Nov. 16, 1937. A. L. DE LEEUW 2,099,161

GRINDING MACHINE

Filed Aug. 30, 1935 3 Sheets-Sheet 1

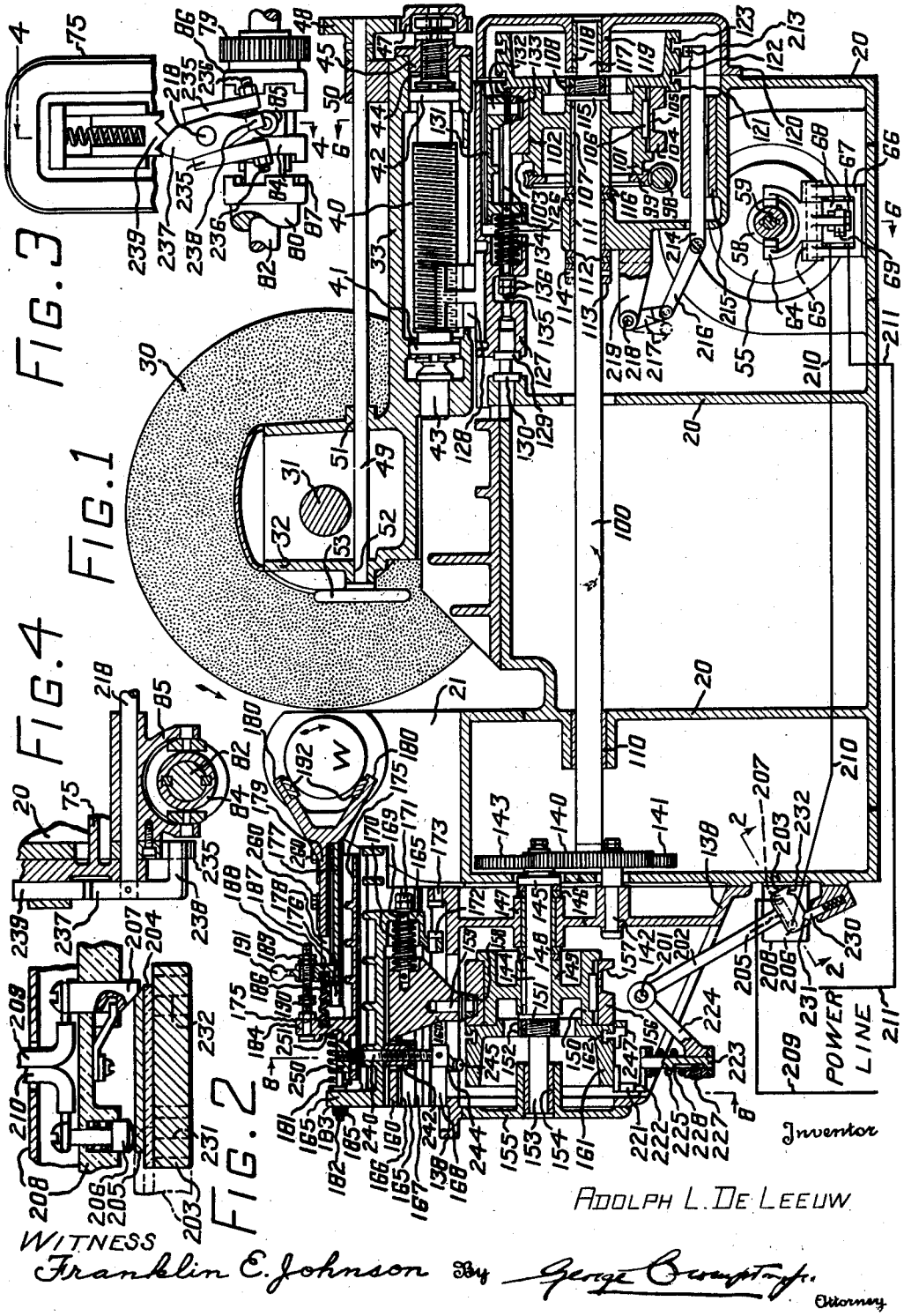


FIG. 3

FIG. 1

FIG. 4

FIG. 2

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Filed Aug. 30, 1935 3 Sheets-Sheet 2

