MACHINE FOR GRINDING LARGE HOLLOW CYLINDERS
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This invention relates to grinding machines and more especially to machines for grinding the lateral and end surfaces of hollow cylinders.

Very large diameter hollow cylinders, such as the bearings for ship propeller shafts, are difficult to machine with the high degree of accuracy desired because the relatively thin wall object of such a cylinder is not rigid enough to support the weight; hence when resting on a side it tends to flatten out of round and when resting on an end it tends to barrel laterally. Internal support is impractical because it interferes with internal grinding.

The principal object of this invention is to provide a machine for grinding the several surfaces of large hollow cylinders in such fashion that in spite of dimensional distortion the outside and inside diameters, wall thickness and surface finish may be ground to dimension within the allowable close tolerances.

Another object is to provide a single grinding machine designed and arranged to support large hollow cylinders with relatively thin wall sections for grinding the outside, inside and end surfaces thereof without the use of centers, spindles, mandrels or other supplemental work supporting means.

Yet another object of this invention is the provision of a centerless grinding machine in which the pressure between the grinding wheel and the work may be maintained substantially constant independently of the weight of the work, so that a uniform predetermined cutting pressure may be maintained.

Still another object is to provide a centerless grinding machine in which the work is rotated independently of the grinding wheel so that it can be maintained at a constant speed regardless of the wheel size and of variations in wheel size due to truing or dressing operations.

A further object of this invention is the provision of a centerless grinding machine in which the grinding wheel is narrow in width compared to the axial length of the work to be ground, and in which the work is traversed relative to the grinding wheel.

Still another object is to provide a centerless grinding machine arranged to operate semi-automatically during grinding operations, but optionally manually controlled not only during setting up operations but also during grinding operations.

A final object of this invention is the provision of a centerless grinding machine which may be adjusted for internal as well as external grinding, for grinding the respective surfaces of large cylindrical work pieces of substantially different diameters within predetermined limits, and for grinding the internal surface tapered instead of straight on large hollow cylindrical work pieces.

In accordance with the foregoing objects as herein illustrated, the machine herein illustrated as grinding wheel, means rigidly supporting the wheel for rotation about a horizontal axis, laterally spaced, horizontally disposed supporting rollers adapted to have contact with the underside and a lateral side of a cylinder placed thereon in a horizontal position to hold the surface adjacent the supporting rollers uniformly straight, means for effecting rotation of the grinding wheel, means for effecting reciprocal motion of the supporting rolls in unison to traverse the surface of the cylinder across the face of the grinding wheel, and means for effecting movement of the supporting rollers in unison to feed the work toward the wheel. For outside grinding, the grinding wheel, which is relatively narrow, is supported above and closely adjacent the supporting roller having contact with the underside of the cylinder, while for inside grinding, the grinding wheel is supported next to the roller having contact with the lateral side and in a common horizontal plane. For end grinding, a cup wheel is employed and is supported at the level of the axis of rotation of the work.

The supporting rollers are mounted upon a cradle pivotally mounted upon and normally secured in fixed relation to a cross-slide in turn supported slidably on a carriage for displacement transversely thereof, the carriage in turn being mounted slidably upon the base of the machine for movement longitudinally thereof. Thus, reciprocation of the supporting rollers in unison may be effected by reciprocating the carriage longitudinally relative to the base of the machine, while transverse movement of the supporting rollers in unison toward and away from the grinding wheel is effected by suitable displacement of the cross-slide transversely of the carriage.

The supporting roller having contact with the underside of the work is freely rotated and bears the preponderant portion of the weight of the cylinder so that the weight, in cooperation with the supporting rollers, holds the cylinder uniformly straight throughout its entire length. The roller having contact with the lateral side of the cylinder is driven and by frictional contact with the cylinder effects rotation of the cylinder about its longitudinal axis.

The supporting rollers are adjustable on the carriage relative to each other and to the axis of the grinding wheel and the roller having engagement with the underside of the work is also adjustable angularly about an axis perpendicular to the plane of the mating surfaces of the bearing housing for the lower roller and the supporting plate thereof and thereby perpendicular to the plane of the parallel sloping ways on the front portion of the cradle, all described in detail below. Thus, with the work disposed in its normal position on the machine, the axis about which the lower roller is adjustable either is or approaches a perpendicular to a plane containing the axis of rotation of the roller and the axis of rotation of the work.

Several other features of the machine described in detail below are worthy of note at this point. To prevent axial movement of the work during the grinding operation relative to the supporting rollers, there are end engaging rollers upon the carriage, one of which is yieldingly urged toward the other. This machine is also provided with means for dressing the grinding wheel during the various grinding operations. The means for effecting rotation, reciprocation and feeding movement of the work relative to the grinding wheel are electrically and hydraulically interconnected to effect semi-automatic and manual operation of the machine. Finally, wiper blades may be arranged adjacent the outer surface of the work for removing abraded and abrasive material. It is to be understood that these wiper blades are secured to fixed structural elements of the respective surfaces of the work piece so that the operative edges of the wiper blades are maintained in contact with these surfaces. Since the use of such wiper blades is well known in the art, for example, as illustrated in U.S. Patent No. 2,044,042 showing wipers 33 engaging rolls being ground and as illustrated in U.S. Patent No. 2,379,281 showing a wiper 26 engaging a work piece supporting roll, and since such wiper blades form no part of the instant invention, these blades are...
not illustrated in the drawings in order to avoid obscuring the showing of other features. The invention will now be described in greater detail with reference to the accompanying drawings wherein:

FIG. 1 is an elevation of the front of the machine;
FIG. 2 is a plan view of the machine;
FIG. 3 is a right hand end elevation;
FIG. 4 is a transverse vertical section of the lower part of the cross-slide of the work-supporting carriage, showing the traversing mechanism;
FIG. 5 is a transverse horizontal section taken on line 5—5 of FIG. 3 showing the mechanism for adjusting the supporting rollers;
FIG. 6 is a fragmentary view partly in section of the roller mechanism for endwise constraint of the work and of the cup wheel truing device;
FIG. 7 is a fragmentary vertical section taken approximately on line 7—7 of FIG. 6 showing the end face grinding arrangement;
FIG. 8 diagrammatically shows the relation of the supporting rollers, the work and the tool when making an outside cut;
FIG. 9 diagrammatically shows the relation of the supporting rollers, the work and the tool when making an outside cut on a work piece of much smaller diameter;
FIG. 10 diagrammatically shows the relation of the supporting rollers, the work and the tool when making inside cuts on work pieces of minimum and maximum diameter; and
FIG. 11 is a diagrammatic layout of the hydraulic and electrical control system for the apparatus.

Referring to the drawings, the apparatus comprises essentially a cutting tool illustrated as grinding wheel 10 supported in a fixed position for rotation about a horizontal axis and supporting rollers 12 and 14 for holding a hollow cylindrical work piece 21 in a horizontal position for rotation about its longitudinal axis, parallel to the axis of rotation of the grinding wheel 10, including a carriage 16 for effecting reciprocation of the work supporting rollers in unison to traverse the work supporting rollers and hence the work piece 21 supported thereby relative to the face of the cutting tool, and a cross-slide 18 for feeding the work toward the cutting tool. The aforesaid components, together with suitable means for affording adjustment of the respective components to make the machine usable for work of different sizes and for internal, external and end grinding operations and the driving means for the several components are supported by a base 20.

The machine is designed especially for grinding the outside and inside surfaces of very large relatively thin walled hollow cylinders in the order of 46⅔" to 61½" in diameter and weighing as much as 4850 pounds. To provide appropriate support for such cylinders without distortion along the line of contact of the cylinder with the grinding wheel, the supporting rollers 12 and 14 may comprise a pair of laterally and vertically spaced, rigid, smooth surface cylindrical rollers which are arranged to have contact with the underside and a lateral side of the cylinder comprising work piece W at opposite sides of its axis of rotation. The roller 12 having contact with the underside of the cylinder bears the proportionate part of the weight of the cylinder and the effective weight of the cylinder operates to hold the wall of the cylinder in contact with the roller uniformly straight and hence to hold the entire cylinder uniformly straight throughout its entire axial length.

