Jan. 12, 1937. J. EDGAR 2,067,178

GRINDING MACHINE

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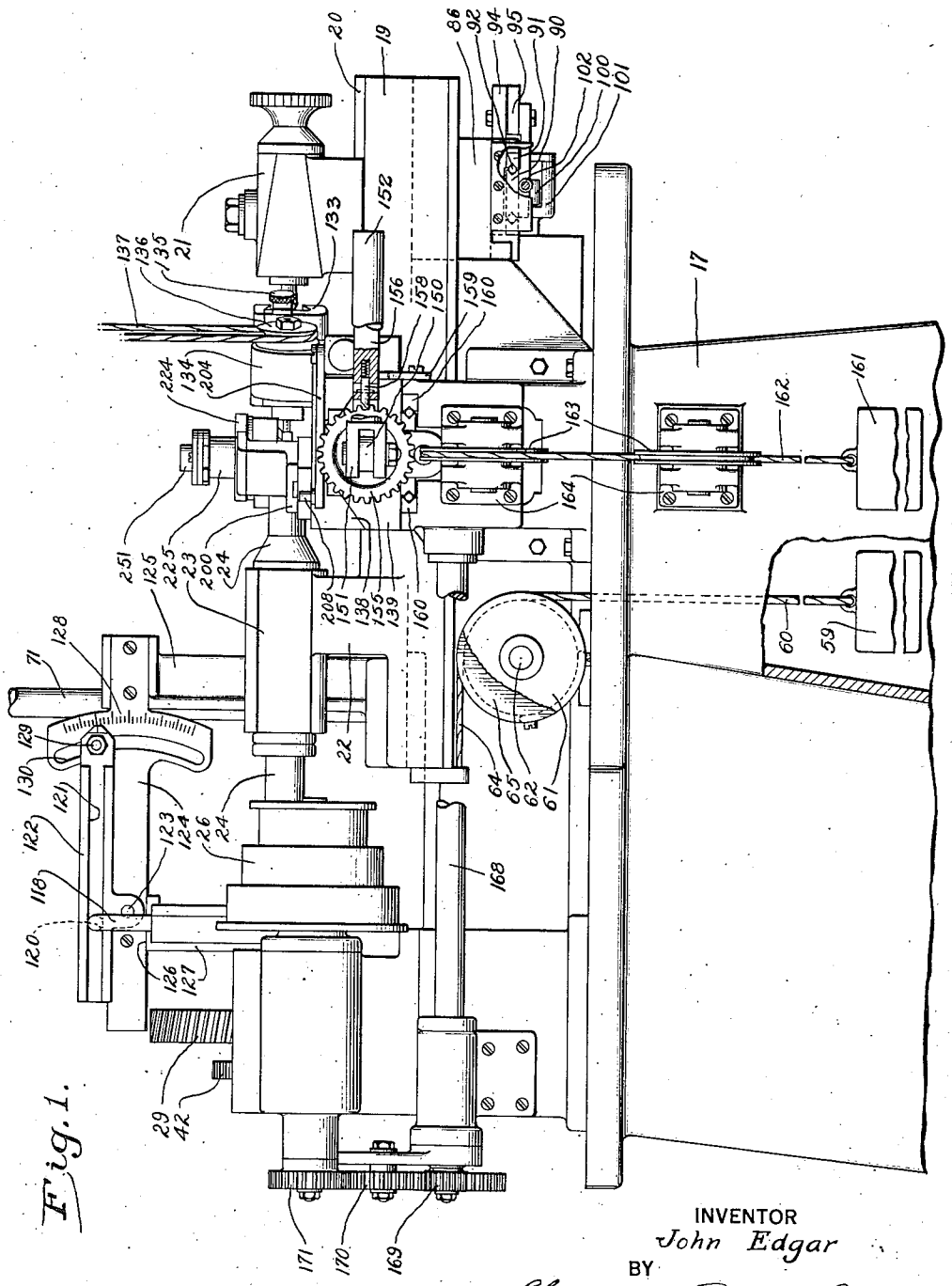


Fig. 1.

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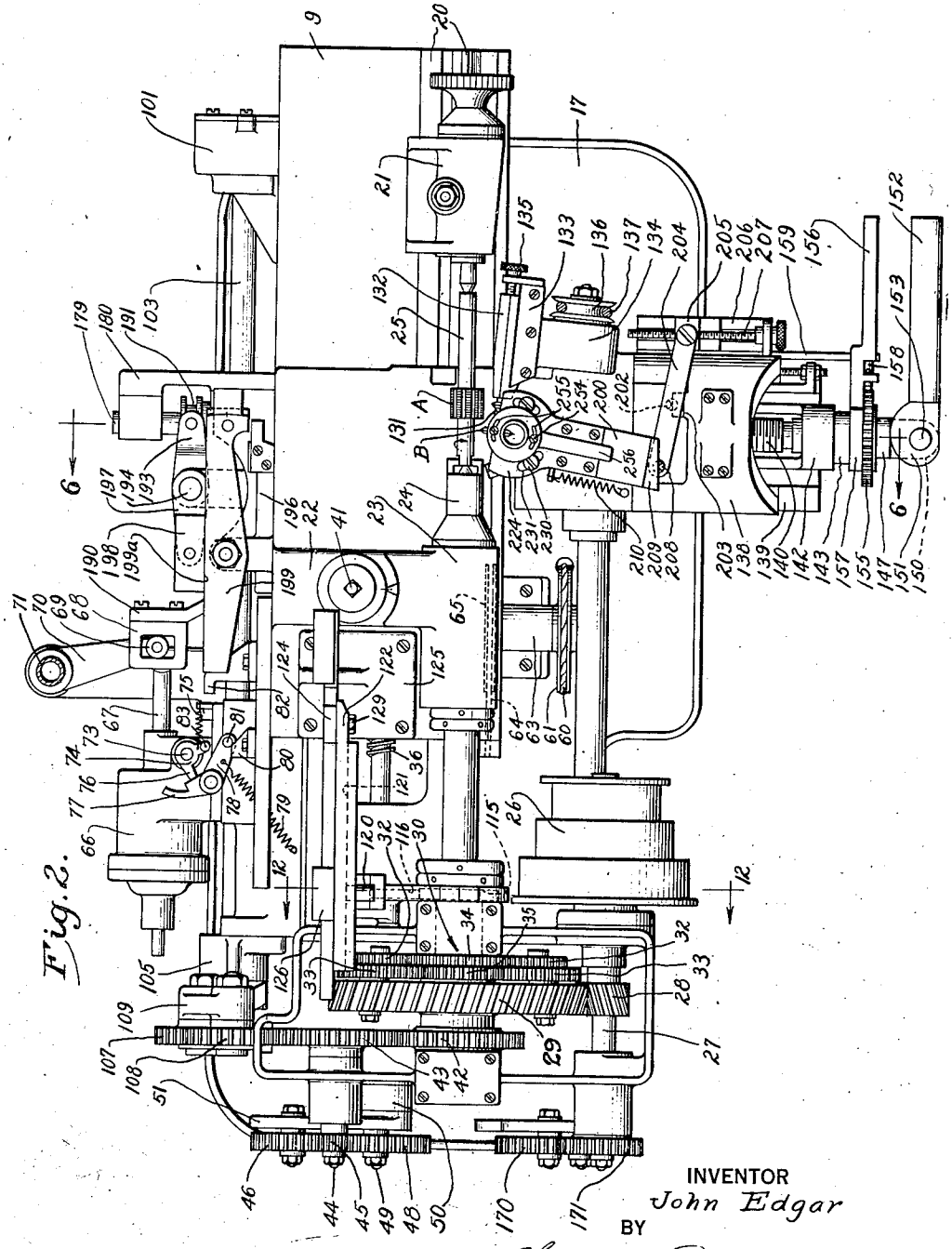


Fig. 2.

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Fig. 3.

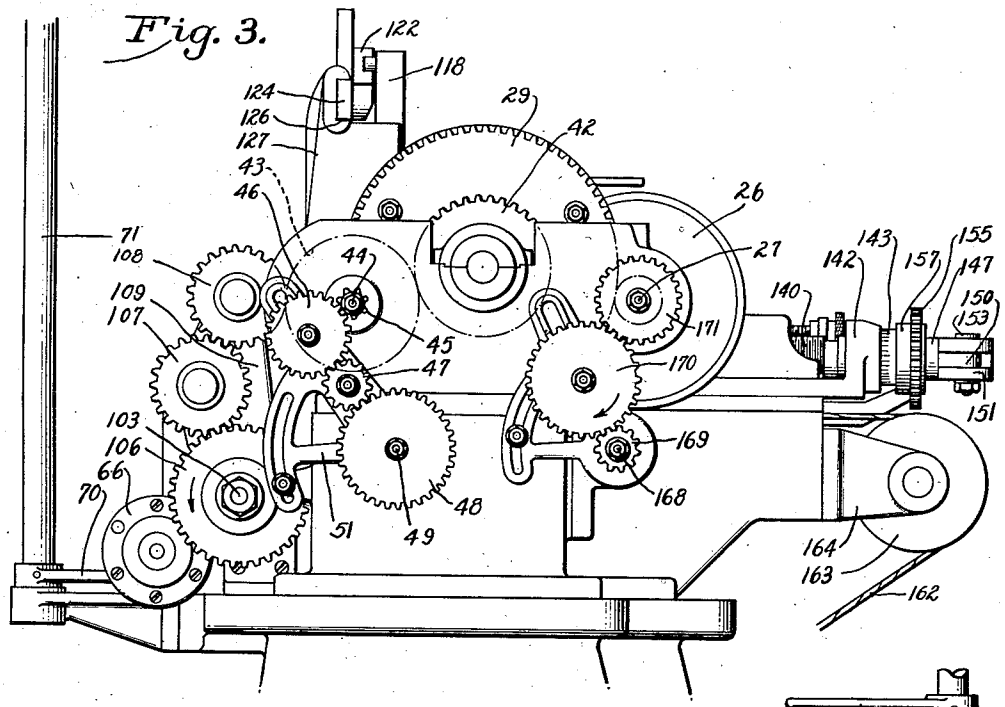
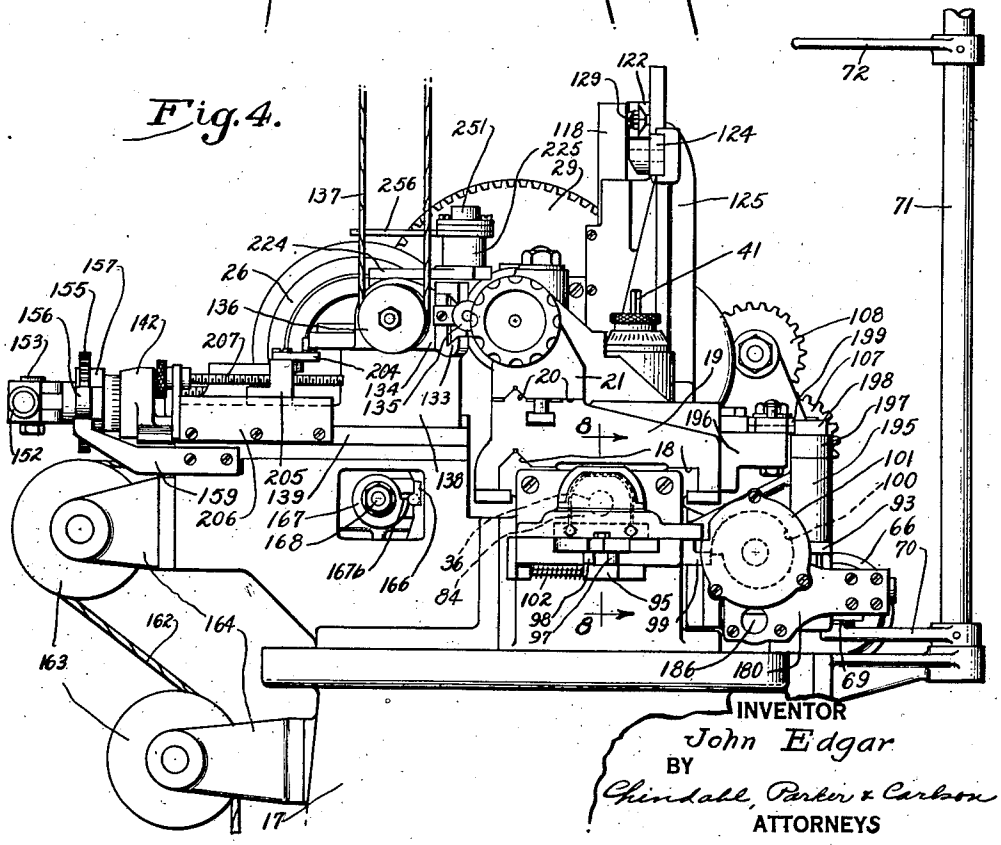


