Oct. 2, 1962

R. S. HAHN

3,056,238

GRINDING MACHINE

Filed June 24, 1960

3 Sheets-Sheet 1

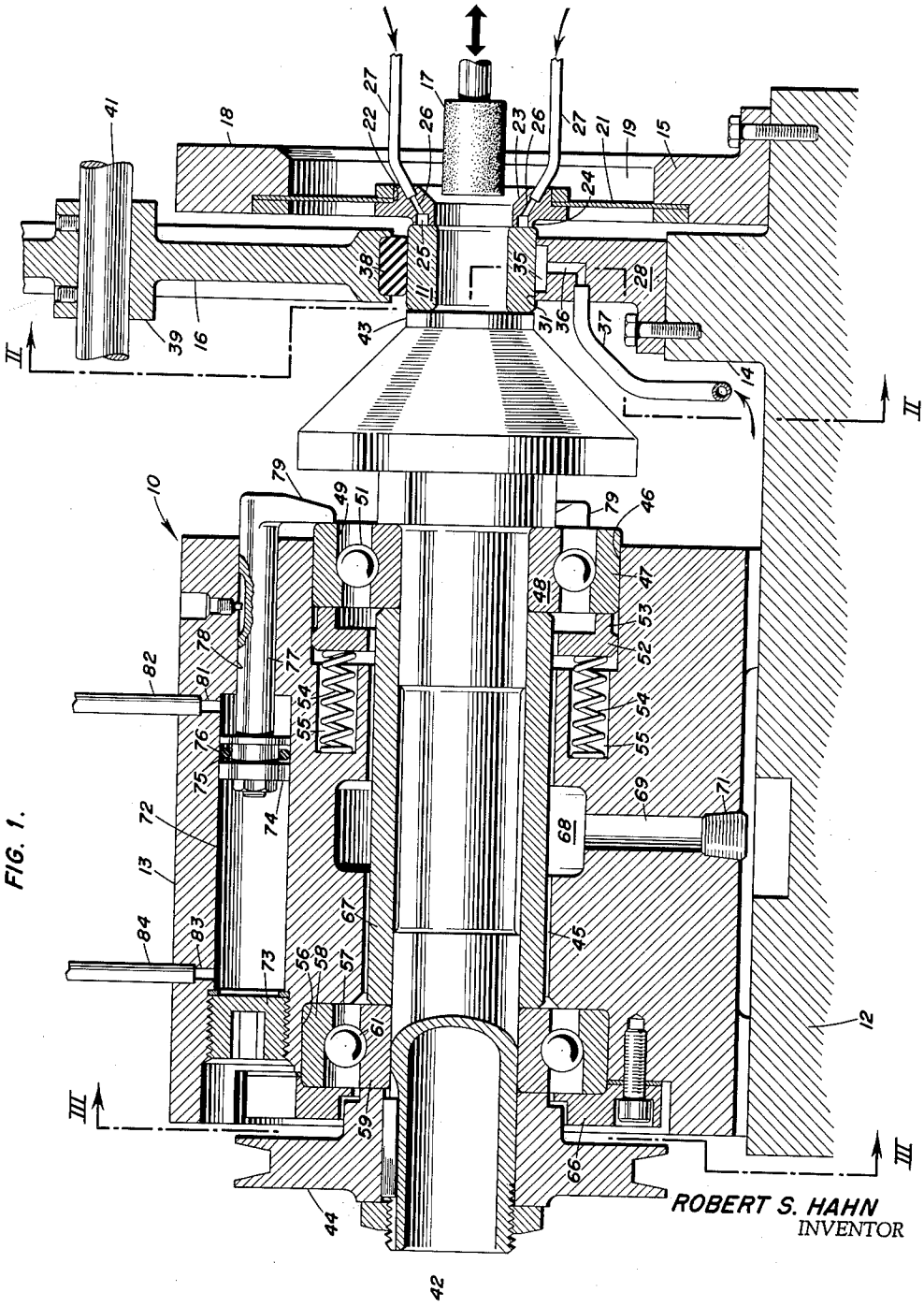


FIG. 1.

