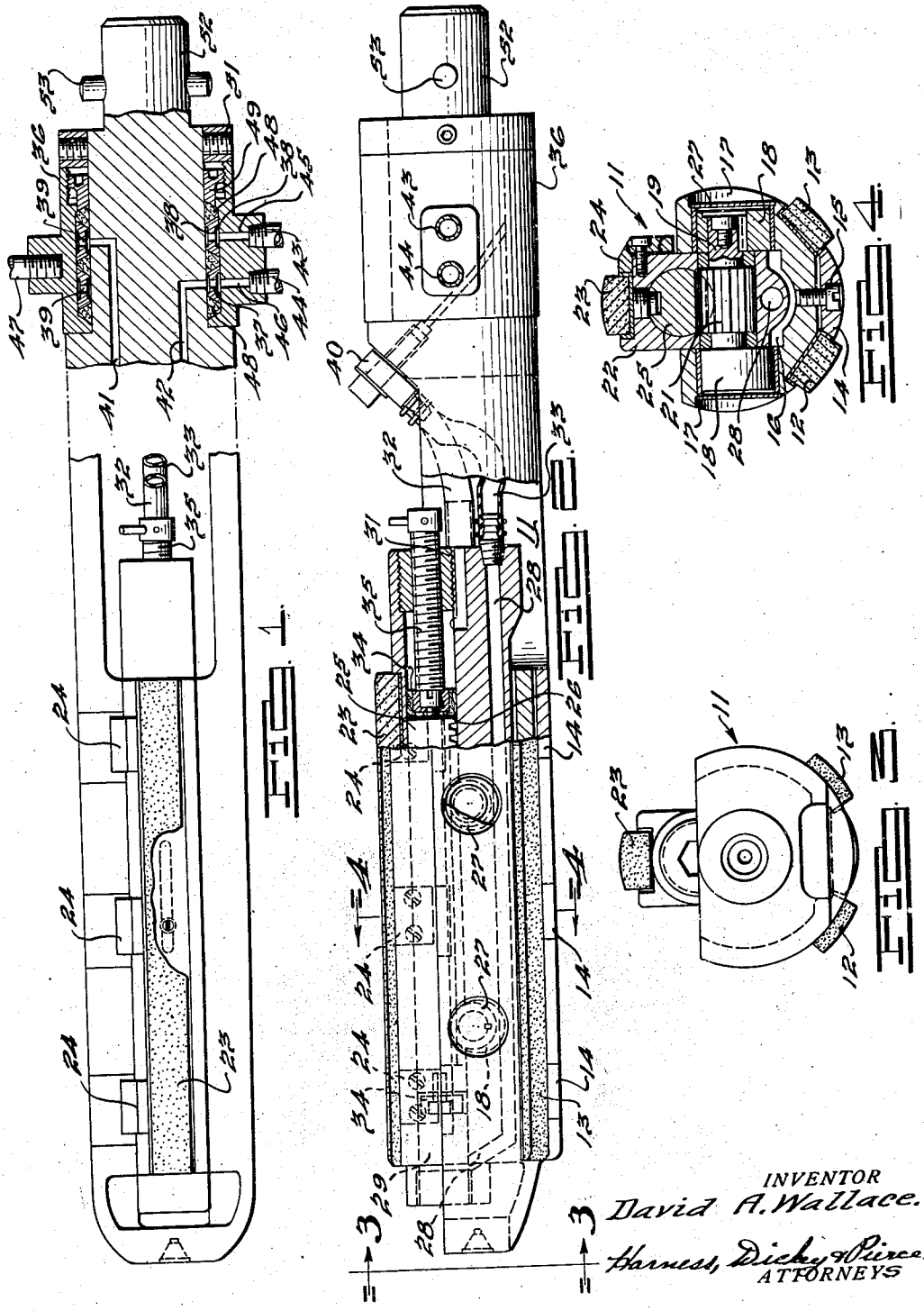
March 26, 1940. D. A. WALLACE 2,195,055

HONING TOOL

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HONING TOOL

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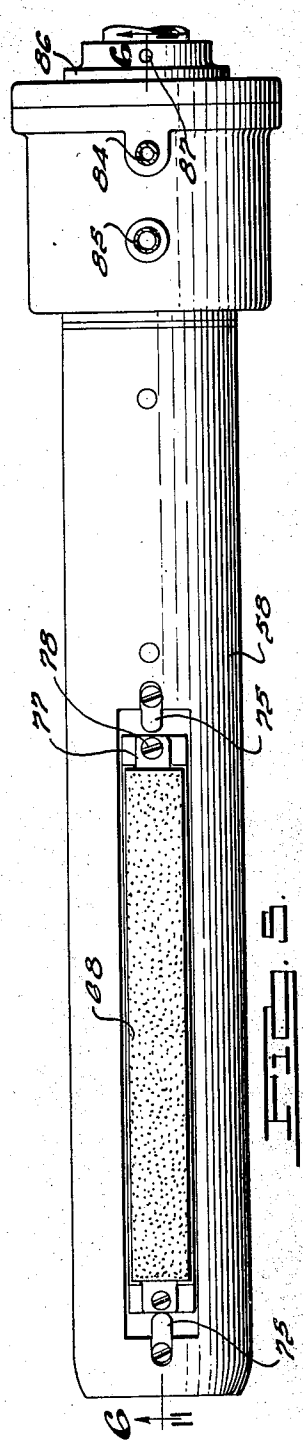


FIG. 5.

