

[54] **DEVICE IN GRINDING MACHINES**

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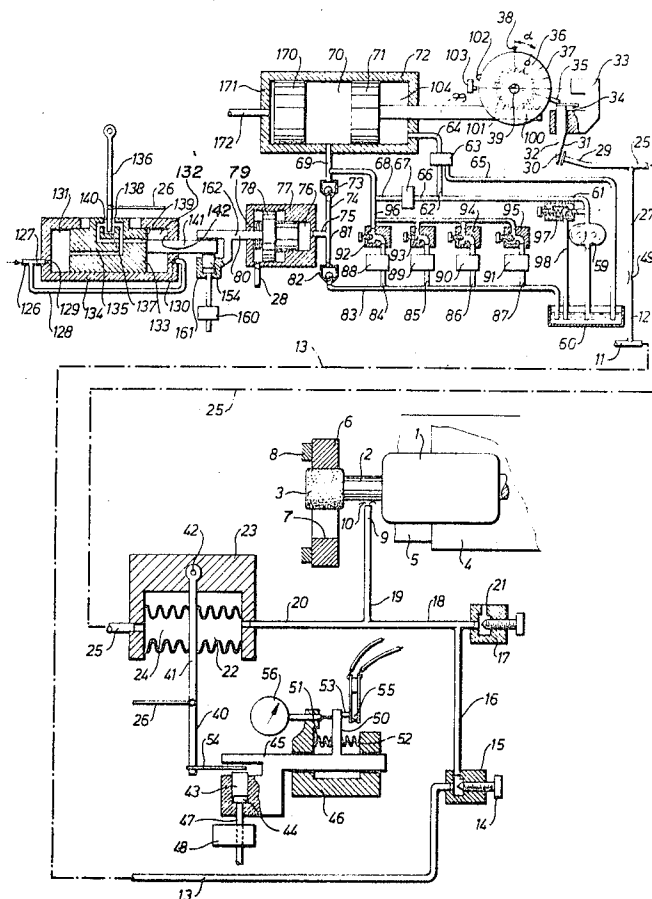
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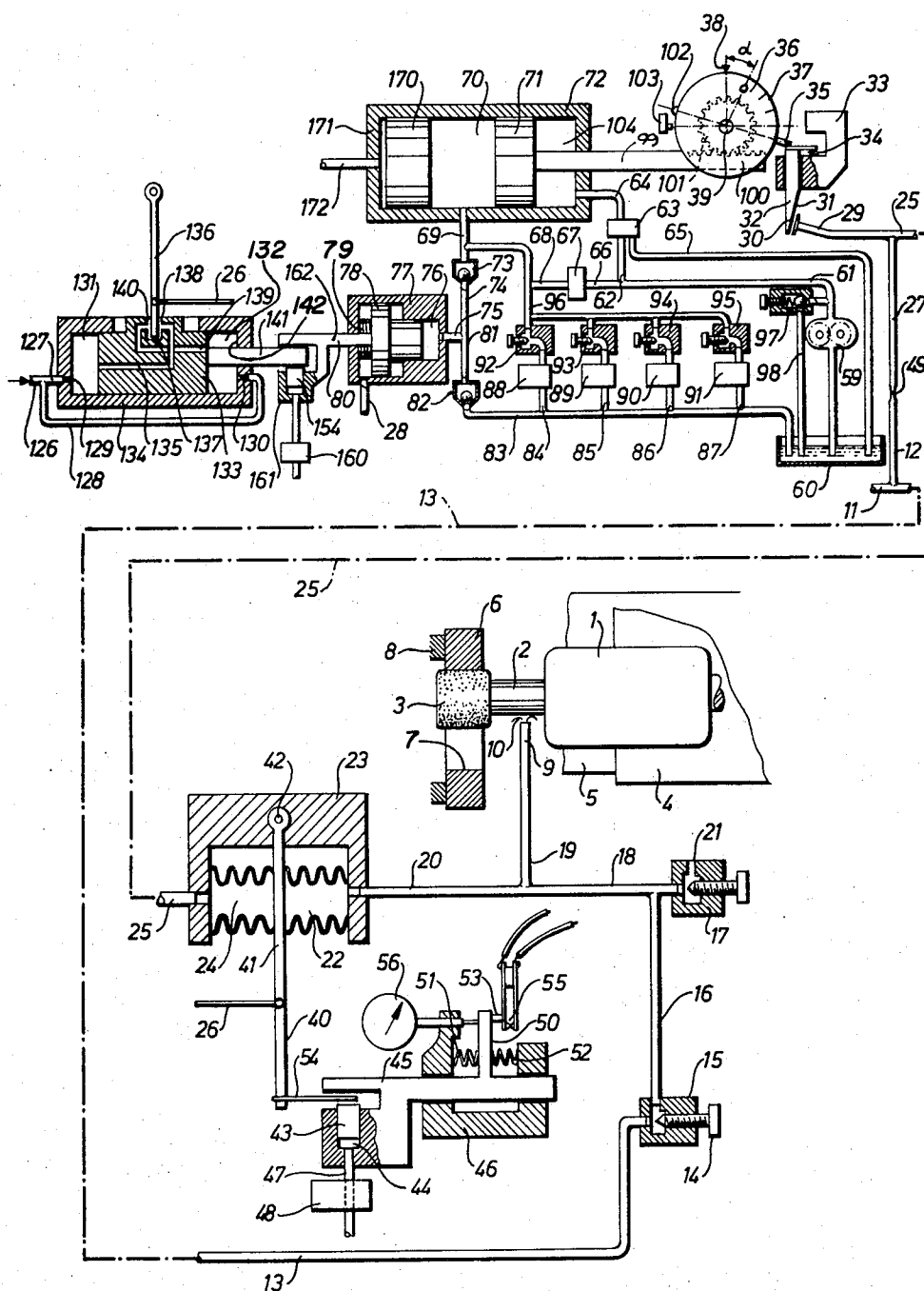
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[57] **ABSTRACT**

