

June 14, 1932.

E. W. BULLOCK ET AL

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MACHINE FOR SHARPENING CUTTERS

Filed Sept. 20, 1927

7 Sheets-Sheet 1

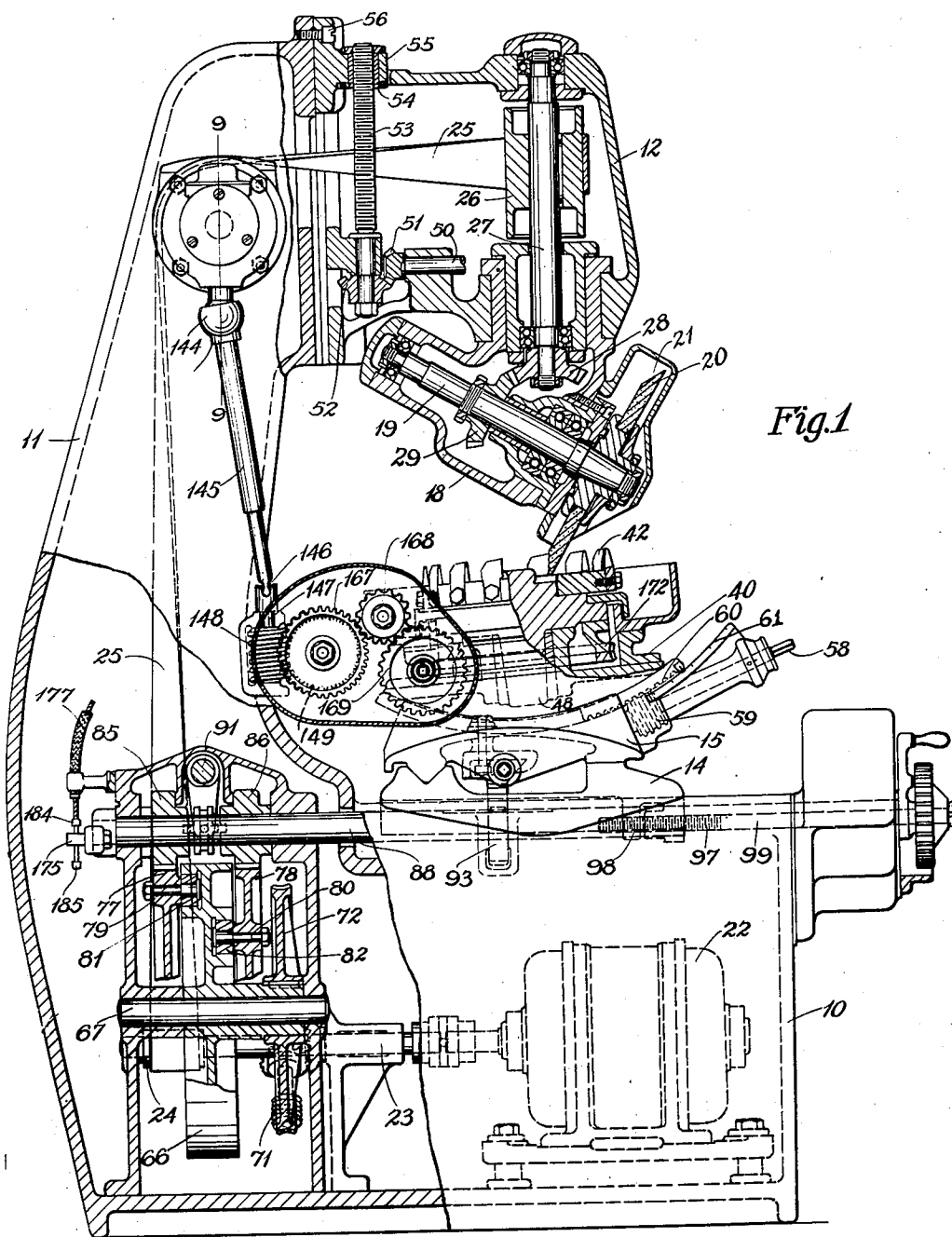


Fig. 1

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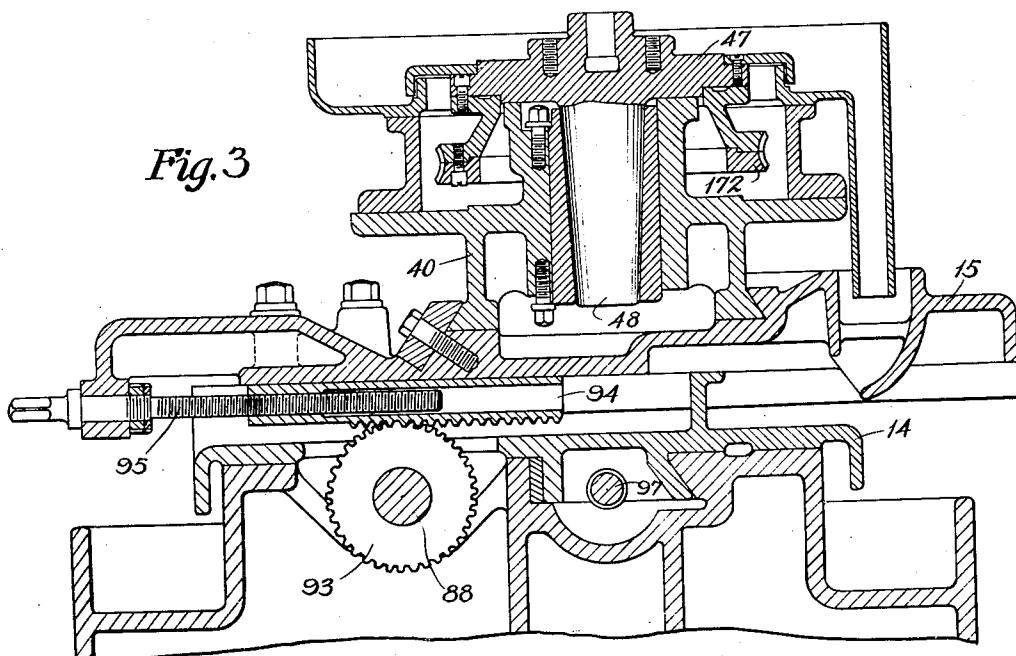
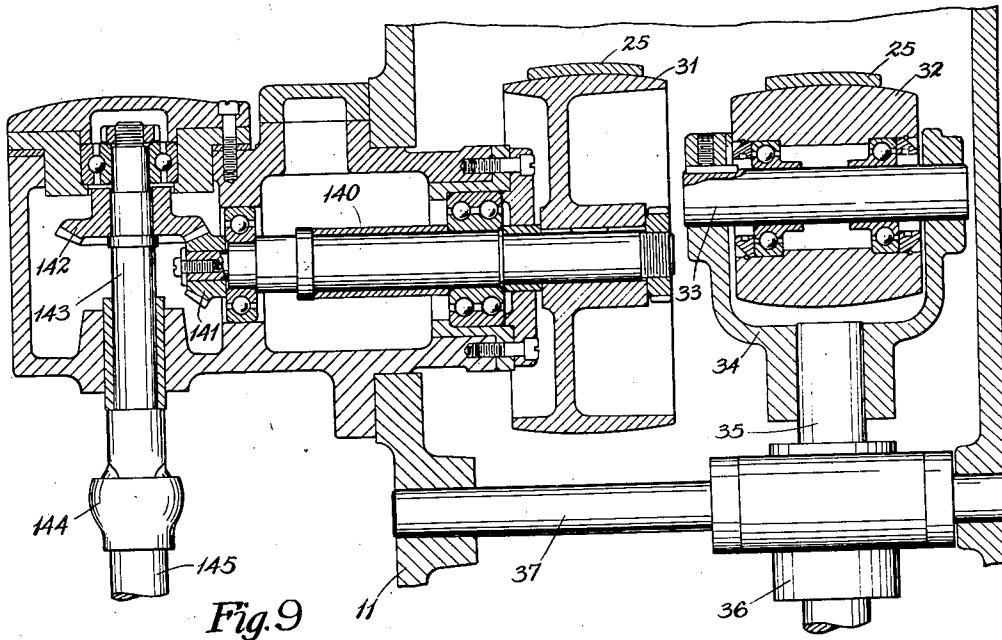
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7 Sheets-Sheet 3