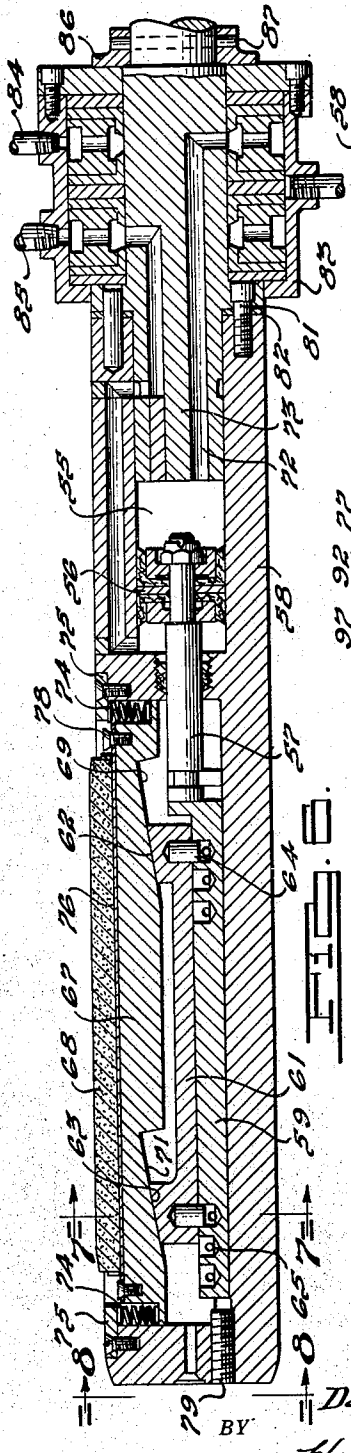


FIG. 6.

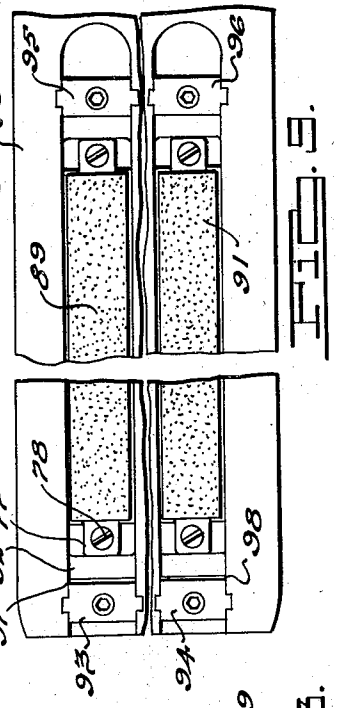


FIG. 9.

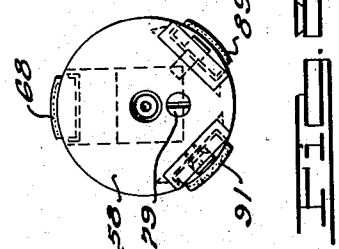


FIG. 8.

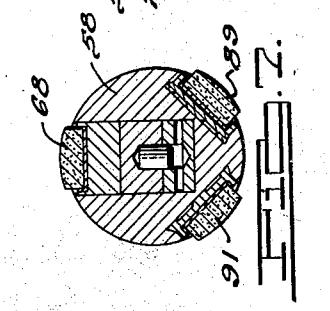


FIG. 7.

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HONING TOOL

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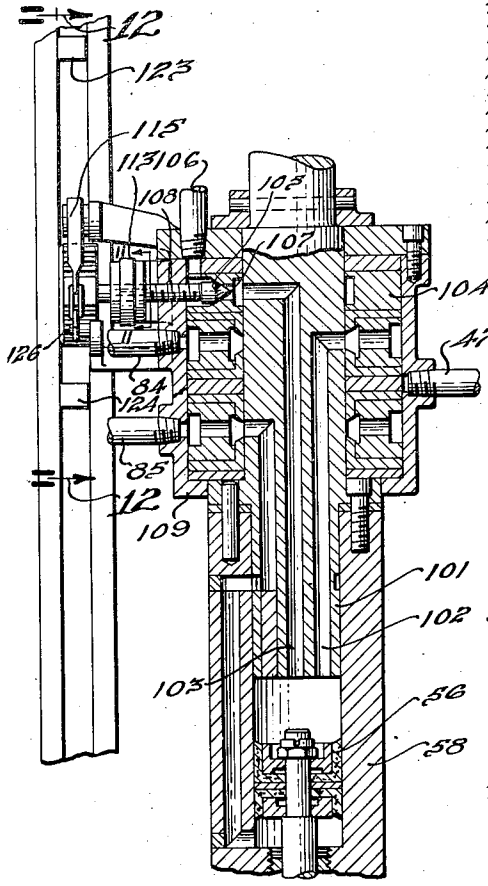


FIG. 10.