A grinding machine includes means for controlling the grinding member so as to allow a grinding operation with a considerable pressure between the grinding member and the work piece up to a predetermined movement of the grinding member corresponding to a predetermined removal of material, to obtain greatest possible removal of material within a minimum interval of time. The control means is arranged to take into account the deflection of the spindle carrying the grinding member and to interrupt the feeding movement of the grinding member when the total movement corresponds to the predetermined movement plus an additional movement, which depends on the said deflection.

6 Claims, 1 Drawing Figure





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DEVICE IN GRINDING MACHINES

This invention relates to a device in grinding machines.

More particularly this invention relates to a device in grinding machines, primarily internal grinding machines, wherein a work-piece carried by a chuck and a grinding disc carried by a spindle in a holder both are rotatable about their axes and at the same time displaceable in radial direction relatively one another by means of a feeding mechanism. In this connection the expression "grinding disc" is to be understood to include grinding rods also. If the work-piece is hardened before the grinding, a certain amount of deformation occurs. All this contributes to the consequence that it is impossible to provide a constant machining allowance for the grinding and the course of events in a grinding machine having an automatic working cycle will therefore usually be the following. The workpiece is secured in the chuck whereupon the grinding disc is rapidly moved towards the surface to be worked on and to a position where the grinding can be expected to commence immediately, which feed is then continued at a suitable rate, usually at a so called coarse or primary feed during which the grinding disc is pressed against the surface to be worked on with a substantially constant, predetermined force. This force is kept as great as possible to bring about the most rapid possible removal of material and therewith optimum utilization of the machine. The relatively great force of contact results in a bending or deflection of the spindle whereby the extent of advance set in the feed mechanism does not correspond to the working position of the grinding disc. Consequently the primary feed must be interrupted before the final dimension has been reached, and a final or secondary grinding operation must be effected with long time for finishing grinding and gradual reduction of the grinding forces and therewith the spindle deflection. Thus the total time required for the grinding becomes relatively long.