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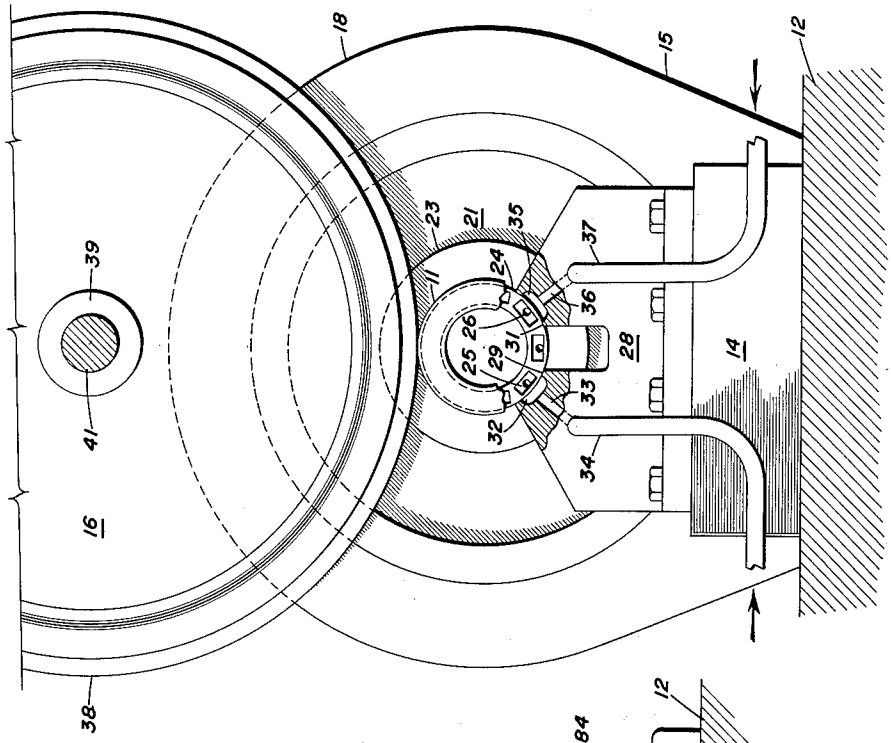


FIG. 2.

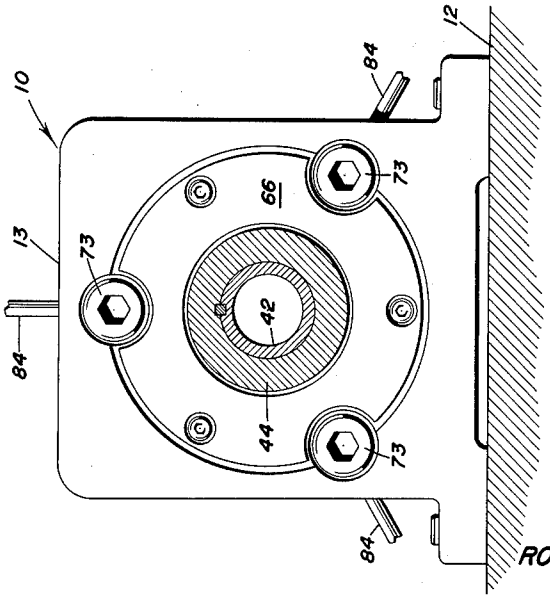


FIG. 3.

