

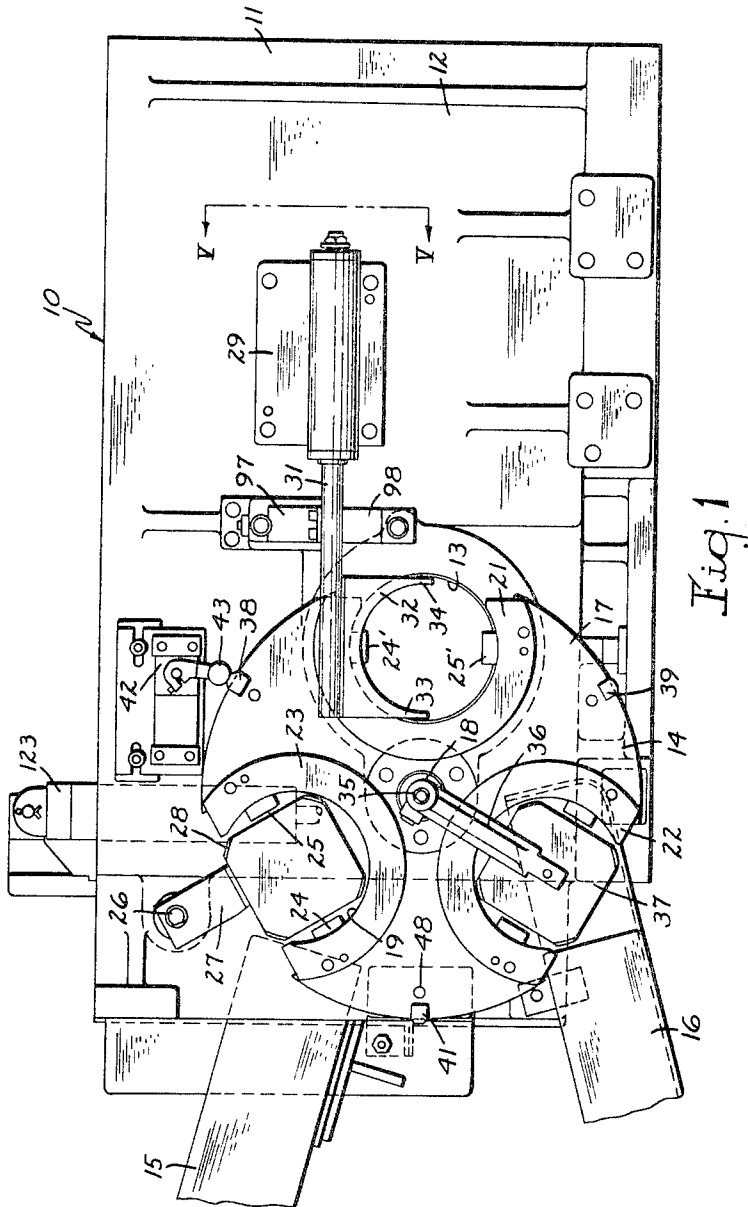
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R. S. HAHN ET AL
GRINDING MACHINE