For work pieces of all diameters, as shown in FIGS. 8, 9 and 10, the lower of the supporting rollers 12 has line contact with the outer surface of the cylinder at a radius passing through the center of rotation of the work which is closer to the vertical diameter than the horizontal diameter and the higher roller 14 has line contact with the outer surface of the cylinder along a radius passing through the center which is closer to the horizontal diameter than to the vertical diameter. As shown in FIG. 8, the axis of the roller 12 lies on a radius passing through the axis of rotation of the work which is 39° to the left of a perpendicular to the axis and for a work piece of minimum diameter (FIG. 9), the axis of the roller 12 lies on a radius passing through the center of the work which is 42° to the left of the perpendicular. Correspondingly, the roller 14 lies on a radius between 14°, 45° below the horizontal (FIG. 8) and 10°, 15° below the horizontal (FIG. 9).

For grinding the outside surface of the work, the centers of rotation of the grinding wheel 10 and the upper roller 12 may be disposed in a common horizontal plane as illustrated in FIGS. 8 and 9, nine inches below the center of rotation of the work W in the first instance and five inches below the center of rotation of the work W in the second instance. Notwithstanding the substantial difference between the diameters of the grinding wheel 10 and the roller 14 as illustrated, the respective radii extending from the center of rotation of the work W to the points representing the respective lines of contact between the grinding wheel and the work and the roller 14 and the work are substantially the same, 13° 20' in FIG. 8 and 9° 10' in FIG. 9 with a line representing a plane intersecting both of these lines of contact.

For grinding the inside surface the relation of the rollers differs somewhat in that while the lower roller 12 remains in the same relative position somewhat closer to the horizontal diameter of the work than the vertical diameter, approximately 40° below the horizontal, the upper roller 14 engages the work on a line intersecting the horizontal radius passing through the centers of the upper roller 14 and the work W.

By supporting the work externally throughout its axial length on the rollers 12 and 14, with the preponderant portion of the weight concentrated on the lower roller 12, the cylinder can be maintained uniformly straight throughout its length. Hence, although the cylinder may be somewhat distorted diametrically, that is, flattened due to its weight, any line in the surface parallel to its axis of rotation will be uniformly straight and consequently any point in the surface can be caused to travel along a line which is uniformly parallel to the tool. It is to be understood that the angles specifically referred to above are not to be considered limiting.

The ends of the rollers 12 and 14 are journaled for rotation in bearing housings 24 and 26, adjustably mounted at the opposite sides of a rigid cradle 28. The cradle, in turn, rests on the cross-slide 18 and is adjustable about a vertically disposed trunnion at its center. By means, which will be described hereinafter, the rollers 12 and 14 and the cradle 28 may be adjusted to maintain the relation of the rollers to the axis of rotation of the work so that the axis of rotation of the work will be substantially vertically above the center of rotation of the cradle on the cross-slide.

The grinding wheel 10, herein shown, is a relatively narrow disc preferably comprising reinforced abrasive, attached to one end of a horizontally disposed drive shaft 34. The shaft 34 is journaled for rotation in a rigid, horizontally disposed arm 36 fastened to a wheel slide 38, the latter being mounted on a transversely disposed bed 40. The bed is bolted to the left end of the base 20. The arm 36 supports the wheel with its axis on the axis of the supporting roller 12, approximately on a level with the axis of the other supporting roller 14 for both outside and inside grinding, as shown in FIGS. 8, 9 and 10. The line of contact of the cutting wheel with the work, however, varying according to the size of the work, being about 12°, 9° below the horizontal for maximum size work and 8°, 10° for minimum size work. For in-
side grinding the line of contact of the wheel with the wheel intersects a line passing through the center of the work and the supporting roller 14. Again, it is to be understood that the angles referred to are exemplary but not limiting.

A key 42 (FIGS. 1, 2, and 3) is fastened to the left end of the shaft 34 and rotation is imparted thereto by a belt 44 entrained about it and about a pulley 46 keyed to the shaft 48 of a motor M mounted on the wheel slide 38 on an adjustable plate 51, movable transversely with respect to the shafts 34 and 48 by means of a screw 55 to permit maintaining the proper centrally driving tension on the belt 44 and also to permit changing the pulley size. For any given grinding operation the wheel 10 is fixed and the work travels back and forth across its face by reciprocation of the carriage 16 and is fed toward the wheel by transverse movement of the cross-slide 18, as will appear hereinafter.

The bearing housing 24, which supports the roller 12, is a rigid casting having a flat bottom 50 (FIG. 7), pivotally mounted on a rigid plate 52 by means of a centrally located stud 54, the plate 52, in turn, being supported for movement along inclined pairs of spaced parallel ways 56–55 at opposite ends of the cradle 28. Feed nuts 59 extend outwardly from the plate 52 between the bearing ways 56–55 and are provided with threaded openings for receiving lead screws 60 also disposed between the bearing ways with their ends rotatably supported in ball bearing assemblies 62. Rotation of the screws will accordingly move the plate 52 and the housing 24 supported thereby up or down and the inclined bearings 56–55 according to the direction of rotation of the screws 60.

Referring specifically to the lower part of FIG. 5, each screw 60 has fastened to it a bevel gear 64 and these bevel gears mesh with bevel gears 66 fixed to the ends of a transversely extending shaft 68 journaled in bearings 70. At the center of the shaft 68 there is a gear 73 which meshes with a gear 74 supported in ball bearings assemblies 76. The gear 74 meshes with a pinion 78 fixed to the end of a shaft 80, the latter extending to the right side of the cradle 28 and having fastened thereto a hand wheel 82, by means of which the shaft 80 may be rotated.

To provide for perfect synchronization between the screws 60 so that movement of the housing 24 will affect movement of both ends of the supporting roller at the same rate, the bearings 62, at the upper end of one of the screws 60, the left one as shown in FIG. 5, is provided with a threaded boss 84 for reception of an adjusting screw 86. The adjusting screw 86 is supported against endwise movement in a thrust bearing 88, the latter being supported for rotation by a ring bearing 90. The adjusting screw 86 may be rotated by applying a wrench to its head 92 to move the screw 60 slidably keyed within the gear 64 in one direction or the other, thereby to bring it into perfect alignment with the right-hand screw so that rotation of the screws will result in movement of the housing 24 uniformly parallel to the surface of the work.

The bearing housing 26, which supports the roller 14, is slidably mounted on horizontally disposed pairs of spaced parallel ways 94–94 at the rearward side of the cradle 28. Feed nuts 96 depending from the underside of the housing 26 so that they extend downwardly between the ways are provided with threaded openings for receiving lead screws 98 (FIG. 5), the latter being disposed between the ways and supported in ball bearing assemblies 102. Bevel gears 102 slidably keyed to the ends of the lead screws mesh with bevel gears 104 fastened to the opposite ends of a horizontally disposed shaft 106. At the center of the shaft 106 there is a bevel gear 108 which meshes with a gear 110 mounted on a short stub shaft 112. The stub shaft 112 extends laterally through the housing 26 to the rearward side of the cradle 28 and has fixed to it a hand wheel 116. By rotating the hand wheel 116 the lead screws 98 may be turned to move the housing 26 inwardly or outwardly.

The left-hand lead screw 98, like the left-hand lead screw 60, is provided with an adjusting screw 118 corresponding to adjusting screw 86 so as to permit synchronizing the two screws 98.