Fig. 4.



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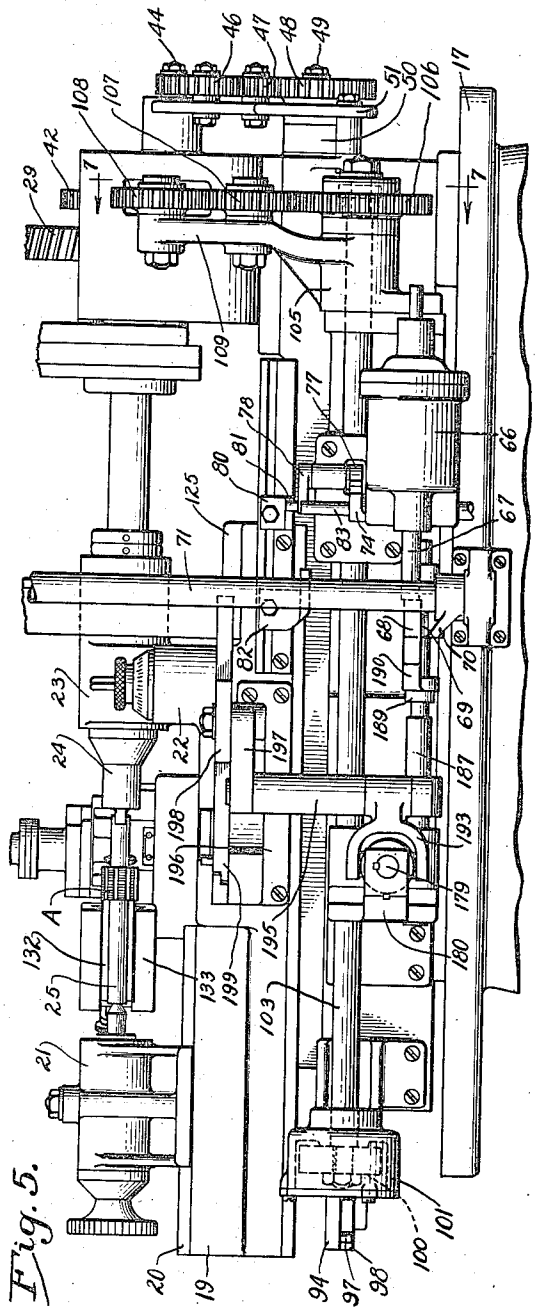


Fig. 5.

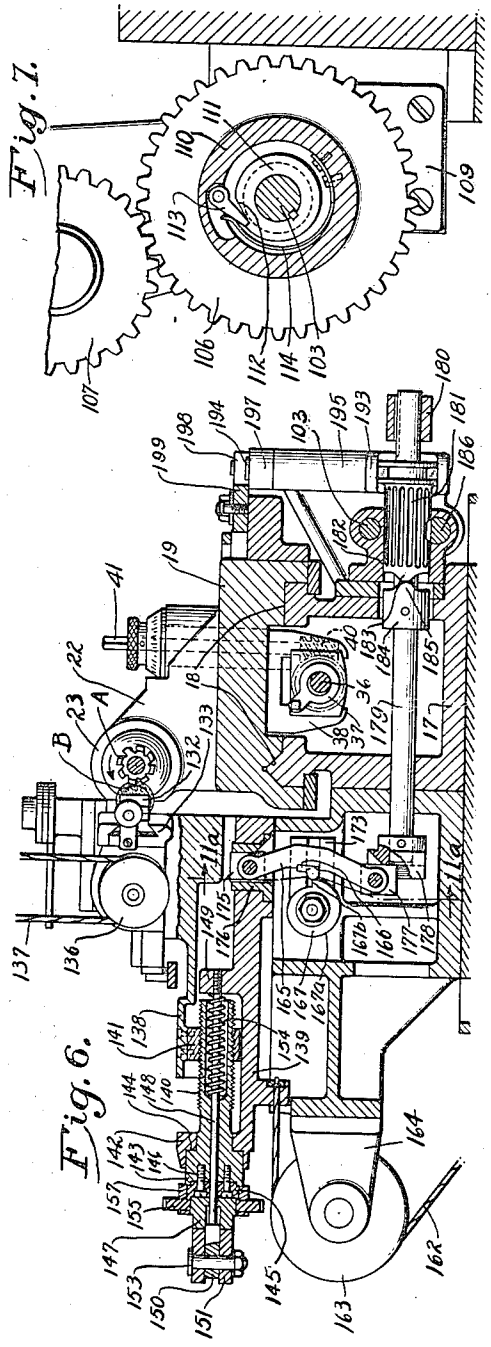


Fig. 7.

Fig. 6.

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GRINDING MACHINE

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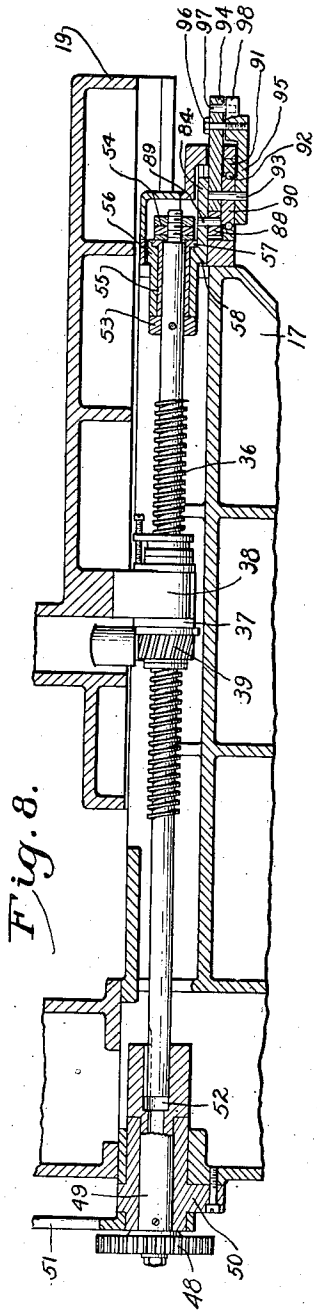


Fig. 8.

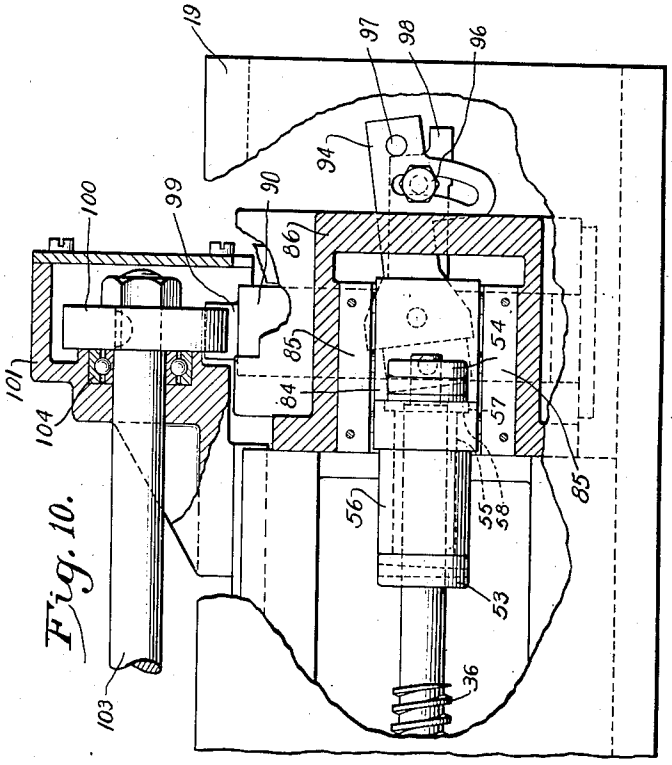


Fig. 10.

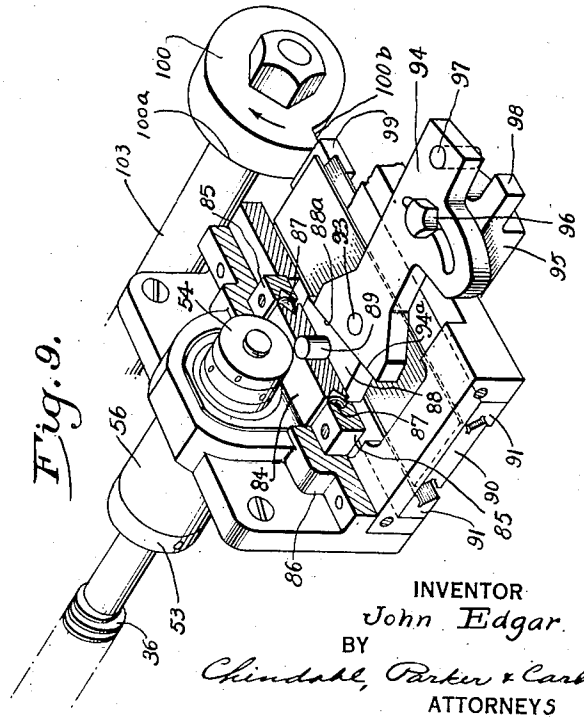


Fig. 9.