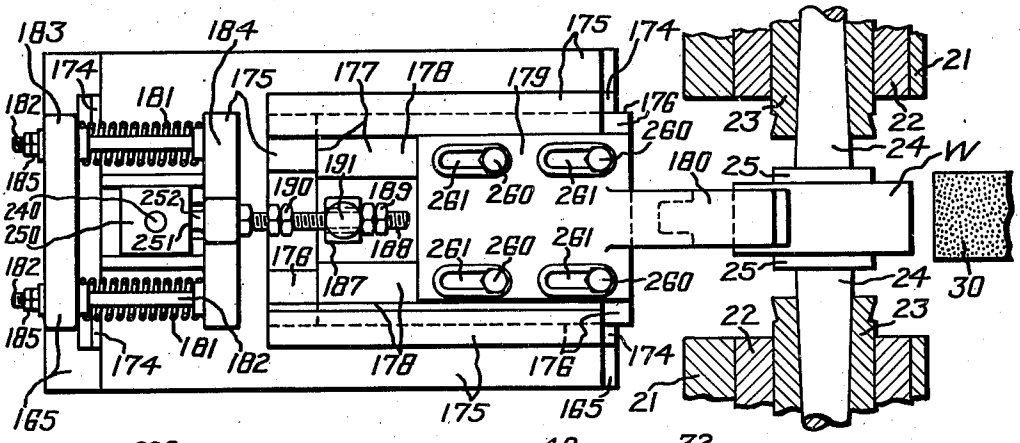


FIG. 7

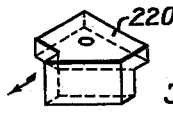


FIG. 5

FIG. 6

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GRINDING MACHINE

Filed Aug. 30, 1935 3 Sheets-Sheet 3

FIG. 8

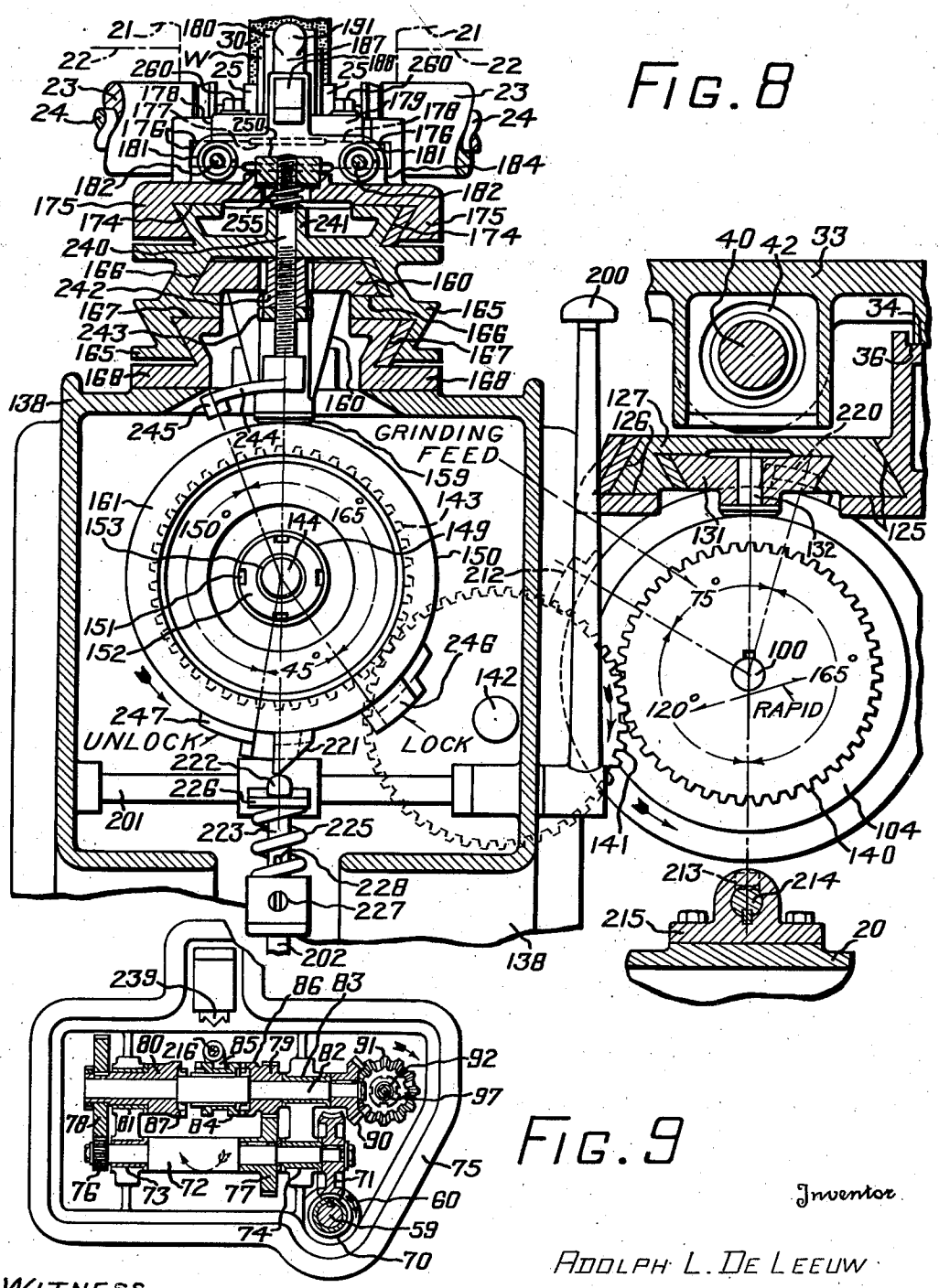


FIG. 9

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UNITED STATES PATENT OFFICE

2,099,161

GRINDING MACHINE

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Application August 30, 1935, Serial No. 38,633

6 Claims. (Cl. 51—105)

The invention relates to grinding machines, and with regard to its more specific features, to a steadyrest mechanism therefor.