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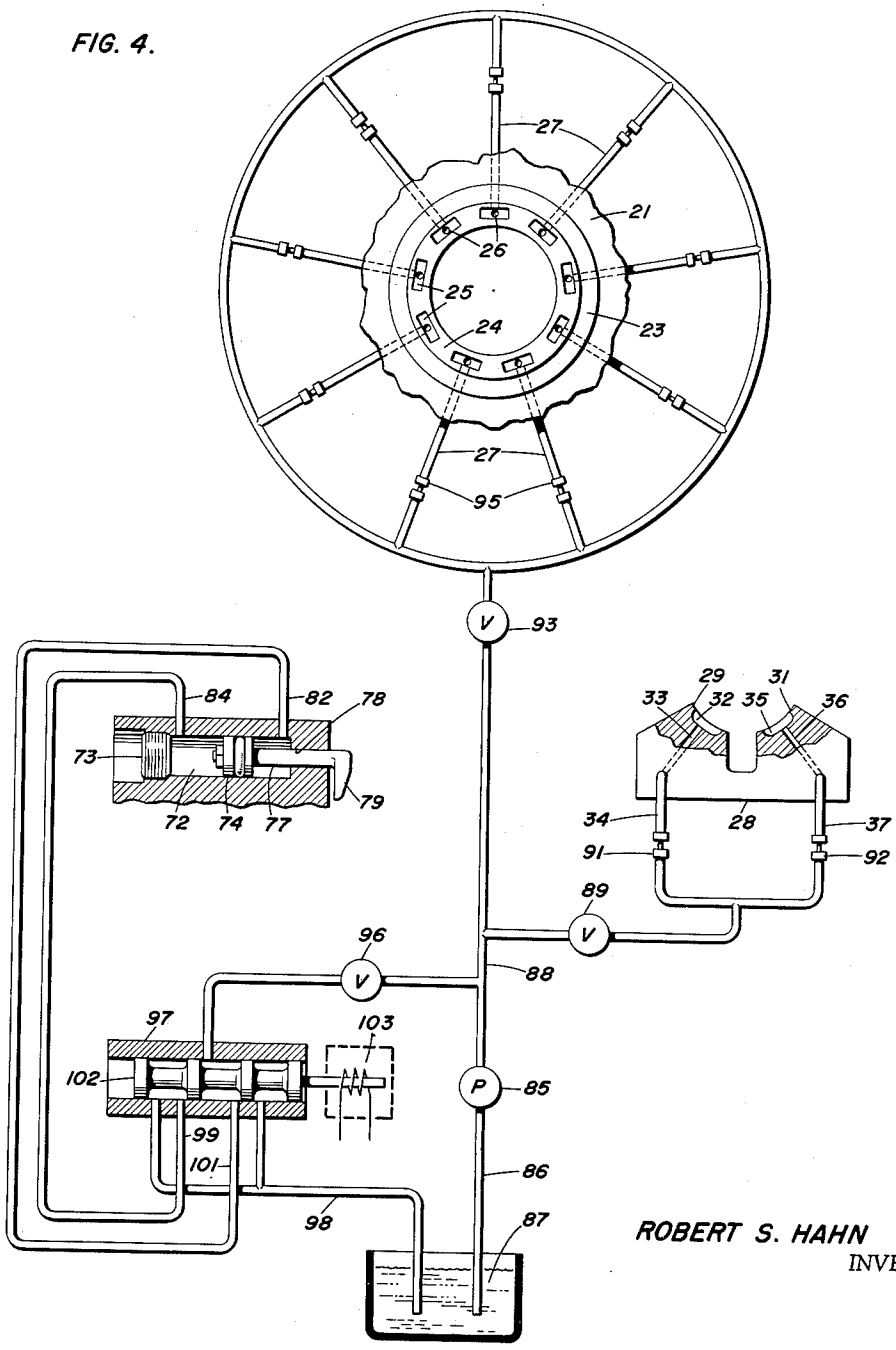
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GRINDING MACHINE

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FIG. 4.



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3,056,238
GRINDING MACHINE

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Filed June 24, 1960, Ser. No. 38,604
16 Claims. (Cl. 51—103)

This invention relates to a grinding machine and more particularly to apparatus arranged to finish a surface of revolution by abrasion.