The supporting roller 13 is mounted to turn freely in its bearing, but the supporting roller 14 is driven to provide the means for imparting rotation to the work relative to the wheel 10. To this end, the supporting roller 14 has at its right hand end (FIG. 2), a drive shaft 120 to which there is fixed a worm gear 122. A worm 124 is journaled in the housing, transversely of the axis of the worm gear 122, so as to be in mesh therewith and has fixed to its outer end a plurality of gears 126 of different diameters. A motor M2 (FIG. 3) is mounted at the right hand side of the cradle 28 and has on its drive shaft a plurality of gears 128. Rotation is imparted to the roller 14 by a toothed belt 130 entrained about a pair of gears of the respective sets of gears 126 and 128, the speed of rotation being determined by the pair of gears about which the belt is entrained.

When the housing 26 is moved in or out the motor M2 must be moved a corresponding amount. Moreover, it is desirable to adjust the motor vertically to maintain the proper tension in the belt 130 and to facilitate changing the belt from one pair of gears to another. Accordingly, the base of the motor is bolted to a plate 127 (FIG. 5), vertically slideable on a plate 129, the latter being mounted on horizontally disposed, spaced parallel tracks 131–131 on the cradle 28. A cylinder 133 is mounted on a flange 133a at the upper edge of the plate 127. A rod 137 extends from the cylinder and is connected to the plate 129. By supplying fluid pressure to one end or the other of the cylinder the motor may be raised or lowered. The plate 129 has a threaded boss 139 on its rearward side containing a threaded opening for receiving a lead screw 132, the right-hand end of which is rotatably supported against endwise movement in a bracket 134. A sprocket 136 is fixed to the screw in alignment with a sprocket 138 (FIG. 5), fastened to the shaft 132 to which the hand wheel 116 is fastened and a chain 135 is entrained about the sprockets 136 and 138. As thus constructed, rotation of the hand wheel 116 effects not only movement of the roller 14 inwardly and outwardly, but a corresponding inward and outward movement of the motor M2.

To prevent endwise movement of the work during the grinding operation there are endwise supporting rollers 140 and 142 (FIG. 6), arranged to bear against the opposite ends of the work. Conveniently, the rollers 140 and 142 are supported by the bearing housing 24, the roller 142 at the left side of the work, with respect to the front of the machine, being adjustably fixed during both external and internal grinding operations and the roller 140 at the right hand side of the machine being adjustable over a substantial range to accommodate various sizes of work and continuously urged toward the roller 142 by a spring so as yieldably to urge the work toward the fixed roller 142.

Referring specifically to FIG. 6, the rollers 140 and 142 are rotatably mounted on spindles 144 and 146. The lower ends of the spindles 144 and 146 have integral bosses 148 and 150 through which there are threaded openings for receiving screws 152. The roller 142 is first adjusted to the desired fixed position. The screw 154, for adjusting its position has an unthreaded extension at its left end on which there is fastened a worm gear 170 which meshes with a worm 172 fastened to a shaft 174. The shaft 174 extends through the front of the machine and is fitted at its outer end to a hand wheel 176, by means of which it may be rotated. The screw 152 is supported in and transversely of the housing 24 in bearings 156 and has at its outer or right hand end a hand wheel 158 by means of which it may be rotated to move the roller 140 axially of the work. The inner end of the screw 152 has an unthreaded extension 162.
which projects through its bearing and has on it a thrust bearing 168, a coiled spring 164 and a nut 166. The spring yieldably biases the screw 152 toward the left, as seen in FIG. 6, urging the roller 140 against the right hand end of the work so as to force the work toward the fixed roller 142.

The work supported between the rollers 12 and 14, at its sides, and the rollers 140 and 142, at its ends, is movable transversely of the carriage 16 to bring either its external surface nearest the front of the machine into contact with the face of the grinding wheel, or its internal surface nearest the back of the machine into contact with the face of the grinding wheel, depending upon whether the outside or inside surface is to be ground by transverse feeding movement of the cross-slide 18 on the carriage 16. In accordance with conventional practice, the cross-slide 18, to which the cradle is fastened, has V-shaped and flat bearing elements 180 and 182, respectively, (FIG. 1), engaged with correspondingly shaped bearing elements on the carriage 16 to insure uniformity of movement independently of the ambient conditions.

Movement of the cross-slide 18 to feed the lateral surface of the work being operated upon toward the face of the grinding wheel may be effected either manually or automatically. Referring specifically to FIG. 4, the cross-slide 18 has at its underside a boss 184 to which there is fastened a half nut 186 meshing with a feed screw 188, the latter being journalned at its left end in an anti-friction bearing 202, slidably and non-rotatably supported by the carriage 16 and at its right end in an anti-friction bearing 202 disposed in a cylindrical member 204 movable axially in a plain bearing 206 integral with the carriage 16. The cylindrical member 204 is connected at its right-hand end to the rod 208 of a piston 210 situated in a cylinder 212 fastened to the right-hand end of the bearing 206. By supplying fluid pressure to the right-hand or rear end of the piston 210 the feed screw 183 may be advanced bodily at a rapid rate to, in turn, move the cross-slide 18 and hence the work up to the face of the grinding wheel 10.

After the work is positioned adjacent to the grinding wheel in the manner described above, the feed screw 183 may be rotated either manually or automatically to effect a fine feed. An unthreaded extension at the left-hand end of the feed screw 188 is keyed in sliding engagement of a work concentrically disposed hollow sleeve 232 rotatably supported in a pair of spaced anti-friction bearings mounted within the carriage 16. The sleeve 232 is provided at its left-hand end with a gear 230 fixedly secured thereto so that rotation of the gear 230 effects rotation of the feed screw 188.

Manual rotation of the feed screw 188 is produced by rotation of the hand wheel 218 operatively connected to gear 230 through an intervening train of gears indicated generally by the reference numeral 229. As illustrated in FIG. 4, the gear train 220 consists of six gears 246, 248, 250, 252, 254 and 256 supported in a suitable gear casing 260 attached to and projecting upwardly from the front of carriage 16. The gear 246 at the lower end of gear train 220 meshes with the gear 230 mounted on the sleeve 232 and the gear 256 at the upper end of the gear train 220 is secured fixedly to the shaft 258 on which the hand wheel 218 is rotatably mounted. An index gear 262 fixedly secured to the shaft 258 behind the hand wheel 218 is provided with suitable teeth around its entire periphery for engagement with a coacting pin 264 projecting rearwardly from a point on the periphery of the hand wheel 218. The pin 264 is mounted as shown in FIG. 4 for slidably non-rotating movement relative to the hand wheel 218 into and out of engagement with the peripheral teeth of the index gear 262. By means of a suitable biasing spring, the pin 264 is normally maintained in engagement with the teeth of index gear 262 so that the hand wheel 218 and the gear 256 are maintained in a fixed angular relationship for concurrent rotation of the shaft 258 on which they are both mounted. The pin 264 is arranged to be manually withdrawn from and maintained out of engagement with the index gear 262 for adjustment of the angular position of the hand wheel 218 relative to the angular position of the gear 256. By means of this adjustment the machine can be set for the desired amount of infeed before the abutment 219 mounted upon the hand wheel 218 engages the limit stop 221 for the purpose and in the manner further described below.