One main object of the invention is thus to provide an apparatus which permits utilization of great contact pressure between the grinding disc and the work-piece and in connection therewith high speed of abrasive action until or substantially until the final dimension. This is achieved substantially by utilizing the deflection of the spindle for automatic control of the feed mechanism in such a manner that an excess of abrasive effect corresponding to the deflection of the spindle is obtained while maintaining a very great pressure between the grinding disc and the work-piece until a final or predetermined dimension has been reached, whereupon the primary feed is stopped rapidly. The final or secondary feed step required with earlier grinding machines can thus be omitted and therefore the entire grinding operation is effected considerably more rapidly than hitherto. According to the invention it becomes possible after that the primary feed has been completed, automatically to effect a surface dressing for some few as the system is relieved from the deflection.

The features essential for the novel apparatus are evident from the claims, and an embodiment of the invention is described below with reference to the enclosed drawing, which diagrammatically shows the apparatus. In the drawing all those details of a grinding machine to which the invention does not relate have

been omitted, since the machine may be of any conventional type. The measuring system shown is a pneumatic one, but it is obvious to an expert that the principles of the invention can as well also be applied to optical measuring systems, for example.

The FIGURE in the drawing illustrates schematically, and partly in section, one embodiment of this invention and one manner in which the hydraulic and electrical controls of a system made in accordance with the invention may be connected to control the feed of the grinding disc of an internal grinding machine relative to the work-piece to be ground.

The drawing FIGURE shows a holder 1 for a spindle 2 which carries a grinding disc 3. The holder 1 is rigidly mounted on a support 4 represented diagrammatically and of conventional type, which is mounted on a bed 5 and displaceable both in the radial and the axial directions of the grinding disc. The support 4 carries a driving motor not shown here for the spindle 2. A work-piece 6, the interior surface 7 of which is to be worked on, is secured in a chuck 8. During the grinding operation the work-piece 6 and the grinding disc 3 are both rotated in opposite directions. In carrying out a grinding operation the grinding disc 3 is moved to and fro axially in relationship to the work-piece 6 while simultaneously being fed radially outwards for removing material from the inner surface 7 of the work-piece until the desired bore diameter is reached.

In the embodiment shown there are mounted on the spindle holder 1 a pneumatically operated measuring tool 9 having a nozzle 10, the opening of which is directed towards and cooperates with the surface of the spindle 2 in a manner to be described below in more detail. A source not shown here for a pressurized gaseous fluid, preferably air, is in communication with a pipe 11, which in turn is connected with a pipe 12 having a place 49 of constantly reduced diameter, and with a pipe 13. A throttle valve 15 adjustable by means of a screw 14 is inserted into the pipe 13 for performing calibration of the sensitivity of the system. Connected to the outlet side of the valve 15 is a pipe 16, which in turn is coupled to the inlet side of a finely adjusting valve 17 and to a pipe 18 which branches into two branch pipes 19 and 20, respectively. The outlet 21 of the valve 17 opens into the free atmosphere. The pipe 19 is coupled to the measuring tool 9 and compressed air thus will flow from the pipe 11 to the nozzle 10 when the valve 14 is open. The branch pipe 20 is connected to one chamber 22 in a differential load measuring device or pressure box 23 which in addition has a chamber 24 which has a central wall (not shown) common with the chamber 22. The pressure chamber 24 is connected to a pipe 25 which is connected to a pipe 27. The pipe 27 is connected to a second pneumatic measuring tool 29, which is fixedly mounted on the machine and which has a nozzle 30 which cooperates with the surface 31 of a wedge-shaped cam member 32. The cam member 32 is slidably mounted on a stationary guide 33 and is pressed upwards by a pressure spring 34. The cam member 32 cooperates with a carrier 35 on a scale disc 36. The scale disc 36 has a graduated scale 37, which is read in relation to a stationary index 38. The shaft 39 of the scale disc 36 is coupled with the support 4 in a manner not shown here, and the position of the scale 37 relative the index 38 indicates the distance of feed of the support in radial direction.