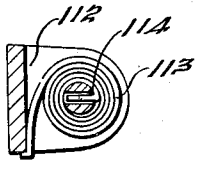


FIG. 11.

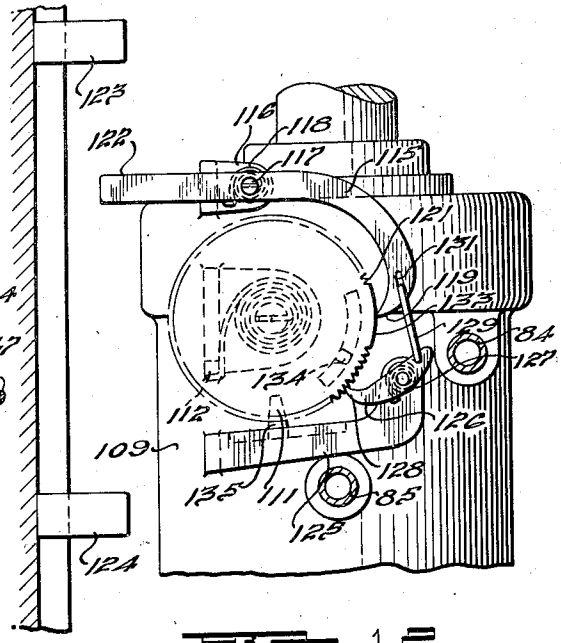


FIG. 12.

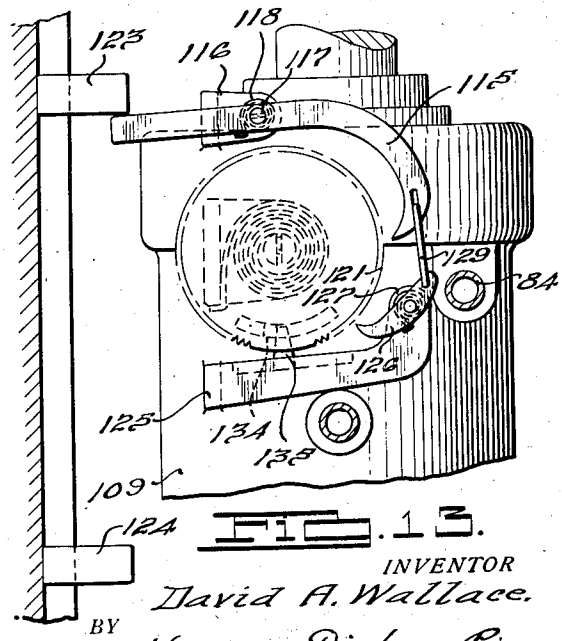


FIG. 13.

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UNITED STATES PATENT OFFICE

2,195,055

HONING TOOL

David A. Wallace, Detroit, Mich., assignor to Chrysler Corporation, Highland Park, Mich., a corporation of Delaware

Application August 21, 1937, Serial No. 160,196

19 Claims. (Cl. 51—278)

My invention re es to honing tools and particularly a simplified tool wherein the radial movement of a single abrading element positively effects the engagement of a plurality of elements with the wall of the cylinder to be machined.

It has been the practice heretofore to expand a plurality of abrading elements radially of the axis of the tool by cones or similar elements which produce a sliding engagement on an inclined plane through mechanical adjusting elements. When wear occurred on one stone a greater amount than on the other, due to the softer bond and abrading material, such stone became ineffective to cooperate in producing the machining operation and an unbalanced condition occurred to the abrading head.

In practicing my present invention, I employ at least three abrading elements, two of which are relatively fixed to the body of the abrading head, while a third is radially movable to cause all of the abrading elements to contact with the cylinder wall. In the case of employing two fixed stones and moving a third stone, contact will be obtained between all of the stones and the cylinder wall, irrespective of the irregular wear of the various stones. A universally jointed driving driving head is utilized to permit the axis of the abrading head to shift relative to the axis of the cylinder being honed so that positive contact with the surface being machined will be had at all times by all three of the abrading elements. If one of the stones should wear faster than the other, constant pressure between all of the stones and the surface to be machined will be maintained through the shifting of the axis of the tool under the force of the movable abrading element. As a result of this unique construction, constant pressure is at all times maintained on all of the abrading elements when engaged with the surface of the cylinder being machined.