In the finishing of cylindrical surfaces and the like by grinding, it is common practice, particularly in the so-called "centerless" grinding technique, to clamp the workpiece at its ends between two members while its periphery is held in a supporting apparatus such as a set of shoes. Usually, one of the clamping members is driven to rotate the workpiece while the abrasive wheel is held against the surface to be finished. For extremely accurate grinding, particularly when the workpiece is of a thin-walled variety, the stresses set up in the workpiece by the clamping members and the supporting apparatus can bring about irregularities in the form of the surface generated by the grinding operation. Analyses of the forces which exist between the backing plate, the workpiece, the abrasive wheel, and the supporting shoes have been made; the backing plate forces have been studied particularly for two commonly-encountered special cases: first, where the work contacts the backing plate at three equally spaced points and, secondly, where contact is made at only two diametrically opposite points. This type of two- or three-point contact between the end of the workpiece and the backing plate takes place because of irregularities in manufacture of the end surfaces. In most workpieces, such as a race of a ball bearing, the end surfaces need not be finished with extreme accuracy, so that such irregularity of contact with the clamping plates is quite possible. Theoretical studies of the two- and three-point situation indicate that large speed fluctuations occur under this type of contact condition. Also, excessive variations in the skewing force which urges the work into the supporting shoes may also occur under certain conditions. This would appear to be the cause for a two-lobed and a three-lobed bore. Furthermore, in the previously-known centerless internal grinding machines, it has been necessary to have considerable friction between the supporting shoes and the periphery of the workpiece; otherwise, the abrasive wheel would speed up the workpiece well beyond the speed of the driving plate. This action would, of course, reduce the difference in speeds between the abrasive wheel and the workpiece, leading to inefficient grinding. At very high speeds, even the friction of the supporting shoes has not been sufficient to prevent such action and this has been a limiting factor preventing grinding at the more efficient high speeds. 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 in which irregularities in the finished surface are eliminated.

Another object of this invention is the provision of a centerless grinding machine in which variations in driving friction force on the workpiece are reduced to a minimum.

A further object of the present invention is the provision of an internal grinding machine in which the ends of the workpiece are clamped between plates and driven and the periphery is supported on shoes in which irregularities in contact between the end of the workpiece and the backing plate do not bring about irregularities in the formation of the finished bore.

It is another object of the instant invention to provide an internal centerless grinding machine having an outboard clamping plate of novel construction.

It is a further object of the invention to provide an internal centerless grinding machine having shoes for supporting the periphery of the workpiece, which shoes present relatively little friction force on the workpiece, which will not score the external surface of the workpiece, and which may be used at high work speed.

A still further object of this invention is the provision of a centerless grinding machine having an integrated hydraulic system for supporting and clamping the workpiece.

It is a still further object of the present invention to provide an internal centerless grinding machine having a novel means for aligning the axis of the workpiece with the axes of rotation of the clamping members.

A further object of this invention is the provision of an internal grinding machine of the centerless type in which the shoes, instead of presenting appreciable friction to the periphery of the workpiece, as in prior art machines, acts as a frictionless bearing for the workpiece, so that high speeds may be used without scoring of the workpiece, wearing of the shoes, and uncontrollable spinning of the workpiece at high grinding forces and high work speeds.

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.

The character of the invention, however, may be best understood by reference to one of its structural forms as illustrated by the accompanying drawings in which:

FIG. 1 is a vertical sectional view through the center of a grinding machine embodying the principles of the present invention;

FIG. 2 is a view of the invention taken on the line II—II of FIG. 1;

FIG. 3 is a view of the invention taken on the line III—III of FIG. 1, and

FIG. 4 is a somewhat schematic view of the hydraulic system provided in the machine.

Referring to FIG. 1, it can be seen that the grinding machine, indicated generally by the reference numeral 10, is shown in use in finishing an internal bore of a workpiece 11, which is shown as a short, tubular member, such as a bearing race. The machine is provided with a base 12 on which is mounted a work head 13, a support 14, an outboard clamping plate 15, and a pressure roll 16. The machine also includes the usual abrasive wheel 17.

The outboard clamping plate 15 consists of an annular frame 18 having a large bore 19 extending therethrough. A diaphragm 21, which may be formed of a thin metallic sheet, is fastened at its periphery to the frame. The diaphragm is provided with a central circular aperture 22 to the edge of which is fastened a contact member 23 which is provided on one side with an annular lip 24

adapted to contact one end of the workpiece **11**. Generally speaking, the width of this lip is less than the thickness of the workpiece. Opening on the face of the lip are a series of pockets **25** which are connected by passages **26** to tubes **27** leading to a source of pressure lubricant.

