

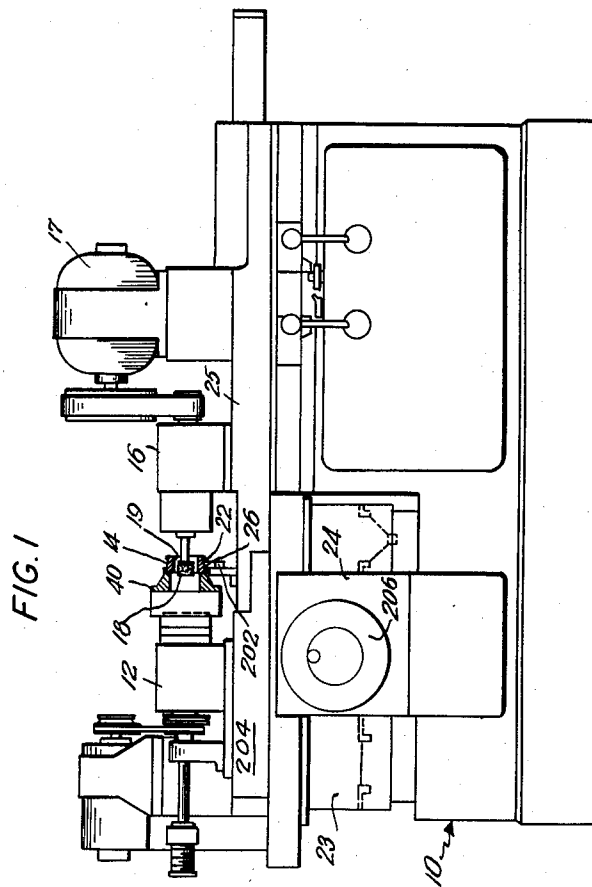
Oct. 20, 1959

W. D. SCHMIDT ET AL
GRINDING MACHINES

2,909,009

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4 Sheets-Sheet 1



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