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Fig. 11.

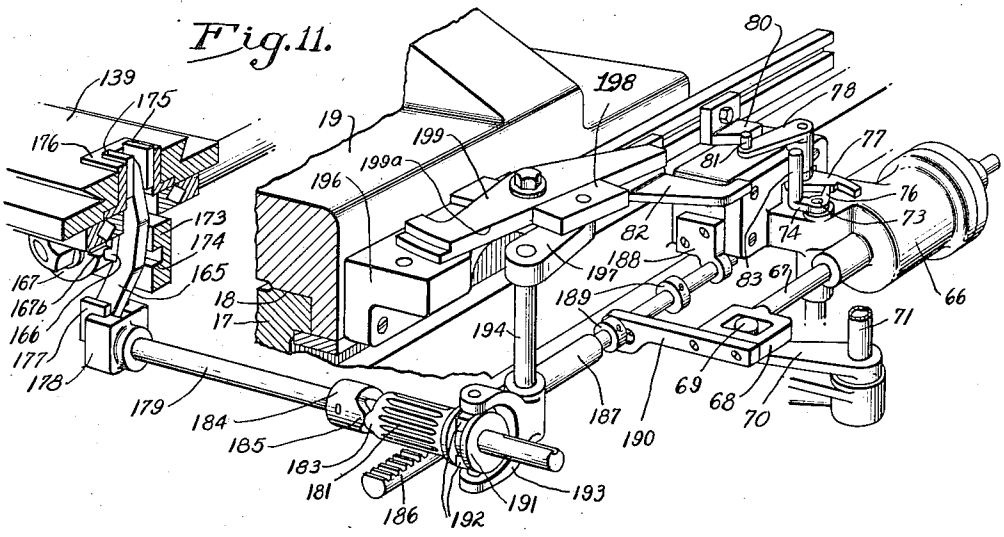


Fig. 12.

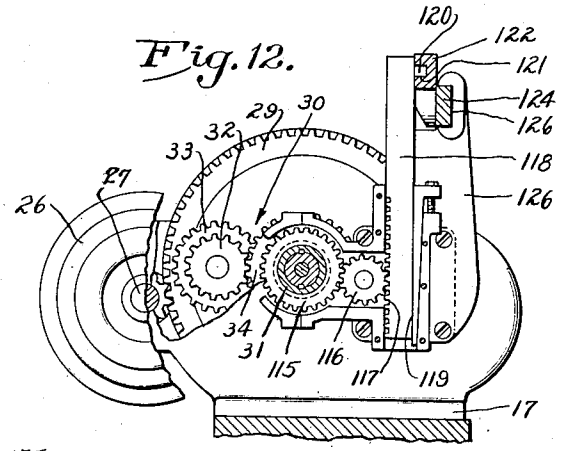
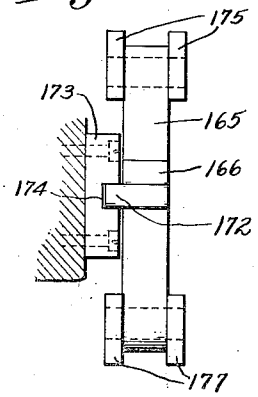


Fig. 11a.



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Fig. 13.

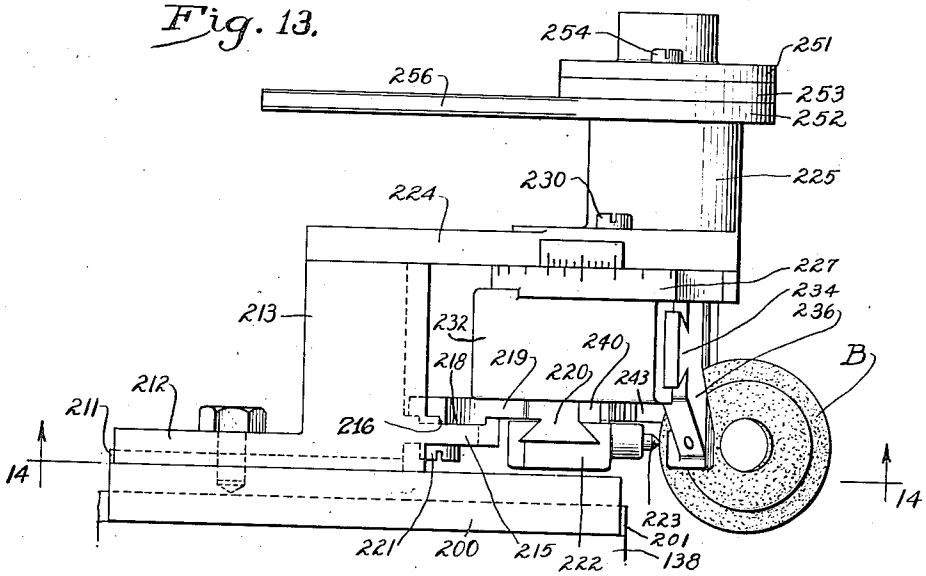


Fig. 14.

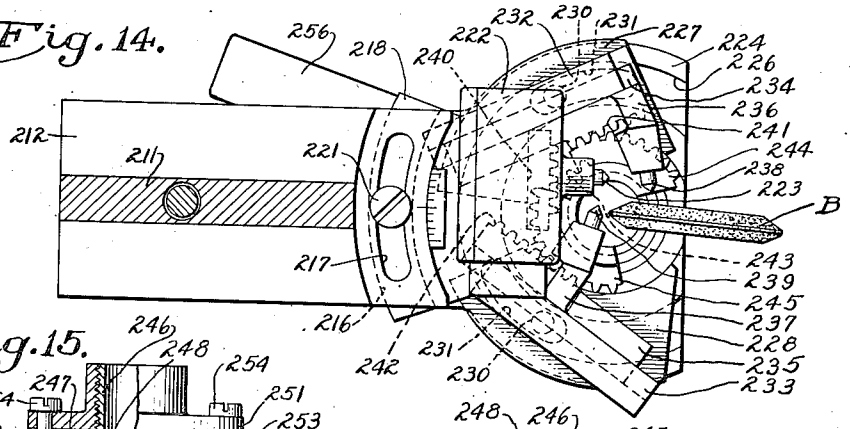


Fig. 15.

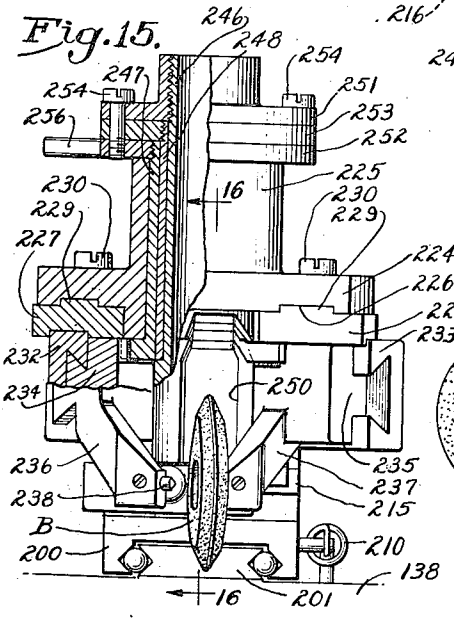
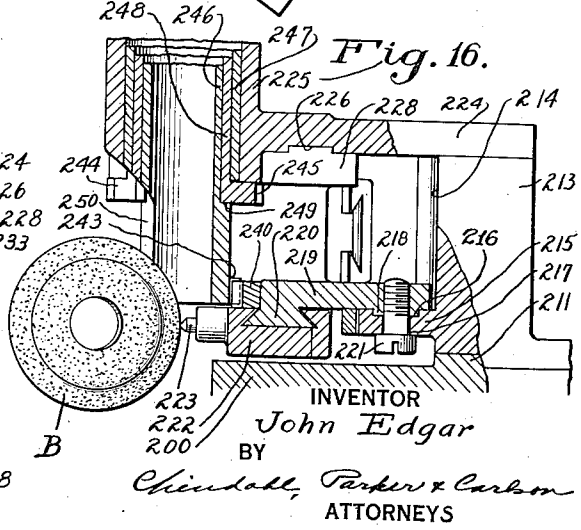


Fig. 16.



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Patented Jan. 12, 1937

2,067,178

UNITED STATES PATENT OFFICE

2,067,178

GRINDING MACHINE

John Edgar, Rockford, Ill., assignor to Barber-Colman Company, Rockford, Ill., a corporation of Illinois

Application October 24, 1932, Serial No. 639,262

40 Claims. (Cl. 51—45)

The present invention relates to improvements in grinding machines, and has particular reference to a new and improved machine of the type disclosed in my copending application Serial No. 466,764, filed July 9, 1930.

One of the primary objects of the present invention resides in the provision of a novel grinding machine which will correctly grind the teeth of rotary cutters having either straight or inclined gashes, and being either cylindrical or tapered axially in form.

Another important object resides in the provision in a machine of the foregoing character of a novel traversing mechanism which is selectively available to provide either a continuous or a step-by-step axial feeding movement of the work blank relative to the grinding wheel, thereby adapting the machine at will for the grinding of rotary cutters having either annular rows of teeth, as in thread mills, or helically arranged teeth, as in hobs.

Further objects and advantages will become apparent as the description proceeds.

In the accompanying drawings, Figure 1 is a front elevational view, partially broken away, of a grinding machine embodying the features of my invention.

Fig. 2 is a plan view of the machine.

Fig. 3 is a fragmentary left end view.

Fig. 4 is a fragmentary right end view.

Fig. 5 is a fragmentary rear elevational view.

Fig. 6 is a fragmentary vertical transverse sectional view taken along line 6—6 of Fig. 2.

Fig. 7 is a fragmentary detailed sectional view taken along line 7—7 of Fig. 5.

Fig. 8 is a fragmentary vertical longitudinal sectional view taken along line 8—8 of Fig. 4.

Fig. 9 is a fragmentary perspective view of the traversing mechanism.

Fig. 10 is a fragmentary sectional view on an enlarged scale of the mechanism shown in Fig. 9.