The support **14** is provided with a shoe **28** having two contact surfaces **29** and **31** adapted to engage the outer cylindrical surface of the workpiece **11**. The surfaces **29** and **31** are curved to fit the outer periphery of the workpiece **11** but are provided with a radius of curvature slightly greater than the radius of curvature of the workpiece, in accordance with the teachings of the patent to Blood Reissue No. 24,202. The surface **29** is provided with a shallow pocket **32** leading through a passage **33** to a tube **34** leading to a source of pressure lubricant. In the same way, the surface **31** is provided with a pocket **35** connected by a passage **36** to a tube **37**, which tube is also connected to a source of lubricant under pressure.

The pressure roll **16** is provided at its outer periphery with a rubber tire **38** and is provided centrally with a hub **39** by which it is mounted on a shaft **41** by means of set screws extending through the hub and contacting the shaft. It will be understood that the shaft and wheel are associated with a well-known mechanism serving to remove the wheel from the workpiece for unloading and loading operations, but normally it is spring-biased toward the surfaces **29** and **31** of the shoe **28**.

The workhead **13** is provided with a drive shaft **42** which extends therethrough and is provided on the end of the work head closest to the workpiece with a backing plate **43** adapted to engage that end of the workpiece which is opposite the end contacted by the outboard clamping plate **15**. The other end of the drive shaft **42** extends from the workhead and has keyed thereto a pulley **44** which is connected to a motor (not shown). The work head is provided with a horizontal bore **45** through which the drive shaft extends. At the end adjacent the backing plate **44** a counterbore **46** is provided. In this counterbore is located a ball bearing **47** having an inner race **48**, an outer race **49**, and spherical balls **51**. Located between the ball bearing and the bottom of the counterbore **46** is a pressure plate **52** having an annular flange **53** which engages the inner side of the outer race **49**. The pressure plate is biased toward the workpiece area by a series of coil springs **54** located in small bores **55** drilled horizontally into the bottom of the counterbore **46**. At the other end of the workhead is a counterbore **56** and in this counterbore is located a ball bearing **57** having an outer race **58**, an inner race **59** and spherical balls **61**. A retainer plate **66** holds the bearing **57** in the counterbore **56**. Within the bore **45** and extending between the inner races **48** and **59** of the bearings is a sleeve **67**. Centrally of the bore **45** the work head is provided with a groove **68** from which a passage **69** extends to the exterior of the workhead for the purpose of providing the groove **68** with a supply of lubricant for the bearings. The outer end of the passage **69** is normally provided with a plug **71**. The upper part of the workhead **13** is provided with a bore **72** which opens on the side adjacent the pulley **44** and which is normally closed by a plug **73**. In this bore is located a piston **74** having a groove **75** extending around its central portion in which resides an O-ring **76**; the O-ring is large enough to be slightly compressed against the sides of the bore to act as a piston ring. The piston is provided with a piston rod **77** which extends through a bore **78** opening on the face of the workhead adjacent the workpiece. The outer end of the piston rod **77** is provided with an arm **79** which extends downwardly and in line for contact with the outer face of the outer race **49** of the bearing **47**. At one end of the bore **72** (which it will be understood constitutes the cylinder of a hydraulic linear actuator) a passage **81** is provided leading to a tube **82** connected to a source of fluid under pressure; in the same way the other end

of the bore **72** is provided with a passage **83** leading to a tube **84**, which in turn is connected to a source of fluid under pressure. It will be understood that there are three such hydraulic linear actuators spaced 120° apart in the work head, all having arms which can contact the outer race of the ball bearing **47**; for the purposes of simplifying the drawings and description, however, only one of these actuators is shown, it being understood that the pistons and their controls are connected in parallel for simultaneous operation.