The partition wall (not shown) of the differential pressure box 23 which wall in a gas-tight manner separates the two pressure chambers 22 and 24 from one another, is at point 41 coupled to a lever arm 40. The upper end of the arm 40 is pivotably mounted on a pivot 42. The arm 40 carries at its lower end a coupling pin 54 adapted by means of a piston 43 in a pneumatic cylinder 44 prior to the beginning of the grinding operation to be coupled with a switch member 45 formed as a plunger slidably mounted in a guide sleeve 46. Via a conduit 47 and a controllable valve 48, such as a magnet valve, for example, the cylinder 44 is connected to the source not shown for compressed air.

In the embodiment shown the member 45 is provided with a vertical contact arm 50 which is loaded by two pressure springs 51 and 52. The contact arm 50 has a stud 53 which actuates a contact 55 when the plunger is displaced to the right. Coupled to the contact arm 50 is an indicator 56 which indicates the movements of the arm 50.

The drawing shows diagrammatically a hydraulic driving system for the transversal radial movement of the feed equipment 4. A pump 59, for example a gear pump, pumps oil from a storage receptacle 60 through a pipe 61 to a branch pipe 62. At the outlet of the pump 59 there is attached to the branch pipe 61 a pressure release valve 97 with a return pipe 98 to the storage receptacle 60, which valve opens when the pressure in the pipe 61 for some reason or other should exceed a predetermined, adjustable value. The branch pipe 62 is connected to a valve 63 which in a first position connects the pipe 62 to a pipe 64 and in another position connects the pipe 62 to a draining pipe 65 leading to the storage receptacle 60. Further a branch pipe 66 terminating into a one-way valve 67 is connected to the pipe 61. Connected to the outlet end of said one-way valve is a pipe 68 which opens into a pipe 69, one end of which opens into a space 70 ahead of a working piston 71 housed within a cylinder 72, and the other end of which is connected to the outlet of a one-way valve 73. The inlet of the one-way valve 73 is coupled to a pipe 74. The pipe 74 has a first branch pipe 75 which is connected to the working space 76 in a regulating cylinder 77 encasing a piston 78 which is loaded by a pressure spring 79 adapted to force the piston 78 in right-hand direction in the FIGURE. The piston 78 has a piston rod 80 which is connected to control member that shall be described more below.

Connected to the pipe 74 is another branch pipe 81 which is connected to the outlet side of a one-way valve 82, the inlet side of which is connected to a pipe 83 extending to the storage receptacle 60. The pipe 83 has a plurality of branch pipes 84, 85, 86, 87, each of which is connected to an associated adjustable one-way valve denoted, respectively, 88, 89, 90 and 91. Each of the valves 88 to 91 has an adjustable throttling valve 92, 93, 94 and 95, respectively, over which the valves are connectable to a pipe 96 which via the pipe 69 is connected to the space 70. The working piston 71 of the cylinder 72 has a piston rod 99 the outer portion of which is formed as a rack 100 which cooperates with a pinion 101 which is fixed onto the shaft 39 driving the feed equipment 4 in radial direction.

The apparatus hitherto described is operated in the following manner: Upon securing of a new work-piece 6 in the chuck 8 compressed air is admitted from the

compressed air source not shown to the conduit 11 and thus streams to the nozzles 9 and 30. The feed equipment or cross-slide 4 is advanced radially until its grinding disc 3 bears against the inner surface of the work-piece 6 with an arbitrary force. Thereafter, the system is calibrated by means of the calibration valve 15 in such a manner as to set the indicator 56 to be adjusted to zero. The calibration is effected by rotating the screw 14 of the valve 15. When the calibration has been completed for various load pressures and the indicator irrespective of the pressure between the grinding disc 3 and the work-piece 6 indicates zero, the cam 32 has been adjusted in relation to the nozzle 30 in such position that the position of the cam 32 exactly corresponds to the deflection of the spindle 2. As is easily understood the pressure in the chambers 22 and 24 is of equal magnitude. A possibly required final adjustment can be made by means of the resetting valve 17.