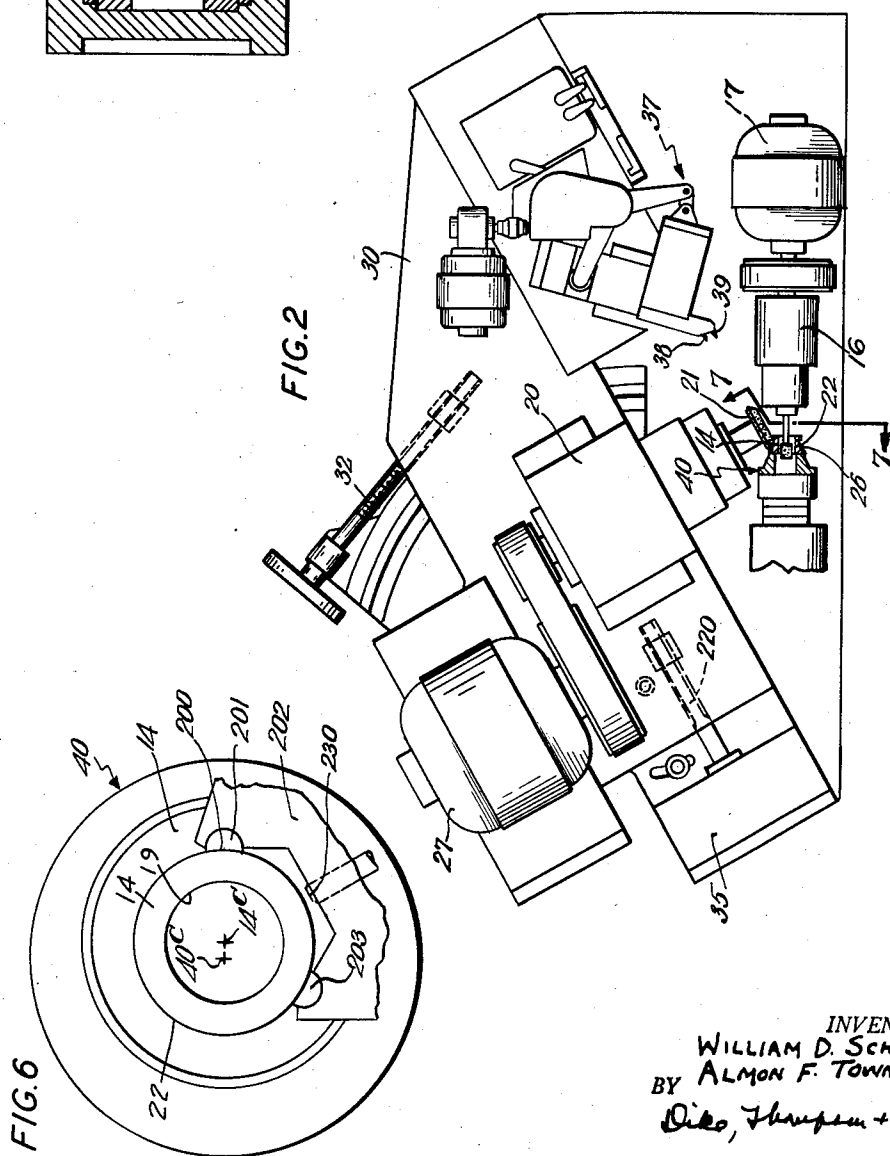
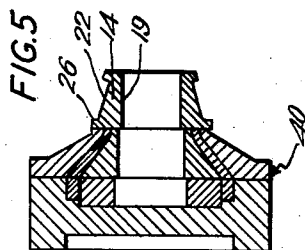
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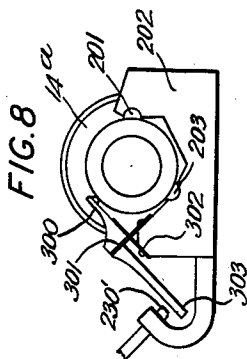
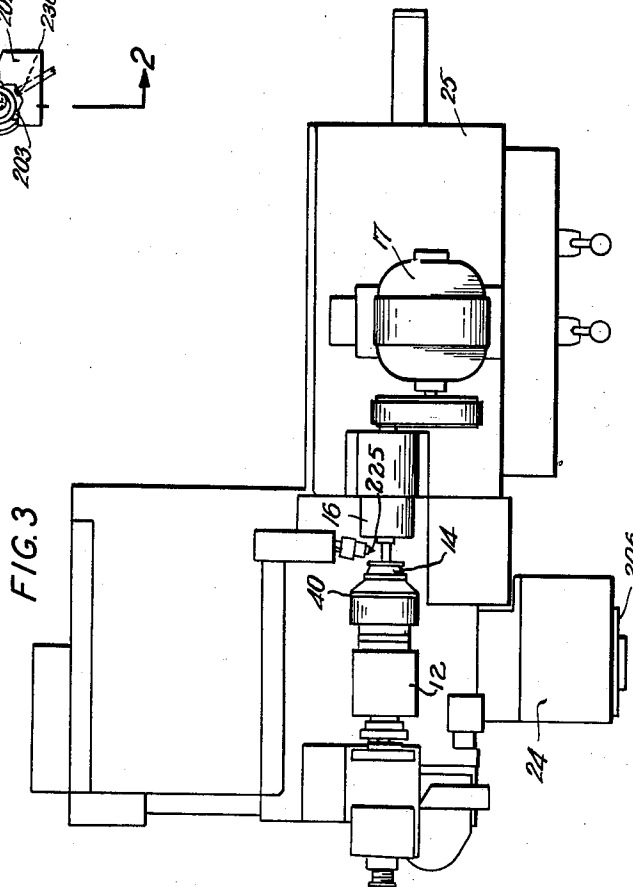