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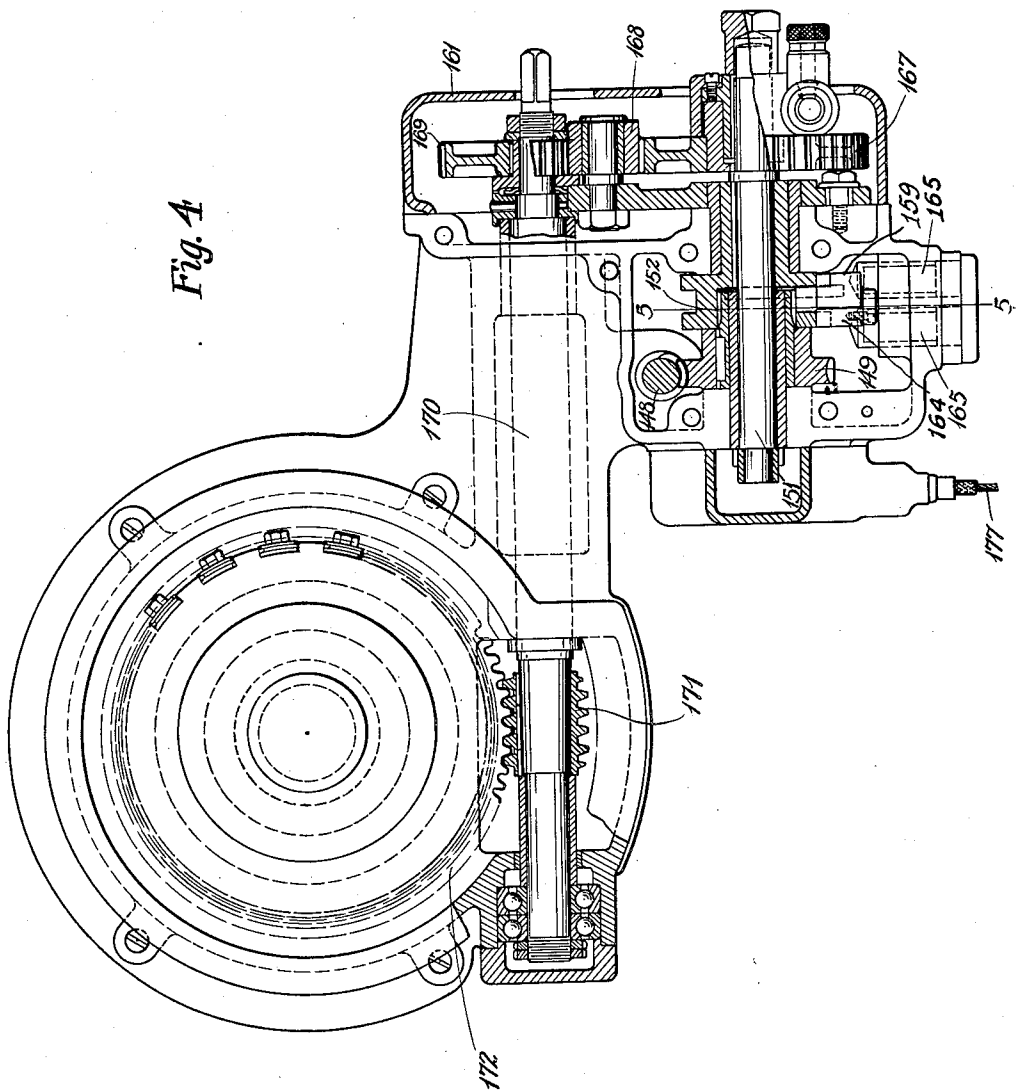
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7 Sheets-Sheet 4



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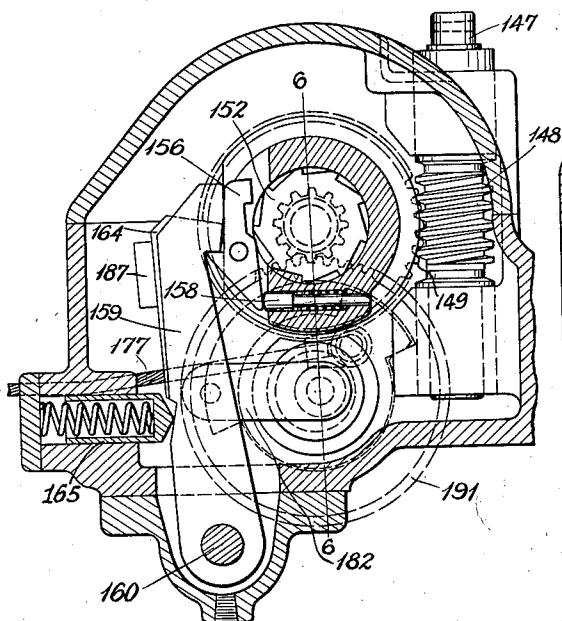


Fig. 5

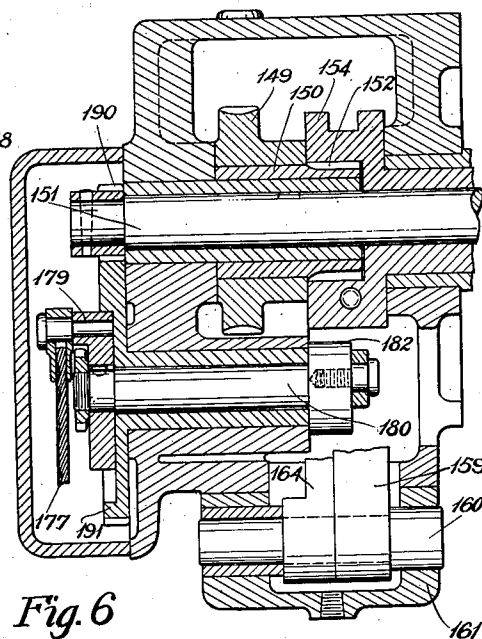


Fig. 6

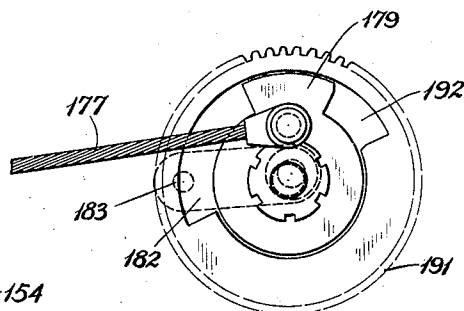
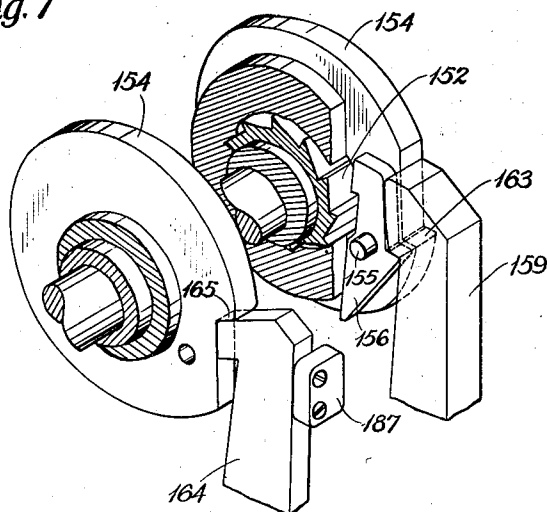


Fig. 7

Fig. 8



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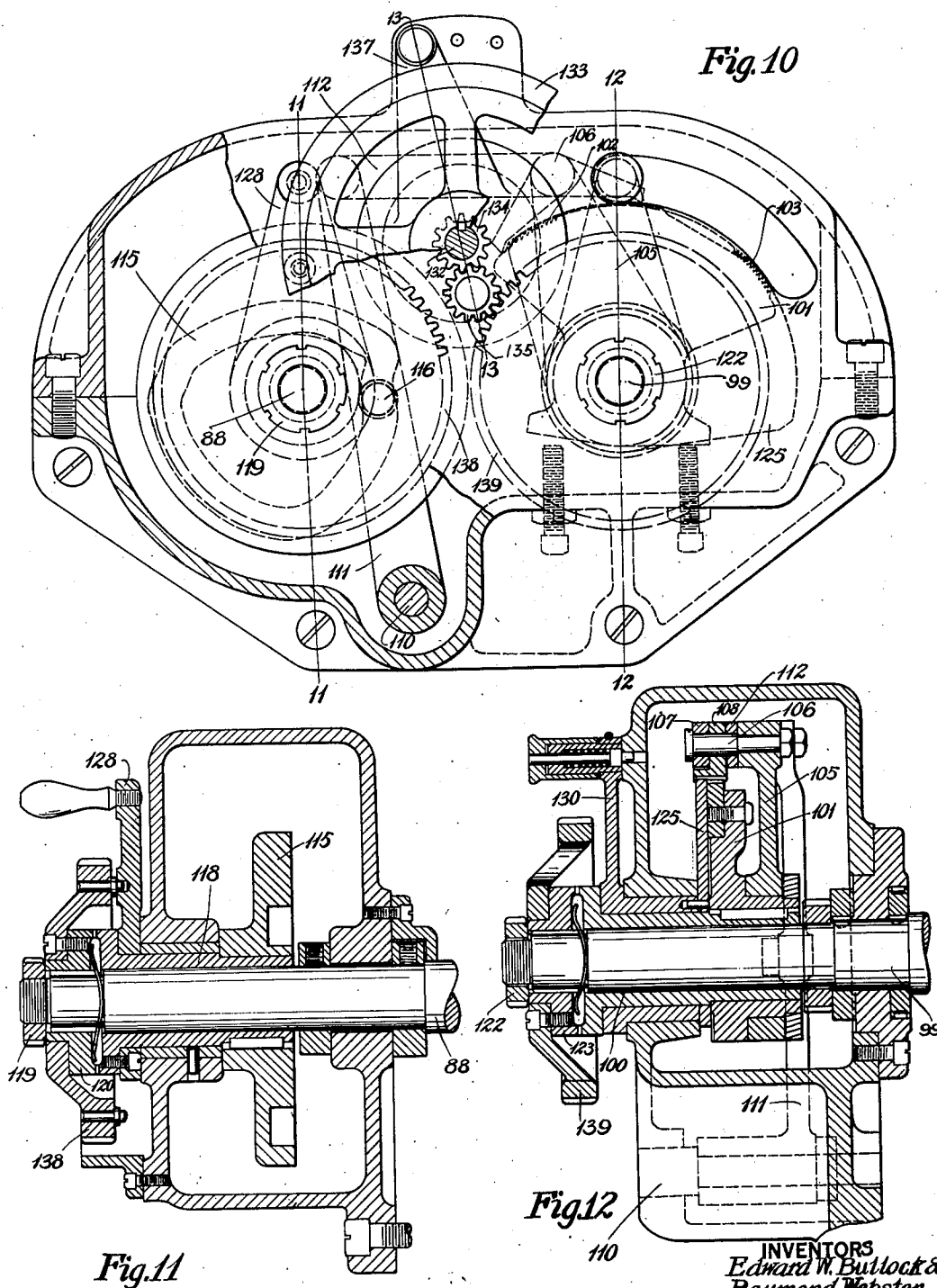


Fig. 10

Fig. 11

Fig. 12

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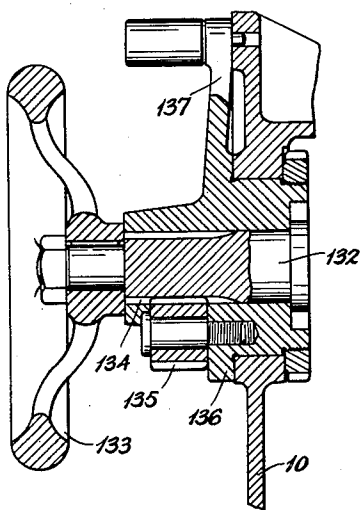