3,269,063

Filed Jan. 17, 1964

5 Sheets-Sheet 1



INVENTORS
Robert S. Hahn
BY George H. Lockwood
Thomas S. Blodgett
Attorney

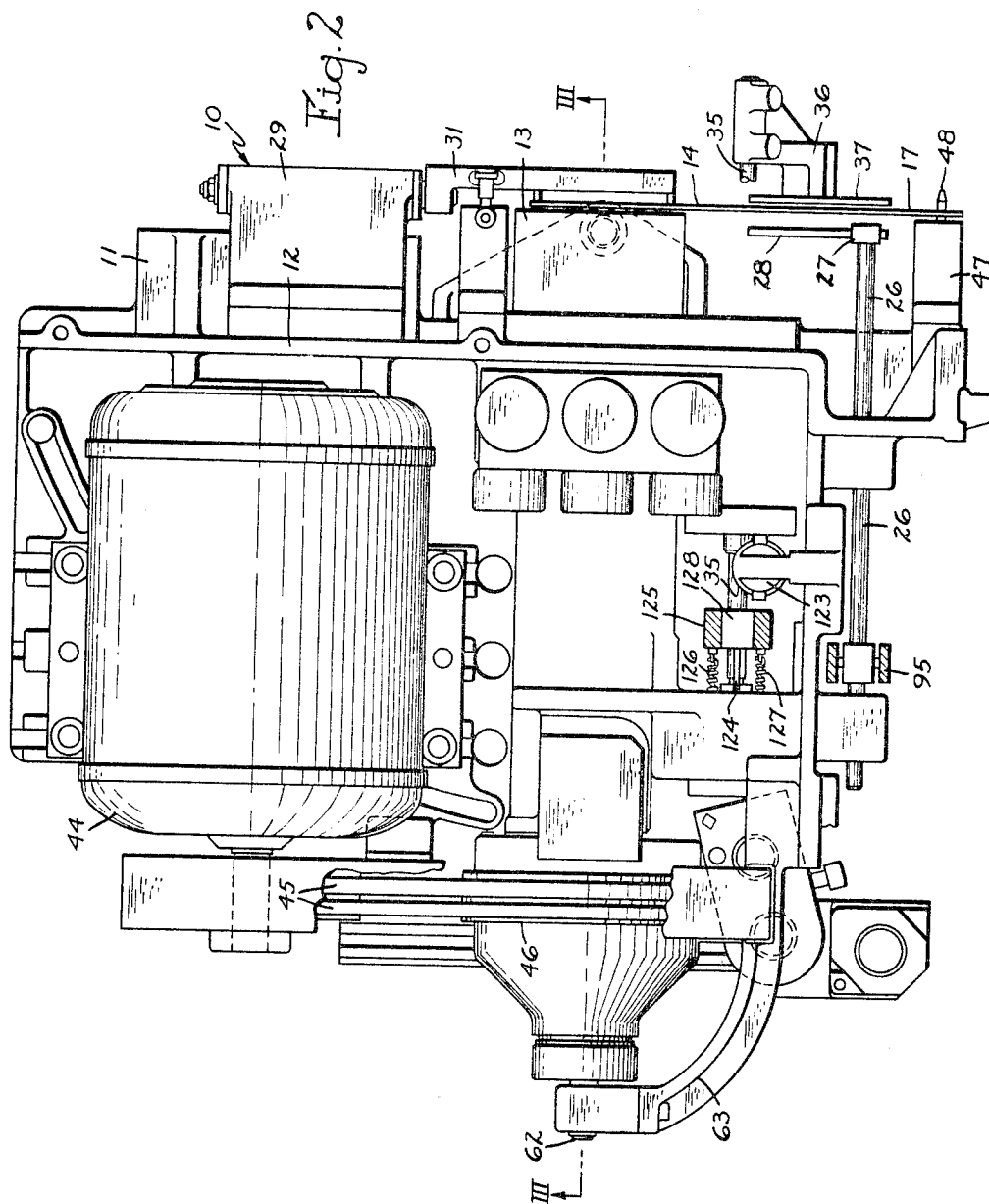
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INVENTORS
Robert S. Hahn
BY George H. Lockwood
Thomas S. Blodgett
Attorney

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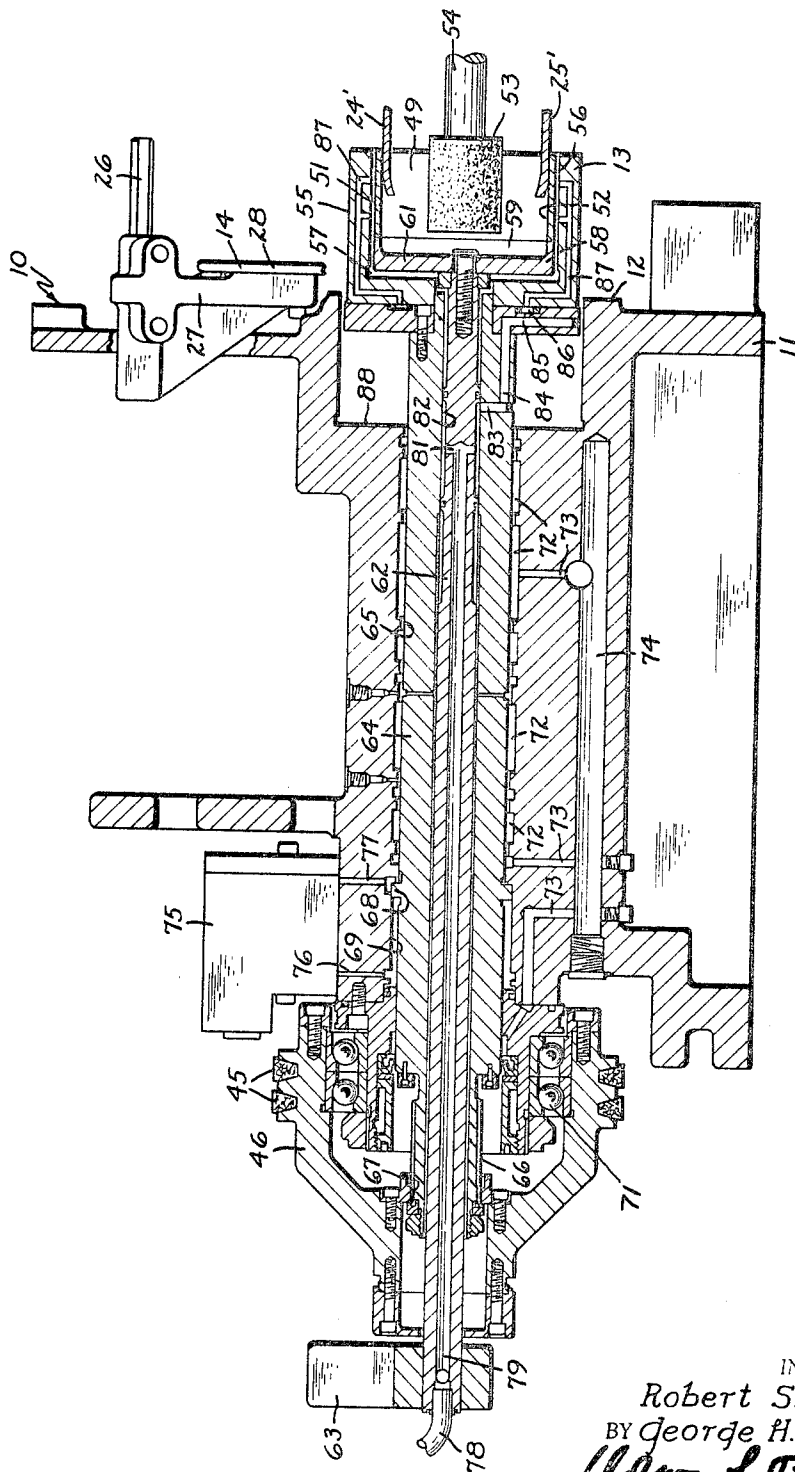