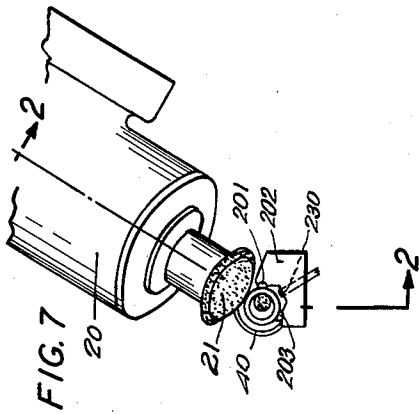
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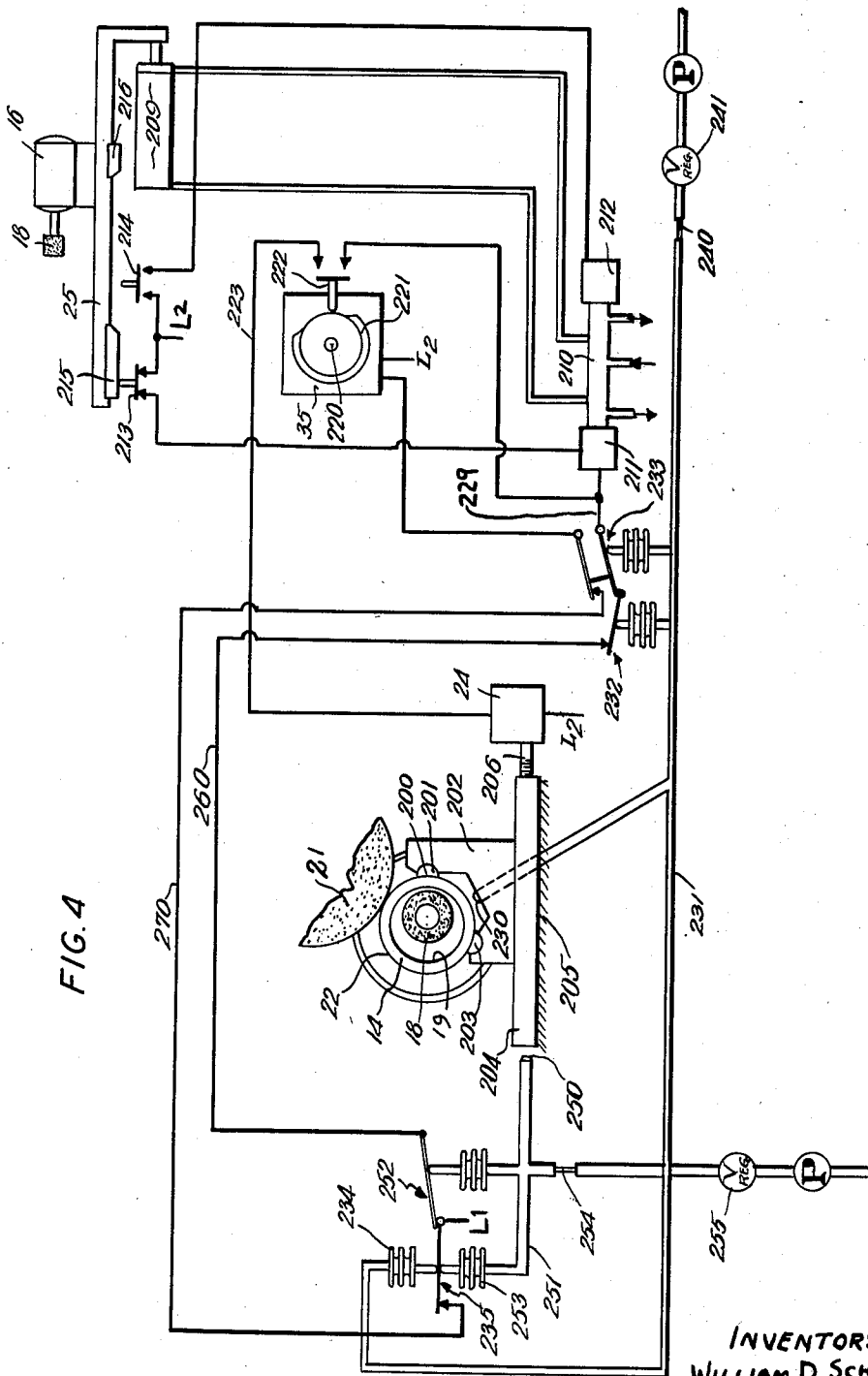
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2,909,009