The feed screw 183 is rotated automatically by axial displacement of the hydraulic piston 214 within the transverse cylinder 216 since the piston 214 projects on its upper side with a rack which engages a gear 222 secured to a sleeve 223 supported on suitable spaced anti-friction bearings fixedly relative to the carriage 16 and provided at its right-hand end with an external gear 225 forming one element of a clutch assembly which also includes an internal gear 227 fixedly secured to the right-hand end of a shaft 224 mounted concentrically in and slidable and rotatable within the sleeve 223 supporting the gear 222. The shaft 224 in turn supports a sleeve 226 keyed in slidable engagement therewith and provided with a gear 228 fixedly secured to sleeve 226 and disposed in engagement with the gear 223. The shaft 224 is provided at its left-hand end with a peripheral grooved collar 234 fixedly secured thereto. A lever 236 rotatably supported on pivot 238 is in the laterally extending bracket 246 projecting from the gear casing 260 is provided at its lower end with a fork 242 fitted with opposing pins 244 and 244 projecting therefrom into interfitting engagement with the grooved collar 234 on the shaft 224. Thus, clockwise displacement of the lever 236 as seen in FIG. 4 shifts the shaft 224 to the left so that the internal gear 227 mounted on the right-hand end of shaft 224 is moved into engagement with the external gear 225 mounted on the right-hand end of the sleeve 232 supporting the gear 222. Thus, rotation of the gear 222 produced by linear displacement of the piston 214 produces rotation of the shaft 224 transmitted through the sleeve 226 and the gear 228 fixedly secured thereto to the gear 230 mounted on the sleeve 232. Conversely, when manual rotation of the feed screw 188 is preferred, the automatic means for producing rotation on the feed screw 188 is disengaged by moving the lever 236 in a counter-clockwise direction to disengage the respective elements of the clutch assembly selectively operable to interconnect the sleeve supporting gear 222 and the shaft 218.

The fine feed achieved by rotation of the feed screw 188 is limited by a suitable stop means best understood by considering the showing in FIG. 11 along with the showing in FIG. 4. The hand wheel 218 is provided with a stop abutment 219 disposed so that it engages the limit stop 221 when the hand wheel 218 has been rotated sufficiently to produce the desired fine feed. The action of the stop abutment 219 is adjustable by virtue of the fact that the angular position of the hand wheel 218 relative to the coaxially mounted gear 256 is adjustable in the manner described above when the pin 264 is withdrawn from engagement with the index gear 262 so that the hand wheel 218 freely manipulated upon shaft 258 may be rotated relative to the gear 256 before the pin 264 is re-engaged with the index gear 262. Thus, with the hand wheel 218 properly adjusted, this hand wheel may be rotated counterclockwise as seen in FIG. 11 until the abutment 219 engages the limit stop 221 to terminate the fine feeding operation when the work has been ground to the desired size. Similarly, since the gear train 220 remains operatively connected to the gear 220 through an automatic feeding movement controlled by the movement of piston 214 within cylinder 216, the gear train 220 will be rotated by gear 230 to effect counterclockwise rotation of the hand wheel 218 until the abutment 219 engages the limit stop 221. Thus, this stop means is rendered equally effective dur-
Longitudinal feeding movement of the work transversely of the face of the grinding wheel is effected automatically by reciprocable movement of the carriage 16, the base 20, the carriage having at its underside V-shaped and flat slides 266 and 268 (FIG. 3), engaged with correspondingly shaped slide-ways on the base 20. Near the right-hand end of the carriage 16 there is a downwardly extending full nut 270 (FIG. 1), through which passes a horizontally disposed lead screw 272, the latter being journaled lengthwise of the base 20 in suitable bearings. The right-hand end of the lead screw 272 has fastened to it a gear 274 (FIG. 3), which meshes with a pinion 276 fixed to the shaft 278 of a hydraulic motor 280 (FIG. 1). Rotation of the screw 272 therefore effects longitudinal movement of the carriage 16.

Reciprocation of the carriage is effected by reversing the rotation of the screw 272 at each end of the carriage movement. To this end, a worm 282 (FIG. 1) is fastened to the left-hand end of the screw 272 and this meshes with a worm wheel 284 having on one face a gear 286. The gear 286 meshes with a gear 288 fast to a horizontally disposed shaft 290, the outer end of which projects through the front of the base through a suitable bearing 292 and has fast to it a sprocket 294. A reversing disc 296 and a sprocket 300 (FIGS. 1 and 11) are fixed on a stub shaft 298 mounted for rotation at the front end of the bed 40, and rotation of the reversing disc is effected by a chain 302 entrained about the sprockets 294 and 300. A chain tighter 303 (FIG. 1) is adjustable fastened to the bed adjacent one run of the chain to keep it uniformly taut and hence to insure accuracy in operation. Four reversing dogs 304, 306, 308 and 310 are mounted on the disc, the two dogs 304 and 306 being rotatable into and out of operative position. An arm 312 (FIG. 11) disposed adjacent the reversing disc 296 is fixed mounted on a rotatable shaft 315 with one end disposed between a pair of spaced limit pins 316—316 projecting from plate 314 which limits the movement of the arm 312 and hence the carriage of the shaft 315 upon which it is mounted, in turn connected to the rotating element of reversing valve 432. The opposite end of the arm 312 is connected by a pin and slot connection to one end of a link 318, the opposite end of which is pivoted on a pin 320 secured to the bed 40, so that arm 312 and link 318 together form an over center toggle linkage. A spring 322, on the link 318, operates to hold the arm 312 biased in either the right or left position against one of the pins 316—316. A pair of staggered lugs 324 and 326 are integral with the arm 312 so as to project radially from its center of rotation and to lie in the path of the dogs on the reversing disc. The dogs operate by engagement with the lugs to rock the arm 312 and shaft 315, and by such movement, to actuate valve 432 to reverse the direction of flow of fluid through the hydraulic motor 280. The details of the valve and valve structure will be described hereinafter.

The grinding wheel 10, fixed during the reciprocable movement of the work relative to it, as previously stated, is supported at the free end of the cantilevered arm 36. To prevent deflection and/or vibration of the cutting wheel the arm is made extremely stiff by radially disposed, reinforcing ribs 325, there being several such ribs disposed transversely of the body and extending the length of the arm.

When the external surface of the work is to be operated upon the wheel 10 occupies a suitable position adjacent the forward end of the bed 40, as shown, for example, in FIGS. 2 and 3. When the inside surface of the work is to be operated upon the wheel is moved transversely of the bed 40 toward the rear of the machine so as to have contact with the inner surface of the work at the opposite side, as shown in dotted lines in FIGS. 2 and 3. Movement of the cutting wheel from left to right and vice versa is effected by movement of the wheel slide 38 lengthwise of the bed 40. For this purpose the upper surface of the bed has spaced parallel ways 327—327 (FIGS. 1 and 2) on which the wheel slide 38 is adapted to slide. A nut 330 extends downward from the under side of the wheel slide between the ways through which is threaded a lead screw 328. A worm wheel 332 is fastened to the rear end of the lead screw and this meshes with a worm 334 fastened to a shaft 336. The shaft 336 is coupled to a motor M4 mounted on a bracket 338 on the side of the bed 40 adjacent its rear end. The transverse movement of the tool is only for the purpose of positioning the wheel for outside and inside work and there is no need for changing its position rapidly, a very small motor is all that is required even though the wheel slide 38 and the arm are quite heavy. T-bolts 335 engaged in suitable T-slots in the bed 40 which clamp the slide to the bed during a grinding operation have to be loosened prior to traversing the slide.

In FIGS. 1 and 2 the apparatus is illustrated as equipped with a cylindrical wheel for grinding the lateral surfaces of the work. It is also necessary to grind the end faces of the work as well. This is accomplished by removing the grinding wheel 10 and replacing it with a face type grinding wheel such as the cup-shaped grinding wheel 10a shown in FIG. 7, or the like. During this grinding operation, the end grinding wheel 10a is disposed as shown in FIG. 7 and maintained in position at the left side of the work, while the work is rotated about its axis by the operation of roller 14 in the manner described above. In setting up the machine for this grinding operation, the work piece is initially disposed as shown in FIG. 7 immediately adjacent to the grinding face of grinding wheel 10a by suitable manipulation of the feed screw 18 causing the work to move a given distance along the guide slot 180 to properly position the cross-slide 18 relative to the carriage 16 and by suitable manipulation of the lead screw 272 to properly position the carriage 16 relative to the base 20. Thereafter the feed screw 188 and the lead screw 272 remain motionless throughout this grinding operation. Hence, the reversing disc 296 effective to produce reciprocation of the carriage 16 is rendered inoperative during end grinding. The work W is fed toward the grinding wheel by rotating the hand wheel 176 to rotate the screw 154 so that the normally fixed roller 142 is moved to the left by manipulation of the hand wheel 176, the spring biased roller 140 acts on the work W to maintain it in contact with the roller 142 and thereby effect the requisite feeding movement of the work relative to the grinding wheel 10a.