One object of the invention is to provide a grinding machine of high precision. Another object of the invention is to provide, in a precision grinding machine, a mechanism facilitating loading and unloading thereof with work pieces. Another object of the invention is to provide a steadyrest and mechanism associated therewith improving the operation of a grinding machine in which the work is gripped by end pressure of rotating devices, the pressure being located along the axis of cylindrical work pieces. Another object of the invention is to improve the machine disclosed in U. S. Letters Patent No. 2,059,895 dated November 3, 1936 to Charles H. Norton and Albert G. Belden (Serial No. 566,738). Another object of the invention is firmly to support a work piece under all conditions of practical operation. Another object of the invention is to increase the production of a precision grinder. Another object of the invention is to improve the machine of U. S. Letters Patent No. 1,779,779 to Charles H. Norton. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is shown one of various possible embodiments of the mechanical features of this invention,

Fig. 1 is a transverse sectional view through a grinding machine embodying the invention particularly illustrating the cross feed for the grinding wheel and the steadyrest feeding mechanism,

Fig. 2 is an enlarged fragmentary sectional view of a switch, the section being taken on the line 2—2 of Fig. 1,

Fig. 3 is a fragmentary elevation of a load and fire device and clutch,

Fig. 4 is a sectional view taken on the line 4—4 of Fig. 3,

Fig. 5 is a perspective view of an actuating dog,

Fig. 6 is an enlarged sectional view of part of the transmission, the section being taken along the line 6—6 of Fig. 1,

Fig. 7 is a fragmentary plan view of the grinding wheel, work piece and steadyrest including the steadyrest slides,

Fig. 8 is an enlarged vertical sectional view of another part of the transmission also of the steadyrest slides, the section being taken along the line 8—8 of Fig. 1,

Fig. 9 is a vertical sectional view of part of the transmission mechanism, the section being taken along the line 9—9 of Fig. 6.

First referring to Fig. 1, I provide a machine base 20 which should be massive enough to hold the various machine elements rigidly enough to obtain precision results but may be hollow and provide mechanism supporting compartments, the shape thereof in a particular embodiment of this invention being clearly illustrated in the drawings wherefor I shall not further describe the same in detail. Uprising from the base 20 is a pair of heads 21, one of which is shown in Fig. 1 and both of which are indicated in section in Fig. 7; these heads as more particularly shown in Fig. 7 support bearings 22 for hollow spindles 23 supporting tapered spindles 24 having disk shaped heads 25; resilient means, not shown, urges the spindles 23 towards each other in order to grip work pieces W, one embodiment of such means together with power means for opening and closing the work holding or chucking mechanism being disclosed in U. S. Letters Patent No. 1,779,779 to Charles H. Norton, to which reference may be had. The machine thus provides a work holding mechanism to hold a work piece W by end contact and pressure in an axial direction, and one or both of the spindles 23 may be driven to rotate the work piece W. I prefer to drive both spindles 23 in so much as thereby a superior drive is effected, and the driving mechanism may be of the type shown in the aforesaid Norton patent, or it may be of any other suitable type. The tapered spindles 24 are removable and a number of them may be provided for various sizes and shapes of work pieces to be operated upon.

Referring now to Fig. 1, I provide a grinding wheel 30 mounted upon a spindle 31 which may be journaled and driven in any usual or desired manner, and in accordance with established practice I rotate the wheel 30 in the direction of the arrow shown in Fig. 1 so that at the point of contact between it and the work piece W it is moving downwardly. It has been usual to rotate the work pieces in the same angular direction as the grinding wheel in machines of this general type, but for carrying out the present invention I prefer to rotate the work piece W in the oppo-

site angular direction to that of the grinding wheel 30, so that at the line of contact their surfaces are moving in the same direction, although at different velocities. I may cause the relative surface velocity between wheel and work piece to be highly efficient for a particular size of work piece and a particular grade of wheel by rotating the grinding wheel 30 at a somewhat higher speed than if the wheel and work piece rotated in the same angular direction, all within the limits of practical requirements, and by this arrangement of the drive the wheel tends to rotate the work so that there is less chance of slippage between the work and the disks 25.