Fig. 3

INVENTORS
Robert S. Hahn
BY George H. Lockwood
Edmund S. Block
Attorney

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GRINDING MACHINE

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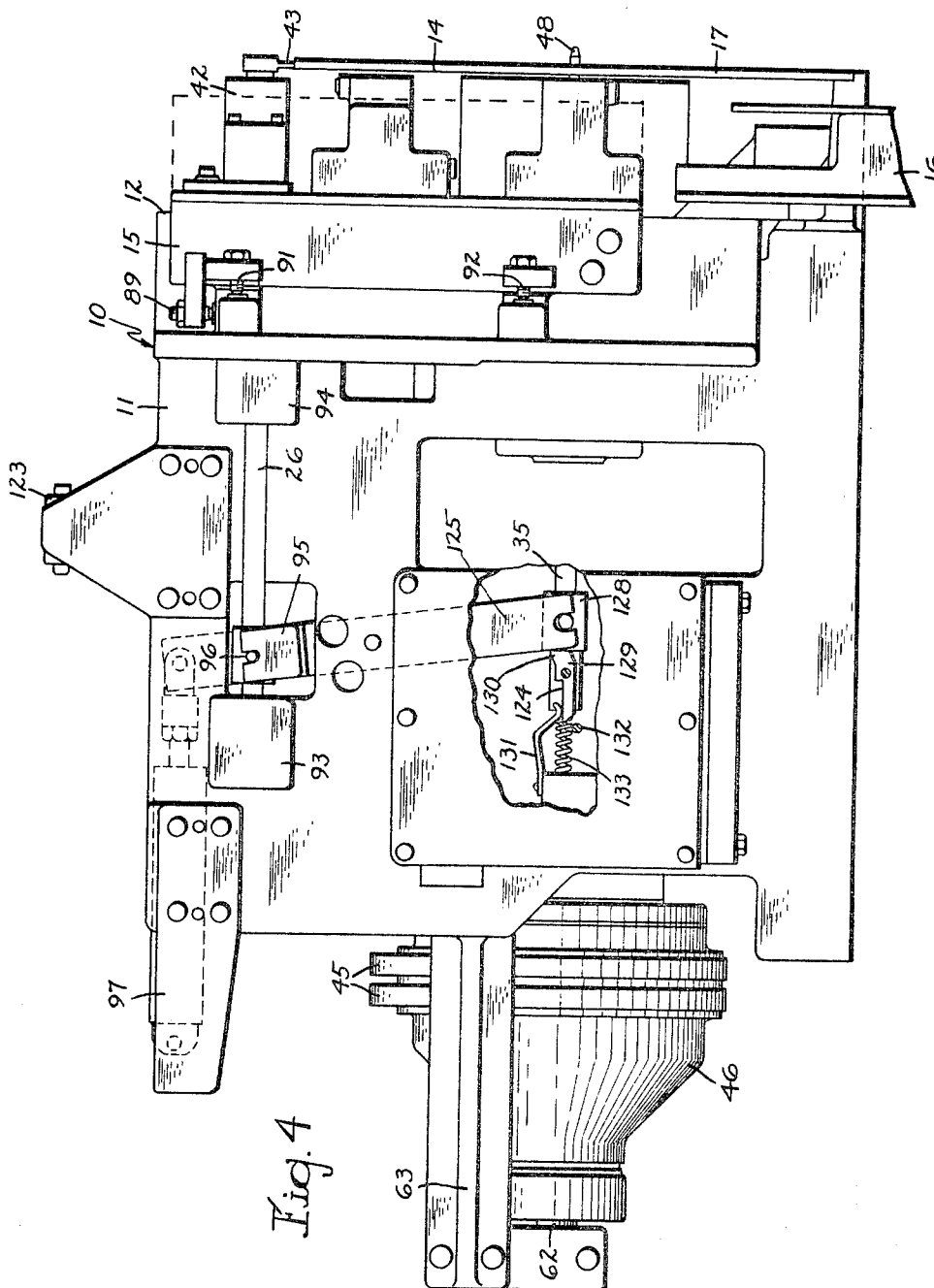


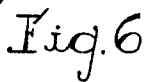
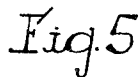
Fig. 4

INVENTORS
Robert S. Hahn
BY George H. Lockwood
Edmund S. Blodgett
Attorney

Filed Jan. 17, 1964

GRINDING MACHINE

5 Sheets-Sheet 5



Robert S. Hahn

BY George H. Lockwood

Wm. S. Bloch
Attorney

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3,269,063

GRINDING MACHINE

Robert S. Hahn, Northbore, and George H. Lockwood, Worcester, Mass., assignors to The Heald Machine Company, Worcester, Mass., a corporation of Delaware
Filed Jan. 17, 1964, Ser. No. 338,332
11 Claims. (Cl. 51—48)

This invention relates to a grinding machine and, more, particularly, to apparatus arranged to finish a surface of revolution by the abrasive process.