Referring to FIG. 3, it can be seen that the hydraulic portions of the clamping plate **15**, the supporting shoe **28**, and the piston **74** are all supplied with grinding fluid from a pump **85** which is supplied with fluid through a conduit **86** from a sump tank **87**. The pump is connected to a conduit **88** from which the various circuits are supplied with fluid. For instance, the pump **85** is connected throught a pressure regulating valve **89** and through fluid resistances **91** and **92** (which are preferably in the form of orifices) to the tubes **34** and **37**, respectively, which provide the passages **33** and **36** and the pockets **32** and **35** with fluid. In a similar manner, the conduit **88** is connected through a pressure regulating valve **93** to a manifold tube **94** which is connected to the outer ends of fluid resistances **95** leading to the tubes **27** which, through the passages **26**, supply the pockets **25** with fluid. The conduit **88** is connected through a pressure-regulating valve **96** which is connected to the input port of a four-way valve **97**. The output ports of the valve are connected through a conduit **98** to the sump tank **87** for discharge. One output port **99** is conected by the tube **84** to one side of the bore **72**. Another output port **101** is connected through the tube **82** to the other end of the bore **72**. The valve is provided with a spool **102** which selectively connects the various ports to one another. In the condition shown in the drawing, the spool connects the fluid originating in the regulating valve **96** to the output port **101** so that pressure fluid is provided at the right hand side of the piston **74**. The other side of the bore **72**, which is connected through the tube **84** to the port **99**, is connected through the tube **84** to the port **99**, is connected to a discharge port for the passage of fluid through the conduit **98** to the sump tank **87**. One end of the spool **102** is provided with a solenoid **103** having an actuating coil which is in the control circuit of a control element of the machine so that, after the pressure wheel **16** has been returned after loading to hold the workpiece **11** in its shoes, fluid is permitted to pass through the tube **82** to the right hand side of the cylinder to move the piston **74** to the left. The nature of this electrical control is not part of this invention, but would be part of the conventional cycling controls of an internal grinding machine.

The operation of the invention will now be readily understood in view of the above description. The drive shaft **42** is operated continuously, is driven through the pulley **44**, and does not have its rotation interrupted during the normal machine cycle. In the same way, fluid would be supplied to the pockets **25** of the outboard clamping plate **18** at all times during the cycle. Similarly, the pockets **32** and **35** of the shoe **28** would be provided with pressure fluid at all times. When a workpiece is not in the machine, the resistances in series with these fluid pockets are sufficient to keep the flow at a reasonable value. At the beginning of a machine cycle, a new workpiece **11** is inserted in the machine and the pressure roll **16** presses on the outer periphery of the workpiece opposite the shoe **28**. As is evident in FIG. 2, the surfaces **29** and **31** form a V, that is to say, the surfaces are symmetrical about a vertical plane passing through the center line of the workpiece in a longitudinal direction. This V-shaped shoe serves to compensate automatically for variations in the outside diameter of the workpiece in a manner well known in the art. The pressure roll **16** serves to keep the workpiece in the shoe despite the tendency of the abrasive wheel **17** to force

the workpiece out of the shoe because of the horizontal force that it exerts on the inner bore of the workpiece. During the loading operation, the plunger 102 of the four-way valve 47 is located by the solenoid 103 in such a position that pressure fluid originating in the pump 85 goes to the left hand side of the piston 74, thus moving the piston rod 77 and the arm 79 to the right. Because of the symmetrical location of the various pistons around the bearing 47, this causes an axial force to be exerted on the outer race 49 of the bearing 47 by the springs; that is to say, the biasing pressure of the springs 54 cause the stressing of the bearing in the horizontal direction. This means that the balls 51 will be tightly squeezed between the inner and outer races of the bearing and the shaft 42 will be rigidly held about the same axis at both ends. As soon as a new workpiece 11 has been loaded into the machine and the pressure roll 16 is in place, the driving action of the backing plate 43 against the end of the workpiece will cause the workpiece to rotate. At the same time, the solenoid 103 is actuated to reverse the valve 97 and to cause the pressure to go to the right side of the piston 74 and so that the left side of the piston is connected to discharge. This causes the arm 79 associated with the piston rod 77 to move toward the outer race of the bearing 47 so that the springs 54 are relieved of biasing operation. This relieves the internal stress in the ball bearing and causes the balls 51 to be loosely held between the inner and outer races. The result of this action is that the end of the shaft 42 on which the backing plate 44 is attached is free to move in any direction transversely of the axis of the shaft. Since the shaft is free to wobble, the skewing action, which takes place when the workpiece 11 and the backing plate 43 are eccentric and rotated on their own independent axes, will cause the backing plate to rotate on the axis of the workpiece, the workpiece itself being fixed by the surfaces 29 and 31 of the shoes and by the pressure roll 16. The workpiece and the drive shaft then rotate as a single shaft and they act as though they are supported in only two bearings, one bearing being the ball bearing 57 at the left side of the workhead and the other being the bearing provided by the surfaces 29 and 31 of the shoe 28.