I mount the spindle 31 in a spindle head 32 part of which is shown in Fig. 1, and which may be integral with or suitably attached to a cross slide 33. Referring now more particularly to Fig. 6, the cross slide 33 has plane and V-surfaces 34 and 35 on its under side which rest upon plane and V-surfaces in ways 36 and 37 which are attached to the machine base 20 and mount the wheel head 32 and the grinding wheel 30 for movement transverse to the axis of the work piece W. As shown in Figs. 1 and 6 I provide a screw 40 which, in this embodiment of the invention, is the medium of transmittal of all movements of the slide 33 on the ways 36 and 37, both for feeding and adjustment. The screw 40 is mounted in radial bearings 41 and 42 and it abuts thrust members 43 and 44, the thrust member 43 being inserted in a bore provided by the slide 33, as shown in Fig. 1, and the thrust member 44 being adjustable in an internally screw threaded member 45 which is located in the bore in the slide 33 and fastened thereto. The screw shaft 40 has a reduced portion which extends through the thrust member 44 and is fastened to a gear 47 which meshes with a gear 48 fastened to a shaft 49 that is mounted in bearings 50, 51 and 52 provided on the slide 33 and in the head 32, and a hand wheel 53 is provided on the shaft 49 in a position convenient to the operator so that the initial position of the grinding wheel 30 may be adjusted, and this adjustment does not interfere with the automatic transverse feed and the limiting stops therefor to be described.

Referring now particularly to Fig. 6, I provide an electric motor 55 secured to the machine base 20 which actuates the power transverse feed and the power feed for the steadyrest, and may rotate the work piece if desired. The armature shaft 56 has fastened thereto a clutch element 57, there being a mating clutch element 58 keyed to a shaft 59 which is mounted in bearing blocks 60 and 61 provided in the machine frame 20. The clutch element 58 is urged to the right in Fig. 6 by means of a spring 62 backed up by a collar 63, and a yoke lever 64 pivoted at 65 in a bracket 66 will move the clutch member 58 out of engagement with the clutch member 57 to disconnect the drive when the yoke lever 64 is moved by the core 67 of a solenoid 68, which core 67 is connected to the lever 64 by a link 69. Fig. 6 shows the solenoid 68 energized and the clutch disconnected, but as soon as the solenoid 68 is deenergized the spring 62 reconnects the clutch.

Referring now to Figs. 6 and 9, the shaft 59 has fastened thereto a worm gear 70 which meshes with a worm wheel 71 fastened to a shaft 72 mounted in bearings 73 and 74 provided in a gear casing 75 which is mounted in the machine base 20. Secured to a shaft 72 are spur gears 76 and 77 which constantly mesh with spur gears 78 and 79. The gear 76 is small and the gear 78 relatively large, while the proportions of the gears 77 and 79 are different, with the result that the gear 78 is rotated at a slow speed while the gear 79 is rotated at a higher speed; gear 78 is fastened to a sleeve 80 mounted in a journal 81 provided in the gear casing 75 while gear 79 is mounted on but not fastened to a shaft 82 journaled in a journal 83 provided in the gear casing 75 and also in the sleeve 80. Shaft 82 has keyed thereto a double clutch element 84 having a groove for the reception of a shifting yoke 85; one end of the clutch member 84 may be brought into engagement with a clutch element 86 integral with the gear 79, while the other end of the clutch member 84 may be brought into engagement with a clutch element 87 integral with the sleeve 80, the clutch member 84 being slidable upon the shaft 82 for the purpose of conecting either the gear 78 or the gear 79 to the shaft 82 and thus driving the shaft 82 at either a slow finishing feed rate or a fast cutting feed rate respectively.

Still referring to Fig. 9, fast upon the end of the shaft 82 is a bevel gear 90 meshing with a bevel gear 91 fast on a shaft 92. Referring now to Fig. 6, the shaft 92 is connected by means of a clutch 93 with a shaft 94 which is journaled in bearings 95, 96 in the machine frame. The purpose of the clutch 93 is to permit the gear box 75 to be removed as a unit and the shaft extends forwardly to a nut 97 for setting up or making adjustments of the machine.

Fixed upon the shaft 94 is a worm 98 which meshes with a worm wheel 99 which is mounted upon and drives a shaft 100. The shaft 100 is thus rotated at a reduced speed through a transmission train involving a pair of worm and worm wheel reduction units and at the selected rate of two feed rates, determined by the change gear mechanism described, that is to say at a rapid feed rate or at a slow or finishing cut feed rate. The shaft 100 is connected to feed transversely the slide 33 and it is also connected simultaneously to feed the steadyrest mechanism in timed relation thereto. In this particular embodiment of the invention, I have disclosed a two-rate feed mechanism and also a start and stop clutch in the transmission train but no reversing mechanism and the retrograde movement of the slide 33 and also the supports for the steadyrest is effected by barrel or track cams. Certain advantages inhere in the use of such barrel or track cams among them being simplicity of operation and flexibility of control.