In the finishing of surfaces of revolution, and particularly in the grinding of the internal bore of an annular workpiece, there are substantial problems which exist in supporting the workpiece and in loading and unloading the workpiece in and out of the support. For instance, if a solid shoe is used with the workpiece, any irregularities on the outer surface of the workpiece are duplicated on the inner surface. Furthermore, the contact of a shoe or a roll with the outside surface of the workpiece may cause a scratching or pattern configuration on the outer support surface. Another difficulty that is experienced is that, when the outside diameter of the unfinished workpiece varies from piece to piece within a wide tolerance, it is very difficult to center the workpiece relative to the grinding wheel to obtain accurate grinding. These problems are particularly accentuated when (as in the case of the external race of a ball bearing) the tolerance on finish, tolerance on diameter, and out-of-round condition of the outer diameter is not too important to the operation of the bearing and, yet, the tolerance in all these respects on the inner bore must be quite good. This means that, when the outside surface is used for support, it is very difficult to obtain a better quality on the inside diameter. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a grinding machine having a means for supporting a workpiece for the finishing of a surface of revolution thereof, the grinding machine operating in such a manner as to avoid reproducing defects of the supporting surface on the surface to be finished.

Another object of this invention is the provision of a grinding machine for finishing an internal bore in an annular workpiece wherein variations in outside diameter are not reproduced on the inside diameter.

A further object of the present invention is the provision of a grinding machine for grinding annular workpieces, wherein the workpiece is supported on one surface of revolution and another surface of revolution is to be finished and wherein any roughness on the supporting surface is not reproduced on the surface to be finished.

It is another object of the instant invention to provide a grinding machine having a workpiece support means which does not scratch or damage the supporting surface of the workpiece and wherein the surface speed of the surface of the workpiece which is to be finished is accurately regulated.

It is a further object of the invention to provide a grinding machine having a fluid work-supporting device and including means for rapidly loading and unloading the said device with successive workpieces.

A still further object of this invention is the provision of a grinding machine having a workholding means with a simple and rugged workpiece loading and unloading mechanism.

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It is a still further object of the present invention to provide a grinding machine having a supporting means for annular workpieces in which the workpiece is automatically centered and is not likely to become uncentered during the grinding operation.

Another object of the invention is the provision of a grinding machine for the accurate finishing of surfaces of revolution of annular workpieces, which machine is simple in construction, inexpensive to manufacture, and is capable of a long life of useful service with a minimum of maintenance.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

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

FIG. 2 is a plan view of the grinding machine,

FIG. 3 is a vertical longitudinal sectional view of the machine taken on the line III—III of FIG. 2,

FIG. 4 is a side elevational view of the machine,

FIG. 5 is a partially-sectioned view of the machine taken on the line V—V of FIG. 1, and

FIG. 6 is a front elevational view of a portion of the machine.

Referring first to FIG. 1, wherein are best shown the general features of the invention, the grinding machine, indicated generally by the reference numeral 10, is shown as comprising a housing 11 having a generally vertical front surface 12. On this front surface are mounted a work-supporting apparatus 13 and a loading-and-unloading apparatus 14. Also fastened on the front surface 12 is an inlet chute 15 and an outlet chute 16.

The loading and unloading apparatus 14 is provided with a disc-like main body 17 which is rotatably mounted on a hollow shaft 18. This hollow shaft extends horizontally and longitudinally into the housing 11 and protrudes from the front surface 12. The main body is provided with three workpiece-holding stations 19, 21, and 22 which are spaced at 120° about the axis of the hollow shaft 18. The station 19 is typical and is shown as a partially circular cutout having an annular plate 23 mounted around its edge and provided with two opposed resilient fingers 24 and 25 which extend inwardly toward the front surface 12 of the housing; these fingers are elongated, resilient members and are best shown in FIG. 3 as fingers 24' and 25'. Extending from the front surface 12 of the housing is a shaft 26 on the outer end of which is keyed an arm 27 having at its lower end a broad pad 28. This pad is of generally rectangular configuration and is large enough to extend into the station 19 and occupy a substantial portion of its area without striking the fingers 24 and 25. The station 21 is shown as occupying a position overlying the work-supporting apparatus 13. Mounted on the front surface 12 of the housing is a horizontally-elongated journal block 29 in which is mounted a shaft 31 which extends as a cantilever away from the journal block and extends horizontally and generally parallel to the surface 12. This shaft lies outside of the plane of the disc-like main body 17 of the loading-and-unloading apparatus 14 and at its extreme free end is provided with a U-shaped pressure device 32 which, because of its configuration, has two depending fingers 33 and 34 spaced apart in such a way that they fit into the opening of the station 21 and into the work-supporting apparatus 13 in a manner to be described more fully hereinafter.