Fig. 11 is a fragmentary perspective view of means for controlling the longitudinal contour of the work blank.

Fig. 11ª is a detailed view taken substantially along line 11ª—11ª of Fig. 6.

Fig. 12 is a fragmentary vertical sectional view taken along line 12—12 of Fig. 2.

Fig. 13 is a side elevational view of the dressing device for the grinding element.

Fig. 14 is a horizontal sectional view along line 14—14 of Fig. 13.

Fig. 15 is a rear elevational view, partially in section, of the dressing device.

Fig. 16 is a fragmentary vertical sectional view taken along line 16—16 of Fig. 15.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Referring more particularly to the drawings, the machine constituting the exemplary embodiment of the invention although adapted for grinding various types of cutters, is illustrated in connection with a thread mill cutter A of the ring type. The cutter comprises a plurality of radially relieved, substantially V-shaped teeth which are arranged in parallel peripheral rows alternating with annular grooves, and which are separated by longitudinal flutes or gashes. In the present instance, the cutter A has straight gashes parallel to the axis of rotation.

The grinding element preferably comprises an abrasive disk wheel B, the periphery of which is adapted to grind the annular cutter grooves and thereby form the cutter teeth, and the cutting contour of which is V-shaped in form when taking the final cut.

Work support and drive

The machine comprises a suitable elongated horizontal bed or frame 17 formed on the top with longitudinal guides 18 on which a work carriage 19 is mounted for translation. The right end of the carriage 19 is formed on the top with longitudinal guides 20 on which a suitable tailstock 21 is mounted for adjustment. On the left end of the carriage 19 and preferably integral therewith is a headstock 22 formed with a tubular bearing 23. A cutter spindle 24 is rotatably journaled in the bearing 23 for endwise movement with the carriage 19. The cutter blank A is removably mounted on an arbor 25 held between the tailstock 21 and headstock 22, and rotatable with the spindle 24.

The power inlet comprises a cone pulley 26 which is secured to a short drive shaft 27 journaled in the upper left front corner of the frame 17, and which is adapted to be connected by a belt (not shown) to an external countershaft (not shown) adapted to be connected through a reversible clutch (not shown) to a suitable source of power. A drive pinion 28 on the shaft 27

meshes with a large drive gear 29 connected through a planetary transmission 30 to a shaft 31 into one end of which the spindle 24 is splined for axial movement.

The transmission 30 preferably is like that disclosed in said copending application, and comprises two sets of cluster gears 32 and 33 rotatably mounted at diametrically opposed points on the drive gear 29, and adjustable thereon to permit the proper angular setting of the work blank A relative to the grinding wheel B. The outer gears 32 mesh with a terminal gear 34 rotatable on the shaft 31, and normally held in fixed position, and the inner gears 33 mesh with a terminal gear 35 keyed to the shaft 31.

Traverse mechanism

The means for effecting a relative traverse between the work carriage 19 and the grinding element B, in either a feeding movement in one direction or a rapid free-return movement in the other direction, along the axis of rotation of the work blank, comprises a driving element 36 having an operative connection with the work carriage 19, and adjustable means available at will for automatically modifying the action of said element to obtain the desired resultant movement.

The driving element 36 preferably is in the form of a feed screw (see Fig. 8) which is in threaded engagement with a nut 37 mounted in a depending lug 38 on the underside of the carriage 19. The nut 37 is normally fixed against rotation so that the carriage 19 will travel along the screw 36 upon operating the latter. However, provision is made for rotating the nut 37 in the lug 38 to adjust the phase relation of the carriage 19 to the screw 36 and the work spindle 24. Thus, the nut 37 is rigid with a worm gear 39 meshing into a worm 40 on a vertical shaft 41 journaled in the headstock 22 and adapted for manual actuation at will.

The screw 36 is driven constantly in timed relation to the work spindle 24, and preferably the drive (see Figs. 2, 3 and 8) is taken from the main gear 29. Thus, a gear 42 rigid with the gear 29 meshes with a gear 43 fixed on one end of a stub shaft 44 journaled in the frame 17. A pinion 45 on the other end of the shaft 44 is connected through change-speed gears 46 and 47 to a gear 48 fixed on the outer end of a short shaft 49 journaled in a bearing 50 on the left end wall of the frame 17. The change-speed gears 46 and 47 are removably mounted on an arm 51 mounted for angular adjustment on the outer end of the bearing 50. The inner end of the shaft 49 is formed with an axial bore 52 into which the adjacent end of the screw 36 is splined for a rotative drive and relative axial movement.

Secured on the opposed end of the screw 36 between a fixed end thrust collar 53 and two lock nuts 54 is a sleeve 55 which is rotatably anchored in a tubular bearing 56 on the right end of the machine frame 17. The sleeve 55 is held in position by means of a peripheral flange 57 on its outer end seating in a groove 58 in the outer end of the bearing 56, and the collar 53 which engages the inner end of the bearing. Back lash between the feed screw 36 and the nut 37 is taken up by a weight 59 (see Fig. 1) which is operatively connected to the carriage 19 to urge the latter to the right. The weight 59 is connected to a cable 60 leading over and anchored to a sheave 61 fixed on the forward end of a shaft 62 journaled in a bracket 63 on the machine frame 17. A cable 64 is anchored at one end to the carriage 19 and at the other end to a sheave 65 fixed on the rear end of the shaft 62 to complete the operative connection from the carriage to the weight 59. Since the screw 36 is free to move axially in the shaft 49, the weight 59 acts to urge the carriage 19 and the screw as a unit against the end of the bearing 56.

The drive for the feed screw 36 is automatically reversible to effect reciprocation of the work carriage 19. More specifically, the carriage 19 is movable repeatedly first in one direction, for example to the right, in a grinding stroke, and then in the reverse direction, for example to the left, in a return stroke in order to traverse the grinding element B recurrently in a series of cuts along the work blank A until the latter is ground progressively to the desired depth or form. The work spindle 24 is rotated in the direction of the arrows during each grinding stroke, and is reversible in rotation simultaneously with each reversal of the feed screw 36.

In the present instance, the means for reversing the drive for the work spindle 24 and the feed screw 36 comprises a piston and cylinder unit 66 (see Figs. 2, 4, 5 and 11) mounted on the rear of the frame 17. The unit 66 has a projecting piston rod 67 which is formed on its outer end with a yoke 68. A roller 69 mounted on the free end of a lever 70 secured to a vertical shaft 71 operatively engages in the yoke 68. The upper end of the shaft 71 is connected to suitable actuating means (not shown) for the reversing clutch (not shown) in the countershaft (not shown) adapted for driving connection with the cone pulley 26. A hand actuator 72 on the shaft 71 provides means for manual actuation.

The supply of pressure fluid, such for example as compressed air, alternately to opposite ends of the unit 66 to effect reciprocation of the piston rod 67 as desired, is under the control of an oscillatory valve 73. The details of the unit 66 and the valve 73 per se form no part of the present invention, and are fully disclosed in said copending application.

To render the valve 73 automatically responsive to the movements of the carriage 19 into the extreme end positions, it is provided on its upper end with a bell crank lever 74. A coil tension spring 75, anchored to the frame 17, is connected to one arm of the lever 74 and tends to oscillate the valve 73 into a position to effect movement of the carriage 19 to the left. The other arm of the lever 74 constitutes a pawl 76 adapted to be swung against the action of the spring 75 into interlocking engagement with the notched end of a latch 77. A lever arm 78 is pivotal with the latch 77, and is connected at its free end to a coiled tension spring 79 anchored to the frame 17 and serving to hold the latch against the pawl 76 at all times. When the pawl 76 is seated in the latch 77, the valve 73 is positioned to effect movement of the carriage 19 to the right.

A trip dog 80 mounted on the carriage 19 for movement therewith has an inclined surface adapted to ride against a pin 81 extending upwardly from the free end of the lever arm 78, and to gradually swing the latter rearwardly until, at the end of the carriage movement to the right during the grinding stroke, the latch 77 suddenly releases the pawl 76. Thereupon, the lever 74 is moved under the influence of the spring 75 to effect reversal of the valve 73, and consequently to institute the return movement of the carriage. A reversing dog 82 mounted on

the carriage 19 is positioned to engage a pin 83 on one arm of the lever 74 at the end of the return movement to reinstitute movement in the original direction preparatory to taking a new depth cut on the work.

Since the screw 36 is rotated continuously, it will, if held against endwise movement, cause the carriage 19 to travel uninterruptedly in either direction in timed relation to the rotation of the work blank A. Such movement is required where the grinding element B is to describe a helical cut, as for example in the grinding of gear cutting hobs or of screw threads. However, where the grinding element B is not to describe a continuous cut, the carriage 19 must be fed in a step-by-step movement during the grinding stroke. Thus, in the case of thread mills having a series of uniformly spaced annular grooves as illustrated herein, the carriage must be advanced in a series of timed steps, each equal in extent to the space between adjacent grooves, and must be at rest during the grinding of each groove.

To adapt the machine for the grinding of these various types of work blanks, adjustable means is provided available at will for modifying the resultant action of the feed screw 36 to the extent desired. In its preferred form, this means (see Figs. 9 and 10) acts periodically during the grinding stroke first to shift the carriage 19 and the screw 36 as a unit against the action of the weight 59 in a direction opposite the relative movement of the carriage along the screw, thereby completely or partially counteracting the normal action of the screw, and then to release said unit for a return movement into initial position, thus utilizing the accumulated feed to advance the carriage sharply in a retarded step. Obviously, the distance through which the unit 19, 36 is shifted determines the extent of each step through which the carriage is indexed. Where the shifting movement completely counteracts the action of the screw 36, the carriage 19 is stationary during the interval between successive steps.

The aforesaid shifting means in its detailed form comprises a slide 84 which supports the end bearing 56, and which is mounted between two opposed guides 85 for movement in a direction parallel to the screw 36. The guides 85 are mounted in a housing 86 rigidly secured on the right end of the frame 17 beneath the work carriage 19. Anti-friction bearings 87 are suitably interposed between the slide 84 and the guides 85. Mounted in the housing 86 on the underside of the slide 84 for pivotal movement is a cam follower 88 having a flat face 88a. Preferably, the follower 88 is in the form of a block having a pivot pin 89 extending upwardly into the slide 84.

A cross slide 90 is mounted between opposed guides 91 on the underside of the housing 86 for reciprocation transversely of the slide 84 and the screw 36. Preferably, anti-friction bearings 92 are interposed between the slide 90 and the guides 91. Mounted on the slide 90 for angular adjustment about a vertical pivot 93 is a fixed cam 94 in the form of an elongated plate having a flat face 94a on one end constantly in engagement with the follower face 88a. The other end of the cam 94 extends out of the housing 86 into overlying relation with a lateral arm 95 fixed on the slide 90 and to which it may be secured in any position of adjustment by means of a bolt and slot connection 96. A depending pin 97 on the outer end of the cam 94 is adapted for movement into engagement with a lug 98 on the arm 95 to define a position in which the cam face 94 is parallel to the line of movement of the slide 90.