Considering now the cam mechanism which drives the slide 33 and still referring to Fig. 1, the worm wheel 99 is fastened to a drum 101 which has a cylindrical surface 102 bounded by a shoulder 103 at one end and of a size to receive any one of a number of barrel or track cams 104 having a cam groove 105 and keyed to the drum 101 by a key 106, it being understood that for different grinding conditions and different work pieces specifically different cams 104 may be employed. The drum 101 is keyed by means of a key 107 to the main control shaft 100 and thus it is that the worm wheel 99 drives the shaft 100.

The drum 101 is maintained upon the shaft 100 by means of a couple of nuts 108 on a screw threaded portion of the shaft 100. The shaft 100 is journaled in main journals 110 and 111 provided in the machine base, and in order that end play may be eliminated washers 112 abut the journal 111 and are backed up by a collar 113

fixed to the shaft 100 by means of a taper pin 114; the nuts 108, a washer 115, the drum 101 and a pair of washers 116 being used to eliminate end play in the other direction and to adjust and tighten the assembly.

The shaft 100 has a reduced portion 117 upon which is fitted a bushing 118 in the central hub 119 of a cover 120 which may be secured by screws, not shown, to the base 20. Inside the cover 120 and fastened by means of screws, not shown, to the drum 101 is an actuating dog drum 121 with a pair of T-slots 122 and 123 in which may be placed at any desired angular position dogs to actuate the control for the change gear mechanism to shift from fast to low feed.

Referring now to Fig. 6, the slideway members 36 and 37 have respectively the opposite slideway surfaces 125 and 126 of a dovetailed slideway which supports for movement, parallel to the slide 33, a slide 127. The slide 127 has secured to the top thereof a half nut 128 which engages the screw shaft 40. Slide 127 also has, as shown in Fig. 1, a stop stud 129 positioned to engage a stationary stop stud 130 located in the machine base 20, so that the forward position of the slide 127 is fixed and predetermined and never varies.

The slide 127 is moved by means of the cam drum 104 but through a resilient connection so that the stops 129 and 130 will determine the final position. Referring now to Figs. 1 and 6, the slideway 127 has formed on the under side thereof dovetailed slideways 137 supporting a slide 131 in the rear part of which is located a vertical stud 132 upon which is mounted a roller 133 fitting in the track 105 of the barrel cam 104. The roller 133 is frusto-conical and the walls of the slot or track 105 are inclined so as to make a nice fit. Rotation of the cam 104 causes a forward movement of the slide 131 which is connected to the slide 127 by means of a compression spring 134 located on a bolt 135 fastened to the slide 131 and projecting through a portion of the slide 127, as shown. When the slide 131 is moved forwardly the slide 127 moves with it in so much as the spring 134 is compressed and by its action it urges nuts 136 on the bolt 135 against a portion of the slide 127, but when a positive resistance is encountered the spring 134 will compress, the nuts 136 moving away from a front surface of the slide 127. Retrograde movement of the slide 131 draws the slide 127 rearwardly by positive action.

According to the invention I may determine the final size of the work piece by bringing the wheel slide to a fixed and predetermined position at the same time holding the work piece against the grinding wheel by surfaces which for the final size are located at a predetermined position. At the same time I may rotate the work by frictional or otherwise end contact, with pressure in an axial direction, and by reason of such construction and mechanism, loading is a momentary matter. Tracing the grinding operation backwards, in order that chatter marks may be eliminated and a drive effected which keeps the rotating spindles coaxial with the work piece, I move the steadyrest away from the axis of the work piece in the opposite direction and as the wheel slide moves backwards. I prefer to provide two work piece supporting surfaces so that the work may be supported at more than two places, including the line of grinding, and I compensate for the change of size of the work piece by moving the steadyrest at a greater rate than the grinding wheel feed slide, which rate is determined by the cosecant of the dihedral angle between the plane through the axis of the work piece and parallel to the advance of the steadyrest and the plane of tangency of either rest with the work piece, such dihedral angles being preferably the same as otherwise one steadyrest surface would leave the work piece or cause undue pressure between the parts at some stage of the operation. Thus as the angle defined becomes smaller the rate of feed of the steadyrest mechanism divided by the rate of feed of the feed slide becomes larger, until with the steadyrest surfaces tangent to the top and bottom of the work piece this ratio is infinity because if such a steadyrest should hold the work piece at the start of an operation, it could never hold it after it had been ground to any extent. By making the dihedral angle defined for the two steadyrest surfaces the same, a single feeding mechanism will suffice and I have selected a dihedral angle of 30 degrees, as the cosecant of 30 degrees is two, and the work piece is thus held in position by a three-point support comprising the grinding wheel and two steadyrest surfaces, all of them tangent supports, and located around the circle 120° apart. This method of holding the work piece cooperates with the relative rotation of wheel and work piece hereinbefore defined and to a large extent reduces pressure and resistance and increases the effectiveness of the three-point support.