GRINDING MACHINES

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This invention relates to grinding machines and more particularly to a machine which simultaneously grinds the inner and outer diameters of a round workpiece.

Contemporary design calls for finish grinding the outer and inner surfaces of a round workpiece, for instance, a cylindrical or tapered ball or roller bearing ring, within tolerances of fractions of a thousandth of an inch. Both surfaces must be finished with roundness and smoothness and with surfaces accurately concentric to preserve uniformity of the wall thickness around the circular workpiece. Such precision requires time and usually a series of operations and, therefore, expense.

It has been one practice first to grind the outer peripheral surface in a centerless type grinding machine to obtain a degree of roundness and smoothness. A centerless type machine has considerable advantage over the checking type machine in which the work is clamped in a chuck and rotated while being ground because it is difficult accurately to center the workpiece in a chuck and therefore many workpieces are ground eccentrically and inaccuracies tend to be compounded. Also, the work is distorted by clamping it in a chuck, and for these and other reasons, centerless grinding is generally more accurate.

After the outer surface of the workpiece is brought to a degree of accuracy it may then be placed in a centerless type of internal grinding machine for the finishing of the inside surface. However, it has been found that when the inner surface is finished stresses are relieved and others are set up which distort the previously finished outer surface. This is caused by the removal of all of the stock from one surface before removing stock from the other.

One method of overcoming this disadvantage has been to grind the inside and outside surfaces progressively utilizing external and internal machines in alternate operations, thereby reducing the inner and outer surfaces in small progressive increments so as to balance the stresses and thereby avoid some of these distortions. Such a series of operations, however, has the disadvantage that it takes too much time and it also subjects the workpiece to inaccuracies which result from moving it back and forth from one machine to another.

Attempts have been made to overcome the latter disadvantages by the use of two grinding wheels in one machine, an internal grinding wheel to grind the inner surface and an external grinding wheel to grind the outer surface, both operating simultaneously. Such prior two-wheel machines have not been successful, partly because the work produced is inaccurate due to the inherent difficulties of supporting the work either by the conventional chucking or centerless methods which have been employed. When the work is clamped in a chuck it is frequently off center and also distorted due to the stresses set up at the clamping points, and when the work is supported by the usual centerless means, inaccuracies result in both surfaces due to the bodily movement of the work-

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piece on the work support due to irregularities in the support surface of the workpiece, and which are further compounded on the inside surface when the workpiece is being supported on the outside surface being ground.

It is therefore an object of this invention to provide the obvious advantages of simultaneous grinding of the inner and outer surfaces of a round workpiece in one machine during at least a part of the operation and at the same time to overcome disadvantages and difficulties in supporting the work with sufficient precision so that errors in out-of-roundness, eccentricity of the surfaces and surface irregularities will be minimized, thus resulting in a grinding operation which produces the work with a great saving of time due to elimination of previously necessary successive steps and which relieves distortion in the work by simultaneous reduction of the surfaces in one operation which removes most of the stock.

Another of the difficulties inherent in two-wheel machines is that initial errors and irregularities in the outer supported surface are reflected in the inner surface and the inner surface cannot be finished with optimum precision while such errors remain on the outer surface. For this reason the prior two-wheel machines have not been capable of sufficient accuracy.

It is therefore another object of this invention to eliminate the aforesaid disadvantage by providing a machine which by simultaneous application of both the internal and external wheels to the workpiece accomplishes most of the stock removal on both surfaces contemporaneously and also operates in such a manner that most of the initial irregularities of the outer surface are first removed and the finishing of the inner surface by the internal wheel is delayed until after this has been done so that accuracy of both surfaces may be obtained to a desirable degree.

It is a further object to provide in such a machine an automatic cycle of operation, the initiation of which is dependent upon the accurate seating or placing of the workpiece in the work support or operating position in order to avoid jamming of the machine and destruction of the workpiece.

It is a further object to provide in such a machine the means to dress the internal wheel, if desired, during or after the grinding of every workpiece. The internal wheel, being necessarily much smaller, wears faster than the larger external wheel and therefore requires dressing more often.