Provision is made for adjusting the supporting roller 12 through a slight angle relative to the roller 14 for the purpose of producing axial or endwise creep of the work toward the roller 142, thereby to assist the spring-pressed roller 140 in holding the work against the roller 142. The angular adjustment of the roller 12 is effected by loosening clamping bolts 97 which clamp the flat bottom 50 of the housing 24 to the plate 52 and swivelling the housing 24 on the pin 54. Adjustment is provided by screws 339 (FIG. 7) at opposite ends of the housing, threaded through brackets 340 fastened to the under- lying plate 52 so that the inner ends of screws 339 bear upon the edge of the flat bottom 50. To permit swivelling of the housing 24, arcuate slots 342 therethrough (FIG. 6) are provided for the bolts 97.

To maintain the axes of the end rolls 140 and 142 radial with respect to the axis of the work, the bosses 148 and 150 at the lower ends of the spindles 144 and 146 are provided with pins 147 and 149. The pins 147 and 149 project through slots 151 and 153 in slotted plates 155 and 157. The plates have rearwardly extending arms 159 and 161 which are adjustable angularly to rotate the spindles about the axes of the screws 152 and 154. Clamping means 163 and 165 are provided for fixing the ends of the arms in a given position relative to slotted
plates 167 and 169 secured to the opposite ends of the housing 24.
The entire cradle 28 is pivoted on the cross-slide 18 for adjustment about a vertically disposed trunion 344 (FIG. 4) fixed on the cross-slide and having at its upper end a round bearing 346 which occupies a central opening 348 in the cradle casting. A roller bearing assembly 350 is interposed between the bearing 346 and opening 348. The coating upper and lower planar surfaces of the cross-slide 18 and cradle 28 respectively, are scraped 349 to provide smooth contacting faces and normally the sides and ends are held clamped together as a rigid unit by a plurality of clamps 352, the clamping means consisting of T-bolts engaging circular T-slots. When it is desirable to swivel the cradle with reference to the slide the clamps are loosened and the cradle is adjusted by screws 354—356 (FIGS. 1 and 3), threaded through brackets 356—350 fastened to the cradle 28 and positioned so as to bear against the edge of the cross-slide 18. Thus, by rotating the screws 354—356 in opposite directions the cradle may be shifted angularly on the cross-slide.
Because of the great weight of the cradle and the work, adjustment of the cradle on the cross-slide may be difficult even though the engaging surfaces are scraped accordingly, it is desirable to relieve this pressure after the clamps have been loosened. This relief is effected by providing annular grooves 358 (FIGS. 4 and 11) in the upper surface of the cross-slide beneath the lower surface of the cradle, near the four corners of the cradle, each fitted with a resilient O-ring 359 and providing recesses 369 and conduits 362 for delivering oil under pressure to the spaces between the cross-slide and the cradle bounded by the O-rings 359. Upward movement of the cradle is very slight, if any, but the load reduction thus achieved is sufficient to break the seal. In any case, relative upward movement of the cradle is limited by a spanner nut 364 threaded onto the upper end of the trunion 344.
The provisions for pivoting the cradle 28 on the cross-slide 18 described above are included so that the cradle 28 of the machine described herein may be rotated after the external lateral surface is ground to finish the cylindrical bearing ground so that the internal lateral surface is tapered slightly axially of the bearing. With the internal surface ground thus, the bearing may be tightened on a corresponding tapered shaft.
To attain the desired smoothness the grinding wheel must be dressed frequently without removing it from its driving spindle. For dressing during external grinding a dressing tool 366 (FIG. 3) is adjustably mounted in a holder 368 at the upper end of an arm 370, the lower end being fastened to the cradle by suitable bolts which may be removed for removing the device when grinding internally and when grinding the end faces of the work. For dressing during internal grinding a dressing tool 372 is adjustably mounted in a holder 374, the latter being permanently mounted on the cradle at the left-hand side. When the cup wheel 18c is used for end grinding, a dressing tool 376 (FIG. 6) is employed and is adjustably mounted in a holder 378. The holder 378 is mounted at the outer end of a radial arm 380 (FIGS. 6 and 7) which is fastened at its inner end to a shaft 382 for swinging movement in a plane parallel to the end face of the cup wheel 18c. The shaft 382 has on it a worm wheel 384 which meshes with a worm 396 fixed to a shaft 388. A bevel gear 390 is fixed to the shaft 388 and meshes with a bevel pinion 400 fastened to a shaft 402. A hand wheel 404, fixed to the shaft 402, provides for effecting swinging movement of the arm 390. The dressing tool 376 and the mechanism for moving it into and out of operative position are mounted on a bracket 406 slidably engaging and adjustably fixed on a slideway on the front of bearing support 24 so that it is rigidly supported thereby and easy to remove when it is not required.
Dressing of the cylindrical grinding wheel 10 is effected during grinding at predetermined intervals or at selected intervals by lengthening the stroke of reciprocation, that is, causing the carriage to move the work far enough beyond the face of the grinding wheel to move the dressing tool across the face of the grinding tool. This is effected by the dogs referred to heretofore, on the reverser disc 296, as will be more fully explained in the description of the control system for this machine.
To further assure surface smoothness of the work, wipers 395 in the form of long flexible rubber blades may be mounted upon the upper sides of the supporting roller bearings 24 and 26 to engage the adjoining surfaces of the work. The wipers tend to remove abraded stock and abrasive particles which might otherwise cling to the surface of the work as it passes over the supporting rollers and thus make rotation of the work relative to the grinding wheel imperfect by scoring the supporting rollers.
Uniformity in wall thickness is of prime importance and to attain this the preferred method of operation is to grind the external lateral surface of the cylinder first so as to form a precise reference from which to measure and then to grind the inside surface and to grind the end surfaces.
Cylindrical grinding operation of the apparatus described above is effected by a combination of hydraulic and electrical means, as shown in FIG. 11, with pull-down control thereto including a control pant 408 (FIGS. 1 and 3), suspended from a carrier 410 movable along a horizontally disposed arm 412. The arm 412 is pivotally mounted at one end at the upper end of a post 414, the lower end of which is fixed to the machine adjoining the base of the machine at the right-hand end thereof, substantially midway between the front and back of the machine. The arm 412 may thus be swung from one side of the machine to the other for convenience in operation and the control pendant is movable along the arm 412 to permit clearing any protruding part of the machine.
Assuming that the operation to be performed is external grinding, that a cylindrical grinding wheel is mounted on the drive shaft 54, and that the wheel slide 38 is at the front of the bed, as illustrated, for example, in FIG. 3, and that the main switch M1 is closed, rotation of the grinding wheel 10 is started by closing a switch SW2 (FIG. 11), which supplies current to the wheel drive motor M1. Rotation of the work is started by closing a switch SW4 to supply current to the motor M3 which drives the work supporting reciprocating bed 13, direction of rotation of the work, that is clockwise as seen in FIG. 3 for external grinding, is determined by properly positioning a selector switch SW3 to control the direction of the current through the motor M2.
Oil for the system is contained in a reservoir 416 and is supplied thereto from the system under suitable pressure by a conventional motor driven pump unit consisting of a pump P and motor M3. A relief valve V is arranged to by-pass oil from the discharge side of the pump back to the reservoir to maintain the pressure in the system constant at the desired level. Current is supplied from a suitable source through lines L1, L2 to the motor M3 by closing switch SW1.
As previously indicated, the work is fed toward the grinding wheel by traverse movement of the cross-slide and it is desirable at the beginning of an operation to maintain the cross-slide in a fully retracted position. Accordingly, the various control valves are set initially so that when the pump P is started fluid pressure is supplied through a four-way valve V1 to the left end of a flow control valve V2, so that the latter is held closed. The actuator is thus held to the right and also through a four-way valve V3, check valve 418 and by-pass valve V4 into the right end of the work feed cylinder 216, so as to move the piston 214 displaced to the left, as shown in FIG. 11, which, in turn, through the pinion 222, gear 228 and gear 230 holds the screw 186 so positioned that the feed
nut 186 depending from the cross-slide 18 is disposed at the right-hand end of feed screw 188 as shown in FIG. 11. Pressure is also supplied through the valve V3 and a pipe 422 to the left end of a backlash take-up valve V5 holding it at the right-hand end and to the left end of the right work traverse cylinder 212, thus holding the cross-slide 18 fully displaced to the rear of the machine. Valves V6, V7, V10 and V12 at this time are blocking flow of oil from the pressurized side of the hydraulic system to the exhaust side.