The stones which are fixed against radial movement may be so mounted as to be shiftable axially preferably disproportionate amounts at each half cycle of reciprocation. The stones will be stationary at the end of the stroke and will be progressively moved to have all the surfaces of the three stones changed relative to each other to thereby control the grain relation presented to the work during each half cycle of reciprocation.

The fluid employed to control the position of the stones is preferably introduced to the actuating element in a large volume at low pressure. This immediately moves the abrading elements into contact with the cylinder wall, which contact is initially light. The stones under light pressure are more effective to rough out the imperfections on the cylinder wall without harming the stones. As the honing progresses, the pressure for urging the stones against the work is increased, either progressively or in steps a predetermined amount, or until the operation is completed.

Accordingly, the main objects of my invention are: to provide an abrading head having at least two fixed abrading elements and an additional element which is movable radially of the axis of the head; to provide positive driving means for moving one of a plurality of abrading elements radially of the axis of the tool; to provide hydraulic means for positively adjusting one of a plurality of abrading elements radially of the axis of the tool; to provide an adjustable stop for limiting the movement of the hydraulically operated device for radially adjusting an abrading element; to drive a tool through a universal connection to permit the axis of the tool to assume any position relative to the axis of the cylinder to be machined; to employ a cam operated by hydraulic means for positively controlling the expansion of an abrading element during a honing operation to initially utilize a minimum pressure for urging the stones into contact with the cylinder wall, which pressure is increased as the honing operation progresses; and, in general, to provide an abrading tool for machining cylindrical elements which is simple in construction, positive in operation, and economical of manufacture.

Other objects and features of novelty of my invention will be 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 view, partly in section and partly in elevation, of a honing tool embodying features of my invention;

Fig. 2 is a side view, partly in section and partly in elevation, of the honing tool illustrated in Fig. 1;

Fig. 3 is an end view of the structure illustrated in Fig. 2, as viewed from the line 3—3 thereof;

Fig. 4 is a sectional view of the structure illustrated in Fig. 2, taken on the line 4—4 thereof;

Fig. 5 is a view of structure, similar to that illustrated in Fig. 1, showing a further form which my invention may assume;

Fig. 6 is a sectional view of the structure illustrated in Fig. 5, taken on the line 6—6 thereof;

Fig. 7 is a sectional view of the structure illustrated in Fig. 6, taken on the line 7—7 thereof;

Fig. 8 is an end view of the structure illustrated in Fig. 5, as viewed from line 8—8 thereof;

Fig. 9 is a broken view of the structure illustrated in Figs. 5 to 8 inclusive;

Fig. 10 is a sectional view of a control head for the tools herein illustrated, showing a further form thereof;

Fig. 11 is an enlarged sectional view of the

structure illustrated in Fig. 10, taken on the line 11—11 thereof;

Fig. 12 is an enlarged sectional view of the structure illustrated in Fig. 10, taken on the line 12—12 thereof with the ratchet and pawl in engaged position; and

Fig. 13 is a view of structure, similar to that illustrated in Fig. 12, with the ratchet and pawl in released position.

My invention comprises, in general, a tool having a body portion supporting a plurality of abrading elements, at least one of said elements being movable radially while opposite elements are fixed against radial adjustment.

In Figs. 1 to 4, I have illustrated one form of tool wherein a body 11 has a pair of abrading elements 12 and 13 fixed thereto by a suitable clamping element 14 secured to the body by screws 15. A lateral slot 16 is provided in the central part of the body having a plurality of transversely disposed circular openings 17 communicating therewith. Cylindrical elements 18 are disposed in the openings and secured in eccentric relation to a shaft 19 which has a pinion 21 machined or otherwise provided thereon. A radially adjustable carriage 22 is disposed in the slot 16 for movement radially of the body of the tool, having an abrading element 23 mounted thereon in any suitable manner, herein illustrated as by clamps 24. An axially reciprocating piston 25 is journaled within the carriage 22 having rack teeth 26 on one face thereof.

After the carriage is disposed in the slot 16, the plurality of shafts 19 are mounted therein with the gears 21 in mesh with the teeth 26 of the rack provided on the piston 25. Thereafter the eccentric elements 18 are secured to the ends of the shaft and suitable sealing washers 27 may be disposed in the opening in the body. A passage 28 is provided lengthwise of the carriage which communicates with the lower end of the cylinder 29 in which the piston 25 operates. The opposite end of the carriage is provided with a passage 31 communicating with the opposite end of the cylinder 29. The passages 31 and 28 are joined by two flexible conductors 32 and 33, respectively, to passages in the body to permit the movement of the carriage while delivering fluid under pressure thereto. Suitable packing washers 34 are provided at each end of the piston 25 to provide a seal for the fluid introduced into the cylinder 29 at either end of the carriage. An adjustable element 35 limits the degree of axial movement of the piston and therefore the expansion of the abrading element 23 to limit the size of the cylinder to be machined by the tool.