One end of the slide 90 carries a hardened plate 99, constituting a follower, which engages a rotary cam 100 enclosed in a housing 101 on the rear of the frame 17. The follower 99 is held constantly against the cam 100 by a compression spring 102 acting through the arm 95 (see Fig. 4). The cam 100 has a true peripheral spiral face 100a terminating in an abrupt drop 100b which determines the range of movement of the slide 90.

The cam 100 is driven in timed phase relation to the work spindle 24 so as to move the drop 100b across the follower 99 to institute each step of the indexing movement during the grinding stroke at the precise moment that the current cut on the corresponding groove of the work blank A is completed. Thus, the cam 100 is fixed on a shaft 103 which extends along the rear of the frame 17, and which is journaled at one end in a bearing 104 in the housing 101 and at the other end in a bearing 105 on the left end of the frame. A gear 106 (see Figs. 2, 3 and 5) rotatable on the left end of the shaft 103 is connected through two speed-change gears 107 and 108 to the gear 43. The gears 107 and 108 are mounted on a bracket 109 integral with the bearing 105. Fixed on the shaft 103 within a hub 110 on the gear 106 is a collar 111 (see Fig. 7) formed with a peripheral notch 112. A pivotal detent 113 in the gear hub 110 is pressed into the notch 112 by a leaf spring 114 to drive the shaft 103 and hence the cam 100 in a clockwise direction as viewed in Fig. 9, but not in the reverse direction.

It will be evident that when the cam face 94a is not inclined, reciprocation of the slide 90 will not effect any movement of the slide 84, and hence the feed screw 36 will move the carriage 19 without interruption in either direction. However, when the cam face 94a is inclined to the direction in which the slide 90 is reciprocated, the screw 36 will be moved gradually to the left and then suddenly released for a quick return movement once for each revolution of the cam 100 to produce a step-by-step indexing movement of the carriage 19 during the grinding stroke. If the carriage 19 is to remain stationary during each cut, the cam 94 should be inclined at such an angle that the screw 36 will be shifted to the left at the same speed as the carriage is fed along the screw to the right. Thus, the inclination of the cam 94 is related to the lead and speed of rotation of the feed screw 36. The extent to which the carriage 36 is indexed in each step may be varied by adjusting the speed of the screw 36 relative to the work spindle 24, and making a corresponding adjustment in the angle of the cam 94.

To return the carriage 19 after each grinding stroke into initial position for a repetition of the cycle, the rotation of the screw 36 is reversed. By reason of the one-way drive for the shaft 103, the cam 100 cannot be driven in a reverse direction, and must remain stationary. Hence, the return stroke of the carriage 19 is uninterrupted regardless of the character of the indexing movement during the grinding stroke.

When the blank A is formed with inclined gashes, the work spindle 24 is angularly adjusted proportionately with each step in the indexing movement so as to compensate for the inclination of the gashes. This adjustment may be positive or negative depending on whether the blank A has right-hand or left-hand gashes. The means for this purpose (see Figs. 1, 2 and 12)

comprises a gear 115 rotatable with the terminal gear 34 of the planetary spindle drive. The gear 115 is connected through an idler gear 116 to a gear rack 117 formed on the lower end of a bar 118 vertically reciprocable in a guideway 119. The upper end of the bar 118 carries a pin 120 which is slidably disposed in a longitudinal guideway 121 in a horizontal bar 122. The bar 122 is pivotally adjustable at 123 on a horizontal arm 124 rigidly secured at one end to an upstanding bracket 125 on the work carriage 19 for movement therewith. The other end of the arm 124 is slidably disposed in a horizontal guide 126 formed on the upper end of an upstanding bracket 127 on the machine frame 17. The free end of the pivotal bar 122 constitutes a pointer movable along an arcuate scale 128 formed transversely on the horizontal arm 124, and carries a clamp bolt 129 adjustable in an arcuate slot 130 extending along the scale. When the pivotal bar 122 is secured in a horizontal position at the zero point on the scale 128, no movement will be imparted to the rack 117 upon translation of the carriage 19 in either direction, and hence the terminal gear 34 will be stationary. However, if the pivotal bar 122 is adjusted above or below the zero point of the scale 128 at an angle corresponding to that of the cutter gashes, translation of the carriage 19 will impart a reciprocatory movement to the rack 117, thereby effecting a compensatory drive through the terminal gear 34. In the present instance, the blank A is shown with straight gashes, and hence no compensatory adjustment is required.

Grinding wheel support

The grinding wheel B is mounted on one end of a drive spindle 131 (see Fig. 2) which is rotatably mounted in a spindle head 132 slidably adjustable on ways 133 formed on the end of a suitable bracket 134. An adjusting screw 135 rotatably anchored on the bracket 134 is in threaded engagement with the spindle head 132. The spindle 131 has an operative drive connection (not shown) with a sheave 136 connected through a belt 137 to a suitable source of power (not shown).

The bracket 134 is fixed on a horizontal feed slide 138 (see Figs. 2 and 6) mounted for adjustment transversely of the blank A on a horizontal relief slide 139. A feed screw 140 in threaded engagement with a nut 141 on the underside of the slide 138 is journaled in a bearing bracket 142 on the front end of the slide 139. The outer end of the feed screw 140 is provided with an enlarged head 143 rotatable in a seat 144 in the front face of the bracket 142. A cylindrical block 145 is rigidly secured to the outer end of the head 143 by means of bolts 146. A cam abutment 147 is seated in a recess in the front end of the block 145 and projects forwardly therefrom. Extending slidably through the screw 140, the block 145 and the abutment 147, is an elongated axial draw bolt 148. Of the bolt 148, the rear end is in fixed threaded engagement with a lug 149 on the relief slide 139, and the front end is formed with a bearing ring or eye 150. A bifurcated rotary cam 151 provided with a hand lever 152 is pivotally mounted on opposite ends of a pin 153 extending through the eye 150 in bearing engagement with the cam abutment 147, and serves as means for anchoring the feed screw 140 rigidly to the slide 139. A coiled compression spring 154 disposed on the draw bolt 148 in end abutment between the screw 140 and the lug 149 serves upon releasing the cam 151 to shift the screw forwardly in the bearing 142, and thereby retract the grinding wheel B from the blank A into inoperative position.

The cross feed screw 140 may be adjusted by any suitable means, for example to advance the grinding wheel B further toward the work blank A once after each grinding cut along the latter. In the present instance, manually operable means is provided comprising a gear 155 rigid with the block 145. A hand lever 156 is rigid on one end with a strap 157 freely rotatable on the block 145, and carries a releasable detent 158 adapted for selective engagement between the teeth of the gear 155. The lever 156 is adapted to be swung into a horizontal rest position against the top of an arm 159 fixed on the frame 17.

Relieving mechanism

Means is provided for effecting a relative relieving reciprocation between the blank A and the grinding wheel B transversely of the blank once for each tooth as it passes through the grinding zone, and for separating the blank and the grinding wheel during each indexing movement and during the free-return stroke (see Figs. 6 and 11). To this end, the relief slide 139 carrying the grinding wheel B is mounted for reciprocation on horizontal transverse ways 160 on the machine frame 17. A weight 161, which is connected to the slide 139 through a cable 162 leading over two sheaves 163 mounted in brackets 164 on the front of the frame 17, tends to urge the grinding wheel B yieldingly away from the blank A.

Pivotally connected at its upper end to the rear end of the slide 139 is a depending cam lever 165 normally fulcrumed about its lower end. A cam follower block 166 is secured to the lever 165 intermediate its ends, and rides on a rotary relieving cam 167 having a spiral face 167*a* terminating in an abrupt drop 167*b*. The cam 167 is secured to a longitudinal shaft 168 journaled at its ends on the machine frame 17 and connected at its left end through a train of speed-change gears 169, 170 and 171 (see Figs. 1 to 3) to the main drive shaft 27. The rotation of the cam 167 is so timed to the blank A that the grinding wheel B will be fed rearwardly during the grinding of each tooth so as to generate a suitable radial relief, and will then be returned quickly to initial position for the succeeding tooth.

To maintain the cam follower 166 always in the same horizontal plane as the axis of the cam 167, one side of the follower is extended to form a pivot 172 (see Fig. 11[a]) rotatably mounted and slidable in a horizontal guideway 174 in a block 173 for supporting the lever 165. The upper end of the lever 165 is journaled in two blocks 175 slidable vertically in a guide 176 in the slide 139. Likewise, the lower end of the lever 165 is journaled in two blocks 177 slidable vertically in a guide 178. Thus, each end of the lever 165 has a floating connection.

The drop 167*b* of the cam 167 is of such depth that the work blank A and the grinding wheel B are separated sufficiently after the grinding of each tooth to permit indexing on occasion. The relieving cam 167 is accurately timed to the index cam 100 so that each step of the indexing movement will take place immediately after movement of the follower 166 past the drop 167*b*, for example, while the blank A and the wheel B are apart.

Separating mechanism

The work blank A and the grinding wheel B are held in spaced relation, independently of the action of the relieving cam 167, during the continuous free-return stroke of the carriage 19 after each grinding stroke. This is accomplished by automatically adjusting the fulcrum of the lever 165, i. e. the guide 178, rearwardly upon movement of the carriage 19 into its extreme right end position at the end of the grinding stroke. To this end, the guide 178 is rigidly secured on the forward end of a plunger 179 which is mounted for reciprocation transversely of the frame 17. The plunger extends through a bracket 180 mounted on the rear wall of the frame 17, and is splined therein against rotation. An elongated pinion 181 is rotatably and slidably mounted on the rear end of the plunger 179, and is in peripheral bearing engagement with a bore 182 in the bracket 180. The pinion 181 is normally held against endwise movement, and is formed on its inner end with a forwardly projecting cam 183. Fixed on the plunger 179 is a sleeve 184 which is formed with a rearwardly projecting cam 185 adapted for movement into and out of engagement with the cam 183. A gear rack 186 extends slidably through the bracket 180 in mesh with the pinion 181, and is provided on one end with a rod 187 slidably supported in a bracket 188 on the rear of the frame 17. Two spaced collars 189, constituting abutments, are adjustably secured on the rod 187 for engagement respectively with opposite sides of an arm 190 on the yoke 68.