The accomplishment of these and other objects will be understood by reference to the following description of a preferred illustrative embodiment of the machine and several modifications together with the drawings in which:

Fig. 1 is a front view of part of the machine;

Fig. 2 is a view of part of the machine taken on a slanted plane indicated by the lines 2—2 in Fig. 7 from in front of and above the machine;

Fig. 3 is a top plan view, most of the mechanism shown in Fig. 2 having been removed;

Fig. 4 is a wiring and flow diagram illustrating the cycle of operation;

Fig. 5 is a longitudinal section showing the magnetic chuck and a workpiece therein;

Fig. 6 is an enlarged end view of the chuck and workpiece together with the work support and external air gage;

Fig. 7 is a view of part of the machine taken on the lines 7—7 of Fig. 2; and

Fig. 8 is an end view of the workpiece in the work support showing a modified form of the external gage.

In the drawings, Figs. 1 to 3 show a machine having a base 10 upon which is mounted a work head 12 associated with means for supporting and rotating a workpiece 14, an internal grinding wheel head 16 having an internal

grinding wheel 18 applicable inside the bore of the workpiece for grinding its inner surface 19, and an external grinding wheel head 20 having an external grinding wheel 21 applicable to grind an external surface 22 and also the rib portion 26 of the workpiece.

The work head 12 is mounted upon a slide 23 on which it is fed in and out on the base 10 relative to the internal grinding wheel 18 in order to apply the wheel to the inner surface of the workpiece 14. The feed motion of the work head is imparted by conventional feed mechanism 24, which may include an electric motor operated feed screw 206. The internal wheel head 16 and its conventional drive motor 17 are mounted on a table 25 slidably movable to the left and right, as viewed in Figs. 1 and 4, thus allowing it to be moved in to the left, as viewed in Fig. 1, in the conventional manner to insert the internal wheel 18 in the workpiece, to reciprocate the wheel relative to the workpiece during grinding and to withdraw the wheel out to the right from the work for a dressing operation and to allow the workpiece to be removed at the end of the cycle.

Since the workpiece 14 shown is a roller bearing ring having a cylindrical inner surface 19 and a tapered outer surface 22, the axes of rotation of the workpiece and of the internal grinding wheel may be substantially parallel to grind the inner surface 19, but to grind the tapered outer surface 22 and also the rib portion 26, the external wheel 21 has a cutting surface adapted as shown for this purpose and it is mounted so that its axis is slanted at an acute angle to the axis of the workpiece and arranged to be fed with its axis moving in a plane which intersects the workpiece axis but which is neither vertical nor horizontal. This is best seen by comparing Figs. 2 and 7, the view in Fig. 2 being taken in the slanted plane described.

The external wheel 21 with its conventional drive motor 27 is mounted on a slide 30 whose ways are angularly adjustable by means of a screw 32 with respect to the axis of rotation of the workpiece. The external wheel 21 is fed relative to the workpiece by conventional electric feed mechanism 35 for moving the slide 30 and wheel toward the external surface to be ground.

Conventional external wheel truing mechanism is indicated at 37, including a pair of truing diamonds 38, 39, mounted on the slide 30 and arranged to move the diamonds 38, 39 against the cutting surfaces of the wheel 21.

Generally speaking, therefore, in the machine illustrated, the internal wheel moves in and out of overlapping relation with the workpiece, the workpiece is moved relative to the internal wheel to feed the internal wheel against the inner workpiece surface, and the external wheel is moved relative to the moving workpiece to feed the external wheel against the workpiece outer surface. The internal wheel is withdrawn from the workpiece during the cycle to dress the wheel prior to its finishing operation and for purposes to be further described.