The body 11 of the tool has a collar 36 secured thereto which is rotatable relative to the body and employed as a means for delivering the fluid under pressure to the carriage 22. Suitable fluid delivering rings 37 are mounted on the shank of the tool within the collar 36, having grooves 38 therein to permit the flow of fluid thereabout and through apertures 39 into apertures 41 and 42 within the body. The apertures 41 and 42 communicate through connectors 40 with flexible conductors 32 and 33, respectively, hereinabove described.

Fluid is delivered through conductors 43 and 44 and apertures 45 and 46 in the collar 36, into the recesses 38 provided in the oil delivering rings 37. The collar 36 is also provided with a stud 47 which abuts against a stop element (not shown) to prevent the rotation of the collar while permitting the reciprocation and rotation of the tool. Suitable packing glands 48 are disposed between the rings 37 beneath the collar for sealing the rings relative to the tool shank and collar 36.

The rings and packing gland are retained in clamped relation by a threaded collar 49, mounted within the collar 36. The collar 36 is retained on the end of the shank of the tool by a suitable clamping ring 51 through which the end 52 of the tool extends and forms a projection to be received by a bayonet type of socket which engages a pin 53 for locking the tool thereto.

The socket, preferably, is provided with the universal joint to permit the axial shifting of the tool relative to the driving element to permit the tool to center itself within a cylinder to be honed. This is necessary in view of the fact that the one stone or abrading element 23 is movable while the abrading elements 13 and 12 are retained in fixed relation to the tool axis. When the abrading element 23 is moved outwardly, the axis of the tool shifts relative to the axis of the work and the universal driving connection is therefore a desirable feature. It is to be understood, however, that the work could be mounted to shift relative to the tool so that the tool could be retained in fixed relation relative to the driving head so that the work could align itself relative to the axis of the tool as the axis changes.

In operation, when fluid is introduced into the conductor 43 it will flow through the passages 41 and 28 into the lower end of the cylinder 29 to impinge upon the piston packing 34 on the end of the piston 25 and cause the piston to move upwardly in the tool, as viewed in the figures. The upward movement of the piston rotates the gears 21 and therefore the cam elements 18 to cause the abrading element 23 to move outwardly and force the abrading elements 13 and 12 along therewith into engagement with the sides of the cylinder being honed. The feeding of the element 23 will continue during the honing operation through the continued upward movement of the piston 25 until the upper end thereof engages the end of the stop element 35, after which no more radial feeding of the element 23 can occur.

After the honing operation has been completed, fluid is introduced into the conductor 44 and the conductor 43 operates as a return conduit for the fluid in the lower part of the cylinder 29. The fluid under pressure now flows through the passages 46 and 42 to impinge upon the upper piston packing 34 to move the piston 25 downwardly to rotate the gears 21 and cams 18 to their original position, which is that in which the abrading element 23 is retracted.

In Figs. 5 to 9, I have shown a further form which my invention may assume, that wherein a cylinder 55 encompasses a piston 56 secured to a piston rod 57 within the body 58 of the tool. The piston rod moves a carriage 59 axially of the body 58 and has adjustably secured thereto a cam block 61 containing a pair of cam surfaces 62 and 63. The cam block 61 is retained by a pair of pins 64 in fixed relation to the carriage 59, the elements being adjustable longitudinally of each other by a plurality of apertures 65 which selectively receive the pins 64. Through the shifting of the pins in the apertures 65, the surfaces 62 and 63 are positioned axially of the body relative to the piston 57 so that the backing element 67 for the abrading stone 68 is shifted to provide a greater or lesser diameter to the honing tool. The backing element 67 is provided with a pair of sloping surfaces 69 and 71 which mate with

the sloping surfaces 62 and 63, respectively, of the cam block 61. The piston 56 is moved downwardly through the introduction of fluid through the aperture 72 in the driving head portion 73 to thereby move the cam block 61 to effect the radial movement of the backing element 67 against the bias of a pair of springs 74 retained by suitable clips 75 to the tool body. The abrading element 68 is secured to a metal sheath 76 by friction or by a suitable adhesive material such as resin, glue, lead, and the like. The sheath is provided with projecting ends 77 which are secured to the backing element 67 by suitable screws 78.

An adjustable screw 79 is provided at the end of the tool in the line of movement of the carriage 59 to bar further axial movement of the carriage at a predetermined point and thereby to limit the diameter of the hole which will be finished by the tool. It is to be understood that the screw 79 may be adjusted from time to time as the surface of the abrading stone 68 becomes worn.