Considering now the mechanism for the movement and support of the steadyrest surfaces, and referring to Figs. 1 and 8, the shaft 100 has mounted thereon at its front end a gear 140 which is keyed to the shaft 100 and which meshes with a gear 141 mounted on a stud 142 mounted in a steadyrest mechanism frame unit 138 and projecting through the machine base 20 and the gear 141 meshes with a gear 143 secured to a shaft 144. Shaft 144 has an enlarged portion 145 spaced by washers 146 from the end of a bearing 147 provided by the frame unit 138. The bearing 147 is both a radial and thrust bearing and at its front end there are washers 148 abutting it and also the hub 149 of a drum 150 similar to the drum 101. At the other end of the hub 149 is a washer 151 and nuts 152 the latter mounted on a threaded portion of shaft 144; the shaft 144 has a reduced portion 153 fitting in a journal 154 provided in a cover member 155 secured to the frame unit 138.

Keyed to the drum 150 is a barrel or track cam 156 having a cam slot 157 in which is a roller 158 on the end of a stud 159 depending from a slide unit 160. Secured to the drum 150 is an operating or dog drum 161 having a single T-slot 162. This mechanism is thus similar to the mechanism for advancing the slide 33 but in this embodiment of the invention the throw of the cam slot 157 is double that of the cam slot 105.

Referring now to Fig. 8, there is provided a slideway 165 having dovetailed ways 166 to receive the slide 160 and having further dovetailed ways 167 mounting it upon a stationary dovetailed sildeway 168 which is affixed to the casing 138. Between the slideway 160 and 165 is a bolt 169, a spring 170 and nuts 171 similar to the bolt 135, spring 134 and nuts 136, and likewise cooperating stops 172 and 173 like the stops 129 and 130 are provided. The slide 165 has a third set of ways 174 for the support of a slide 175 and the slide 175 has, as shown in Fig. 7, ways 176 for the support of a slide 177 which itself has ways 178 for the support of the steadyrest member 179 which, as shown in Fig. 7, comprises an

integral rectangular slide portion integral with a pair of rest arms 180, the part being Y-shaped in cross section as shown in Fig. 1.

Referring now to Fig. 7, the slide 175 is ordinarily in advanced position, that is to say in the direction of the work piece with respect to the slide 165, being held in that position by springs 181 around bolts 182 which extend between standards 183 and 184 provided respectively on the slide 165 and the slide 175. Nuts 185 limit the forward position of the slide 175 with respect to the slide 165. The slide 177 is, during the grinding operation retracted with relation to the slide 175, being held merely temporarily in the position shown in Fig. 1 by a spring 186 extending between the standard 184 and a standard 187 provided on the slide 177, and there being a bolt 188 and nuts 189 to limit the advanced position of the slide 177 and nuts 190 to provide a solid backing for slide 177. Thus these three slides during certain parts of the operation function as one, and the operator may grasp a knob 191 to pull the slide 177 away from the work piece when loading. Likewise the springs 181 provide for relative movement between the slides 165 and 175 at the first part of the grinding operation to facilitate the grinding of out-of-round work pieces, but prior to the finishing of the grinding operation I may positively move the slide 175 to its advanced position with respect to the slide 165 by a mechanism which will presently be described. It may be noted here that for certain operations and certain classes of work one of these slides may be dispensed with, and for certain operations I prefer an altogether rigid mechanism, and I contemplate that the grinding wheel and the steadyrest shoes 192 shall hold the work piece coaxial with the driving heads 25 especially for the final and finishing cuts.

Considering now the grinding of a work piece W, and assuming that the cam drums 104 and 156 are in such angular position as to withdraw both slides, the operator grabs the handle 191, and withdraws the slide 177 and thus the steadyrest arms 180, while at the same time setting in operation mechanism disclosed in the patent to Norton referred to, to retract the work gripping disks 25. He may then insert a work piece W and cause the disks 25 to approach to grip the work piece, and he may then actuate mechanism to rotate the work piece. The grinding wheel is at that time spaced away from the work piece, but the rest shoes 192 may be allowed to engage it lightly under pressure of the light spring 186, and the operator may now grasp the lever 200 shown in Fig. 8 which is mounted upon a shaft 201 having, as shown in Fig. 1, an arm 202 fastened to it, which arm has secured to the lower end thereof a shoe 203 of a switch which is more particularly shown in Fig. 2. Secured to the shoe 203 is an insulating plate 204 to which is secured a metal plate 205 that is contacted by spring pressed contacts 206 and 207 in a switch box 208. When the arm 202 is moved clockwise, Fig. 1, the plate 205 leaves the contact 207, and thus breaks a circuit between lines 209 and 210 which, together with line 211 energize the solenoid 68. Then when the operator pushes the lever 200 away from him, the solenoid 68 is deenergized, permitting the spring 62 to cause engagement of the clutch member 58 with the clutch member 57 thus actuating the feeding mechanism. The drums 101 and 150 are thereupon rotated causing the slides 165 and 33 to approach each other at the relative rates hereinbefore specified, and at this time the clutch 84 is in the position shown in Fig. 9 to cause a rapid movement. The rate is constant, however, only so far as the angular velocity of the barrel cams 104 and 156 are concerned, and any desired rate or change of rate may be incorporated in the shape of the cams; I prefer to make the cam tracks 105 and 157 similar in pitch at a definite ratio to each other in order that the work piece W may be centered upon a three-point support comprising the steadyrest shoes 192 and the grinding wheel 30 at all times during the grinding operation.