The scale disc 36 is then turned in counter-clockwise direction and a scale line corresponding to the desired working depth is set, e.g., in relation to the index 38. As a consequence of the setting of the disc 36 the cam 32 is displaced upwardly by the spring 34 which results in that the pressure in the chamber 24 is reduced, while the pressure prevailing in the chamber 22 remains unchanged. Thereby the arm 40 is swung in clockwise direction and the arm 50 is displaced to the left, viewed in the plane of the drawing. Thereupon a valve determining the advance feed for the cross-slide, for example the valve 88, is opened. This valve has a throttling device 92 which permits a maximum of escape of oil from the space 70 in the cylinder 72 and therewith the maximum advance speed whereas other valves 89, 90, 91 cooperate with throttling devices 93, 94 and 95, respectively, which permit gradually reduced escape only of oil from the chamber 70 and therewith lower speeds of advance. The pump 59 is started and pumps oil through the pipe 61 and through the valve 63 adjusted to its one position to the pipe 64 and into the working space 104 behind the piston 71 which in a sealing manner fits with the inner wall of the cylinder 72, and simultaneously therewith the grinding disc 3 and the work-piece 6 are caused to rotate. By pumping oil into the space 104 the piston 71 will be displaced from its starting position, which is more to the right of the piston shown in the drawing and forces oil out of the space 70 through the pipe 69, the pipe 96, the throttling device 92 and the open valve 88 to the pipe 83 and therethrough into the storage receptacle 60 wherefrom oil is sucked up by the pump 59. During this movement the rack 100 will be displaced to the left in the drawing and turn the pinion 101 and therewith the shaft 39 in clock-wise direction, whereby the cross-slide or feed equipment is advanced radially.

In response to the progress of the removal of material the scale disc 36 is rotated in clock-wise direction and its carrier 35 begins to force the cam member 32 downwards against the action of the spring 34 whereby the interspace between the cam surface 31 and the nozzle 10 is reduced gradually so that the pressure in the conduit 25 gradually increases in direct proportion to the movement of the scale disc 36 and therewith the feed equipment 4. At that moment when the zero point of the scale disc 36 reaches the index 38 the set feed has been reached, but since the spindle 2 is deflected

downwards the final size of grinding has not been reached, which is indicated by the fact that the air pressure in the pipe 20 exceeds the pressure in the pipe 25. This pressure difference is a direct measure of the deflection and therewith also of the additional bit of material, which must be removed in order to attain the final, predetermined dimension for the work-piece 6. Therefore, the pump 59 continues to pump oil into the space 104 in the cylinder 72 and an excessive advance is effected as is indicated by the angle α on the scale disc 36. When this angle α has been transgressed the carrier 35 has forced the cam 32 downwards into that position which had been set by the calibration, and thus the indicator 56 has returned to zero position. Simultaneously, with this arrival at the predetermined measure limit, the contact 55 is closed and completes a current circuit to a returning member not shown here for the cross-slide which is rapidly conveyed back so that no additional material is removed. Now the work-piece 6 has reached its final dimension and the entire grinding operation has been carried out with so great speed of advance as possible and thus without the last removal having been effected with low speed of advance.

In some cases it may be desirable to accomplish a finishing treatment of the inner surface 7 of the work-piece. This finishing treatment which must not be mixed up with the finishing grinding step, is accomplished by making use of the servo-motor coupled with the piston rod 80. Said servo-motor is connected to the source not shown of compressed air through a pipe 126 which is branched into two branch pipes 127 and 128, respectively, which through stationary portions 129 and 130, respectively, of constant diameter open into cylinder spaces 131 or 132, respectively, on either side of a piston 133 which is displaceable within a cylinder 134 and in a sealing manner fits to the inner wall of said cylinder. The piston 133 is formed with a passage 135, one end of which communicates with the space 131 and the other end of which opens in front of a control arm 136 which is pivotably connected by a link member 26 with the bellows-actuated arm 40. Since said control arm 136 is pivoted at its upper end, it will follow the movements of the arm 40. The lower end of the control arm 136 projects downwards into a recess 137 formed in the piston 133. An interspace 138 exists between the opening of the passage 135 into the recess 137 and the side of the arm 136 facing said opening; and the width of this interspace depends on the pivoting position of the arm 136.