The driving head 73 is fastened to the body 58 by suitable screws 81 and sealed thereto by a suitable gasket 82. A relatively rotatable collar 83 is mounted on the driving head 73 and is provided with rings and packing elements similar to those described hereinabove with relation to the structures illustrated in Figs. 1 and 2, for delivering fluid to either side of the piston. The conductor 84 delivers fluid to the top side of the piston while the conductor 85 provides a return passage when the abrading operation is to be performed, and the conductor 85 introduces fluid to the lower end of the piston while the conductor 84 functions as a return passage when the abrading stone 68 is retracted. The collar is retained on the body by a thrust ring 86 which is secured to the head by a pin 87.

The side of the body 58 opposite to that in which the abrading stone 68 is disposed, has a pair of abrading stones 89 and 91 fixed against radial movement while permitting a slight axial movement relative to the body. Dovetail carriers 92 are mounted within the body and having the abrading stones 89 and 91 secured thereto by screws 78 passing through the sheath ends 77. Stop elements 93 and 94 are provided in the bottom of the slots containing the dovetail carriers 92, while suitable stop elements 95 and 96 are provided at the top thereof. In the figure, the abrading elements are disposed against the top stop elements, and it will be noted that the space 97 between the carrier 92 and stop element 93 is greater than the space 98 disposed between the carrier 92 and the element 94. It is evident that during each change in direction of reciprocation of the tool, the abrading stones 91 and 92 will shift lengthwise slightly relative to the tool body disproportionate amounts and will change the grain relation of the stones in a radial plane.

It is understood by those skilled in the art that the grain surface of the stone produces minute scratch marks on the surface being abraded; the softer stone having a fine grain structure operated under proper pressure will produce finer marks and a highly polished finish. These marks may vary because of the variation in grain structure of the stones and the overlapping of certain of the grains may cause a greater number and deeper marks on the surface to be finished. By shifting all of the three stones relative to each other at each half cycle of reciprocation of the tool, such a condition is broken up and different grain structure will be presented in a radial plane by the various stones.

In operation, the tool is disposed within the work and fluid is introduced through the conductor 84 to cause the downward movement of the piston 56 and carriage 59 to thereby effect expansion of the abrading stone 68. The radial movement of the abrading stone 68 will cause the axis of the tool to shift relative to the body and, as the stone engages the wall to be machined, the tool will shift bodily in the opposite direction to bring the stones 89 and 91 into contact with the wall after which a predetermined pressure will be provided between the three stones and the wall. The driving head of the tool is provided with a universal joint to permit such shifting, or the tool is mounted in a machine in which the work is permitted to shift relative to the axis of the tool. The expansive movement of the stone 68 will continue until the carriage 59 strikes the stop 79. After the honing operation is completed, the fluid circuit is changed to have the fluid introduced through the conductor 85 and returned through the conductor 84 to return the piston and permit the spring 74 to retrieve the abrading stone 68. It is to be understood that during the honing operation the driving head for the tool reciprocates the tool and provides a movement or rotation thereto. At each half cycle of movement the stones 89 and 91 will shift longitudinally different amounts and assume new positions relative to the abrading stone 68 which is retained against such longitudinal movement. As a result, the relative position of all of the stone faces which contact the cylinder wall shift relative to each other to produce a finer and more uniform abrading operation.

Referring to Figs. 10, 11, 12 and 13, I have illustrated a further novel construction which may be employed with any of the tools herein illustrated, or any other type of honing tool wherein abrading elements are expanded under pressure. The cylinder wall to be machined is rough and will vary in diameter due to certain surface defects. It was found advantageous to initially operate the honing tool with the abrading elements expanded under a minimum pressure to produce honing in the nature of a roughing operation to clear up the defects before material pressure is applied to the stones. This prevents the rapid break-down of the stones and produces more uniform abrading when effecting a finishing operation. Accordingly, the fluid admitted to the piston is so controlled as to initially provide a large volume to immediately actuate the piston to produce expansion and at the same time to have the pressure at a minimum. As the tool operates, a valve or other means is actuated through the rotation, reciprocation or combined movement of the tool or otherwise, to increase the pressure on the piston as the machine operation progresses. The increase of pressure may be produced in a uniform or non-uniform rate which may be intermittent or constant, depending upon the means employed to control the flow of fluid. It is to be understood that the increase in pressure may occur from the initial movement of the abrading elements into contact with the cylinder wall through only a small portion of the cycle of operation or may extend over a greater portion of or the entire cycle of machining, or such increase in pressure may occur sometime after the operation is started.