In Fig. 1 I have shown the steadyrest shoes 192 in contact with the work W prior to engagement of the wheel with the work piece. Until the grinding wheel engages the work piece, however, the shoes have no effect upon the work piece, and in fact the principal reason for providing a separate slide 177 and the spring 186 is to facilitate centering the work between the disks 25, 25, for the operator may place the work piece W tangent to the shoes 192 with the slide 177 forward in order to find the correct position for the work piece; the spring 186 is a very light spring and in certain cases the nuts 189 may be tightened up to hold the standard 187 between them and the nuts 190.

The slow feed comprising the gears 76 and 78 is provided to give the machine greater capabilities within the limits of a reasonable sized cam drum and at a predetermined but adjustable position a dog 212 located in the T-slot 123 engages a detent 213 which as shown in both Figs. 6 and 1 causes the shifting of a rod 214 toward the front of the machine, which rod is slidable in a bearing bracket 215 fixed to the machine base 20. This may happen at or after the commencement of grinding. Referring now to Fig. 1, a link 216 connects the rod 214 to an arm 217 which is fastened to a shaft 218 mounted in a stationary bracket 219, which shaft 218 passes through and controls the yoke 85 in the gear change box 75 in order to shift the clutch 84. Accordingly forward movement of the shaft 214 shifts the clutch 84 to cause the transmission to act through the fine or slow feed gearing. The grinding operation proceeds until such a time as cam slots 105 and 157 have advanced the wheel and the steadyrest to the limit of travel, whereupon the cam slots reverse the direction of movement and separate these parts. At the reversal of movement, the grinding is completed, and in order to save time the pitch of the cam slots may be high for the movement of separation and the rapid feed may be engaged. I provide a dog 220 to engage the detent 213 and move the rod 214 rearwardly to bring the parts back to initial position rapidly in order to save time, and in the preferred embodiment of the invention the cam drums rotate 360° for each grinding operation and then come to a stop by reason of the engagement of a dog 221 on the drum 161 with a spring pressed detent 222 on the end of a rod 223 which is mounted in an arm 224 integral with arm 202. As shown in Figs. 1 and 8, a spring 225 around the rod 223 acting against a head 226 constitutes resilient means for maintaining the detent in its upper position, there being a screw 227 and a slot 228 to prevent twisting of the rod 223. Engagement of dog 221 with detent 222 returns the arm 202 to the position shown in Fig. 1, and as shown a spring pressed dagger 230 fitting in notches 231 and 232 may be provided to hold the arm 202 resiliently in its two extreme posi-

tions. The machine may be started in spite of the engagement of dog 221 with detent 222, because the spring 225 will compress allowing the switch controlling the solenoid 68 to be opened; the machine comes to a stop with the parts in the initial position when the drums have traveled 360° and the arm 202 has been moved again to reenergize the solenoid 68.

In order to avoid possible failure of the mechanism by reason of the clutch 84 hanging in mid or neutral position, I provide a load and fire device which is especially illustrated in Figs. 3 and 4, and which comprises a pair of spaced arms 235 connected to the yoke 85 having adjustment screws 236, there being a dagger member 237 fastened to the shaft 218 which has an arm 238 located between the screws 236. A spring pressed detent 239 having a pair of notches as shown engages a dagger 237 and thus the dogs 212 and 220 may be formed to throw the dagger 237 from one notch partially into the other but without disengaging the clutch by so doing, owing to the lost motion, whereupon the spring will carry the dagger and shaft 218 the rest of the distance to shift the clutch member from one side to the other.

For the grinding of many work pieces the mechanism and mode of operation which has been described may be sufficient and give the best results, but in certain cases I may use the springs 181 to permit the steadyrest to back away especially at the start of a grinding operation, providing mechanism to lock the slides 165 and 175 in definite spaced position automatically before the finish of the grinding operation. It may be understood, however, that in many respects the provision of simple spring means will effect this result and in certain cases I prefer to use a steadyrest which is always maintained in geometrically correct position with a firm pressure.