It should be pointed out that, although the bearing 57 is relieved of its preloading stress by the same action that relieves the preloading stress in the front bearing 47, it is not as subject to wobbling action, since it is so far from the workpiece and since it is pressed to one side by the tension in the drive belt acting on the pulley 44. Then the machine proceeds with the usual grinding operation; once the wheel 17 is removed, the pre-loading pressure is applied to the ball bearing 47 and the workpiece is removed. The loading of the workpiece between the backing plate 43 and the clamping plate 18 takes place because of the natural resilience inherent in the plate 23 because of the diaphragm 21. The workpiece is thus squeezed very readily between the two clamping members. There is no scratching of the workpiece since the lubrication supplied from the pockets 25 prevents such action. Furthermore, if, because of differences in outside diameter of successive workpieces, the clamping plate 18 is slightly eccentric with regard to the workpiece, there is no skewing action which would tend to defeat the purpose of the invention because of the lubrication. The film between the clamping plate and the workpiece is provided in a hydrostatic manner by the fluid in the pockets 25. It will be understood that, as the workpiece begins to rotate at operating speed, an additional hydrodynamic film may be formed, thus clearly separating the workpiece from the thrust plate 23. The type of lubrication described above is also to be found in connection with the surfaces 29 and 31 of the shoe 28. Pressure fluid from the pockets 32 and 35 operate hydrostatically when the workpiece is coming up to speed, but, when it reaches its operating speed, there may be a degree of hydrodynamic film developed, so that scratching of the workpiece will be eliminated and also resistance to rotation of the workpiece will be avoided. Furthermore, as has been described above, the clamping plate 15 produces little in the way of friction force on the workpiece surface. Therefore, most of the torque supplied to the workpiece will be that required to rotate the workpiece despite the peripheral forces on the interior of the bore provided by the abrasive wheel 17. It will be understood that, because there is no necessity for slippage between the backing plate 43 and the workpiece, the workpiece is clamped tightly against the backing plate. The backing plate, therefore, not only drives the workpiece, but also prevents it from speeding up under the action of the abrasive wheel. This permits operation at high wheel speeds and loads.

It will be understood that while the energy of rotation has been supplied in the preferred embodiment through the drive shaft 42, the machine could be built with an idling shaft and with the force supplied to the workpiece by the pressure wheel 16.

In the preferred embodiment, it will be noted that the inner races of the two ball bearings are held in place by a shoulder at the right end of the drive shaft 42 which contacts the outboard side of the inner race 48 of the ball bearing 47 and a boss on the pulley 44 which engages the outer side of the inner race 59 of the ball bearing 57. Furthermore, the outer race 58 of the ball bearing 57 is locked in place by the plate 66 so that the bearing is under an initial pre-loading stress and the balls 61 are tightly held between the inner and outer race so that that end of the shaft 42 is fixedly located, although, of course, rotation can take place. So far as the bearing 47 is concerned, the inner race is locked in place tightly, because of the shoulders and bosses which combine with the sleeve 67 to hold the inner races in place; the outer race, however, is permitted to move, on occasion, to remove the pre-loading so that the shaft 42 is capable of wobbling at the backing plate end.