Upon operation of the piston and cylinder unit 66 to institute movement of the carriage 19 to the left, the arm 190 will move into engagement with one of the collars 189 to effect rotation of the cam 183 out of engagement with the cam 185, thus effecting a substantial separation of the work blank A and the grinding wheel B. At the end of the free-return stroke, the piston and cylinder unit 66 will move the arm 190 into engagement with the other of the collars 189 to engage the cams 183 and 185, thereby causing the relief slide 139 to advance the grinding wheel B into operative position.

Taper grinding

For taper grinding, the grinding wheel B is adjusted progressively toward the axis of the work in accordance with the longitudinal indexing movement. To provide adjustable means available at will for controlling the longitudinal contour of the work blank, the pinion 181 is formed on one end with an annular groove 191 in which two shifter shoes 192 are slidably disposed. The shoes 192 are pivotally mounted in the arms of a yoke 193 fixed on a vertical rock shaft 194 journaled in an upstanding tubular bearing 195 on the bracket 180. A lever 197 is fixed on the upper end of shaft 194, and on its free end carries a pivotal follower block 198. Pivotally mounted for angular adjustment on a bracket 196 on the rear of the frame 17 is a contour bar 199 having a guide face 199*a* adapted for engagement by the follower 198.

When the bar 199 is adjusted into zero position, the face 199*a* will travel along the follower 198 without rocking the shaft 194, thus adapting the machine for grinding cylindrical work blanks. However, when the bar 199 is inclined, it will cause the weight 161 to shift the grinding wheel B laterally of the work in timed relation to the movement of the carriage 19, thus adapting the machine for the grinding of tapered work blanks. It will be understood that the taper may be varied by adjusting the bar 199 into different angular positions.

Dressing mechanism

Means is provided for dressing the grinding wheel B from time to time to maintain the desired form and to remove glaze from the grinding surface. This means (see Figs. 13 to 16) comprises a base slide 200 mounted on a guide 201 on the feed slide 138 for adjustment transversely of the grinding spindle 131. Since the grinding spindle is inclined to the work spindle 24, the slide 200 is inclined on the slide 138. Fulcrumed intermediate its ends on a knife edge pivot 202 against a bearing lug 203 on the slide 138 is an adjusting lever 204. One end of the lever 204 is pivotally connected to a block 205 slidable along a guide 206 secured along one side of the relief slide 139. An adjusting screw 207 rotatably anchored in the guide 206 is in threaded engagement with the block 205. The other end of the lever 204 has a knife edge pivot 208 engaging a bearing block 209 on the forward end of the slide 200. A coiled tension spring 210 anchored to the slide 138 acts to hold the slide 200 against the pivot 208.

Rigidly mounted on the slide 200 for adjustment along a longitudinal guide 211 is a bracket 212 having a vertical standard 213 on one end. The rear of the standard 213 has an arcuate face 214 and is formed with a horizontal shelf 215 having an arcuate guide groove 216 and an elongated slot 217 along the groove. Mounted for angular adjustment on the shelf 215, with an arcuate tongue 218 fitting into the groove 216, is a support 219 having a straight transverse guide 200 on the underside. The support 219 may be secured in adjusted position by means of a bolt 221 extending through the slot 217. A slide 222 is reciprocably mounted on the guide 200, and carries a dressing tool 223 adapted to act on the peripheral face of the grinding wheel B.

Rigidly mounted on the standard 213 is a rearwardly extending bracket 224 formed on its free end with an upstanding tubular bearing 225, and in its underside with an arcuate guide groove 226 concentric to the bearing. Two supports 227 and 228, with arcuate tongues 229 fitting into the groove 226, are mounted for angular adjustment on the underside of the bracket 224 generally at opposite sides of the tool 223. Bolts 230 extending through spaced arcuate slots 231 in the bracket 224 are provided for securing the supports 227 and 228 in adjusted position. Secured on the underside of the supports 227 and 228 are two rectilinear guides 232 and 233 in which two slides 234 and 235 are respectively mounted for horizontal reciprocation. The slides 234 and 235 respectively are formed with depending arms 236 and 237 in which suitable tools 238 and 239 for dressing the opposite sides of the grinding wheel B are mounted. The tools 223, 238 and 239 are located in the horizontal axial plane of the grinding wheel B and hence of the grinding spindle 24. Since the grinding wheel B has a V-shaped contour, the supports 227 and 228 are so adjusted that the tools 238 and 239 describe the correct angular paths.

To afford means for simultaneously adjusting the dressing tools 223, 238 and 239, the slides 222, 234 and 235 are provided respectively with longitudinal gear racks 240, 241 and 242. These racks mesh respectively with gear sectors 243, 244 and

245 which are fixed respectively on the lower ends of three telescoping shafts 246, 247 and 248. The inner shaft 246 with the gear sector 243 extends substantially below the gear sectors 244 and 245 and is formed with a peripheral shoulder 249 engaging the lower end of the intermediate shaft 248. The lower end of the inner shaft 246 is cut away in the rear side as indicated at 250 to receive the grinding wheel B and avoid interference with the dressing tools 233, 238 and 239. The gear sectors 244 and 245 bear against the underside of the bracket 224, and the outer shaft 247 is cut away to permit the gear sector 244 to project outwardly into operative engagement with the rack 241.

Threaded respectively onto the upper ends of the shafts 246, 247 and 248 and disposed in closely superimposed relation are three adjusting disks 251, 252 and 253 of which the second rests against the upper end of the bearing 225. The disks 251, 252 and 253 are adapted to be adjustably secured for rotation as a unit by means of two clamp screws 254 extending through two diametrically opposed sets of arcuate slots 255 adapted to be moved into various degrees of registration. A hand lever 256 is integral with the lower disk 253. It will be evident that the shafts 246, 247 and 248 may be adjusted into different relative angular positions so as to vary the order of movement of the dressing tools 223, 238 and 239. Preferably, the shafts are so adjusted that upon unitary movement thereof, the dressing tools will be moved in clockwise or counter-clockwise order so as to avoid interference. By adjusting the various supports 219, 227 and 228, the contour of the grinding wheel B may be varied as necessitated for different types and forms of work blanks. Upon feeding the slide 138 rearwardly to advance the grinding wheel B toward the work, the lever 204 will automatically advance the dressing device proportionately toward the grinding wheel so as to position same for dressing.

Résumé of operation

The operation of the machine will be clear from the foregoing description. Briefly summarized, the cutter blank A is rotated slowly in a counter-clockwise direction as viewed in Fig. 6, and the grinding wheel B is driven at a relatively high speed. At the start of the operation, the blank and the wheel are positioned longitudinally of the blank to grind the first annular groove, and are relatively adjusted laterally of the blank through the cross feed screw 140 to effect a light initial cut. A relieving reciprocation transversely of the blank A is imparted to the grinding wheel B once for each tooth. During the rotation of the blank A through one complete revolution, the work carriage 19 is held stationary while the feed screw 36 is shifted to the left by the index cam 100. When all of the teeth in the initial row have been ground, the index cam 100 releases the screw 36 to index the carriage 19 through one step so as to advance the blank into position to grind the next groove. The indexing movement is timed to occur while the blank A and the wheel B are separated at the start of a relieving reciprocation.

The foregoing operation is repeated until all of the rows of teeth have been ground with an initial cut, i. e. until the blank A has been completely traversed across the grinding wheel B in a step-by-step grinding stroke. Thereupon, the dog 80 institutes operation of the piston and cylinder unit 66 to effect movement of the grinding wheel B into inoperative position spaced from the blank A, and to reverse the drive for the feed screw 36, and incidentally the work spindle 24, so as to traverse the blank in a free return stroke to initial position. The index and relieving cams 100 and 167 are not rotated, and hence the return stroke is continuous and the relief slide 139 is not reciprocated. At the end of the return stroke, the dog 82 institutes operation of the unit 66 to effect return of the grinding wheel B into operative position and reversal of the drive for the feed screw 36 preparatory for the next cut along the blank A. During the free return stroke, an incremental feed toward the blank A is imparted to the grinding wheel. On occasion, the grinding wheel B may be dressed by actuating the hand lever 256, the dressing device being automatically advanced toward the grinding wheel in proportion to the feed to compensate for wear. Successive cuts of increasing depth along the blank A are taken until the teeth are ground to the desired depth.

For cylindrical cutters with straight gashes, the bars 122 and 199 are adjusted into zero position. It will be understood, however, that for cutters with inclined gashes, the bar 122 is angularly adjusted to impart a compensatory rotation to the spindle 24, and for cutters with a tapered contour the bar 199 is angularly adjusted to advance the grinding wheel toward the work automatically in response to indexing movement of the carriage 19. Obviously, the bar 199 may be shaped to adapt the machine for grinding contour cutters having other than a straight taper.

I claim as my invention:

1. In a machine tool, in combination, a base, a carriage mounted for rectilinear movement on said base, a depending lug on the underside of said carriage, a nut fixed in said lug, a feed screw in threaded engagement with said nut, said nut being rotatably adjustable in said lug, drive means for rotating said feed screw continously to advance said carriage relatively along said screw in one direction, and means for adjusting said screw axially in the other direction to modify the resultant movement of said carriage.

2. In a machine tool, in combination, a base, a machine element mounted for movement on said base, a nut on said element, a feed screw in threaded engagement with said nut, drive means for effecting relative continuous rotation between said feed screw and said nut to advance said element relatively along said screw in one direction and means automatically operable during said rotation in one direction for reciprocating said screw axially through a predetermined range first in one direction and then in the reverse direction to obtain a resultant movement of variable speed of said element on said base.

3. In a machine tool, in combination, a base, a machine element mounted for movement on said base, a nut on said element, a feed screw in threaded engagement with said nut, drive means for effecting relative continuous rotation between said feed screw and said nut to advance said element relatively along said screw in one direction and means for reciprocating said screw axially through a predetermined range, each reciprocation consisting of a slow movement at the same rate as but opposite in direction to the advancement of said element along said screw during which said element is stationary relative to said base and a quick return movement in said one direction, whereby said element is given a step-by-step movement on said base.

4. In a machine tool, in combination, a base, a

machine element mounted for rectilinear movement on said base, drive means for said element and including a continuously movable adjustable member in operative engagement with said element for translating said element continuously in one direction of said movement relatively to said member, and means automatically operable during the operation of said drive means in said one direction for periodically moving said element and said member bodily as a unit reversibly first to offset said translation of said element and then quickly in said one direction so as to obtain a step-by-step movement of said element relative to said base.

5. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, a nut on said carriage, a feed screw in threaded engagement with said nut, drive means having an axial spline connection with one end of said screw for rotating said screw to advance said carriage in a continuous movement along said screw in one direction, said drive means being reversible to return said carriage in the opposite direction, a bearing for rotatably anchoring the other end of said screw, said screw and said bearing being axially adjustable as a unit, a slide movable transversely of said screw, an angularly adjustable cam member on said slide, a pivotal cam follower on said bearing in operative engagement with said cam member, yieldable means tending to hold said follower against said cam member, a rotary drop cam in operative engagement with one end of said slide, yieldable means for holding said slide against said rotary cam, and means for rotating said cam in timed relation to said screw.

6. In a machine tool, in combination, a support, a machine element movable on said support, drive means for moving said element relatively in one direction, said drive means being reversible to return said element in the opposite direction, and means operable in timed relation to said drive means upon movement of said element in said one direction for periodically reciprocating said element and said drive means as a unit, each reciprocation having a slow stroke in said opposite direction at a rate substantially equal to the movement of said element along said drive means in said one direction, and a quick return movement in said one direction, whereby a step-by-step movement in said one direction relative to said support is imparted to said element.

7. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, a nut on said carriage, a feed screw in threaded engagement with said nut, said screw being mounted for axial adjustment, drive means for effecting relative rotation between said nut and said screw to advance said carriage in a continuous movement along said screw in one direction, said drive means being reversible to return said carriage in the opposite direction, yieldable means tending constantly to move said screw axially in said one direction, control means acting on said screw in opposition to said yieldable means and defining a normal position for said screw, said control means being automatically operable periodically to move said screw against the action of said yieldable means from said normal position in said opposite direction gradually through a predetermined distance and then to release said screw for a quick return movement into said normal position, and drive means for said control means, said last mentioned drive means being timed to said first mentioned drive means and being inoperable during movement of said carriage in said opposite direction.

8. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, a slide mounted for reciprocation transversely of said carriage, drive means for reciprocating said slide, a nut on said carriage, a feed screw in threaded engagement with said nut, said screw being mounted for axial adjustment, drive means for effecting relative rotation between said nut and said screw to advance said carriage in a continuous movement along said screw in one direction, yieldable means tending constantly to move said screw axially in said one direction, control means acting on said screw in opposition to said yieldable means and defining a normal position for said screw, said control means being automatically operable periodically to move said screw against the action of said yieldable means from said normal position in the opposite direction gradually through a predetermined distance and then to release said screw for a quick return movement into said normal position, drive means for said control means, said last mentioned means being timed to said two first mentioned drive means so that said carriage will be moved along said base in said one direction step-by-step, with each step occurring while said slide is remote from said carriage.

9. In a machine tool, in combination, a base, a carriage mounted for movement on said base, a nut on said carriage, a feed screw in threaded engagement with said nut, said screw being mounted for axial adjustment, drive means for effecting relative rotation between said nut and said screw to advance said carriage in a continuous movement along said screw in one direction, yieldable means tending constantly to move said screw axially in said one direction, adjustable control means acting on said screw in opposition to said yieldable means and defining a normal position for said screw, said control means in one position of adjustment acting to maintain said screw in said normal position, and in other selective positions of adjustment being automatically operable periodically to move said carriage against the action of said yieldable means from said normal position in the opposite direction gradually through a predetermined distance and then to release said screw for a quick return movement into said normal position, and drive means for said control means, said drive means being timed to said first mentioned drive means.

10. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, a nut on said carriage, a feed screw in threaded engagement with said nut, said screw being mounted for axial adjustment, drive means for effecting relative rotation between said nut and said screw to advance said carriage in a continuous movement along said screw in one direction, said drive means being reversible to return said carriage in the opposite direction, a bearing for rotatably anchoring said screw, a cam slide movable transversely of said screw, an adjustable cam member on said slide, a cam follower on said bearing in operative engagement with said cam member, yieldable means tending to move said screw axially in said one direction to hold said follower against said cam member, and means for reciprocating said slide in timed relation to the rotation of said screw.

11. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation

on said base, a rotary spindle journaled on said carriage, a cross slide mounted on said base for movement transversely of said spindle, a rotary relieving cam for reciprocating said cross slide in a gradual approaching movement and a quick separating movement, a nut and feed screw drive for reciprocating said carriage axially of said spindle first in one direction and then in a return direction, means operable in timed relation to said drive for separating said cross slide from said spindle during the return movement, and means operable during movement of said carriage in said one direction periodically to shift said carriage and said feed screw drive as a unit in the opposite direction to effect a step-by-step movement of said carriage in said one direction, with each step being timed to occur while said slide is remote from said spindle.

12. In a machine tool, in combination, a base, a carriage movable on said base, a slide movable on said base transversely of said carriage, an adjustable stop, means coacting with said stop for determining the position of said slide relative to said spindle, an axially shiftable non-rotatable rod supporting said stop, a cam abutment on said rod, an elongated pinion rotatably and slidably mounted on said rod, said pinion having a cam on one end coacting with said abutment, gear means for rotating said pinion in any axial position to adjust said stop, a templet movable with said carriage, and means coacting with said templet in the progressive movement of said carriage to control the axial position of said pinion and therethrough the position of said stop in accordance with the pattern of said templet.

13. In a machine tool, in combination, a base, a carriage movable on said base, a slide movable on said base transversely of said carriage, yieldable means tending to urge said slide from said carriage, an adjustable stop, a lever fulcrumed intermediate its ends and coacting at one end with said stop and at the other end with said slide for determining the position of said slide relative to said carriage, an axially shiftable rod for supporting said stop, a templet mounted on said carriage and having a face of predetermined form, said templet being adjustable relative to the direction of movement, and means coacting with said face for positioning said rod during the progressive movement of said carriage in accordance with the contour and setting of said face.

14. In a machine tool, in combination, a base, a carriage movable on said base, a slide movable on said base transversely of said carriage, an adjustable stop, a lever coacting with said stop and said slide for determining the position of said slide relative to said carriage, means acting as a fulcrum for said lever, a templet movable with said carriage, said templet having a face with a contour extending generally along said base, and means mounted on said base and coacting with said face for controlling the position of said stop as determined by said contour during the progressive movement of said carriage.

15. In a machine tool, in combination, a base, a carriage reciprocable on said base between two opposed predetermined end positions, a spindle on said carriage, a slide movable on said base transversely of said spindle, a stop, means coacting with said stop for determining the position of said slide relative to said spindle, means responsive to the movement of said carriage into either of said end positions to adjust said stop into either of two relative corresponding positions, and means for independently adjusting said stop automatically in response to the progressive movement of said carriage.

16. In a machine tool, in combination, a base, a carriage slidable on said base, a slide movable on said base transversely of said carriage, yieldable means tending to move said slide from said carriage, a stop, means coacting with said stop for determining the position of said slide under the influence of said yieldable means, a bearing on said base, an elongated pinion rotatable in said bearing, said pinion having an annular end face cam on one end, a non-rotatable rod supporting said stop, a follower on said rod coacting with said cam face, a gear rack meshing with said pinion, and means responsive to the movement of said carriage for actuating said rack to rotate said cam to adjust said stop selectively into different positions.

17. In a machine tool, in combination, a base, a member movable on said base, a tool slide adjustably mounted on said member, screw means for adjusting said slide in a feeding movement on said member, yieldable means tending to move said member in one direction, a stop abutment adjustably mounted on said base and independent of said member and said screw means, means coacting with and interposed between said abutment and said member for determining the position of said member under the influence of said yieldable means, and two means independently available for translatably adjusting the position of said stop abutment to control the position of said member, each of said last two means being automatically operable in timed relation to the movement of said member.

18. In a machine tool, in combination, a base, a slide movable on said base, yieldable means tending to move said slide in one direction, a stop, means coacting with said stop for determining the position of said slide under the influence of said yieldable means, a shiftable support for said stop, a cam follower on said support, a rotary cam engaging said follower, means for rotating said cam to adjust said stop, and means for shifting said cam to adjust said stop.

19. In a machine tool, in combination, a base, a relieving slide mounted for reciprocation on said base, a rotary relieving cam, a cam lever in operative engagement intermediate its ends with said cam, one end of said lever having an operative engagement with said slide, a fulcrum coacting with the other end of said lever, yieldable means for holding said lever against said cam, a non-rotatable rod supporting said fulcrum, said rod being axially shiftable, a cam follower on said rod, a rotary cam having an annular end face in operative engagement with said follower, means for rotating said last mentioned cam to adjust said fulcrum, and independent means for shifting said last mentioned cam to adjust said fulcrum.

20. In a machine tool, in combination, a support, a member reciprocable on said support, a lever having a floating connection with said member, a fulcrum, said lever having a floating connection with said fulcrum; yieldable means tending to move said member in one direction, means coacting with an intermediate portion of said lever for oscillating said lever about said fulcrum against the action of said yieldable means, and means for constraining said portion of said lever to move in a rectilinear path parallel to the movement of said member.

21. In a machine tool, in combination, a support, a member movable horizontally on said

support, a rotary cam, a vertical lever having a cam follower intermediate its ends coacting with said cam, slide means reciprocable in a horizontal rectilinear direction transversely of the axis of said cam, said follower being pivotally mounted on said slide means, the upper end of said lever having a floating connection with said member, a fulcrum mounted in said support, the other end of said lever having a floating engagement with said fulcrum, and yieldable means acting to hold said cam and said lever in operative engagement.

22. In a machine tool, in combination, a support, a member movable on said support, a rotary cam having a gradual throw terminating in an abrupt drop, a lever pivotally mounted intermediate its ends for rectilinear shifting movement and coacting with said cam in the plane of said movement, one end of said lever having an operative floating connection with said member, a fulcrum mounted in said support, the other end of said lever having a floating engagement with said fulcrum, and yieldable means acting to hold said cam and said lever in operative engagement.

23. In a machine tool, in combination, a base, a carriage mounted on said base, a work spindle rotatably mounted on said carriage, means for driving said carriage axially of said spindle in a step-by-step indexing movement in one direction, a tool slide mounted on said base for reciprocation transversely of said spindle, a rotary relieving cam on a horizontal axis in said base, a lever coacting with said cam, said lever at said cam being constrained for horizontal rectilinear shifting movement transversely of said axis, one end of said lever having a floating connection with said slide, a fulcrum for said lever, yieldable means acting to hold said lever against said cam and tending to retract said slide from said spindle, and means for driving said cam in timed relation to said spindle and said carriage to effect a relieving reciprocation of said slide during said indexing movement and to cause each step of said indexing movement to occur when said slide is retracted from said spindle.

24. In a machine tool, in combination, a base, a carriage mounted on said base, a work spindle rotatably mounted on said carriage, means for reciprocating said carriage axially of said spindle, a tool slide mounted on said base for reciprocation transversely of said spindle, a rotary relieving cam, a lever pivotally supported intermediate its ends for rectilinear shifting movement and coacting with said cam in the plane of said movement, one end of said lever having a floating connection with said slide, a fulcrum, the other end of said lever having a floating connection with said fulcrum, yieldable means acting to hold said lever against said cam and tending to retract said slide from said spindle, and means operable upon movement of said carriage in one direction for driving said cam in timed relation to said spindle to effect a relieving reciprocation of said slide.