Fig. 13

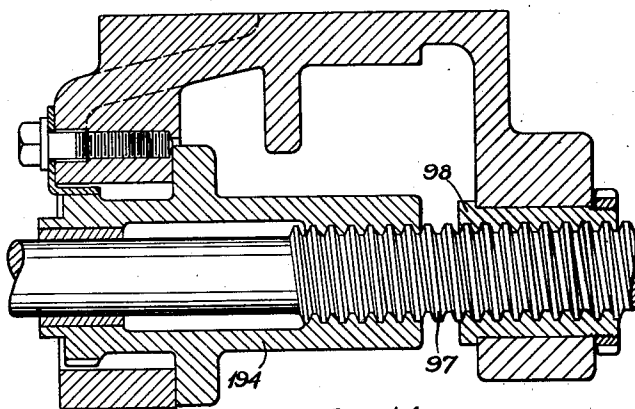


Fig. 14

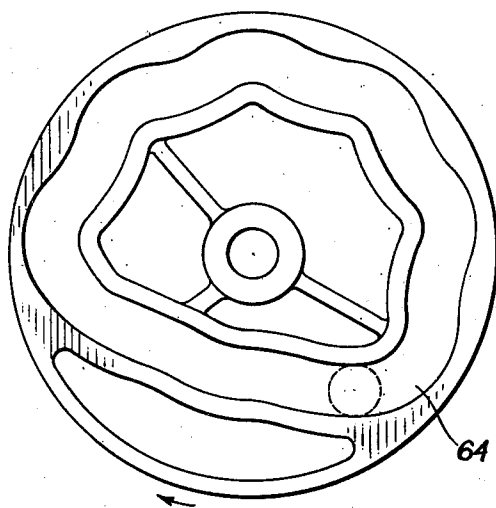


Fig. 15

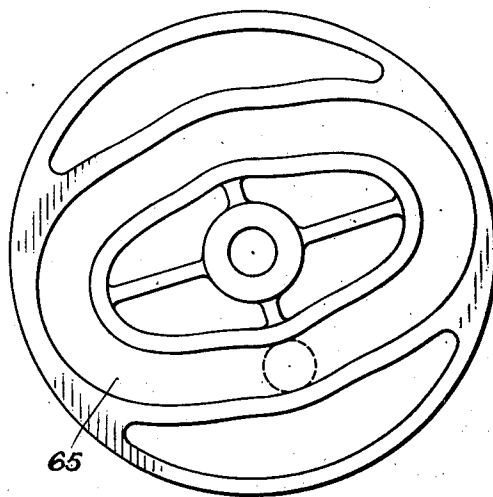


Fig. 16

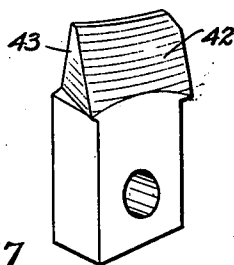


Fig. 17

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UNITED STATES PATENT OFFICE

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MACHINE FOR SHARPENING CUTTERS

Application filed September 20, 1927. Serial No. 220,784.

The present invention relates to a machine for sharpening cutter blades and particularly to a machine for sharpening the cutter blades of a rotary annular face mill cutter such as is employed in the production of longitudinally curved tooth gears.

One object of this invention is to provide a machine of the character referred to which will be fully automatic in operation and upon which the cutter blades may be both rough and finished ground.

Other objects of the invention will be apparent hereinafter from the specification when read in conjunction with the accompanying drawings, the novel features being pointed out in the claims appended hereto.

In the drawings:

Figure 1 is a side elevation, partly in section, of a cutter grinder constructed according to one embodiment of our invention;

Figure 2 is an isometric view of the machine, showing details of the drive;

Figure 3 is a sectional view of the work head and carrier;

Figure 4 is a plan view of the work support showing parts of the index mechanism in section;

Figure 5 is a section on the line 5—5 of Figure 4 looking in the direction of the arrows;

Figure 6 is a section on the line 6—6 of Figure 5;

Figure 7 is a perspective view showing the lock-up part of the index mechanism, the two halves of the stop plate being separated for clearness;

Figure 8 is a detail of the index trip mechanism;

Figure 9 is a sectional view showing the arrangement of the pulley drive to the grinding wheel, the section being taken generally on the line 9—9 of Figure 1;

Figure 10 is a front elevation of the mechanism controlling the adjustments of the work support and the feed thereof;

Figure 11 is a section on the line 11—11 of Figure 10;

Figure 12 is a section on the line 12—12 of Figure 10;

Figure 13 is a section on the line 13—13 of Figure 10;

Figure 14 is a detail sectional view showing the mounting of the feed screw and nut;

Figure 15 is a side elevation of the cam controlling the roughing operation of the machine;

Figure 16 is a corresponding side elevation of the finishing cam; and

Figure 17 is a perspective view of one of the cutter blades to be ground.

The present invention is intended primarily for sharpening the cutter blades of rotary annular face mills, the sharpening operation being accomplished by grinding back the front cutting faces of the blades. In the machine illustrated, a rotary grinding wheel is employed having a conical operating surface. The cutter head, in which the blades are mounted upon the gear cutting machine, may be used on the machine of the present invention to support the cutter blades to be ground or a separate head may be employed for carrying these blades. Suitable adjustments are provided for bringing the work support and grinding wheel into correct operative relation. Thus, the work support has a straight line adjustment to permit offsetting the plane of engagement of the grinding wheel from the axis of the cutter in accordance with the shear angle to be ground on the blade, and an angular adjustment to insure that the correct cutting edge will be obtained in the offset grinding position. The work support has a straight line adjustment, also, in a direction at right angles to the first mentioned adjustment to allow bringing the cutter into operative relation with the wheel.

Alternate blades of a face mill gear cutter are designed ordinarily to cut on opposite sides of the gear teeth so the front faces of alternate blades have oppositely directed shear angles. The work support is offset in opposite directions, therefore, to grind the opposite side cutting blades.

The cutter head is locked against rotation on the work support during the grinding operation upon each blade and is indexed after

each blade is ground to bring a new blade into operative position.

To effect grinding, the work support is reciprocated to move the blades being
5 ground across the rotating grinding wheel. The reciprocating movements are effected from a cam through an oscillatory shaft which has a geared connection with the reciprocable work support. The machine is
10 provided with two cams, one for roughing, the other for finishing and either cam may be selectively brought into operative relation with the oscillatory shaft to permit rough grinding or finish grinding of the
15 cutter blades. The cams are mounted on a shaft which rotates continuously in one direction. The roughing cam produces a series of oscillating movements of the oscillatory shaft through a short arc and
20 then an oscillating movement through a long arc to pass the cutter blade being ground a number of times across the grinding wheel and then move it clear of the wheel to permit indexing of the cutter head. The finishing
25 cam in the machine illustrated produces oscillating movements through a long arc only so that in the finishing operation each cutter blade is passed once back and forth across the grinding wheel and then the cutter head
30 is indexed.

During the roughing operation and between each forward and back stroke or any desired number of such strokes, the cutter blade being ground is fed toward the
35 grinding wheel so that on each grinding stroke more stock may be ground off and the front face ground back the desired distance. This feed movement is effected by a ratchet and pawl mechanism operating a feed screw
40 to advance the carrier upon which the work support is mounted toward the grinding wheel. The advance and return movements of the feed screw are effected from the oscillatory shaft. The movement of this shaft oscillates a cam which causes the pawl carrier
45 to oscillate on movement of the shaft in each direction. The pawl carrier carries two oppositely directed pawls arranged to engage respectively with oppositely directed ratchet teeth on a ratchet member secured to the feed screw. During the short oscillating movements of the shaft in roughing one pawl engages one set of ratchet teeth and imparts a
50 step by step feed movement to the screw. But when the shaft is oscillated through the large arc, the other pawl is brought into engagement with the other set of ratchet teeth and caused to move the ratchet member and the screw back through the same distance
55 that the screw was advanced by the step by step movement of the feed, thus returning the carrier to initial position. The cutter head is indexed and the grinding and feed movements proceed as before, on the new blade.
60 The cam actuating the pawl carrier during

the short arc movements of the shaft controls the direction of feed movement. This cam may be inverted on the shaft to change the direction of feed, the feed being in opposite directions for opposite directions of rotation of the cutter head.

The movement of the oscillatory shaft through the large arc during either the roughing or finishing operation causes the mechanism which locks the cutter head against rotation to be released and simultaneously connects the gearing for indexing the cutter head with a continuously driven member to rotate the cutter head through the distance required to bring the next cutter blade to be ground into operative position.

In a machine constructed according to this invention, a conical grinding wheel is preferably employed, as this type of grinding wheel has only a line contact with the front face of the cutter blades as distinguished from the complete surface contact which a plane surfaced grinding wheel would have, and with a conical grinding wheel, therefore, any possibility of "burning" the cutter blades during the grinding operation is obviated.

Referring now to the drawings by numerals of reference; 10 indicates the base or frame of the machine. The base or frame is provided at one end with an upright portion or standard 11 upon which the tool support head 12 is slidably adjustable. Slidably mounted on the frame 10 is a reciprocable carrier 14 (Figures 1 and 3) which is guided in its sliding movement on the frame by suitable ways formed in the base and cooperating with guide-ports formed on the carrier as shown in Figure 3. The carrier is provided with one V-shaped and one flat guide way serving as guide surfaces, as shown particularly in Figure 1, for cooperating portions of the work table 15 which is reciprocable on the carrier. The work table moves on the carrier in a direction at right angles to that of the carrier upon the base or frame.

Swivelly mounted on the tool support 12 is the wheel carrier 18 in which is suitably journaled the shaft 19 to which grinding wheel 20 is secured. As previously stated, the grinding wheel is preferably of the conical form having a conical operating surface 21.