To advance the work from its retraced position into position for grinding a switch SW5 is closed which energizes a solenoid S5 so as to move the four-way valve V3 to the left, thus allowing pressure fluid to flow to the right end of the cylinder 212 and to the left end of the cylinder 210 through the valve V4. The cross-slide 18 is moved forward rapidly by the resultant displacement of piston 210 to the left until the piston 210 closes the port 424 so that fluid exhausting from the port 424 is cut off and is required to pass through a regulator valve 426 at a slower rate to decelerate the movement of the piston and hence cushion it as it moves into engagement with the left end of the cylinder 212. At the same time, fluid traversing the right-hand end of the backlash eliminator valve V5 moving it to the left at a rate controlled by a regulator valve 430, which allows a predetermined amount of oil to exhaust from the right end of the cylinder 216 by way of the pipe 420 at a rate determined by the throttle valve 435. The resultant displacement of the right-hand piston 214 moves the cross-slide 18 forward by a predetermined additional amount at a slower rate by effecting rotation of the feed screw 188. This should place the work adjacent to the peripheral face of the grinding wheel 16, if the cross-slide 18 has previously been properly positioned relative to the feed screw 188. Otherwise, the clutch lever 236 (FIG. 4) may be pulled to disengage the clutch interconnecting the gear 222 and the gear 228, whereupon the cross-slide may be advanced manually to bring the work into contact with the grinding wheel by additional rotation of the hand wheel 215.

If the final dimension of the work is to be controlled by engagement of the abutment 219 with the limit stop 221, it may also be necessary to adjust the hand wheel 218 angularly relative to the index gear 262. This adjustment is accomplished in the manner described above by when the hand wheel 218 is in engagement with the index gear 262 so that the hand wheel 218 may be displaced by the angular amount necessary to properly position the abutment 219 to effect the proper final work size.

Since the detailed features of the means for mounting the pin 264 in the hand wheel 218 form no part of the instant invention, the relationship between these parts has been described only in general terms. However, it is to be understood that the pin 264 may conveniently comprise a micrometer adjusting device of the type illustrated in FIG. 9 and described in column 19 of U.S. Patent #2,572,529 to H. A. Silven. In such a device fine adjustments may be achieved by disengaging a detent restraining the pin against rotation so that a pinion formed on the end of the pin and disposed in engagement with the index gear as illustrated in FIG. 11 may be rotated in engagement with the index V8 until the abutment 219 is disposed in the desired precise position.

When it is desirable to operate the cross-slide manually without disengaging the clutch and without disturbing the micrometer stop on the hand wheel 218, a switch SW6 is closed which energizes a solenoid S6 in valve V6. This moves the valve V6 to the right, allowing pressure fluid to enter the right-hand end of the valve V4 so as to move it to the left and this, in turn, allows oil to flow freely from one end of the cylinder 216 to the other when the hand wheel 218 is rotated. With cylinder 216 thus bypassed, the hand wheel may be employed to rotate the screw and hence to effect manual positioning of the cross-slide. Automatic feeding of the work toward the grinding wheel, at each end of the traverse of the work, is controlled in conjunction with the reversing mechanism as will appear hereinafter.

The work traversing carriage 16 is driven by the hydraulic motor 290 and the screw 272. Reversal of the movement of the carriage to effect reciprocation of the work with respect to the face of the grinding wheel is attained through the reversing dogs 300 and 310 and offer levers 324 and 326 (FIG. 5 and 11). As shown, the carriage is moving toward the left from the extreme right-hand position for a wheel dressing operation and the disc 296 is turning clockwise. With the dressing dog 304 rotated inwardly to an inoperative position the dog 306 will pass the lug 324 and the reversing disc will continue to turn until the work has moved to the left beyond the grinding wheel, whereupon the dog 310 will strike the lug 324 and rotate the arm 312 and shaft 315 in a counterclockwise direction. Counter-clockwise rotation of the arm 312 and shaft 315 rotates a reversing valve 432 counterclockwise thus supplying fluid in the opposite direction to the motor 290. The rotatable dog 306 will strike the lug 326 on the reverse movement when the carriage has traversed the work to the right beyond the grinding wheel, thereby rotating valve 432 to reverse motor 280.

The dogs 310 and 306 control the reciprocation of the carriage for the grinding operation while the dogs 304 and 308 control the reciprocation of the carriage for the dressing operation. Thus by rotating the dog 304 outwardly it will engage the lug 326 after a short interval of travel from the position illustrated in FIG. 1 so as to reverse the direction of the carriage and hence traverse the dressing tool back and forth across the face of the wheel.

To initiate reciprocation of the carriage 16 to move the work back and forth across the face of the tool and to feed the work toward the tool at the end of each pass, a switch SW7 is closed to energize a solenoid S7, which in turn moves a two-way valve V7 to the right, allowing fluid under pressure to enter the rotary valve 432 which, as described above, is rotated by the arm 312 positioned by the dogs on the reversing disc 296. With the dogs 310 and 306 and the lugs 324 and 326 in the position shown in FIG. 11, fluid under pressure enters the valve 432 from the valve V7 and leaves through a pipe 434 to the right-hand end of a valve V9, either holding it displaced in its left-hand position or moving it to the left. The valve V9 is moved from one end to the other at each reversal of the valve 432 and the carriage 16, its rate of movement being controlled by a pair of regulator valves 440 and 442. As the valve V9 moves from right to left and left to right it allows a predetermined amount of oil to exhaust from the right end of the cylinder 216 causing the cross-slide to move the work toward the grinding wheel a predetermined increment according to the amount to be ground off the work on each reverse movement of the carriage.

Fluid is also supplied through the pipe 434 to the left-hand end of a two-way valve V8, moving the latter toward the right at a rate which is controlled by a regulator valve 436 to provide a dwell at the reversal of the carriage. When the valve V8 is moved to the right allowing fluid under pressure to pass to the right-hand end of a valve V10, moving it to the left so that pressure fluid flows from the pipe 417 to the motor 280 to rotate it clockwise and hence to rotate the lead screw counter-clockwise, that is in the direction indicated in FIG. 11 by the arrow encircling lead screw 272. Counter-clockwise movement of the lead screw 272 effects clockwise movement of the reversing disc 296 and moves the carriage to the left at a rate controlled by an exhaust valve 444 located beyond the valve V2.

The carriage and work move to the left until the dog 310 strikes the lug 324 rotating arm 312 and shaft 315
which thereby rotates the valve 432 counter-clockwise.
Fluid under pressure then passes through a pipe 438 and branch 446 into the left-hand ends of valves V9 and V11, moving them to the right. As the valve V9 moves to the right, it once more allows oil to exhaust from the cylinder 216 to feed the work toward the grinding wheel. The valve V11 moves to the right at a rate controlled by a regulator valve 249, once again providing a dwell at the reversal of the carriage. When the valve V11 finally reaches its right-hand position it allows fluid under pressure to flow to the left-hand end of the valve V10, moving it to the right so that pressure fluid is supplied from the pipe 417 to the motor 280 in the opposite direction. Rotation of the motor in the opposite direction moves the carriage toward the right and the reversing disc counter-clockwise until the dog 366 strikes the lug 326, rotating the valve 432 clockwise into the position shown in FIG. 11 and repeating the above procedure until the work has been ground to the desired size which is determined by the setting of the abutment 219 on the hand wheel or by manually measuring it.