The hollow shaft 18 carries a shaft 35 in its bore and this shaft extends outwardly of the main body 17 and has keyed to it an arm 36 carrying at its outer end a pad 37 similar to the pad 28 associated with the arm 27. This pad is, of course, adapted to fit closely into the opening of the station 22 without engaging the resilient fingers. The arm 36, of course, must be configured so that it does not strike the main body 17 or the edge of the station 22 even when the pad 37 has been moved into the station opening. Mounted on the periphery of the main body 17 are cam members 38, 39, and 41 located midway between the stations 19 and 21, between the stations 21 and 22, and between the stations 22 and 19, respectively. Mounted on the front surface 12 of the housing 11 is a microswitch 42 having an actuating finger 43 which is located so as to be engaged by one of the cams 38, 39, or 41 as the main body 17 is rotated about the axis of its shaft 18.

Referring now to FIG. 2, which is a plan view of the grinding machine 10, it can be seen that an electric motor 44 is mounted on the housing 11 at one side of the axis of the work-supporting apparatus 13 and is connected by belts 45 to a pulley 46. The journal block 29 is clearly shown in this view, as is the shaft 31 which is rotatably carried in it. Extending from the front surface 12 of the housing is a cylinder 47 which is hydraulically operated and which has a piston rod formed with a pin 48 adapted, on occasion, to extend through apertures in the main body 17 of the loading-and-unloading apparatus 14 to lock it in place. Particularly evident in this figure is the pad 37 on its arm 36 which, in turn, is mounted on the shaft 35. Visible also is the shaft 26 carrying the arm 27 and the pad 28.

Referring now to FIGURE 3, it can be seen that a workpiece 49 is shown being held by the work-supporting apparatus 13; the workpiece is shown as being of annular configuration having an outer surface 51 and an inner surface 52 which is to be finished by an abrasive wheel 53 which is mounted on a spindle 54. The spindle is, of course, mounted on the usual workhead permitting it to be rotated and to be fed laterally and longitudinally relative to the axis of the rest of the apparatus. The workpiece is shown as held in a cup 55 having a smooth bore 56 which is only slightly larger than the outside surface 51 of the workpiece 49, as will be more fully described hereinafter. The bore is provided with a relief groove 57 located adjacent its bottom and this permits a backing plate 58 to reside against the bottom surface of the cup, if need be. The backing plate is generally disc-like but is provided with a counterbore 59 defining a forwardly-extending peripheral flange 61 which engages the inner end of the workpiece. The backing plate 58 is mounted on one end of a rod 62, the other end of which is attached to a bracket 63. This bracket (as is evident in FIG. 2) extends around the pulley 46 and is attached to the side of the housing 11, so that the rod 62 is held against longitudinal and rotative movement relative to the housing 11.

The rod 62 is carried in the bore of a hollow shaft 64 which is attached at one end to the cup 55 and is carried in a bore 65 formed in the housing 11. The end of the shaft 64 opposite the cup 55 is provided with splines 66 which extend longitudinally of the shaft a substantial distance and these splines engage female splines 67 formed on the inside of the pulley 46 so that power is transmitted from the belts 45 through pulley 46 to the hollow shaft 64. The shaft 64 is provided with an outwardly-extending flange 68 which slides smoothly in a counter bore 69, so that the flange 68 and the bore 69 act as the piston and cylinder of a hydraulic linear actuator. A suitable ball bearing 71 is mounted in the housing 11 to support the pulley 46. The surface of the bore 65 which extends through the housing 11 is provided with a series of shallow pockets 72 to which are connected passages 73 which lead

hydrostatic oil from a main oil passage 74 for supporting the hollow shaft 64 on hydrostatic bearings. Mounted on the top of the housing is a hydraulic valve 75 which is connected to the opposite ends of the counterbore 69 by passages 76 and 77 to lead oil to opposite sides of the flange 68 to produce longitudinal movement of the shaft 64. A conduit 78 connected to a source (not shown) of 600W viscous oil under pressure is connected to a passage 79 extending longitudinally through the rod 62 and terminating in a cross passage 81. This cross passage leads outwardly to a relief groove 82 formed on the inner surface of the hollow rod 64 and having a length approximately equal to the stroke of the flange 68 and the counterbore 69 operating as a piston and cylinder. This relief groove, therefore, is always in communication with a radial passage 83 formed in the hollow sleeve 64 and connected to a longitudinal passage 84 which, in turn, is connected to a radial passage 85 formed at the rear of the cup 55. The passage 85 is connected to an annular passage 86 extending entirely around the axis of the cup 55 and connected by a number of small passages 87 leading to the inner bore surface 56 of the cup 55 to supply hydrostatic lubrication between the surface 56 and the outer surface 51 of the workpiece 49. The housing 11 is provided with a counterbore 88 to provide a space for the cup 55 when the hollow shaft 64 is moved to the left.

FIGURE 4 shows the manner in which a supporting flange of the inlet chute 15 is attached to the housing 11, the main part of the chute being shown in dotted lines. A number of adjusting screws 89, 91, and 92 are provided to give accurate adjustment of the chute relative to the pickup station 19. The shaft 26 is shown as slidably supported in abutments 93 and 94 which extend from the side of the housing 11 and as operated by a yoke 95 engaging a pin 96 which extends from the side of the shaft 26. This yoke is actuated by a hydraulic cylinder 97 mounted at the top of the housing 11.