During the operation of the machine the grinding wheel is rotated continuously on its axis being driven from the motor 22 which is mounted in the base of the machine (Figs. 1 and 2) through the shaft 23 which is connected to the armature shaft of the motor, the pulley 24, the belt 25, the pulley 26, the shaft 27 to which the pulley 26 is keyed and the bevel gears 28 and 29 connecting the shaft 27 with the grinding wheel shaft 19. The shaft 27 is vertical and extends in a direction at right angles to the horizontal shaft 23. A pair of pulleys 31 and 32 (Figs. 2 and 9) are

provided for guiding the belt 25 in its movement. One of these pulleys 32 (Fig. 9) is journaled on a shaft 33 which is supported in a U-bracket 34 which is secured to a rod 5 35 mounted in a socket-member 36 secured to the shaft 37 which is journaled in the upright or standard 11. A weight (not shown) of any suitable size is secured to the rod 35 adjacent its lower end, serving to swing the 10 pulley 32 about the axis of the shaft 37 to maintain the belt 25 taut.

The work support 15 is provided with an upper concave guide surface on which seats the tiltably adjustable support 40 upon 15 which the cutter head carrying the blades to be ground is mounted.

The mechanism illustrated is for sharpening the blades of rotary annular face mills. These tools are provided with a plurality of 20 annularly arranged cutting blades constructed as shown in Figure 17. The blades 42 are provided with a front cutting face 43 and are relieved on both sides and the top, back of the front face, to provide the necessary 25 clearance for the side and top cutting edges.

As previously stated, the original cutter head upon which the blades were mounted in the gear cutting machine may be used on the machine of this invention for holding the blades 30 to be ground or a special head may be provided for the purpose. The blades 42 are secured to the cutter head by bolts 45 and the cutter head is mounted upon and secured in any desired manner to the head 47 of the 35 shaft 48 which is journaled in the tiltable support 40.

Rotary annular face mills are arranged to rotate in one or the other direction and the cutter blades are oppositely arranged upon 40 the cutter heads depending upon the direction of rotation thereof. The tool carrier 18 may be swivelled about the axis of the vertical shaft 27 to position the grinding wheel 20 in the correct relation for grinding the cutter 45 blades depending on the direction of rotation of the cutterhead. Since the drive gear 28 and the shaft 27 are coaxial with the axis about which the swiveling adjustment of the wheel carrier 18 takes place, this adjustment 50 may be effected without affecting the drive to the grinding wheel.

The tool support 12 as previously stated, may be adjusted on the standard 11, enabling the grinding wheel to be positioned in 55 the correct vertical position for grinding the cutter blades. This vertical adjustment can be effected by rotating the shaft 50 (Fig. 1) by a crank or other suitable means to rotate, through the gearing 51, 52, the screw 53 which 60 is secured to the tool support 12 and which threads into the nut 54 which is mounted upon the arm 55 secured to the standard 11 by the screw 56.

The tiltable support 40 may be adjusted 65 on the work support 15, to incline the face of

the cutter blade to the correct angle for operation by the grinding wheel, by rotating the worm shaft 58 which is journaled in the work support 15 and carries a worm 59 meshing with the worm wheel segment 60 secured 70 to the tiltable support 40. An index mark and scale, such as indicated generally at 61 in Figure 1, may be employed to insure accurate setting of the cutting blades. The work support 15 can be adjusted upon the carrier 75 14 and the carrier 14 can be adjusted upon the frame 10 in directions at right angles to each other to further assist in correctly positioning the cutter blades in operative relation to the grinding wheel. The means for effecting these two adjustments will be described 80 hereinafter.

After the grinding wheel and a cutter blade have been properly positioned, the machine may be started up. During the roughing operation a series of short reciprocating movements are imparted to the work table 15 to move one of the cutter blades back and forth across the grinding wheel to grind back the front face of the blade. Then the work table 90 is moved through a long stroke to carry the cutter head away from the grinding wheel and while the cutter head is clear of the grinding wheel, the cutter head is given a partial rotation to index the head to bring 95 the next blade to be ground into operative position. In the finishing operation, using the cam shown, each stroke of the work table is a long stroke. The cutter is passed back and forth across the grinding wheel to finish 100 grind a blade and then moved clear to permit indexing. The alternate grinding and indexing proceeds until, in either case, all the blades have been rough ground or finish ground. Separate cams are employed to 105 govern the roughing and finishing operations. These are mounted upon the same shaft and preferably formed on opposite sides of the same disc as shown in Figures 1 and 2. 64 indicates the roughing cam and 65 110 the finishing cam. The construction of these cams is shown clearly in Figures 15 and 16. The cam disc 66, in the opposite faces of which the cam grooves are cut, is keyed to a shaft 67 which is continuously rotated in the 115 same direction from the shaft 23 through the bevel gears 68 and 69, the worm shaft 70, the worm 71, and the worm wheel 72 which is keyed to the cam shaft 67.

Pivoted upon a stud 74 mounted in the base or frame of the machine and extending on opposite sides of the cam disc 66 are a pair of arms 75 and 76 respectively, provided respectively, with segmental tooth portions 77 125 and 78. These arms are provided respectively, intermediate their ends with studs, 79, 80, upon which are mounted respectively the rollers or followers 81, 82 which engage in the cam grooves 64 and 65, respectively. The cam grooves 64 and 65 are so formed that as 130

the shaft 67 and the cam disc 66 rotate continuously in one direction the segmental arms 75 and 76 will be oscillated back and forth. The cam groove 64 will produce six oscillations through a small arc of the segment arm 75 and one oscillation through a large arc during each complete rotation of the cam disc, whereby with the roughing cam in operative engagement, the cutter support will be reciprocated six times to pass the cutter blades back and forth twelve times across the grinding wheel, the last stroke being a long stroke to carry the cutter head clear of the grinding wheel to permit indexing of the cutter head. The groove 65 of the finishing cam is so formed as to oscillate the segment arm 76 twice through relatively large arcs during one complete revolution of the disc 66, so that in each complete revolution of the finishing cam the work support is given two long stroke reciprocating movements to effect two reciprocations of the cutter head relative to the grinding wheel in each of which the work support is carried clear of the grinding wheel for indexing whereby two blades are finished ground and the cutter head twice indexed in each revolution of the finishing cam. With the roughing cam, one cutter blade is operated upon in one complete revolution of the cam disc 66. With the finishing cam, two cutter blades are operated upon in one complete revolution of the cam disc.

The segment 77 meshes with a segmental gear 85 and the segment 78 with a segmental gear 86. The gears 85 and 86 are rotatably mounted upon the shaft 88 which is journaled in the bed of the machine and may be operatively engaged selectively with the shaft 88 by engaging the clutch member 89, which has a splined connection, with the shaft 88 with either gear. The clutch member 89 may be operated by hand by the lever 90 which is pivoted upon the stud 91 which is secured in the base of the machine.

Mounted on the shaft 88 and having a splined connection therewith is a segmental gear 93 which meshes with a rack 94 (Figures 2 and 3). The rack 94 is slidably adjustable in a slot in the work table 15 and is connected therewith by a screw 95. By rotating the screw 95 the work table can be adjusted in one direction to properly position it relative to the grinding wheel. The screw 95 serves to hold the rack 94 in any adjusted position and through the rack and the gear 93 the work table 15 is reciprocated.

From the foregoing description, it will be obvious that as the cam disc 66 rotates, oscillating movements are imparted to the segment arms 75 and 76 and to the gears 85 and 86 and that by connecting either of these gears with the shaft 88 through the clutch 89 the shaft 88 will be oscillated and the gear 93 therewith, thus imparting reciprocating movements to the rack 94 and work support

15 to move the work support back and forth relative to the grinding wheel. With the roughing cam shown, the work support is moved back and forth to pass the cutter blades 42 several times across the grinding wheel and then to carry the cutter head clear of the grinding wheel to permit indexing, in one complete revolution of the cam disc 66. With the finishing cam, in one complete revolution of the cam disc a cutter blade is moved back and forth, the cutter head indexed and a second cutter blade moved back and forth and the cutter head again indexed.

Between each short back and forth movement of the cutter head during the roughing operation, as already described the carrier 14 is fed forward to advance the cutter blade toward the grinding wheel to permit grinding off more stock and on the long stroke of the work support the feed mechanism is reversed and operated to return the carrier to initial position so that the next blade to be ground will go through the same operations as the preceding blade. The feed and return movements of the carrier 14 are effected by rotation in opposite directions of the screw 97 (Figs. 1, 2, 3 and 14) which threads into a nut 98 secured in the work carrier 14.

Rotatable on the shaft 99 which carries the screw 98 is a sleeve 100 (Figs. 10 and 11) to which is keyed a ratchet member 101 provided with two sets of oppositely directed ratchet teeth 102 and 103 (Figs. 2 and 10). Oscillatably mounted on the sleeve of the ratchet member 101 is an oscillatable pawl carrier 105 (Figs. 10 and 12). Pivotaly mounted on the stud 106 of this pawl carrier are a pair of oppositely directed pawls 107 and 108. Oscillatably mounted upon a stud 110 provided in the base of the machine is a lever arm 111 to which is pivoted the link 112 which connects the lever arm 111 with the stud 106.

Were the pawl carrier 105 oscillated directly from the oscillatory shaft 88 a feed movement would be produced but once in each complete oscillation of the shaft. To effect a feed on each stroke of the work table, both backward and forward, a cam 115 is provided. While this cam is provided with a complete cam groove, only one half of the groove operates at any one time. The lever arm 111 carries between its ends a roller 116 which engages in the cam groove of the cam 115. Each half of the cam groove 115 is so constructed as to cause the lever arm 111 and the pawl carrier 105 to make two oscillations with each oscillation of the shaft 88, thereby to produce a feed movement of the work carrier on each stroke of the work table.

The cam 115 is keyed to a sleeve 118 rotatable on the shaft 88. The sleeve 118 can be connected to the shaft 88 by threading up on the nut 119 to engage the clutch member 120, which is keyed to the shaft 88, with the clutch

teeth formed on the end of the sleeve 118. When the cam is connected to the shaft 88, each oscillation of the shaft produce two oscillating movements of the arm 111 and of the pawl carrier 105. The ratchet wheel 101, as stated, is keyed to a sleeve 100 which is rotatable on the shaft 99. The sleeve 100 may be connected to the shaft 99 to operate the feed screw with each oscillation of the ratchet member by threading up on the nut 122 to engage the teeth of the clutch member 123 with the clutch teeth formed on the end of the sleeve 100.