Referring to Figs. 1, 4, 5 and 6, the workpiece 14 abuts against and is rotated by a magnetic back plate 40 of sufficient power to hold the workpiece in an endwise direction and to rotate it against the friction created by the forces of the two wheels grinding simultaneously, and which is eccentrically mounted with its center at 40c in relation to the center 14c of the workpiece, as seen in Fig. 6, so as to force the workpiece down with its outer surface 22 in sliding contact with a fixed work support comprising a concave surface 200 of a support member 201 which may be arranged to rock in a support block 202 better to follow the surface of the work, and a second support member 203 of the same type. The support block 202 is mounted on the slide 204 which is movable on a slideway element 205 on the base 10 by the feed screw 206 of the internal feed mechanism 24, which feeds the workpiece toward the left, as viewed in Fig. 4, against the internal wheel 18. It is preferable to locate the internal wheel 18 so that it will be opposed substantially

directly by the support 201, as shown, to minimize deflection of the work and consequent vibration.

The external wheel 21 is fed by its feed means 35 relative to the slide 204 against the outer surface 22 of the workpiece, and is arranged to make this contact close to the support member 201, where its force is substantially opposed by the support member 203 and where it is most effective in rounding up the work because of its position relative to the two support members 201 and 203, which causes errors due to irregularities in the outer surface to be reflected in a direction nearly tangential to the surface of the external wheel.

The table 25, carrying the internal wheel 18 and wheel head 16, is reciprocated by a hydraulic cylinder 209 controlled by a reversing valve 210 operated by solenoids 211 and 212, which are energized by switches 213 and 214 which, when closed alternately by table dogs 215 and 216, operate to reciprocate the table back and forth to move the wheel across the surface face of the work during grinding and, when operated as further described, cause the table to move out to the right, as viewed in the drawings, to withdraw the wheel from the work.

As previously stated, the machine has a control system which assures that the work is properly seated in its support before the internal wheel is allowed to enter the work, which stops the feed of the external wheel when the outer surface of the work reaches the desired size and which causes the inner surface of the work to be finished with its diameter to a closer tolerance than required for the outer diameter.

For this purpose, gage means working on the outer diameter of the workpiece prevents grinding until the work is seated in the support and also gages the outer diameter of the workpiece to stop the feed of the external wheel when size is reached. Associated with the external gage means is a so-called differential gage arrangement for controlling the distance of feed of the workpiece with respect to the internal wheel.

Referring to Fig. 4, an air nozzle 230 extends through the work support block 202 between the support members 201 and 203, nearly touching the outer surface 22 of the workpiece. Air leakage between the nozzle and the workpiece, determines the pressure in an air line 231 connected to two pressure operated switches 232 and 233 and an upper bellows 234 of a differential switch 235, and supplied with air under pressure through an orifice 240 at a constant pressure from a regulating valve 241.

As seen in Figs. 4 and 6, the support members 201 and 203 define a sector of less than 180 degrees centered at the workpiece axis 14c and within which the air nozzle 230 is located.

Another air nozzle 250 nearly touches the internal wheel feed slide 204 and air leakage between the nozzle 250 and the slide 204, determined by the position of the slide, governs the pressure in a line 251 connecting a pressure operated switch 252 and the lower bellows 253 of the pressure operated switch 235, this air being supplied separately through an orifice 254 from a pressure regulating valve 255.

In Fig. 4 the workpiece has just been placed in the support elements 201 and 203, raising the pressure in the gage nozzle 230 enough to close the switches 232 and 235, but not sufficiently to raise the switch 233.

Closure of the switch 232 connects one leg L¹ of an electric power supply line through the switch 252, a line 260, the switches 232 and 233 to a line 229 energizing the solenoid 211, which is connected to another leg L² of the supply line through the switch 213 held closed by the table dog 215, thereby causing the table 25 to move to the left and the internal wheel to enter the work, but only after the workpiece has been seated in its support.

Closure of the switch 235 connects the line L¹ through a line 270 and the upper leg of the switch 233 to the

external feed mechanism 35, which starts feeding the external wheel.

The external feed mechanism 35 includes a feed screw 220 which turns a cam 221 which closes a switch 222 in a line 223 to the internal feed mechanism 24 and operates to start internal feed after the external wheel starts grinding, thus giving the latter a head start over the internal wheel. This delay gives the external wheel time to remove the larger irregularities from the outer surface of the work so that they will not be reproduced by the internal wheel when it starts to grind. It would otherwise take an undesirable amount of time to remove such irregularities if reproduced on the inner work surface. In other words, the external wheel is given an opportunity to prepare a sufficiently smooth support surface on the outside of the workpiece.