The mechanism for controlling the pressure

of the fluid illustrated in Figs. 10, 11, 12 and 13 is shown more for the purpose of illustration rather than by way of limitation as it will be understood by those skilled in the art that other structures could be devised for producing the novel control of the pressure. The body **58** of the tool is similar to that illustrated and described with regard to the structure illustrated in Figure 6. The driving element **101**, therefore, is provided with an aperture **102** through which a fluid is conducted to the top side of the piston **56** to effect expansion of the abrading element **68**. A passageway **103** is also provided in the driving element **101** communicating with a conductor ring **104** which is connected through a valve seat **105** to a discharge conduit **106**. A valve **107** is threaded at **108** in the collar **109** which is similar to the collar **83** shown in Fig. 6, except for additional length to encompass conductor ring **104**. The valve is secured to a ratchet wheel **111** adjacent to the supporting brackets **112** between which a spring **113** is mounted, having one end fixed to the bracket while the other end is secured in a slot **114** in the valve shank. A ratchet lever **115** is pivoted on the bracket **116** by a pin **117** about which a spring **118** is disposed for urging the lever **115** in a clockwise direction to have the actuating end **119** thereof engage the teeth **121** of the ratchet wheel **111**. The opposite end **122** of the lever projects outwardly between lugs **123** and **124** provided on the side or other fixed portion of the machine. The lugs may be mounted in dovetail slides to be adjusted from time to time as the stroke of the honing tool is changed in accordance with the lengths of the different work pieces operated on. An additional bracket **125** is provided on the sleeve **109**, the end of which pivotally supports a pawl **126** which is biased by a spring **127** to have the end **128** thereof engage teeth **121** of the ratchet wheel **111**. A link **129** is pivoted to the pawl **126** and connected to a slot **131** in the end of the lever **115**.

In Fig. 10, I have illustrated valve **107** as being adjusted against the seat **105** to close, or at least substantially close the passage therethrough. In this position, the full pressure of the fluid entering passageway **102** is delivered to the piston **56** for applying a pressure to the abrading stones. This is the position which the valve and valve seat will maintain toward the end of the abrading operation. At the end of the abrading operation the tool is withdrawn from the work at which time the end **122** of the lever **115** will engage lug **123** and move the end **119** of the lever and the end **128** of the pawl **126** out of engagement with the teeth **121** of the ratchet wheel **111**, which is the position illustrated in Fig. 13. As soon as the ends are released from the teeth, the bias of the spring **113** will operate to turn the valve **107**, which operating in the thread **108** will move from the seat **105** and open the passageway to the conduit **106**.

Upon inserting the tool within the cylinder to be machined, the introduction of the fluid through the passageway **102** will immediately provide a sufficient volume of oil to operate the piston **56** to effect the contact of the abrading element with the cylinder wall. The fluid, however, is free to flow from the cylinder through the passageway **103** and valve **107** through the outlet conduit **106**. In this manner, a large volume of fluid under minimum pressure is provided for the initial operation of the abrading element into contact with the cylinder wall. At the end of each cycle of reciprocation as the tool operates, the end **122** of the lever **115** will engage the lug **124** to cause the end **119** of the lever to engage a tooth of the ratchet wheel **111** and to advance the ratchet wheel in rotation a predetermined amount. Such advancement of the ratchet wheel will continue at each cycle of reciprocation until the end **119** of the lever passes over a portion **133** on the peripheral edge of the ratchet wheel upon which no teeth are provided. The continued operation of the tool in reciprocation will thereafter have no effect in advancing the ratchet wheel or to change the position of the valve **107** relative to its seat **105**.

The amount of rotation of the ratchet wheel and valve may be controlled through the change of position of the portion **133** relative to the valve stem and also through a change in position of a stop **134** relative to an adjustable lug **135** as illustrated in Fig. 13 which provides further control of the amount of change in pressure produced during the tool operation. The extent in time of the change in the pressure with relation to the entire time of the machining operation may be adjusted through the size of the teeth **121**, the amount of tilting to the lever **115**, change in size of the ratchet wheel, and through other changes well known to one skilled in the art.

Accordingly, when using the structure as illustrated in Figs. 10 to 13 inclusive, the immediate expansion of the abrading elements into contact with the cylinder wall is effected upon the delivery of the fluid to the cylinder, which contact will be produced under a minimum pressure irrespective of the pressure of the fluid being delivered. The fluid will pass from the cylinder through the control valve which will begin to close the passage as the honing operation progresses to thereby increase the pressure in the cylinder and to provide greater pressure to the abrading elements. This pressure will continue to increase as the operation progresses until a predetermined amount of pressure is reached, after which the operation may be discontinued or maintained under a fixed pressure until the machining operation is completed.

While I have described and illustrated several embodiments of my invention, it will be apparent to those skilled in the art that various changes, omissions, additions 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 honing tool having a body portion with adjacent abrading elements thereon fixed against radial movement, a carriage in said body portion oppositely disposed to said elements, an abrading element on said carriage, and means for adjusting said carriage and abrading element radially to force said three abrading elements into contact with the wall of a cylinder to be machined.

2. A honing tool having a body portion on which a plurality of abrading elements are fixed against radial movement, a radially adjustable carriage on said body portion diametrically disposed relative to a medial point between said elements, an abrading element on said carriage, a longitudinally movable element in said tool for effecting the radial movement of said carriage to cause all of said elements to contact the wall of a cylinder under pressure through the shifting

of the body of the tool, and fluid means for actuating said longitudinally movable means.