On oscillation of the shaft 88 through a small arc, one of the pawls as, for instance, 107 (Fig. 2) engages one set of ratchet teeth as, for instance, the teeth 102 and depending on the position of the cam 115 produces a step by step feed movement of the work carrier 14 to feed the cutter blades being ground toward the grinding wheel between both the forward and return strokes of the work table. When the shaft 88 is oscillated through the large arc the pawl 108 is brought into engagement with a tooth of the ratchet member 103 and oscillates the ratchet member through a long arc of such extent as to rotate the screw 99 backward through the same distance that it was advanced by the pawl 107, thereby returning the work carrier 14 to initial position so that when the next blade is presented to the grinding wheel the same operations will be performed upon it as were performed upon the preceding blades.

A guard plate 125 is provided to control the amount of feed at each oscillation of the pawl 107. This guard plate 125 is mounted on the sleeve 100. During the finishing operation, the guard plate will be so positioned as to prevent any feed movement taking place.

When it is desired that the feed take place in the opposite direction, as where the rotary face mill cutter to be ground is to rotate in the opposite direction from that shown, the pawl 108 will accomplish the step by step feed movement and the pawl 107 will act to return the carrier to initial position. The reversal of direction is effected by rotating the cam 115 through 180° to bring the other half of the cam into operative position. The cam may be rotated by the hand lever 128 which is connected to the sleeve 118 to which the cam is keyed.

The guard plate 125 can be adjusted by hand by means of the hand lever 130 which is connected therewith.

Journaled in the base intermediate the shafts 88 and 99 is a shaft 132 (Figs. 10 and 13) on which is mounted the hand wheel 133. This shaft 132 is toothed intermediate its ends to provide a gear member 134 which meshes with a pinion 135 secured to the sleeve 136 of a hand lever 137 which is rotatably mounted in the frame. The hand lever is

provided with a spring pressed plunger grip by which the hand lever may be held in any one of three positions selectively, a neutral position, a position in which the pinion 135 meshes with a gear 138 secured to the clutch member 120, and a position in which the pinion 135 meshes with a gear 139 secured to the clutch member 123. When the pinion 135 is engaged with the gear 138 and this gear is connected through the clutch member 120 with the shaft 88, the shaft 88 may be moved by hand by the hand wheel 133 to bring the work table and cutter blade into operative position. When the lever 137 is so positioned as to mesh the pinion 135 with the gear 139 and the clutch member 123 is disengaged from the sleeve 100, the shaft 99 may be rotated by the hand wheel 133 to adjust the work carrier to bring a cutter blade into the correct position for grinding, with the grinding wheel engaging the front face of the blade in a position offset from, that is, non-radial to the axis of the cutter head. The amount of offset will be determined from the side rake or shear angle of the blade. The reduction provided by the gears 134 and 135 and either of the gears 138 or 139 makes the movement of the shaft 88 or 99 a facile operation.

When the cutter head is moved clear of the grinding wheel during the long stroke of the work table, the cutter head is indexed to bring a new blade into position to be ground. The indexing mechanism will now be described. The pulley 31 already referred to is keyed to a shaft 140 which is journaled in the upright 11 (Figs. 2 and 9). Secured to this shaft 140 is a bevel pinion 141 which meshes with and drives a bevel gear 142 secured to the vertical shaft 143 which is connected through the universal joint 144 with the telescoping shaft 145. The telescoping shaft 145 is connected through a second universal joint 146 with a worm shaft 147 upon which is mounted a worm 148 (Fig. 1) which meshes with a worm wheel 149 (Figs. 1 and 5) secured to a sleeve 150 (Fig. 6) rotatably mounted upon a shaft 151. The sleeve 150 has formed integral with it a ratchet wheel 152.

Secured to the shaft 151 and surrounding the ratchet wheel 152 (Figs. 6 and 7) is a stop plate 154 which is provided with a circumferential groove within which is pivotally mounted upon a pin 155 a pawl 156. The pawl is adapted to be urged into engagement with the ratchet wheel by a spring pressed plunger 158 which is housed within the stop plate 154. The pawl is held out of engagement with the stop plate by means of a dog 159 which engages the tail piece of the pawl. The dog 159 is mounted upon a stud 160 that is pivoted in the housing 161 formed on the tiltable work support 40. The dog 159 serves also as a stop or locking member engaging the ledge 163 formed on the stop plate to prevent rotation of the stop plate in one direc-

tion during the grinding operation. A second locking dog 164 is also provided which is also mounted upon the pivotal stud 160 and this dog engages a ledge on the other position of the stop plate 154 to prevent rotation of the stop plate in the opposite direction during the grinding operation. The dogs 159 and 164 are held normally in locking position by spring-pressed plungers 165 (Figures 4 and 5). The shaft 151 is connected through the gear 167, the idler pinion 168 and the gear 169 (Figs. 1 and 4) with the worm shaft 170 which carries the worm 171 that meshes with the worm wheel 172 (Figs. 1, 3 and 4) which is secured to the head 47 of the shaft 48. When the dogs 159 and 164 are disengaged from the stop plate 154 and the pawl 156, to free the stop plate and permit the pawl 156 to engage the ratchet wheel 152, the continuously rotating ratchet wheel 152 is connected to the shaft 151 to rotate this shaft and, through the gearing 167, 168, and 169, the worm shaft 170, to impart rotation to the worm wheel 172 and the cutter head to move the cutter head through an angle sufficient to bring the next cutter blade into position to be operated upon by the grinding wheel.

The cutter head may have blades operating, all of them, upon one side face of a gear tooth, or alternate blades may be arranged to operate upon adjacent side tooth surfaces of the gear blank to be cut. The index change gears 167, 168 and 169 will be so selected, in the first instance, as to impart a sufficient periodic rotary movement to the cutter head to bring each blade successively into grinding position. Where alternate blades cut upon adjacent side tooth faces of the gear blank, the index change gears will be so selected as to rotate the cutter head periodically for indexing through an arc sufficient to bring alternate blades successively into grinding position.

During the grinding operation upon any blade the cutter head is locked against rotation by means of the dogs 159 and 164, and the pawl 156 is held out of engagement with the ratchet wheel 152 by means of the dog 159. On the long stroke of the work table, the dogs 159 and 164 are tripped to release the stop plate and the pawl. This tripping action is effected from the oscillating shaft 88 in a manner now to be described. Secured to this shaft 88 adjacent one end is an arm 175 (Figs. 2 and 1). This arm is provided with an aperture through which passes a cable 177 which is connected to a member 179 keyed to the shaft 180, (Figs. 5, 6 and 8). Eccentrically mounted on the shaft 180 is an arm 182 which is connected through the pin 183 with the locking dog 159. The cable 177 is provided with two stops 184 and 185. During the short arc movement of the cam 88 the arm 175 swings to and fro but not far enough to engage either of the stops 185 or 184 but during

the oscillation of the shaft 88 through the long arc the arm 175 will engage one of these stops, depending upon the direction of the oscillation. When the arm engages one of the stops the cable 177 is pulled, rotating the member 179 and the shaft 180 to rotate the arm 182 and rock the locking dog 159 from locking position. As the locking dog 159 is rocked from locking position it simultaneously disengages the locking dog 164, through engagement of the lug 187 secured to the dog 164 with the dog 159.

Disengagement of the dogs 159 and 164 permits the pawl 156 to engage the ratchet wheel 152 to drive the stop plate 154, the shaft 151 and the worm wheel 172 to rotate the cutter head and index the same.

To insure the member 179 always returning to the same position after the indexing operation is completed, a pinion 190 (Fig. 6) is provided which is secured to the shaft 151 and which is rotated with that shaft periodically during the time the pawl 156 is in engagement with the ratchet wheel 152. This pinion 190 meshes with a gear 191 which is rotatable on the shaft 180 which carries the number 179. The gear 191 is provided with a recess 192 in its front face within which the member 179 travels. When the shaft 88 oscillates through the large arc the cable 177 is pulled to rotate the member 179. This movement, as stated releases the stop plate and causes the shaft 151 to be rotated. The rotation of the shaft 151 rotates through the gear 190, the gear 191, and as this gear 191 rotates, the shoulder on the gears defining one end of the recess 192 will be brought into engagement with the member 179 and rotate the member 179 back to initial position.

To take up for wear on the feed screw 97, a nut 194 (Fig. 14) may be provided which is secured on the carrier and which engages the screw. This nut may be rotated by hand to advance the screw to take up for any looseness.

The operation of the machine will be understood from the foregoing description but may be briefly summed up here. After the grinding wheel has been adjusted into correct position by means of the screw shaft 53 and by adjusting the tool carrier 18 correctly on the tool support 12 and after the cutter head has been correctly positioned to bring a blade into operative relation with the grinding wheel by rotation of the worm shaft 58, the screw shaft 99 and the screw 95, the machine may be set in operation. The grinding wheel will be rotated continuously through the gearing described. One or other of the cams 64 or 65 will have been brought through the clutch member 89 into operative engagement with the shaft 88. If the roughing cam 64 is being used it will impart, through the segment arm 75 and gear 85 and the clutch member 89, in each revolution of the cam disc 130

66, a series of short oscillating movements to the shaft 88 and then an oscillating movement through a long arc. The oscillating movements of the shaft 88 will reciprocate the work table 15 back and forth through the gearing 93, 94. During the short oscillating movements of the shaft 88, the ratchet member 101 will be moved in one or the other direction, depending upon the portion of the cam 115 in operative engagement with the roller 116 of the lever arm 111, and the step by step movement of the ratchet member will produce a step by step feed of the cutter blade being operated upon toward the grinding wheel. The feed movement will take place twice for each complete reciprocation of the work table. During the long arc movement of the shaft 88, the cutter head will be moved clear of the grinding wheel, the index mechanism will be tripped and the work table indexed to bring the next blade into operative position. The indexing mechanism is tripped when, on the long swing of the shaft 88, the arm 175 comes into contact with one of the stops 184 or 185 and pulls the cable 177. The pull on the cable 177 rotates the member 179, the shaft 180 to which this member is keyed, and the arm 182 which is pivoted to the locking dog 159. The rotation of the arm 182 (Figures 5 and 8) withdraws the locking-dog 159 from engagement with the stop plate 154 and with the pawl 156. As the locking-dog 159 is moved out of locking position, the locking-dog 164 is disengaged from the stop plate 154, also, for the dog 159 engages the lug 187 (Fig. 7), as it moves outwardly and thus trips the dog 164 out of locking position.