Connected to the cylinder space 132 is a second passage 139 formed in the piston 133, which passage opens on the recess 137 and is directed towards the opposite face of the arm 136. Between the opening of the passage 139 into the recess 137 and the arm 136 there exists an interspace 140 the width of which also depends on the pivotal position of the arm 136. The piston 133 has a piston rod 141 which extends through the space 132 and in a sealing manner through the right-hand end wall 142 of the cylinder 134. The free end of the piston rod 141 projects into a fork 162. During the grinding operation the piston rod 141 is coupled with the fork 162 by means of a piston 154 which is slidably housed within a cylinder 161 to which pressure fluid is supplied via a valve 160. The piston 154 forces the end of the piston rod 141 against the upper shank

162 of the fork. The servo-motor is operative in the following manner. When at the start of a grinding operation the arm 136 is turned in clockwise direction by the link member 26, the interspace 140 of the piston 133 is reduced and the interspace 138 increased. Therefore the pressure in the cylinder space 131 will become lower than the pressure in the cylinder space 132 and the piston 133 moves in left-hand direction according to the FIGURE. As the piston 133 is locked together with the piston 78 this latter will suck oil through the conduit 81, the one-way valve 82 and the pipe 83 from the storage receptacle 60. The quantity sucked up of oil is directly proportional to the movement of the piston 133 and thus also to the deflection of the spindle 2. After the arm 40 has been pivoted in clockwise direction immediately after the calibration and a quantity of oil has been sucked up into the space 76, the valve 10 is closed and the piston rod 80 is disengaged from the servo-motor. The spring 79 shown in the drawing has so little power that it is not capable of forcing the piston 78 to the right, said piston thus remaining in its adjusted position. The spring 79 has for its only purpose to displace the piston to the right for emptying the system when not in operation. The spring 79 may be omitted. As soon as final measure or dimension set on the scale 36 for the grinding operation has been reached, a signal is emitted from the contact 55, a mentioned above, and if a finishing adjustment of the ground surface is to be effected, said signal opens a valve for pumping oil through the one-way valve 73 into the cylinder space 70 whereby the piston 71 is forced to the right and draws back the feed equipment 4 so much that the grinding continues with very insignificant force of engagement between the grinding disc 3 and the surface 7 of the work-piece 6. In order to render possible transfer of oil from the space 76 into the space 70, the valve 67 must be closed as well as that of the valves 88 to 91 which hitherto has been open, and further the valve 63 must be readjusted to such a position that oil can escape from the space 104 via the pipe 65 into the storage receptacle 60.

During the grinding operation the grinding disc 3 in most cases must repeatedly be dressed while being returned radially and drawn axially from the work-piece 6. In order to obtain exact control of the radial displacement the cylinder 72 is provided with a return piston 170 which normally rests on the end wall 171 of the cylinder which has an opening to which is attached a conduit 172 for pressure oil which conduit in turn is connected to a source not shown for pressurized oil. The cylindrical surface of the piston 170 fits in a sealing manner to the inner wall of the cylinder 72 and thus the pistons 170 and 171 encase between themselves an oil volume determined by the position of the piston 71. When dressing of the grinding disc 3 is to be effected, all those valves which are in communication with the pipe 69 are closed and the valve 63 is adjusted so that the pipe 64 is connected to the draining pipe 65. Thereafter, oil is injected through the conduit 172, the piston 170 then being moved in right-hand direction according to the FIGURE. The oil volume in the space 70 forces the piston 71 in right-hand direction and the cross-feeding slide is conveyed back to a zero position which is indicated when an actuator 102 on the scale 36 closes switch 103. This interrupts the feed of oil

through the conduit 172. After the dressing of the grinding disc 3 has been effected the piston 170 is drawn back to its bottom position in engagement with the end wall 171. During the movement of the piston 170 the piston 71 returns to the starting position, whereupon the system is restored for renewed grinding. A very essential advantage of the new system consists therein that an automatic retraction of the grinding disc can be obtained when this becomes dull. When the disc no longer brings about any noteworthy removal of material or too low removal, the forces produced between the grinding disc 3 and the feed equipment 4 and therewith the deflection of the spindle 2 will increase during the radial advance. This results in that the arm 40 will be turned in counterclockwise direction from a normal position and actuate a switch, for example, the contact 55, and bring about the required resetting signal.