When the slide 204 has moved a predetermined distance toward the air gage nozzle 250, the air leakage between the nozzle and the slide is inhibited, causing the pressure in the nozzle and its line to rise sufficiently to open the switch 252, thus cutting the circuit from the supply line L¹ to the solenoid 211 through the line 260 and associated switches and de-energizing the solenoid 211 so that the table 25 moves all the way out to its right-hand position. Cutting the power in the line 229 also stops the internal wheel feed mechanism 24. During this "table-out" movement, the internal wheel is trued by the truing device 225 which is positioned in the conventional way to pass over the internal wheel during the "table-out" movement.

Thus far the internal wheel has completed a roughing operation and the rate of feed of the external wheel, which normally can cut faster, is adjusted to complete the external grinding operation at about the same time the roughing operation by the internal wheel is completed, or shortly thereafter. It is desirable in this invention that the internal finishing operation be delayed until after the operation has progressed sufficiently to round up the outer surface to a high degree of accuracy, and therefore means are provided to prevent contact between the internal wheel, after it has been trued for a finishing operation, and the inner work surface until after the external wheel has rounded up the outer surface.

As the outer surface of the workpiece is reduced by the external wheel, it approaches the external gage nozzle 230 until the reduction of the air leakage between the nozzle and the workpiece causes the pressure in the nozzle and its associated pressure line 231 to rise sufficiently to raise the switch 233. This stops the external feed mechanism by cutting off the current from the lines L¹ and 270 through the upper leg of the switch 233, and also energizes the solenoid 211 starting the table 25 to the left by connecting the solenoid 211 through the lower leg of the switch 233 to the line 270 and the line L¹. As the internal wheel moves on the table back to the left it may again cross the truing device to complete the truing operation. As the wheel enters the hole, the internal feed mechanism resumes feeding by current from the line 229.

The internal wheel having been again applied to the internal surface of the workpiece for a finishing operation, while the external wheel is sparking out, the slide 204 approaches closer to the air gage nozzle 250 causing the pressure in its air line to rise, as above described, to a point at which the bellows 253 overcomes the opposing bellows 234 and opens the switch 235. It will be seen that this is a differential pressure arrangement which co-operates with the external air gage nozzle 230.

If the outer diameter of the workpiece is comparatively small as the result of some inaccuracy or because the action of the external wheel sparking out causes variations in outer diameters of various workpieces, which as above described may not need to be finished to such close tolerances as the inner surfaces, pressure in the nozzle 230 and its bellows 234 will be comparatively high due

to closer proximity of the outer workpiece surface to the nozzle 230, and therefore higher pressure will be required in the bellows 253 to open the switch 235 against the bellows 234 and the slide 204 must consequently approach closer to the nozzle 250, causing the work support 201 to approach closer to the internal wheel in order to maintain the tolerance of the inner surface in a workpiece which has moved closer to the work support 201 because the outer diameter is smaller. In other words, the smaller the outer diameter the further the support 201 must be moved toward the center of the work to grind an inner surface having a predetermined diameter.

When the switch 235 is opened, as has been described, the circuit from the line L¹ to line 270 is broken, de-energizing the solenoid 211 and causing the table 25 and internal wheel to move out to the right, withdrawing the internal wheel from the work and stopping its feed.

When the finished workpiece is unloaded, the mechanism cannot be operated but is in position to repeat the cycle and ready to operate when a new piece is seated in the work supports 201 and 203.

One advantage of the air gage 230 is that it is a non-contacting type of gage and may not be damaged by new work dropped into the supports by the usual work loading means. However, this advantage may not always be necessary, and Fig. 8 shows a modified form of gage which may be substituted. It comprises a feeler arm 300 supported by a pair of reeds 301 and 302 on the opposite side of the workpiece 14a from the supports 201, 203. Its rear end 303 cooperates with an air gage nozzle 230' in such a manner that reduction of the outer diameter of the workpiece causes the rear end 303 to approach the nozzle and to raise the pressure therein in the same manner. Such a gage is associated with the fixed work support shoes but not located between them as is the gage 230.