As soon as the locking-dog 159 is disengaged from the pawl 156, the pawl is snapped into engagement with the ratchet wheel 152 by action of the spring-plunger 158. The ratchet-wheel is rotating continuously, being driven from the pulley-shaft 140 through the gears 141 and 142, the shaft 143, the universal joint 144, the shaft 145, the universal joint 146, the worm 148 and the worm wheel 149. When the pawl 156 engages the ratchet wheel 152, then, the rotation of the ratchet-wheel is transmitted through the gearing 167, 168 and 169, to the worm shaft 170 and the worm 171 to rotate the worm wheel 172. This causes the cutter head to be indexed and another blade of the cutter is brought into position for sharpening.

During the rotation of the stop-plate, the shaft 151 is driven, rotating the pinion 190 and the gear 191. The gear 191, in its rotation, carries the member 179 back to its starting position so that it is in position for the next indexing operation.

When the stop-plate has made one revolution, it is locked up again, the locking-dogs 159 and 164 being forced back into locking position by the spring pressed plungers 165 (Figures 4 and 5). When the locking dog

159 returns into engagement with the stop-plate 154 it simultaneously engages the pawl 156, withdrawing this pawl from engagement with the ratchet wheel. The indexing operation is completed.

During the movement of the shaft 88 through the long arc, the feed screw 97 will, also, be reversed by engagement of one of the pawls 107 or 108 with the corresponding set of ratchet teeth 102 or 103, the set depending upon the direction of feed of the blades during sharpening, as described above. Thus, the carrier 14 will be returned to initial position, so that the next blade to be sharpened will be in position to partake of the same feeding and grinding operations as the blade previously ground.

The direction of rotation of the shaft 88 is now reversed by the cam 64 and the cutter is carried back into engagement with the grinding wheel. Then the sharpening operation proceeds, as before, and the new blade is sharpened.

If the cutter being sharpened is provided with alternate blades which cut on opposite sides of the teeth of a gear blank, then, when all of the blades which cut on one side have been ground, the cutter support will be adjusted sidewise so that the front faces of the remaining blades may be ground with the proper shear angle.

If the blades are to be finish ground only, the clutch 89 is adjusted to connect the gear 86 to the shaft 88, thus causing the finishing cam 65 to oscillate this shaft. There will then be imparted to the work table alternate reciprocating movements of sufficient length to carry the cutting blades across the grinding wheel on the forward stroke to receive a finishing grind and to carry the cutter head clear of the grinding wheel on the back strokes during which the cutter is indexed. There will be two complete reciprocating and indexing movements of the cutter head for each complete revolution of the finishing cam. During the finishing operation, the feed mechanism will preferably be disengaged. The indexing mechanism will be tripped and actuated during finish grinding in the same way as during rough grinding and as described above.

The grinding wheel may be dressed periodically by any suitable means. While the reciprocating, feeding and indexing movements have been described as being imparted to the work, it will be understood that any or all of them might instead be imparted to the grinding wheel and the term "relative" as employed in the claims is intended to indicate that the movement described may be imparted wholly to the work support or wholly to the grinding wheel or part to the work support and part to the grinding wheel.

While the invention has been described in connection with a particular embodiment and

in connection with a particular use for such embodiment, it will be understood that the invention is capable of further modification and use within its scope and that this application is intended to cover any variations, uses, or adaptations of the invention, following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art and may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described our invention, what we claim is:

1. In an automatic grinding machine, a rotatable work support, means for producing alternately a series of reciprocating movements of relatively short length between the grinding wheel and the work and then a reciprocating movement in the same direction as the short strokes but of relatively greater length during which the work and wheel are moved clear of one another, means for producing a relative feeding movement between the grinding wheel and the work between the successive short movements to enable more stock to be ground off the work on successive short strokes, means operative on the periodic long strokes to index the work when it is clear of the wheel, and means operative on the long strokes, also, to reverse the feed mechanism to cause the work and wheel to be withdrawn from one another the distance of the feed movement in the preceding series of short strokes.

2. In an automatic grinding machine, a rotary grinding wheel, a rotatable work support, a carrier upon which one of said members is mounted, a cam adapted to be rotated to produce a series of reciprocating movements of relatively short length defining a limited working path alternately with a reciprocating movement of relatively greater length but in the same direction as the short strokes, during which the work and wheel are moved clear of one another, means for rotating the cam and means operative to index the work support during these periods when it is clear of the wheel.

3. In an automatic grinding machine, a rotary grinding wheel, a rotatable work support, a carrier upon which one of said members is mounted, a cam adapted to be rotated to impart to said carrier in one revolution of the cam a series of reciprocating movements of relatively short length defining a limited working path alternately with a reciprocating movement of relatively greater length during which the work and wheel are moved clear of one another, means for rotating the cam, means for producing a relative feeding movement between the grinding member and work between the successive short movements of the carrier to enable more stock to be

ground off the work on successive short strokes, means for locking the work support against rotation during grinding, means actuated on the periodic long strokes to release said locking means, means for indexing the work support during the periods of release, and means operative on the long strokes, also, to reverse the feed mechanism through the distance it has been advanced on the preceding series of short strokes.

4. In an automatic machine for sharpening face mill cutter blades, a tool support, a rotary grinding wheel journaled in said tool support, said grinding wheel having a conical operating surface, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, means for positioning the grinding wheel in operative relation with one of the blades, means for reciprocating one of said supports through a limited working path and operable periodically to reciprocate said support through a path which is an extension of the working path, said movement taking place in a direction inclined to the axis of the work support, means for locking the work support against rotation during grinding, means actuated during the periodic movements of increased length for releasing said locking means, and means for rotating the work support, when released, to index the same.

5. In an automatic grinding machine, a grinding wheel, a work support, means for reciprocating the grinding wheel and work support relatively to each other to effect grinding operations and for periodically separating the grinding wheel from the work support to permit indexing of the work, and means for feeding the work relative to the wheel during each period of grinding operations for the removal of the desired amount of stock from the work and for automatically withdrawing it, during each periodic separation, the same distance it was fed during the previous period of grinding operations.

6. In an automatic grinding machine, a grinding wheel, a work support, means for producing alternately a series of reciprocating movements of relatively short length between the grinding wheel and the work and then a reciprocating movement in the same direction as the short strokes but of relatively greater length during which the work and wheel are moved clear of one another, means for producing a step by step feed movement between the wheel and work during the short stroke movements to enable the work to be ground to the desired depth, said means being operative on the periodic long stroke to reverse the feed mechanism to withdraw the work and wheel from each other the distance of the feed movement in the preceding series of short strokes, a common means for actuating said last named means and the re-

reciprocating mechanism, and means for indexing the work support on the periodic long strokes when the work is clear of the wheel.

7. In a machine for sharpening face mill cutter blades, a rotatable work support adapted to carry a cutter to be ground with the blades of the cutter extending in a direction generally parallel to the axis of the support, a grinding wheel having a conical operating surface, means for positioning the wheel in operative relation with a blade to be ground, means for reciprocating the work support relative to the wheel in a direction inclined to the axis of said support to move the wheel across the faces of the blades transversely thereof, said means comprising a rotary cam, a swinging arm carrying a roller adapted to engage the track of said cam, a shaft, means connecting the arm to the shaft to oscillate the shaft on oscillation of said arm, and means connecting the shaft to the work support to reciprocate the work support on oscillation of said shaft, said cam being constructed to produce, in one revolution thereof, a number of oscillations of the arm through a small arc and then an oscillation through a large arc whereby to cyclically reciprocate the support through a number of short strokes and then through a long stroke, and means for intermittently indexing the work support on the long strokes.

8. In a machine for sharpening face mill cutter blades, a rotatable work support, a grinding wheel having a conical operating surface, one of said parts being reciprocable relative to the other, said work support being adapted to carry a cutter to be ground with the blades of the cutter extending in a direction generally parallel to the axis of the support, said reciprocable support being reciprocable in a direction inclined to the axis of the work support and means for reciprocating the reciprocable support comprising a rotary cam, a swinging arm carrying a roller adapted to engage the track of said cam, a shaft, means connecting said arm to said shaft to oscillate said shaft on oscillation of said arm, and means connecting said shaft to said reciprocable part to reciprocate said part on oscillation of said shaft, said cam being constructed to produce in one revolution thereof a number of oscillations of said arm through a small arc and then an oscillation through a large arc, and means carried by said shaft for tripping said index mechanism on the movement of said arm through the large arc.

9. In an automatic grinding machine, a work support, a grinding wheel, means for imparting reciprocating movements of a cyclical nature to one of said parts in which the cycle may comprise selectively either a number of reciprocating movements of short stroke in a limited working path alternating with one of long stroke during which the

work is carried clear of the wheel or single long stroke movements only on each of which the work is carried clear of the wheel, and indexing mechanism for the work support adapted to be actuated on each long stroke movement regardless of the cycle employed.

10. In a machine for sharpening face mill cutter blades, a rotatable work support, a grinding wheel having a conical operating surface, one of said parts being reciprocable relative to the other in a direction inclined to the axis of the work support, said work support being adapted to carry a cutter to be ground with the blades extending in a direction generally parallel to the axis of said support, means for adjusting the work support bodily in a direction transverse to the axis of said support, means for adjusting the work support angularly to bring the front face of a blade into the correct operating plane, means for adjusting the work support in a direction at right angles to the first adjustment, and means for imparting a reciprocating movement of a cyclical nature to said reciprocable part in which the cycle may comprise selectively either a number of reciprocating movements of short stroke in a limited working path followed by one of long stroke during which the work is carried clear of the wheel or single long stroke movements only on each of which the work is carried clear of the wheels, and means adapted to intermittently index the work support on each long stroke movement regardless of the cycle employed.