25. In a machine tool, in combination, a base, a carriage mounted on said base, a work spindle rotatably mounted on said carriage, means for reciprocating said carriage axially of said spindle in a step-by-step indexing movement in one direction and then in a continuous return movement in the opposite direction, a tool slide mounted on said base for reciprocation transversely of said spindle, a rotary relieving cam, a cam lever pivotally supported intermediate its ends for rectilinear shifting movement and coacting with said cam in the plane of said movement, one end of said lever having a floating connection with said slide, a fulcrum adjustably supported in said base, the other end of said lever having a floating connection with said fulcrum, yieldable means acting to hold said lever against said cam and tending to retract said slide from said spindle, means for driving said cam in timed relation to said spindle and said carriage to effect a relieving reciprocation of said slide during said indexing movement and to cause each step of said indexing movement to occur when said slide is retracted from said spindle, and means automatically operable in response to each reversal of movement of said carriage to shift said fulcrum to locate said slide in operative position during said indexing movement and in retracted inoperative position during said return movement.

26. In a machine tool, in combination, a base, a carriage mounted on said base, a work spindle rotatably mounted on said carriage, means for reciprocating said carriage axially of said spindle in a step-by-step indexing movement in one direction and then in a continuous return movement in the opposite direction, a tool slide mounted on said base for reciprocation transversely of said spindle, a rotary relieving cam on a horizontal axis in said base, a vertical lever coacting intermediate its ends with said cam, said lever being pivotally supported for horizontal rectilinear shifting movement transversely of said axis, the upper end of said lever having a floating connection with said slide, a fulcrum adjustably supported in said base, the lower end of said lever having a floating connection with said fulcrum, yieldable means acting to hold said lever against said cam and tending to retract said slide from said spindle, means for driving said cam in timed relation to said spindle and said carriage to effect a relieving reciprocation of said slide during said indexing movement and to cause each step of said indexing movement to occur when said slide is retracted from said spindle, means for automatically adjusting said fulcrum in timed relation to said indexing movement to vary the relative position of said slide and said spindle, and means automatically operable in response to each reversal of movement of said carriage to shift said fulcrum to locate said slide in operative position during said indexing movement and in retracted inoperative position during said return movement.

27. In a machine tool, in combination, a base member, a work spindle, a support slidable on said base member transversely of said spindle, a grinding wheel mounted on said support, means for adjusting said support to advance said wheel toward said spindle, a dressing device adjustably mounted on said support in operative relation to said wheel, and means interconnecting said base member, said support and said device and being automatically operable by the relative movement of said support and base member in the adjustment of said support on said base member toward said spindle to adjust said device on said support proportionately but at a slower rate toward said grinding wheel.

28. An index mechanism comprising, in combination, a lead screw, an index cam, a work holder, a cutting tool, a relief cam periodically rotatable out of an initial position to advance said tool relatively toward said holder in a relief movement, means for continuously rotating said screw and said first mentioned cam in timed relation to said work holder and said relief cam, and means operable by said index cam whereby

relative longitudinal axial movement between said cutting tool and the work is arrested during one or more revolutions of work and a quick indexing movement of the cutting tool relatively longitudinally of the work is made at a time when said relief cam is in said initial position.

29. In a machine tool, in combination, a base, a work spindle operatively mounted on said base, a support slidable on said base transversely of said spindle, a grinding wheel mounted on said support, means for adjusting said support to advance said wheel toward said spindle, a slide mounted on said support for adjustment toward said wheel, a dressing device supported on said slide in operative relation to said wheel, spring means tending to retract said slide from said wheel, and means automatically operable upon adjustment of said support on said base toward said spindle for adjusting said slide against the action of said spring means proportionately but at a lower rate toward said grinding wheel.

30. In a machine tool, in combination, a base, a work spindle operatively mounted on said base, a support slidable on said base transversely of said spindle, a grinding wheel mounted on said support, means for adjusting said support to advance said wheel toward said spindle, a slide mounted on said support for adjustment toward said wheel, a dressing device supported on said slide in operative relation to said wheel, spring means tending to retract said slide from said wheel, a guide rigid with said base and extending perpendicularly of said spindle, a block secured for adjustment along said guide, and a lever pivoted to said block and having a pivotal bearing engagement with said slide and a second bearing engagement with said support to adjust said slide automatically against said spring means toward said wheel upon adjustment of said support toward said spindle.

31. In a machine tool, in combination, a stationary support, relatively rotatable screw elements, an axial thrust anchor on said support for one of said elements, power drive means for effecting relative rotation of said elements in one direction, and means automatically operable during said rotation in one direction for adjusting said anchor axially of said elements first in one direction and then in the reverse direction whereby to effect a variable speed movement of the other of said elements relative to said support.

32. In a machine tool, in combination, a stationary support, two relatively rotatable screw elements, an anchor on said support for limiting the axial position of one of said elements, reversible power drive means for effecting relative rotation of said elements in opposite directions, and means automatically operable during rotation in one direction for adjusting said anchor axially of said elements to obtain a translation of the other of said elements relative to said support other than the relative axial translation between said elements, said last mentioned means being inoperative upon relative rotation of said elements in the opposite direction.

33. In a machine tool, in combination, a base, a member movable on said base, yieldable means tending to move said member in one direction, a lever coacting with said member, a relieving cam engaging one side of said lever, a stop engaging the other side of said lever and adjustable to pivot said lever about said cam as a fulcrum against the action of said yieldable means, said cam being adjustable to pivot said lever about said stop as a fulcrum against said yieldable means, and two means independently available for adjusting the position of said stop, one of said last mentioned means being operable upon movement of said member into a predetermined position, the other of said last mentioned means being operable progressively during the movement of said member.

34. In a machine tool, in combination, a base member, a work spindle, a support slidable on said base member transversely of said spindle, a grinding wheel mounted on said support, means coacting with said base member for adjusting said support on said member to advance said wheel toward said spindle, a dressing device slidably mounted on said support in operative relation to said wheel for adjustment transversely of the axis of said wheel, and means independent of said first mentioned means and responsive to the movement of said support on said member for adjusting said dressing device, said last mentioned means comprising a lever extending generally transversely of said support, a pivot connecting one end portion of said lever to said base member, the other end portion of said lever having a pivotal bearing connection with said dressing device, and a fulcrum on said support engaging an intermediate portion of said lever and operable to oscillate said lever about said pivot to adjust said device on said support toward said wheel upon adjustment of said support on said base by said first mentioned means toward said spindle.

35. In a machine tool, in combination, a base member, a work spindle, a support slidable on said base member transversely of said spindle, a grinding wheel mounted on said support, screw means anchoring said support to said base member, and for adjusting said support to advance said wheel toward said spindle in a feed adjustment, a dressing device slidably mounted on said support in operative relation to said wheel for adjustment transversely of the axis of said wheel, a lever independent of said screw means and extending generally transversely of said support, a pivot connecting one end portion of said lever to said base member, the other end portion of said lever having a pivotal bearing connection with said dressing device, and a fulcrum on said support engaging an intermediate portion of said lever and operable to oscillate said lever about said pivot to adjust said device toward said wheel in a dressing adjustment upon adjustment of said support toward said spindle, said fulcrum being located at a greater distance from said pivot than from said bearing connection so that feed adjustment will be greater than said dressing adjustment.

36. In a machine tool, in combination, a base, a carriage movable on said base, a member movable on said base, yieldable means tending to move said member in one direction relative to said carriage, a stop abutment separate from said member, means connected to said member and anchoring against said stop abutment for limiting the position of said member under the influence of said yieldable means, said means including a member operable recurrently to reciprocate said first mentioned member relative to said stop abutment, and two means independently operable for adjusting the position of said abutment and thereby to control the position of said first mentioned member, each of said two means being automatically operable in response to predetermined movements of said carriage.

37. In a machine tool, in combination, a base,

a work spindle mounted on said base, a slide reciprocable on said base transversely of said spindle, a support mounted on said slide for movement transversely of said spindle, a nut and screw device directly connecting said slide and support for adjusting said support, a grinding wheel mounted on said support, a dressing device slidably mounted on said support in operative relation to said wheel for adjustment transversely of the axis of said wheel, a horizontal lever extending generally transversely of said support, a pivot connecting one end portion of said lever to said slide at one side of said support, means for adjusting said pivot on said slide along said support, the other end portion of said lever having a pivotal connection with said dressing device, and a fulcrum on said support for an intermediate portion of said lever and operable to oscillate said lever about said pivot so as to adjust said device on said support toward said wheel upon adjustment of said support by said screw device toward said spindle.

38. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, drive means for reciprocating said carriage and including two coacting parts relatively movable in the direction of reciprocation, one part being connected to said carriage, an anchor in said base for the other of said parts, means for effecting a continuous relative movement of said one part along said other part in one direction, a cam slide movable transversely of said carriage, an adjustable cam member on said slide, a cam follower on said anchor in operative engagement with said cam member, yieldable means tending to hold said follower against said cam member, and means for reciprocating said slide in timed relation to the relative movement between said parts whereby to reciprocate said parts as a unit in a direction opposite said one direction at a rate substantially equal to the relative movement between said parts and then at a fast rate in said one direction, whereby a step-by-step movement in said one direction is imparted to said carriage.

39. In a machine tool, in combination, a base, a carriage mounted for rectilinear reciprocation on said base, two coacting parts relatively movable in the direction of reciprocation, one of said parts being connected to said carriage, and the other of said parts being mounted for adjustment in the direction of said reciprocation, drive means for effecting relative continuous movement of said parts in one direction, yieldable means tending constantly to move said parts as a unit in said one direction, control means acting on said other part in opposition to said yieldable means and defining a normal position for said other part, said control means being automatically operable periodically to move said parts as a unit against the action of said yieldable means from said normal position in a direction opposite said one direction gradually through a predetermined distance and then to release said parts for a quick return movement into said normal position, and drive means for said control means, said last mentioned drive means being timed to said first mentioned drive means so that said carriage will be moved along said base in said one direction in a step-by-step movement.

40. In a machine tool, in combination, a base, a carriage reciprocable on said base, reversible drive means normally operable to translate said carriage continuously in either direction, and means operable only during translatory movement of said carriage in one direction for reciprocating said drive means and said carriage as a unit to superimpose a reciprocatory movement on said translatory movement, said reciprocatory movement serving alternately to offset and augment said translatory movement.

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