Considering, however, the additional mechanism which may be used upon occasion, (at other times the slide 175 being pinned or rigidly fastened to the slide 165 and the parts particularly to be now described being altogether removed from the machine) there is a wide hole through the slide 160 permitting a screw rod 240 which passes through a boss 241 in the center of the slide 165 to extend downwardly through the slide 160. A nut 242 is mounted on the rod 240 and this may be locked in position by a check nut 243, which holds the rod 240 from rising above a certain position. To the lower end of the rod 240 is fastened an arm 244 which has a portion 245 in position to be engaged by dogs 246 and 247 adjustably secured in the T-slot 162 of the drum 161. The former dog moves the arm 245 to lock the slide 175 to slide 165 in advanced fixed position, while the latter unlocks the parts. This is effected by means of a wedge member 250 having, as shown in Fig. 1, an inclined surface 251 on its right hand side adapted to engage a stationary wedge 252 secured to or integral with the standard 184, the wedge member 250 being in the form of a nut so that turning of the screw shaft 240 will effect the wedging action indicated positively to drive and hold the slides 175 to a fixed predetermined position. A spring 255 may be provided to lift the wedge nut 250 when the parts are unlocked.

Considering now Fig. 7, the steadyrest member 179 may be readily removed from its supporting slide 177 by removing bolts 260 which fit in slots 261 in the steadyrest member 179 and screw into holes in the slide 177. This constitutes means for readily adjusting the position of any steady rest with respect to its supporting slide 177.

Comparing now Figs. 6 and 8, an example of the timing of the machine is shown. It should be remembered that the change of feed rate may be inaugurated either at the commencement of grinding or at some later time; in the first instance fast feeding is for the purpose of bringing the parts together into grinding position and in the second instance fast feeding performs what may be called the rough grinding. These variations are all within the contemplation of the invention, being made by mere adjustments of the machine. By way of example only, therefore, turning to the right hand side of Fig. 8 it will be seen that the dog 212, which is moving in this view counterclockwise, will move 120° before it contacts the detent 213 at which point the slow feed is inaugurated. For seventy-five more degrees of angular movement the grinding takes place at a slow feed and at the end thereof there is practically a dwell in the cams and as the cams commence to withdraw the slides the second dog 220 causes the mechanism to feed rapidly again. Compare Fig. 6 with Fig. 8 remembering that direction of rotation is opposite in these two figures.

Referring now to the left hand side of Fig. 8, 165° subsequent to the start of an operation the slides 165 and 175 are locked together by means of the dog 246, while the unlocking operation takes place 45° thereafter which is 210° from the start of the operation or 15° after the reversal in direction. It must be emphasized, however, that this is only one of a great many ways of setting up the machine and is given for a clearer understanding of the mechanism. Ultimately after 360° of rotation dog 221 operates the detent 222 whereupon the machine stops and is ready for another cycle of grinding.

In the grinding of successive work pieces the grinding wheel 30 will ultimately wear, but this can be advanced with respect to the slide 127 by means of the hand wheel 53, and a dressing operation may be performed to bring the vertical plane of tangency with the wheel to a fixed position so that rigid control over the ultimate size of work pieces may be readily achieved.

It will thus be seen that there has been provided by this invention an apparatus in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a grinding machine, a work holder, a grinding wheel, a steadyrest, a slide for said grinding wheel, a slide for such steadyrest, power means to advance and retract the first named slide, power means to advance and retract the second named slide, means synchronizing movement of said slides, and automatic means to cause said slides to stop at a predetermined position.

2. In a grinding machine, a grinding wheel, a steadyrest, a slide to relatively advance the steadyrest relatively to the axis of a work piece, feeding means to move said slide, and means automatically to change the rate of feed.

3. In a grinding machine, a grinding wheel, a rotatable member to rotate a work piece, means

to relatively move the wheel and member, a steadyrest having a steadyrest surface, means to relatively move the steadyrest and member, a plane of tangency at the contact surface making an acute angle to the direction of motion last specified, and means to bring the steadyrest surface to a position a given distance away from the center of the member while the grinding wheel is a greater distance therefrom whereby initially to locate the work piece relative to the member and thereafter to locate the nearest point of the grinding wheel and the steadyrest surface tangent to a circle of the center of the member.

4. In a grinding machine, the combination with three elements, viz. a grinding wheel, and a pair of steady rest elements having surfaces for contact with the work piece, of means to move the grinding wheel, means to move the steady rest elements, the grinding wheel and the steady rest surfaces being all of them tangent to a given circle and the lines of tangency for each being on the circle more than 180° remote from one of the others in each angular direction, the means to advance the grinding wheel and the means to advance the steady rest elements being synchronized so that as grinding proceeds the three elements are maintained tangent to smaller and smaller circles all of which are concentric to the given circle, whereby to achieve accuracy in the grinding of a work piece located concentric with the given circle.

5. In a grinding machine as claimed in claim 4 the combination with the parts and features therein specified of driving means for the work piece constituting a pair of pressure plates urged against it in opposite directions along the axis of the given circle.

6. In a grinding machine as claimed in claim 4 the combination with the parts and features therein specified of a rigid connection between the two steady rest elements.

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