11. In a machine for sharpening face mill cutter blades, a rotatable work support, a grinding wheel, one of said parts being reciprocable in a direction inclined to the axis of said work support, said work support being adapted to carry a cutter to be ground with the blades of the cutter extending in a direction generally parallel to the axis of said support, means for reciprocating the reciprocable part comprising a pair of cams either of which may be operatively connected to said reciprocable part to reciprocate the same, one of said cams being constructed to produce in one revolution a number of reciprocating movements of short stroke in a limited working path followed by one of long stroke during which the work is carried clear of the wheel, and the other of said cams being constructed to produce in each revolution reciprocating movements of long stroke only during each of which the work is carried clear of the wheel, and means for rotating said cam, and means for indexing the work support on the long strokes regardless of the cam in use.

12. In a machine for sharpening face mill cutter blades, a rotatable work support, a grinding wheel, one of said parts being reciprocable relative to the other in a direction inclined to the axis of the work support, said work support being adapted to carry a cut-

ter to be ground with the blades of the cutter extending in a direction generally parallel to the axis of the work support, means for reciprocating the reciprocable part comprising an oscillatory shaft, means connecting said shaft to said reciprocable part to reciprocate said part on oscillation of said shaft, and a pair of cams either of which may be operatively connected to said shaft to oscillate the same, one of said cams being connected to produce in one revolution a number of oscillations of said shaft through a small arc followed by an oscillation through a long arc, the other of said cams being constructed to produce oscillating movements through the long arc only, said oscillations through the small arc acting to reciprocate the reciprocable part through a limited working path and said oscillations through a long arc acting to carry the reciprocable part through the working path and beyond the same, means for indexing the work support, and means carried by said shaft adapted to trip said index mechanism on oscillation of said shaft through a long arc.

13. In a machine for sharpening face mill cutter blades, a work support, a grinding wheel, one of said parts being reciprocable relative to the other in a direction inclined to the axis of the work support, said work support being adapted to carry a cutter to be ground with the blades of the cutter extending in a direction generally parallel to the axis of said support, and means for reciprocating said reciprocable part comprising a pair of cams, a pair of swinging arms each of which carries a roller adapted to engage the track of one cam, an oscillatory shaft, means adapted to connect selectively either of said arms with said shaft to oscillate the same, and means connecting said shaft to said reciprocable part to reciprocate the same on oscillation of said shaft, one of said cams being constructed to impart to the corresponding arm oscillations through a short arc followed by one oscillation through a long arc in one revolution of the cam and the other of said cams being constructed to impart to the corresponding arm oscillations through a long arc only, said oscillations through the small arc acting to reciprocate the reciprocable part through a limited working path and said oscillations through a long arc acting to carry the reciprocable part through the working path and beyond the same and means adapted to index the work support when the work is moved clear of the grinding wheel during each movement of the shaft in a long arc.

14. In a grinding machine, a grinding member, a work support, means for moving the grinding member and work support back and forth relatively to each other, and means actuated on both the forward and return strokes for feeding the grinding member and work

support relatively to each other for removal of stock.

15. In a machine of the character described, a work support, a tool support, a carrier on which one of said supports is mounted, means for moving said carrier including a screw, a ratchet member carried by said screw and provided with two sets of oppositely directed ratchet teeth, an oscillatable pawl carrier, a pair of oppositely directed pawls mounted on said pawl carrier, an oscillatory shaft for oscillating said pawl carrier, means for imparting an oscillating movement to said shaft through a relatively short arc to cause one of said pawls to engage one set of ratchet teeth to produce a step by step movement of the carrier in one direction and for periodically producing an oscillation of the shaft through a relatively large arc to cause the other pawl to engage the other set of ratchet teeth and move the carrier in the opposite direction to return the carrier to initial position, and a cam adjustably mounted on said shaft and provided with two oppositely directed cam ways for controlling the direction of operative movement of the pawl carrier.

16. In an automatic grinding machine, a rotatable work support, a tool support, a grinding wheel rotatably mounted on the tool support, an oscillatory shaft, means operatively connecting said shaft to one of said supports to reciprocate said support on oscillation of said shaft, means for locking the work support against rotation during grinding, means for indexing the work support, means operatively connecting the shaft to the locking means adapted to release the locking means and permit connection of the indexing mechanism to the work support when the shaft moves through an arc great enough to cause the reciprocating mechanism to separate said supports from one another far enough for the wheel to clear the work, and means for imparting to said shaft cyclical movements of which each cycle comprises oscillation of the shaft a plurality of times through a short arc and then a single time through a long arc, said movements through the long arc being for the purpose of carrying the wheel clear of the work.

17. In an automatic grinding machine, a rotatable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports through a limited working path and operable periodically to impart to said support an extended movement to carry it beyond its working path, means operative during reciprocations in the limited working path to impart to one of said parts a step-by-step feed movements for removal of stock to the desired depth from the work, means operative when the reciprocable support is carried beyond its working path to reverse the

feed mechanism and return the part which is fed through the distance which it was fed on the preceding working strokes, locking means preventing indexing movement of the work support during grinding and means actuated on the periodic movement of the reciprocable support beyond its working path to index the work support.

18. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted on the tool support, an oscillatory shaft, means operatively connecting said shaft to one of said supports to reciprocate said support on oscillation of said shaft, means for oscillating said shaft through a relatively short arc to reciprocate said reciprocable part through a limited working path and operable periodically to oscillate said shaft through a relatively long arc to carry said reciprocable support beyond its working path, means actuated by the shaft in its oscillation through the short arc, to impart a step-by-step feed movement by one of said parts to permit the wheel to remove stock to the desired depth from the work, means actuated by the shaft in its periodic oscillation through the long arc to reverse the feed mechanism and withdraw the part through the distance it has been fed while the shaft was being oscillated through the short arc, means for locking the work support against rotation while the reciprocable support is moving in its working path, means operable on the periodic oscillations of the shaft through the long arc, to release said locking means, and means for indexing the work support when released.

19. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted on said tool support, a rotatable work support, means for reciprocating one of said supports through a limited working path and operable periodically to reciprocate said support an extended distance in the same direction as on the working strokes to carry said support beyond the working path, a continuously driven gear, means for locking the work support against rotation during grinding and means actuated on the periodic movement of the work support beyond its working path, to release the locking means and simultaneously connect the continuously driven gear operatively with the work support to impart an indexing rotation to the same.

20. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted on said tool support, a rotatable work support, an oscillatory shaft, means operatively connecting said shaft with one of said supports to reciprocate the same on oscillation of said shaft, means for oscillating said shaft, feed mechanism for one of said parts, and means for actuating said feed mechanism comprising a ratchet and pawl

mechanism, an oscillatable pawl carrier on which the pawl is mounted and a cam mounted on the oscillatory shaft and having an operative connection with the pawl carrier to effect oscillation of said pawl carrier on movement of said shaft in both directions whereby a step-by-step movement is imparted to said feed mechanism on both the forward and return movements of said shaft.

21. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted thereon, a work support, means for reciprocating one of said supports including a cam shaft and a pair of cams mounted thereon, one of said cams being constructed to produce in one revolution thereof, a series of reciprocating movements in a limited work path and a reciprocating movement of relatively great length on which the reciprocable support is moved beyond said working path, and the other cam being constructed to impart to the reciprocable support movements of relatively great length only, on each of which said reciprocable support is carried through its working path and beyond the same, and means for selectively connecting either of said cams operatively with the reciprocatory support to actuate the same.

22. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support, means for reciprocating one of said supports including a cam shaft and a pair of cams mounted thereon, one of said cams being constructed to impart in one revolution a series of reciprocating movements in a limited working path and then a reciprocating movement of relatively great length on which the reciprocable support is carried beyond its working path, the other cam being constructed to produce reciprocating movements of great length only, on each of which the reciprocatory support is moved through its working path and beyond the same, means for selectively connecting either of said cams operatively with the reciprocable support to actuate the same, means for locking the work support against rotation during movement of the reciprocable support in its working path and means actuated on the reciprocating movement of great length to release said locking means, and means for indexing the work support when released.

23. In an automatic grinding machine, a rotatable work support, a tool support, a grinding wheel rotatably mounted on the tool support, a ratchet member provided with two spaced sets of oppositely directed ratchet teeth, an oscillatable pawl carrier and a pair of pawls mounted thereon, means for oscillating said pawl carrier through a relatively short distance to engage one pawl with one set of ratchet teeth and impart to one of said supports a step by step feed movement in one direction for removal of stock from

the work to the desired depth, and means for oscillating the pawl carrier in the opposite direction periodically through a relatively long arc to engage the other pawl with the other set of ratchet teeth to reverse the direction of movement of the movable support and return said support through the distance previously fed.

24. In an automatic grinding machine, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support, an oscillatory shaft, means operatively connecting said shaft to one of said supports to reciprocate the same on oscillation of said shaft, a ratchet member provided with two sets of oppositely disposed ratchet teeth, an oscillatable pawl carrier and a pair of oppositely directed pawls mounted on said pawl carrier for cooperation, respectively, with the two sets of ratchet teeth, means for oscillating the shaft through a relatively short arc to move the reciprocable support through a limited working path and operable periodically to oscillate said shaft through a relatively long arc in which the support is carried beyond said working path, means mounted on said shaft adapted to cause one of said pawls to engage one set of ratchet teeth to produce a step-by-step feed movement between the grinding wheel and work on the movement of the shaft through the short arc, said means operating to cause the other pawl to engage the other set of ratchet teeth on the movement of the shaft periodically through its long arc, to cause the grinding wheel and the work to be separated through the distance they have been previously fed, and means for indexing the work support during the periodic extended movements of the reciprocable support, when the grinding wheel is clear of the work.