3. A honing tool having a body portion on which a plurality of abrading elements are fixed against radial movement, a radially adjustable carriage on said body portion, an abrading element on said carriage, a longitudinally movable element in said tool for effecting the radial movement of said carriage, fluid means for actuating said longitudinally movable means, said radial movement producing the bodily shifting of the tool and fixed abrading elements.

4. In a honing tool, a body portion having a plurality of abrading elements fixed against radial movement, a radially adjustable abrading element disposed in said body portion, an axially movable carriage in said body portion, and a cam block on said carriage adjustably secured thereto for movement therewith while engaging said radially adjustable abrading element.

5. In a honing tool, a body portion having a plurality of abrading elements fixed against radial movement, a radially adjustable abrading element disposed in said body portion, an axially movable carriage in said body portion, a cam block on said carriage adjustable longitudinally thereof for movement therewith while engaging said radially adjustable abrading element, a cylinder in said body portion, and a piston in said cylinder connected to said carriage.

6. In a honing tool, a body portion having a plurality of abrading elements fixed against radial movement, a radially adjustable abrading element disposed in said body portion, an axially movable carriage in said body portion, a cam block on said carriage adjustable longitudinally thereof for movement therewith while engaging said radially adjustable abrading element, a cylinder in said body portion, a piston in said cylinder connected to said carriage, a collar on said body portion rotatable relatively thereto, and means for delivering a fluid through said collar to said cylinder.

7. In a honing tool, a body portion having abrading elements thereon supported against radial movement, means for so mounting said elements in said body portion as to permit a single longitudinal shifting of said stones therein, and an abrading element mounted in said body portion adjustable radially thereof.

8. In a honing tool, a plurality of abrading elements, means for mounting said abrading elements in said honing tool to permit a slight relative axial shifting thereof disproportionate amounts at each change of direction in the reciprocation of the tool.

9. In a honing tool, a body portion having a plurality of abrading elements secured thereto, at least one of said abrading elements being adjustable radially, the other said abrading elements being so mounted as to shift slightly relative to each other longitudinally of the tool.

10. In a honing tool, a body portion having a plurality of abrading elements secured thereto, one of said abrading elements being adjustable radially while secured against longitudinal movement, others of said abrading elements being secured against radial adjustment while being mounted to shift slightly disproportionate amounts longitudinally of the tool.

11. In a honing tool having abrading elements, means for moving the abrading elements into engagement with the wall of the cylinder to be machined with a predetermined minimum pressure, and means including a valve on said tool for increasing the pressure thereafter.

12. In a honing tool having abrading elements, means for moving the abrading elements into engagement with the wall of the cylinder to be machined, means for introducing a volume of fluid under low pressure to said moving means to produce a rapid initial movement of the abrading elements into contact with said wall and to initially machine under low pressure, and means for thereafter increasing the pressure between said elements and wall.

13. In a honing tool having abrading elements, means for moving the abrading elements into engagement with the wall of the cylinder to be machined, means for introducing a volume of fluid under low pressure to said moving means to produce a rapid initial movement of the abrading elements into contact with said wall and to initially machine under low pressure during the roughing operation, and means for thereafter progressively increasing the pressure between the abrading elements and said wall.

14. In a honing tool having abrading elements, means for moving the abrading elements into engagement with the wall of the cylinder to be machined, means for introducing a volume of fluid under low pressure to said moving means to produce a rapid initial movement of the abrading elements into contact with said wall and to initially machine under low pressure, and means for thereafter progressively increasing by steps the pressure between the abrading elements and said wall.

15. The method of abrading which includes the steps of, initially abrading with a light pressure, thereafter abrading with a greater pressure, and finishing with a third pressure.

16. In an abrading device, an abrading element, means for advancing said element into contact with a surface to be machined, means for initially applying a low pressure between said element and surface, means for thereafter applying a higher pressure between said element and surface, and means for controlling the duration of operation under said low pressure.

17. The method of abrading which includes the steps of moving an abrading element into contact with and upon a surface to be machined, maintaining pressures between said element and said surface proportionate to their area of contact as the character of said surface changes during operation thereon.

18. The method of lapping a piece of work which comprises applying with a predetermined force a lapping element to a surface of a piece of work to establish a predetermined unit lapping pressure during one stage of lapping of said surface, and increasing said force thereafter as the area of contact between said surface and said lapping element is increased by the removal of irregularities from said surface.

19. The method of lapping a piece of work which comprises applying with a predetermined force a lapping element to a surface of a piece of work to establish a predetermined unit lapping pressure during initial lapping of said surface, producing relative lapping movements between said lapping element and said surface, and intermittently increasing said force to a higher predetermined value without decreasing said force between each of a selected number of said lapping movements.

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