Referring now to FIGURE 5, it can be seen that the rod 31 is slidably carried in the journal block 29 and is provided in its intermediate portion with an upstanding finger 97 and a downwardly-depending finger 98. The upper finger is provided with a hardened metal pad 99 which is in position to be engaged by the piston rod 101 of a hydraulic cylinder mounted in the housing 11. An adjusting screw 102 is mounted in an abutment 103 extending from the front surface 12 of the housing and has its head lying in position to be engaged by the pad 99 of the finger 97 to limit the outward motion due to the action of the piston rod. The lower finger 98 has attached to it a small block 104 having a bore 105 in which is slidably mounted a piston 106. This piston has a rod 107 which extends outwardly at the rear of the block 104 and is in position to engage a hardened metal pin 108 which extends forwardly and is fixedly mounted in the housing 11. Within the bore 105 is a coil spring 109 which extends between the piston 106 and a plug 111 threaded into the entrance to the bore 105. Also evident in this view is the manner in which the U-shaped pressure device 32 is provided with its rearwardly-directed finger 34.

FIGURE 6 shows the mechanism for indexing the loading-and-unloading apparatus 14. Inside of the housing the hollow shaft 18 is keyed to a ratchet wheel 112 having only three teeth 113, 114, and 115. These teeth are engaged successively by a pawl 116 which is pivoted to a block 117 by means of a pivot pin 118. The pawl 116 is biased toward the axis of the shaft 18 by a coil spring 119 extending between the outer end of the pawl and the block 117. The pawl is provided with a single right-angled tooth 121 for engaging the teeth of the ratchet wheel 112. The block 117 is pivotally mounted on the shaft 18 and, on occasion, is so pivoted by the piston rod 122 of a cylinder 123, this cylinder being evident in FIGS. 1, 2 and 4.

Referring now to FIGURE 2, the manner is shown by which the shaft 26 is connected to the yoke 95. Also

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evident in this figure is the manner in which the shaft 35 is provided with a trigger mechanism 124 at the central portion of the housing 11. A yoke 125 is operated by the same cylinder as the yoke 95, i.e., the cylinder 97; both yokes are biased to the rear of the housing by coil springs 126 and 127. The yoke 125 is connected to the shaft 35 to move the pad 37 rearwardly at the same time that the shaft 26 is moving forwardly with the pad 28. The yoke 125 is connected (as is particularly evident in FIG. 4) by a pin to a block 128. This block is slidable on the shaft 35. Now, pivoted in a slot in the end of the shaft 35 is a trigger 129 forming part of the trigger mechanism 124. This trigger is pivoted and is normally biased by a leaf spring 131 to such a position that a finger 130 extends above the surface of the rod 35 and stops the rod 35 from sliding relative to the block 128, so that, as the yoke and block move to the left, they carry the rod 35 with it. Eventually, an inclined surface on the left end of the trigger 129 strikes a pin 132 and lifts that end of the trigger upwardly while lowering the other end. This causes the finger 130 to disappear in the slot in the rod. This, in turn, causes a coil spring 133 to operate on the rod 35 and push it to the right. The effect is to allow the rod 26 to remain in its extended position to the right, while the rod 35 proceeds to the right immediately rather than remaining to the left. This permits the pad 37 to leave the station 22 of the loading-and-unloading mechanism so that the main body 17 may be indexed, while the pad 28 remains pressed against the workpiece which rests on the fingers 24 and 25. Permitting the pad 28 to remain in place against the workpiece in this manner assures that the subsequent unfinished workpieces lying in the chute 15 are not allowed to roll downward into position to be loaded. In other words, the pad 28 acts as a release mechanism to permit a new workpiece to roll into place in front of the loading station 19 ready to be pushed onto the fingers 24 and 25 by the pad 28.

In the preferred embodiment, the oil which is supplied to the work support is of 600W viscosity and is supplied at 90 p.s.i. The backing plate and cup are arranged with the workpiece so that workpiece lags behind the rotation speed of the cup by 20 to 40 r.p.m. The cup utilizes the viscosity of the thick fluid to drive the workpiece. The fluid is supplied through a set of hydrostatic restrictors consisting of the passages 87 which are of small diameter. The clearance between the cup and the workpiece is in the range from .001 to .003 inch. The hydrostatic bearing operated in this manner tends to centralize the workpiece in the chuck. When grinding takes place, torque is applied by the abrasive wheel 53 to the workpiece 49 which causes a slip speed, N_1 , to occur. According to the present invention, it is preferable to employ a stationary backing plate to assist in producing this slip speed. In this way, a bias torque is imposed on the workpiece which causes a continuous slippage to take place. This slippage improves the concentricity of the ground bore with the O.D. of the workpiece and also suppresses to some degree eccentricity and bearing errors in the cup and in the workhead itself. The cup can also accommodate reasonable O.D. size variations, thereby permitting accurate internal grinding by the method of grinding which involves determining the final grinding position of the wheel by dressing the wheel to a known plane and then feeding the wheel laterally by a known amount. This method of accurate grinding is not possible, of course, where the workpiece is not accurately centered. This cup permits high workhead speeds to be attained in the "conventional" sense, i.e., with the workpiece rotated in opposition to the wheel, and "climb" grinding is also possible.