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 workpiece comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a work head, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis.

2. A grinding machine for finishing a workpiece, comprising a grinding wheel, a spindle adapted to contact one end of the workpiece, a plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a work head, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, and a pressure wheel to press the workpiece into contact with the support means.

3. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a support adapted to contact the periphery of the workpiece, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm.

4. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece for the rotation thereof, a non-rotating clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, and means supplying the lubricant to the clamping plate to cause a film to exist between the plate and the said other end of the workpiece.

5. A grinding machine as recited in claim 4 wherein means is provided for supplying lubricant to the supporting means to cause a film to exist between the means and the said periphery of the workpiece.

6. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a work head, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm.

7. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece for the rotation thereof, a non-rotating clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm, and means for supplying the lubricant to the clamping plate to cause a film to exist between the plate and the said other end of the workpiece.

8. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece for the rotation thereof, a non-rotating clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, means supplying lubricant to the clamping plate to cause a film to exist between the plate and the said other end of the workpiece, the spindle being mounted for rotation in a workhead, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis.

9. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece for the rotation thereof, a non-rotating clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a workhead, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm, and means supplying lubricant to the clamping plate to cause a film to exist between the plate and the said other end of the workpiece.

10. A grinding machine for finishing a workpiece, comprising a grinding wheel, a spindle adapted to contact one end of the workpiece, a plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, and a pressure wheel to press the workpiece into contact with the support means, the said plate having a flexible diaphragm whose outer periphery is securely held in the frame and having a contact member mounted in the central portion of the diaphragm.

11. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece for the rotation thereof, a non-rotating clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm, means supplying lubricant to the clamping plate to cause a film to exist between the plate and the said other end of the workpiece, and means supplying the lubricant to the supporting means to cause a film to exist between the means and the said periphery of the workpiece.

12. A grinding machine for finishing a workpiece comprising a grinding wheel, a spindle adapted to contact one end of the workpiece, a non-rotating plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a work head, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, a pressure wheel to press the workpiece into contact with the support means, means supplying lubricant to the plate to cause a film to exist between the plate and the said other end of the workpiece, and means supplying lubricant to the supporting means to cause a film to exist between the means and the said periphery of the workpiece.

13. A grinding machine for finishing a workpiece, comprising a grinding wheel, a spindle adapted to contact one end of the workpiece, a non-rotating plane adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in a work head, a substantial length of the spindle at the end thereof which contacts the said one end of the workpiece being capable of movement in any direction transversely of its axis, a pressure wheel to press the workpiece into contact with the support means, the said plate having a flexible diaphragm whose outer periphery is securely held in a frame and having a contact member mounted in the central portion of the diaphragm, means supplying lubricant to the plate to cause a film to exist between the plate and the said other end of the workpiece, and means supplying the lubricant to the supporting means to cause a film to exist between the means and the said periphery of the workpiece.

14. A grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the spindle being mounted for rotation in two longitudinally-spaced ball bearings in a work head, each bearing having inner and outer races and balls held therebetween, means for axially pre-loading the bearings, and means for selectively relieving the said pre-loading in the bearings to render a substantial length of the spindle at the end of which contacts the said one end of the workpiece capable of movement in any direction transversely of its axis.

15. An internal grinding machine for finishing a workpiece, comprising a grinding wheel, a driving spindle adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a V-type supporting shoe adapted to contact the periphery of the workpiece, the said clamping plate having a flexible diaphragm whose outer periphery is securely held in a frame, the clamping plate having a circular aperture cen-

trally thereof, and an annular contact member fastened to the edge of the aperture.

16. A grinding machine for finishing a workpiece, comprising a grinding wheel, a backing plate adapted to contact one end of the workpiece, a clamping plate adapted to contact the other end of the workpiece, a support means adapted to contact the periphery of the workpiece, the backing plate being mounted for rotation in a work head, the backing plate being capable of movement in any direction transversely of its axis, and means supplying lubricant to the supporting means to cause a film to exist between the means and the said periphery of the workpiece.

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