25. In a machine for sharpening face mill cutter blades, a rotary grinding wheel having a conical operating surface, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, means for imparting relative reciprocating movements between the grinding wheel and work support in a direction inclined to the axis of the work support to move the grinding wheel across a blade transversely thereof to grind the same back, and means for periodically indexing the work support to bring successive blades into operative position.

26. In an automatic machine for sharpening face mill cutter blades, a tool support, a rotary grinding wheel mounted on said tool support and having a conical operating surface, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, means for adjusting the work and tool supports angu-

larly relative to one another to adjust the inclination of the front face of a blade relative to the grinding wheel, means for adjusting said supports relative to one another to offset the operating face of the grinding wheel relative to the axis of the work support, means for rotating the grinding wheel on its axis, means for reciprocating one of said supports in a direction inclined to the axis of the work support to move the grinding wheel across a blade transversely thereof to grind its front face, and means for periodically indexing the work support to bring successive blades into operative position.

27. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted on said tool support, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, a rotary cam, means operatively connecting said cam to one of said supports to reciprocate the same, said cam being constructed to impart to said support during one revolution a series of reciprocating movements in a limited working path and then a reciprocating movement in the same direction but through an extended path during which the work is moved clear of the wheel, said reciprocating movements being in a direction inclined to the axis of the work support, means for rotating the cam, and means for indexing the work support during each long stroke.

28. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted on said tool support, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, means for imparting to one of said supports reciprocating movements in which said support is moved cyclically a plurality of times in a limited working path and then an extended distance beyond said working path, said movements being in a direction inclined to the axis of the work support, means for producing a step-by-step relative feed movement between the grinding wheel and the work, during the relative reciprocating movements in the limited working path, to permit grinding of the blades to the desired depth, means operative on the periodic long strokes to withdraw the work and the grinding wheel from each other through the distance they have been fed relatively on the preceding series of short strokes, and means for indexing the work support on the periodic long strokes.

29. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted on said tool support, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to

the axis of the work support, means for reciprocating one of said supports in a direction inclined to the axis of the work support cyclically through a series of short strokes in a limited working path alternating with a long stroke which carries said support beyond said working path, means for imparting a relative feed movement between the grinding wheel and the work support with each short stroke of the reciprocable support both forward and backward to permit sharpening of the blades the desired amount, means operative on the periodic long strokes of the reciprocable support to separate the grinding wheel and the work support from one another through the distance they were fed toward one another on the preceding series of short strokes, and means for indexing the work support during each long stroke.

30. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, a rotary cam, means operatively connecting said cam to one of said supports to reciprocate said support in a direction inclined to the axis of the work support on rotation of said cam, said cam being constructed to impart to the reciprocable support in one rotation a series of reciprocating movements in a limited working path then a reciprocating movement of increased length during which the work is carried clear of the wheel, means for producing a relative feed movement between the grinding wheel and the work during the short strokes to permit sharpening of the blades to the desired extent and for withdrawing the grinding wheel from the work on the periodic long strokes through the distance of feed on the preceding series of short strokes, and means for indexing the work support on each long stroke.

31. In a machine for sharpening face mill cutter blades, a tool support, a rotary grinding wheel mounted thereon, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, and means for imparting to one of said supports reciprocating movements in a limited working path alternating with reciprocating movements in which said support is carried beyond said working path to carry the wheel clear of the work, said reciprocating movements taking place in a direction inclined to the axis of the work support, a ratchet member having oppositely directed sets of ratchet teeth, a pair of pawls adapted to engage, respectively, with said sets of ratchet teeth, means for causing one of said pawls to engage one set of ratchet teeth, during the short strokes, to feed a blade

relative to the wheel to remove stock and for causing the other pawl to engage the other set of ratchet teeth, during the long strokes, to withdraw the blade relatively through the distance fed on the short strokes, and means for indexing the work support on each long stroke when the work has cleared the wheel.

32. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, means for imparting to one of said supports reciprocating movements through a limited working path which alternate with reciprocating movements through an extended path in which said support is carried beyond said working path, said reciprocating movements taking place in a direction inclined to the axis of the work support, a ratchet member having two sets of oppositely directed ratchet teeth, a pair of pawls adapted to cooperate, respectively, with said sets of ratchet teeth, means for oscillating one of said pawls between both the forward and backward short strokes of the reciprocable part to impart a step-by-step feed movement between the work support and the grinding wheel to effect removal of stock from the cutting blades, means for oscillating the other pawl during the periodic long strokes of the reciprocable part to reverse the feed movement and separate the work support and the wheel through the distance fed on the preceding short strokes, and means for indexing the work support on each long stroke.

33. In a machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, a cam shaft, a pair of cams mounted thereon, means for selectively connecting either of said cams to one of said supports to reciprocate the same on rotation of said cam shaft, one of said cams being constructed to impart in one revolution a series of reciprocating movements in a limited working path and then a reciprocating movement in an extended path during which the work is moved clear of the wheel, and the other cam being constructed to produce in one revolution reciprocating movements in the extended path only, means for producing a relative feed movement between the grinding wheel and the work support during the short stroke movements caused by the first cam to permit sharpening of the blade to the desired extent, means for withdrawing the work support from the grinding wheel, the amount it has been fed on the short strokes, during the periodic long strokes caused by the first cam, and means for indexing the

work support during the long strokes of either cam.

34. In an automatic machine for sharpening face mill cutter blades, a tool support, a grinding wheel rotatably mounted thereon, a rotatable work support adapted to carry the blades to be ground with the blades extending in a direction generally parallel to the axis of the work support, an oscillatory shaft, means operative on oscillation of said shaft to reciprocate one of said supports in a direction inclined to the axis of the work support, means for oscillating said shaft in cycles, each comprising a plurality of oscillations through a short arc and then an oscillation through a long arc, means for feeding the work relative to the grinding wheel for removal of the desired amount of stock from the separate cutting blades, means operatively connecting the shaft to the feed mechanism to impart a feeding motion to the same on oscillation of the shaft through the short arc and to reverse said feed mechanism on oscillation of said shaft through the long arc and cause the feed mechanism to be returned through the distance it has been fed on the preceding series of oscillations of the shaft through the short arc, indexing mechanism for the work support, and means actuated on each movement of the shaft through the long arc to trip said index mechanism.

35. In a machine of the class described, a tool, a work support, means for reciprocating one of said parts relative to the other, means including a ratchet member and a pawl engageable therewith for imparting a relative feed movement between the work support and the tool, and means for actuating said pawl into engagement with the ratchet member on both the forward and return strokes of the reciprocable part to effect a feed movement on both strokes.

36. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports relative to the other and operable to produce a series of short strokes in a limited working path alternately with a long stroke during which the wheel is carried clear of the work, and means for indexing the work support during the periodic long strokes when the wheel has cleared the work.

37. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports relative to the other and operable to produce a series of short strokes in a limited working path alternately with a long stroke during which the wheel is carried clear of the work, means operative during each series of short strokes to feed the work toward the wheel for the purpose of enabling the wheel to remove more stock from the work piece

during different short strokes and operative on the periodic long strokes to return the part previously fed through the distance which it has been fed on the preceding series of short strokes and means for indexing the work support during the periodic long strokes.

38. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports relative to the other to effect the grinding operation, means for feeding the work relative to the wheel for the purpose of enabling the wheel to remove more stock from that portion of the work being operated on on different strokes of the reciprocable support, means operative periodically to index the work support, and means operative for each indexing operation to reverse the feeding mechanism and return the part that has been fed through the distance which it was fed on the preceding series of strokes.

39. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports relative to the other to effect the grinding operation, means for feeding the work relative to the wheel between successive strokes in opposite directions of the reciprocable support, means operative periodically to carry the work clear of the wheel, means for indexing the work during the periods of relative separation between the work and the wheel, and means also operative during each period of relative separation to return the part that has been fed through the distance through which it was fed during the preceding grinding strokes.

40. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, means for reciprocating one of said supports relative to the other through a limited working path, means operable between successive strokes in opposite directions to impart a step-by-step feed movement to one of said supports to enable the grinding wheel to remove more stock from the portion of the work piece being operated on on successive strokes in both directions, means for periodically reciprocating the movable support through an extended path in the same direction as it is moved during its working strokes to carry said support beyond said working path, means for indexing the work support during said periodic extended reciprocations and means operable on the periodic extended reciprocations to reverse the feed mechanism and return the part that has been fed back through the distance it was fed during the preceding period of grinding.

41. In a machine of the class described, an indexable work support, a tool support, a

grinding wheel rotatably mounted on the tool support, an oscillatory shaft, means operatively connecting the shaft to one of said supports to reciprocate said support on oscillation of said shaft, indexing mechanism for the work support, means operatively connecting the shaft with the index mechanism adapted to trip said index mechanism when the shaft has moved through an angle great enough to have caused the reciprocating mechanism to separate said supports from one another far enough for the wheel to clear the work, and means for oscillating said shaft.

42. In a machine of the class described, an indexable work support, a tool support, a grinding wheel rotatably mounted on the tool support, an oscillatory shaft, means operatively connecting the shaft to one of said supports to reciprocate said support on oscillation of said shaft, means for locking the work support against rotation during grinding, means for indexing the work support, means carried by said shaft operative to release the locking means and permit connection of the index mechanism to the work support on movement of the shaft through an arc great enough to cause the wheel to be separated from the work, and means for oscillating said shaft.

43. In an automatic grinding machine, a rotatable work support, a tool support, a grinding wheel rotatably mounted on the tool support, an oscillatory shaft, means operatively connecting said shaft to one of said supports to reciprocate said support on oscillation of said shaft, means for locking the work support against rotation during grinding, means for indexing the work support, means operatively connecting the shaft to the locking means adapted to release the locking means and permit connection of the index mechanism to the work support when the shaft moves through an arc great enough to cause separation of the work from the wheel, and means for imparting to said shaft cyclical movements of which each cycle comprises movement of the shaft a plurality of times through a short arc and then a single movement through a long arc on the latter of which the work is moved clear of the wheel.

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