If it is desired to manually effect the reciprocation of the carriage independently of the dogs 364, 365, 368 and 318, a switch SW9 is closed momentarily which, by energizing the solenoid S9, shifts a valve V12 to the right, allowing fluid pressure to flow to the left end of a cylinder 450 which moves the valve 432 to the position shown in FIGURE 11 by rotating the plate 314 to the right to force arm 312 over center, thereby causing the carriage to move to the left. By momentarily closing a switch SW9, so as to energize a solenoid S9, the valve V12 is moved to the left, allowing fluid pressure to enter the right-hand end of the cylinder 450 so as to rotate the valve 432 counter-clockwise by rotating plate 314 to the left to force arm 312 over center, thereby traversing the carriage to the right.

In order to dress the grinding wheel, the dog 364 is rotated clockwise so that it will engage the lug 326. This causes the carriage to be reversed after a short interval of the carriage in the same manner as above described for traversing a work piece. However, during the dressing operation, a switch SW14 is closed, energizing a solenoid S14 to move valve V1 and thence valve V2 to the left, which causes a slower traversing speed as controlled by the regulator valve 454 instead of the faster valve 444.

When the work has been ground to size the switch SW3 is opened so as to de-energize the solenoid S5, whereupon the piston 210 in the cylinder 212 moves the cross-slide transversely to the rear and the piston 214 in the cylinder 216 to the left to rest the hand wheel 218 and abutment 219. Switch SW7 is also opened to de-energize solenoid S7 and thereby stop the carriage 16.

If it is desirable to swing the cradle 28 for a taper grinding or to correct for undesired taper found to be present, a manually operable two-way valve V16 is moved to the left to allow fluid to enter the recesses 366 at the underside of the cradle by way of a pipe 456 and branches 362 to hydrostatically relieve the pressure between the surfaces and thereby eliminate most of the friction so that the cradle can be swivelled easily.

An hydraulic cylinder 133 is also provided for lifting the motor M2 so that the belt 130 may be changed from one pair of pulleys to another in order to vary the work drive speed. A valve 462 is closed manually and a valve 464 is closed manually when it is desired to lift the motor.

The valve 462 is closed and the valve 464 is opened when it is desired to lower the motor. This can only be done when the cross-slide is in its extreme rearward position.

When changing from external to internal grinding, the wheel slide 38 is moved transversely and this is done setting a selector switch SW18 in a position opposite to that shown in FIG. 11 to reverse the direction of rotation of the motor M4. The motor is started by closing the switch SW20 and, providing the hold-down T-bolts 335 have been loosened in the T-slots, it will move the slide to the rear.

Now assuming that the operation to be performed is internal grinding, that selector switch SW3 has been shifted to reverse the direction of the current through the motor M2 so that the roller 14 will be driven to rotate the work counter-clockwise as seen in FIG. 3, and that the wheel slide 38 has been shifted toward the rear of the machine in the manner described above so that the grinding wheel 10 is disposed in the position indicated in dot-dash lines on the right-hand side of FIG. 3, the internal grinding operation is accomplished in exactly the same manner as described above for the external grinding operation by the operation of the same elements of the control system in the same sequence and in the same manner as described above. The work is first advanced to a position adjacent the grinding wheel by similar operation of the same feed mechanism for the cross-slide 18.

Reciprocation of the carriage 16 to traverse the work across the grinding wheel is controlled by the dogs 364 and 368 effective through the mechanism described above to control the position of valve 432 and thereby determine the direction of rotation of the motor 280. The automatic infeed after each pass is similarly controlled by operation of the valve V9. Reciprocation of the carriage for dressing the grinding wheel with the tool 372 is controlled by the dogs 364 and 368 operative to effect reversal of the motor 280 to traverse the tool 372 across the grinding wheel. Finally, the desired dimension of the work may be determined either by engagement of the abutment 219 with the limit stop 221 or by measuring the work.

While a range of sizes for the work pieces to be finished on this machine has been specified above, it is to be understood that this range is exemplary only and that this machine is suitable for finishing a range of sizes of substantially larger work pieces if the respective elements of the machine are scaled up to accommodate such larger work pieces.

For the end grinding operation on one end of the work the machine elements are positioned relative to the work as shown in FIGS. 6 and 7 after a cut-off type wheel 16a has been substituted for the cylindrical grinding wheel 10. Thereafter, the work is fed to the fixedly positioned grinding wheel by rotation of the hand wheel 176 in the direction to shift the roller 142 to the left as seen in FIG. 6 on the screw 154. During this grinding operation the wheel may be dressed at the necessary time by rotating the hand wheel 494 to swing the tool 376 across the grinding face of the wheel 16a. When one end of the work has been ground, the work is reversed end for end on the machine so that the other end may be ground by repeating the same operation sequence.

Furthermore, the machine described herein is further characterized by a configuration suitable for regrinding the supporting rollers 12 and 14. From the showing in FIG. 3, it will be apparent that the supporting roller 14 may be ground in situ by an operation corresponding to the internal grinding operation on the work. This roller regrinding operation is accomplished by positioning the grinding wheel 10 substantially in the position indicated in dash lines in FIG. 3 and by feeding the roller 14 against and traversing the roller 14 across the grinding wheel. It will be noted that the tool 372 may be suitably positioned for dressing the grinding wheel during such regrinding operations. Roller 12 can also be reground in the same manner by making it identical to and interchangeable with the roller 14 so that this roller may be installed in the position occupied by roller 14 as illustrated in FIG. 3 for the regrinding operation. For this regrinding operation, the switch SW3 must be set to produce rotation of the motor M2 which will drive the roller driven thereby in a clockwise direction as seen in FIG. 3.

From consideration of the structural features best il-
Illustrated in FIGS. 3, 5, 6 and 7, it will be evident that the desirable relationship between the work W, the grinding wheel 10, and the supporting rollers 12 and 14 illustrated in FIGS. 8, 9 and 10 can be achieved or closely approximated for cylinders of various diameters within the range of sizes that can be ground on this machine by suitable adjustment of the housing 24 along the ways 56—58 and 16—18 accompanied by suitable adjustment of the housing 26 along the ways 94—96 after which the respective housings are secured in the proper positions by the clamping means provided for this purpose. Similarly, cylinders of various lengths are secured in a fixed position on the cradle 28 by proper adjustment of the roller 140 along the screw 152.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. A grinding apparatus for hollow cylindrical work pieces of large diameter, comprising a grinding wheel, means rigidly supporting the grinding wheel for rotation about a horizontal axis, mounting means for a pair of spaced horizontally disposed rollers mounted for rotation about their longitudinal axes, said rollers being respectively disposed at one side of and beneath a hollow cylinder adjacent the other side thereof so that a cylinder so supported is held uniformly straight lengthwise thereof under its own weight with its longitudinal axis horizontally disposed, means pivotally supporting said mounting means for adjustment about a vertical axis of a cylinder so supported parallel to the axis of rotation of the grinding wheel, and means for adjusting the rollers on said mounting means individually relative to each other to bring the axis of a cylinder supported by said rollers into a plane containing the vertical axis about which the mounting means is adjusted and into a predetermined vertical relationship to the axis of rotation of the grinding wheel.

2. In a grinding machine, a grinding wheel, a pair of laterally and vertically spaced, smooth cylindrical elongated supporting rollers for supporting a large hollow cylindrical work piece for rotation about a horizontal axis coincident with its longitudinal axis with a cylindrical surface engaged by the grinding wheel, drive means for rotating the grinding wheel, means for rotating a work piece on the supporting rollers and reciprocating the supporting rollers in unison to present an entire cylindrical surface of a work piece to the face of the grinding wheel, and first and second restraining means, the first restraining means being fixedly positioned lengthwise of the supporting rollers adjacent one end of a work piece and the second restraining means being yieldingly supported and biased against the other end of a work piece, so that a work piece disposed between said first and said second restraining means is maintained in engagement with said first restraining means by said second restraining means.