Another important feature of the workholding apparatus is the absence of copying of defects in the outside diameter of the workpiece. Lobes on the outside diameter are not copied appreciably. It is interesting to note that non-magnetic workpieces may be driven by this method, since no magnetism is required to drive the work-

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piece. It should be noted that a pure hydrostatic support of the workpiece in this mechanism would present considerable problems because of the necessity that the capillary passages opening onto the bearing area be very small and would be easily clogged by foreign matter in the capillaries. In the present invention, the passages are used in the order of .062" in diameter and, although the hydrostatic bearing effect is not as great, the slip speed between the workpiece and the cup is great enough to produce a substantial hydrodynamic film between the workpiece and the cup. Experimental procedure indicated that a purely hydrostatic workholder has a film which will break down under a certain load, whereas the hydrodynamic situation means that the cup will tend to hold the size of the workpiece better than a purely hydrostatic cup because small changes in grinding forces will not cause large non-linear size changes. Furthermore, the hydrodynamic chuck represented by the present invention is more immune to changes in the clearance between the workpiece and the cup than would be true of a purely hydrostatic chuck. Larger clearances in this area are possible which would mean that greater O.D. size variations can be tolerated without the finished bore size changing measurably. This cup is operated at a relatively low pressure of oil (25 lbs.) to conserve the oil. However, the load-carrying capacity of the cup can be increased at the expense of increased oil consumption by increasing the oil pressure. This cup has an appreciable centering action on the part until a slip speed is present between the workpiece and the cup. This slip speed is caused by the dragging action of the backing plate 58 on the workpiece as well, of course, as the operation of the grinding wheel on the inside surface of the workpiece.

The operation of the apparatus will now be readily understood in view of the above description. Workpieces enter the machine by rolling down the chute 15 and remaining stacked against one another with the bottom workpiece resting against the edge of the pad 28 which prevents it from going any further or from leaving the chute. At the beginning of a cycle, the rod 26 is drawn rearwardly by the cylinder 97 so that a new workpiece 49 can roll down the chute 15 into alignment with the station 19 in the loading and unloading apparatus 14. Eventually, the cylinder 97 will be energized in the other direction so that the rod 26 moves to the right (in FIG. 4) and the pad 28 pushes the workpiece onto the fingers 24 and 25 and remains there holding the workpiece on the fingers so that it cannot fall off. Other workpieces in the chute 15 are maintained up in the chute and cannot roll down because they strike the edge of the pad 28. With a workpiece in the loading position 19 the cylinder 123 is energized and this causes the piston rod 122 to operate through the pawl 116 to rotate the ratchet wheel 12 and, therefore, rotate the hollow shaft 18. This causes the main body 17 to rotate 120° so that the position labeled 19 in FIG. 1 now occupies the former position of station 21. At that time, the workpiece is aligned with the cup 55 which, incidentally, is in the left-hand position with the cup 55 well within the counterbore 88 in the housing. This means that the backing plate 58 has its forward flange or lip in the plane of the outer edge of the cup 55. The workpiece is thus in line with both of them. Then, oil is admitted to the left-hand side of the flange 68 so that the hollow sleeve 64 moves to the right and carries the cup 55 with it. The cup envelops the workpiece. At that time, a cylinder operates the piston rod 101 which moves forward striking the finger 97 and rotating the shaft 31 so that the fingers 33 and 34 move inwardly through the opening in the main body 17 and strike against the outboard end of the workpiece 49. The workpiece is thus pressed tightly against the backing plate 58. The motor 44 operates continuously and by driving the belts 45 rotates the pulley 46 which operates through the splines 67 and 68 to rotate the hollow shaft 64. The cup 55, therefore, rotates continuously whether

a workpiece is in place or not and regardless of whether the cup is in operative or inoperative position. Oil is supplied to the inner surface of the cup, the oil originating in the conduit 78 and passing through the passage 79 and the passage 81 into the groove 82, into the passage 83, through the passages 84 and 85, and then through the capillary passages 87 to the inner surface of the cup. A hydrodynamic and hydrostatic film immediately builds up between the inner surface 56 of the cup 55 and the outer surface 61 of the workpiece 49. The abrasive wheel 53 moves inwardly and performs the grinding operation on the inner surface 52 of the workpiece in the usual manner. When the grinding operation has been completed, the cup 55 is withdrawn into the counterbore 88 by providing oil through the passage 77 behind the flange 68, so that the hollow shaft 64 moves to the left in FIG. 3. The fingers 24' and 25' remain in the workpiece and support it in the station 21 even though the cup 55 has been removed. When the loading and unloading apparatus 14 is again rotated by the operation of the cylinder 123, this station (with the workpiece in question) moves down to the position where the station 22 is in FIG. 1. This is the unloading station and, at that time, the shaft 26 is moved to the left by the cylinder 97 and causes the pad 37 to press the workpiece from the resilient fingers so that it falls downward into the chute 16 and passes on.