It will be understood that the machine described is capable of grinding cylindrical as well as tapered workpieces and may be adapted to grind a rib surface or other external surface which is independent of the external surface upon which the workpiece is supported. In some cases the use of three or more grinding wheels may be employed.

We claim:

1. In a machine for grinding inner and outer surfaces of a round workpiece and in combination, a centerless support for the workpiece, said support having at least two circumferentially arranged radially fixed support elements defining a support-determined axis for a workpiece of predetermined size and adapted to make contact with an external surface of a said workpiece thereby to locate said workpiece with respect to said axis during a grinding operation, an external abrading tool and an internal abrading tool both movable relative to said support for application to said respective workpiece surfaces, means to feed each of said tools relative to said support, and means to control the feed means automatically operable to move said tools simultaneously relative to said support and to bring said external tool first to a finished grinding position, and thereafter and in response to said movement of the external tool, to move said internal tool to a finished grinding position.

2. In the combination as set forth in claim 1, means including a back-plate having a work engaging face in a plane normal to said axis and rotatable eccentrically to said axis to hold the workpiece against said support.

3. In the combination as set forth in claim 1, means including a rotatable magnetic back-plate having a work engaging face in a plane normal to said axis to position the workpiece axially relative to said support.

4. In a machine for grinding inner and outer surfaces of a round workpiece and in combination, a centerless support for the workpiece, said support having at least two circumferentially arranged radially fixed support elements defining a support-determined axis for a work-

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piece of predetermined size and adapted to make contact with an external surface of a said workpiece thereby to locate said workpiece with respect to said axis during a grinding operation, an external abrading tool and an internal abrading tool both movable relative to said support for application to said respective workpiece surfaces, means to feed both said tools relative to said support, and means to control the feed means operable to move said external tool to a finished grinding position and including a gage for said external surface positioned between and cooperating with said support elements, said gage being responsive to the movement of the external tool and operable thereafter to move said internal tool to a finished grinding position.

5. In the combination as set forth in claim 4 said means to control the feed means being operative to feed said tools relative to said support only in response to the contact of a said workpiece with said support.

6. In a machine for grinding inner and outer surfaces of a round workpiece and in combination, a centerless support for the workpiece having at least two circumferentially and radially spaced fixed support elements defining a support-determined axis for a workpiece of predetermined size and arranged to locate said workpiece with respect to said axis during a grinding operation, an external abrading tool and an internal abrading tool both movable relative to said support for application to said respective workpiece surfaces, means to feed both said tools relative to said support, and control means for said feed means including first means for gaging and controlling the movement of said external abrading tool relative to said support, second means for gaging the movement of said internal abrading tool relative to said support, and means responsive to both said gaging means for controlling the movement of said internal tool relative to said support.

7. In the combination as set forth in claim 6, said first means comprising a gage positioned in radial and circumferential spaced relation relative to said support elements.

8. In the combination as set forth in claim 6, said

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means to control the feed means being operative in response to said first gaging means to feed said tools relative to said support only in response to the contact of a said workpiece with said support.

9. In the combination as set forth in claim 1, said feed means being arranged to feed the internal tool relatively from a position opposite one of said support elements and in a path toward said element, and to feed said external tool relatively along a path closely adjacent said element.

10. In the combination as set forth in claim 9, the other said support element being arranged substantially opposite to and in said path of said external tool.

11. In the combination as set forth in claim 1, the said support elements comprising at least one shoe having an arcuate surface and arranged to assume a position in which the said arcuate surface is substantially concentric with said support-determined axis thereby slidably to conform with said external workpiece surface.

12. In the combination as set forth in claim 1, said control means including mechanism first to produce sole movement of said external tool relative to said support and thereafter, in response to said initial movement, to move said tools simultaneously, as set forth.

13. In the combination as set forth in claim 1, means operative in response to said movement of the external tool to true the internal tool prior to the movement of the said internal tool to said finished grinding position.

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