3. A machine according to claim 2, wherein the restraining means engaged with the ends of a cylindrical work piece are rollers mounted to turn on axes lying on a radius passing through the longitudinal axis of a cylindrical work piece engaged thereby.

4. Grinding apparatus for large hollow cylinders, comprising a grinding wheel, means rigidly supporting the grinding wheel for rotation about a horizontal axis, spaced horizontally disposed upper and lower supporting rollers, the upper supporting roller being disposed in engagement with one side and the lower supporting roller being disposed beneath and adjacent the other side of a cylinder supported upon said rollers in a horizontal position for rotation about its horizontally disposed longitudinal axis so that the supporting roller bears against the weight of the cylinder so supported rests on the lower supporting roller and cooperates therewith to hold a cylinder uniformly straight throughout its length, means for effecting rotation of the upper supporting roller to turn a cylinder engaged thereby about its longitudinal axis, means for rotating the grinding wheel, means for maintaining the external surface on the other side of a cylinder adjacent the lower supporting roller in contact with the grinding wheel, and means for reciprocating the supporting rollers in unison to traverse the external surface of a cylinder across the peripheral face of the grinding wheel.

5. Apparatus for operating on hollow cylindrical work pieces of large diameter comprising mounting means rigidly supporting a grinding wheel for rotation about a horizontal axis in first and second fixed positions, positioning means selectively operable to move said mounting means between said first and second positions, releasable securing means selectively operable to maintain said mounting means fixedly in said first position and fixedly in said second position, a pair of horizontally and vertically spaced horizontally disposed cylindrical supporting rollers the relatively higher roller disposed at one side and the relatively lower roller disposed beneath and nearer to the other side of a cylindrical work piece cradled thereon with its longitudinal axis horizontally disposed so that any element of either surface of the cylindrical work piece adjacent to the supporting rollers is held uniformly straight lengthwise thereof, means for effecting rotation of a grinding wheel upon said mounting means, reversible driving means for rotating a cylindrical work piece on the supporting rollers, means for reciprocating the supporting rollers longitudinally in unison to traverse a cylindrical work piece supported thereby across a grinding wheel supported by said mounting means, and means for feeding the supporting rollers transversely in unison toward a grinding wheel supported by said mounting means, whereby the external cylindrical surface of a cylindrical work piece may be ground when said mounting means is secured in said first fixed position and said driving means is operated in one direction and whereby the internal cylindrical surface of a cylindrical work piece may be ground when said mounting means is secured in said second fixed position and said driving means is operated in the other direction.

6. An apparatus as described in claim 5, and in addition, restraining means engaging a cylindrical work piece cradled on said supporting rollers and operable to maintain a cylindrical work piece so engaged in a predetermined relation to said supporting rollers longitudinally thereof, an auxiliary feeding means operable to displace said restraining means longitudinally of said supporting rollers whereby a cylindrical work piece engaged by said restraining means may be displaced longitudinally of said supporting rollers into engagement with the face of a grinding wheel supported on said mounting means to grind an end of the cylindrical work piece so displaced.

7. Apparatus for operating on thin walled hollow cylinders of large diameter, comprising mounting means for supporting a grinding wheel in first and second fixed positions for rotation about a horizontal axis, releasable clamping means selectively operable to secure said mounting means in said first fixed position and in said second fixed position, positioning means selectively operable to move said mounting means between said fixed positions, said second fixed position, first and second horizontally disposed supporting rollers the first disposed at one side and the second disposed beneath and toward the other side of a cylinder cradled thereon with its longitudinal axis in a horizontal position so that any element of either cylindrical surface of a cylinder adjacent to the supporting rollers is held uniformly straight lengthwise thereof, reversible driving means for rotating the first supporting roller to turn a cylinder resting on the supporting rollers about a horizontal axis coincident with its longitudinal axis in a given direction, drive means for rotating a grinding wheel supported on said mounting means in
a given direction, means operable to reciprocate the supporting rollers and a cylinder supported thereby longitudinally in unison to traverse a cylindrical surface of a cylinder so supported across a grinding wheel supported on said mounting means, primary feeding means selectively operable to move the supporting rollers and a cylinder supported thereby in unison transversely relative to a grinding wheel supported on said mounting means, and control means for producing coordinated operation of the means for reciprocating the supporting rollers and the primary feeding means to grind a cylindrical surface of a cylinder, whereby the external cylindrical surface of a cylinder may be ground with said mounting means disposed in its first fixed position and the means for rotating a supporting roller operating in one direction, and the internal cylindrical surface of a cylinder may be ground with said mounting means disposed in its second fixed position and the means for rotating a supporting roller operating in the other direction.

8. An apparatus as described in claim 7, and, in addition, a first cylinder restraining means arranged to constrain a cylinder against displacement longitudinally of said supporting rollers, a second cylinder restraining means mounted in opposed relation to said first cylinder restraining means, biasing means continuously effective to bias said second cylinder restraining means toward said first cylinder restraining means to maintain a cylinder disposed therebetween in engagement with said first cylinder restraining means, a secondary feeding means selectively operable to displace said first cylinder restraining means longitudinally of said supporting rollers to feed a cylinder disposed between said restraining means into engagement with a side face of a grinding wheel supported on said mounting means for grinding an end of a cylinder so disposed.

9. An apparatus as described in claim 7, wherein said mounting means is disposed first in its first fixed position for grinding the external cylindrical surface of a cylinder and then in its second fixed position for grinding the internal cylindrical surface of a cylinder, and wherein the axis of rotation of a cylinder cradled on said supporting rollers is disposed within the plane determined by the axis of rotation of the first supporting roller and the axis of rotation of a grinding wheel supported on said mounting means when said mounting means is disposed in said second position, whereby the internal cylindrical surface ground is precisely maintained concentric of the external cylindrical surface ground.

10. Apparatus for grinding the external surface and the internal surface of a large hollow cylinder without removing a cylinder to be ground from the apparatus comprising a first elongated supporting roller rotateable about a first horizontal axis adjustable transversely of said first horizontal axis in a given horizontal plane intersecting said first horizontal axis, a grinding wheel supported for rotation about a second horizontal axis located in the given horizontal plane parallel to the first horizontal axis and adjustable transversely of said second horizontal axis between a first position relatively remote from said first axis for grinding the external surface of a cylinder and a second position relatively near said first axis for grinding the internal surface of a cylinder, a second elongated supporting roller rotatable about a third horizontal axis located below the given horizontal plane and parallel to the first and second horizontal axes so spaced from said first horizontal axis that said second supporting roller is disposed beneath a cylinder cradled by said first and said second supporting rollers and adjacent the side of a cylinder so cradled most remote from said first supporting roller, reversible drive means operable through at least one of said supporting rollers to rotate a cylinder supported thereby, means operable to rotate said grinding wheel in a given direction, means operable to reciprocate said supporting rollers and a cylinder supported thereby collectively axially of the grinding wheel, means selectively operable to feed said supporting rollers and a cylinder supported thereby collectively toward said grinding wheel, adjustment means selectively operable to position said second supporting roller relative to said first supporting roller so that the central axis of a cylinder supported by said rollers is positioned a predetermined distance above the given horizontal plane intersecting said first and said second axes when said grinding wheel is disposed in its first position with said drive means operating in one direction for grinding the external surface of a cylinder and selectively operable to position said second supporting roller relative to said first supporting roller so that the central axis of a cylinder supported by said rollers is positioned in the plane intersecting said first and said second axes when said grinding wheel is disposed in its second position with said drive means rotating in the other direction for grinding the internal surface of a cylinder.

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