Because it is necessary for the pad 28 to remain pressed against the workpiece to prevent new workpieces from rolling down the chute 15 into the mechanism, while it is at the same time necessary to remove the pad 37 from the station as soon as it has pressed the workpiece from the fingers (this being necessary because the pad 37 cannot remain in the station while the loading and unloading mechanism is being indexed), means is provided for causing the shaft 35 to return almost immediately to its original position while the shaft 26 remains in its right-hand position against the workpiece in the loading station. This is done by causing the block 128 to press against the trigger 129 and thus carry the shaft 35 to the left. When the trigger 129 hits the pin 132, however, its finger 132 is drawn down into the slot in the rod 35 so that the rod is free to slide in the opposite direction under the impetus of the spring 133, so that the pad 37 is immediately withdrawn, while the pad 28 remains in place.

Referring to FIG. 5, it can be seen that the ultimate motion of the fingers 33 and 34 is controlled by the adjustment of the screw 102. The spring 109, however, absorbs the shock of quick rotation of the shaft 31 so that the fingers may be pressed against the workpiece with a pre-determined pressure, the screw 102 being normally adjusted so that it only acts as a limiting element, the pressure of the spring 109 (which is adjusted by means of the plug 119) determining the pressure of the fingers 33 and 34 against the end of the workpiece.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. A grinding machine for finishing a surface of revolution of an annular workpiece, comprising

- (a) an abrasive wheel adapted to be rotated and to engage the said surface of revolution for finishing the same,
- (b) a supporting member adapted to extend around a surface of revolution of the workpiece with a small clearance,
- (c) a fixed plate adapted to engage a radial surface of the workpiece,
- (d) means supplying a viscous fluid to the clearance between the supporting member and the workpiece, and

(e) means for rotating the supporting member.

2. A grinding machine for finishing a surface of revolution of an annular workpiece, comprising

- (a) an abrasive wheel adapted to be rotated and to engage the said surface of revolution for finishing the same,
- (b) a cup adapted to extend around an external surface of revolution of the workpiece with a very small clearance,
- (c) a non-rotating backing plate adapted to engage a radial surface of the workpiece,
- (d) means supplying a viscous fluid to the clearance between the cup and the workpiece, and
- (e) means for rotating the cup.

3. A grinding machine as recited in claim 2, wherein the said clearance is in the range from .0005 inch to .0015 inch.

4. A grinding machine as recited in claim 2, wherein the workpiece lags behind the cup in its rotation by a slip speed in the range from 20 to 40 r.p.m. whereby a hydrodynamic film of fluid is formed to support the workpiece.

5. A grinding machine as recited in claim 2, wherein the cup is selectively movable axially of the surface of revolution from a first position wherein the backing plate lies inwardly of the cup to a second position wherein the backing plate lies adjacent the mouth of the cup to eject a workpiece.

6. A grinding machine as recited in claim 2, wherein the cup is mounted on one end of a tubular spindle, the other end of which is driven, and the backing plate is mounted on one end of a rod which extends through the tubular spindle and is held against rotation and axial movement by a bracket attached to the other end.

7. A grinding machine for finishing a surface of revolution of an annular workpiece by means of an abrasive wheel adapted to be rotated in one direction and to engage the said surface of revolution for finishing the same, comprising

- (a) a housing,
- (b) a supporting member mounted in the housing adapted to extend around a surface of revolution of the workpiece with a very small clearance,
- (c) a fixed plate mounted in the housing adapted to engage a radial surface of the workpiece and on occasion to eject a workpiece from the supporting member,
- (d) means supplying a viscous fluid to the clearance between the supporting member and the workpiece,
- (e) means for rotating the supporting member in a direction contrary to the said direction of rotation of the wheel, and
- (f) a loading and unloading apparatus mounted on the housing and adapted to introduce a workpiece into the supporting member and to receive the workpiece when ejected.

8. A grinding machine as recited in claim 7, wherein the loading and unloading apparatus includes a disc-like main body mounted on the housing for rotation about an axis through its own center and spaced from and parallel to the axis of rotation of the supporting member, the main body having three workpiece-holding stations equally spaced about the axis and adapted successively to overlie the supporting member.

9. A grinding machine as recited in claim 8, wherein the loading and unloading apparatus includes a first arm for introducing a workpiece to one of the said stations from an inlet chute, a second arm for pressing a workpiece from another station into the supporting member, and a third arm for introducing a workpiece from the third station into an outlet chute.

10. A grinding machine as recited in claim 9, wherein the first and second arms are mounted at the ends of horizontal operating shafts and are movable simultaneously in opposite directions to move the arms from an original position toward the main body to workpiece-

engaging positions and wherein a release means is provided to cause the third shaft and arm to return immediately to the original position while the first arm and shaft remain in the workpiece-engaging position.

11. A grinding machine for finishing a surface of revolution of a workpiece, comprising 5

(a) an abrasive wheel adapted to be rotated and to engage the workpiece for finishing the same,

(b) a supporting member adapted to extend around a substantial portion of a surface of revolution of the workpiece with a very small clearance, 10

(c) means supplying a viscous fluid to the clearance between the supporting member and the workpiece, and

(d) means for rotating the supporting member.

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LESTER M. SWINGLE, *Primary Examiner*.