While one more or less specific embodiment of the invention has been shown and described, it is to be understood that this is for purpose of illustration only, and that the invention is not to be limited thereby, but its scope is to be determined by the appended claims.

What is claimed is:

1. In a grinding machine having a first member comprising a rotatable chuck for carrying a workpiece, a second member comprising a rotatable spindle having thereon a grinding disc, a movable support for one of said members, and a feeding mechanism for moving said support radially and axially of the spindle axis for grinding engagement of the disc with the workpiece, the combination of
 - a first measuring device operative in response to deflection of said spindle caused by the radial forces produced between the grinding disc and the workpiece, to produce a first signal,
 - a second measuring device disposed to develop a second signal in correspondence to the radial feed position of said support,
 - a control device for said feeding mechanism, operative to stop said feeding mechanism upon completion of a grinding operation, and connected to said measuring devices to compare the signals emitted therefrom, and
 - means for adjusting said control device, so as to add to a predetermined radial feed for said support an additional radial feed, which is substantially as great as the magnitude of deformation of the spindle, before the control device stops the feed movement.
2. A machine as claimed in claim 1 having
 - a differential pressure box having two pressure chambers therein, and a movable partition separating said chambers,
 - a stationary nozzle positioned to direct pneumatic pressure fluid at said spindle,
 - a pressure fluid conduit connecting said nozzle to said first measuring device to transfer pressure variations occurring in the interspace between said nozzle and said spindle, in response to deflection of said spindle, to one chamber of said differential pressure box,
 - a control member movable in response to radial displacement of said support,
 - a second nozzle positioned to direct pneumatic pressure fluid at said control member,

a pressure fluid conduit connecting said second nozzle to the other chamber of said differential pressure box to transfer pressure variations, occurring in the interface between said control member and said second nozzle, to said other chamber, adjustable throttling means in said conduits for calibration of the pressure differential between said chambers, and means connecting said partition to said control device.

3. A machine as claimed in claim 1, including means operative, upon completed feed movement of said feed mechanism, to cause said support to be retracted for a distance slightly less than said additional radial feed for completion of a fine grinding operation, with pressure on the grinding disc being maintained by the gradually reduced deformation of said spindle.

4. A machine as claimed in claim 1, wherein said measuring devices comprise a pair of stationary nozzles disposed in spaced, confronting relation to said spindle and a control member, respectively, a differential pressure gauge has opposite sides thereof responsive to pressure variations occurring in the interspaces between one nozzle and said spindle and between the other nozzle and the control member, respectively, in response to the deflection of said spindle and to the radial displacement of said support, respectively, and throttling means is provided for calibrating the pressure differential produced in said gauge.

5. A machine as claimed in claim 4, wherein said differential pressure gauge is equipped with a movable indicator arm adapted to indicate the prevailing difference in pressure in said gauge, and

selectively actuatable coupling members for coupling said indicator arm to said control device.

6. In a grinding machine having a rotatable chuck for carrying a workpiece, a rotatable spindle having thereon a grinding disc, and a feeding mechanism operable to effect relative movement between said spindle and said chuck radially of said spindle to engage said disc with the workpiece to grind a surface thereon to a predetermined radial depth, the combination comprising

a first measuring device operative, when said disc is in grinding engagement with said workpiece, to develop a first signal proportionate to the deflection of said spindle resulting from the forces produced between the grinding disc and the workpiece,

a second measuring device responsive to relative radial movement between said spindle and chuck and operative to develop a second signal the magnitude of which is proportionate to said radial movement,

control means operative to stop said feeding mechanism when said second signal has reached a predetermined value, and

means for adjusting said predetermined value of said second signal prior to a grinding operation, so that said control means will become operative only when the feeding mechanism has effected a radial feed movement determined by the amount of stock which is to be removed from the workpiece, plus an amount approximately proportional to the deflection of said spindle as determined by said first signal.

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