Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 1

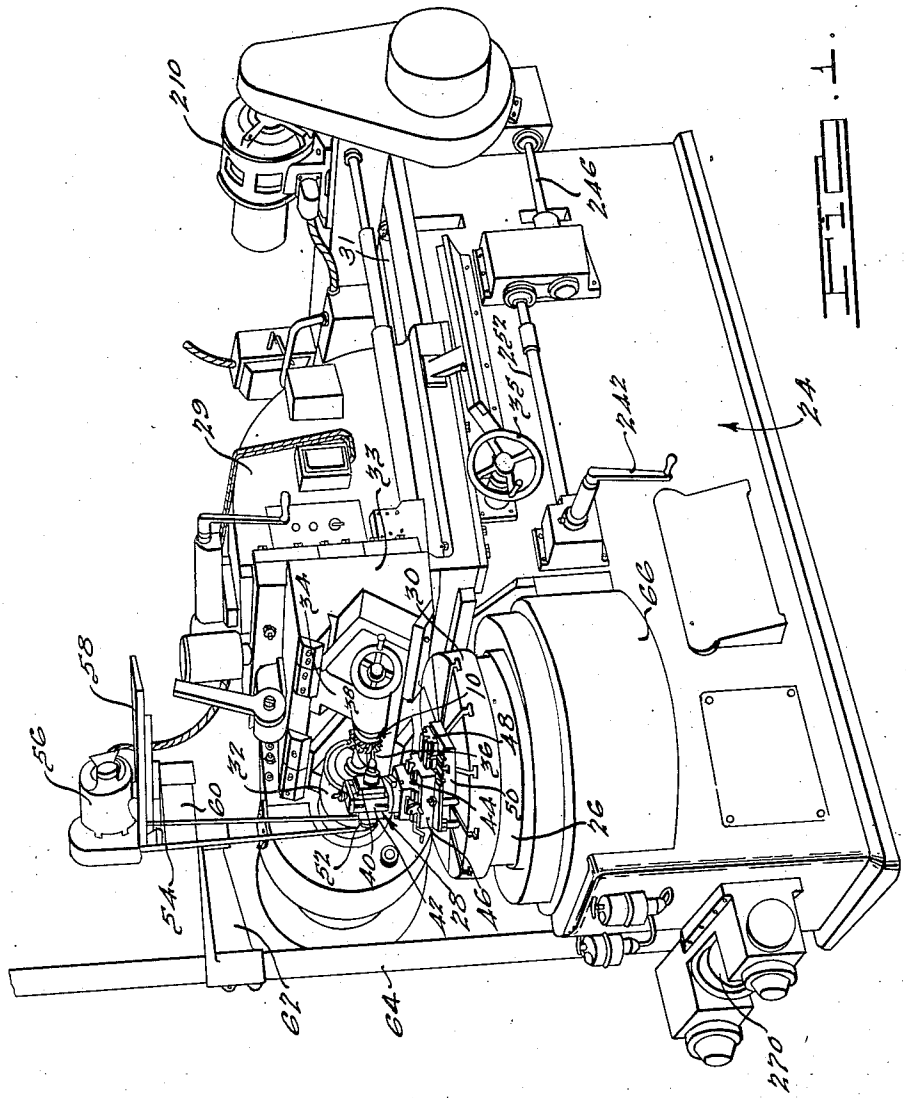


FIG. 1.

INVENTOR
Harry Pelphrey.
BY Harness, Dickey & Pierce.
ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 2

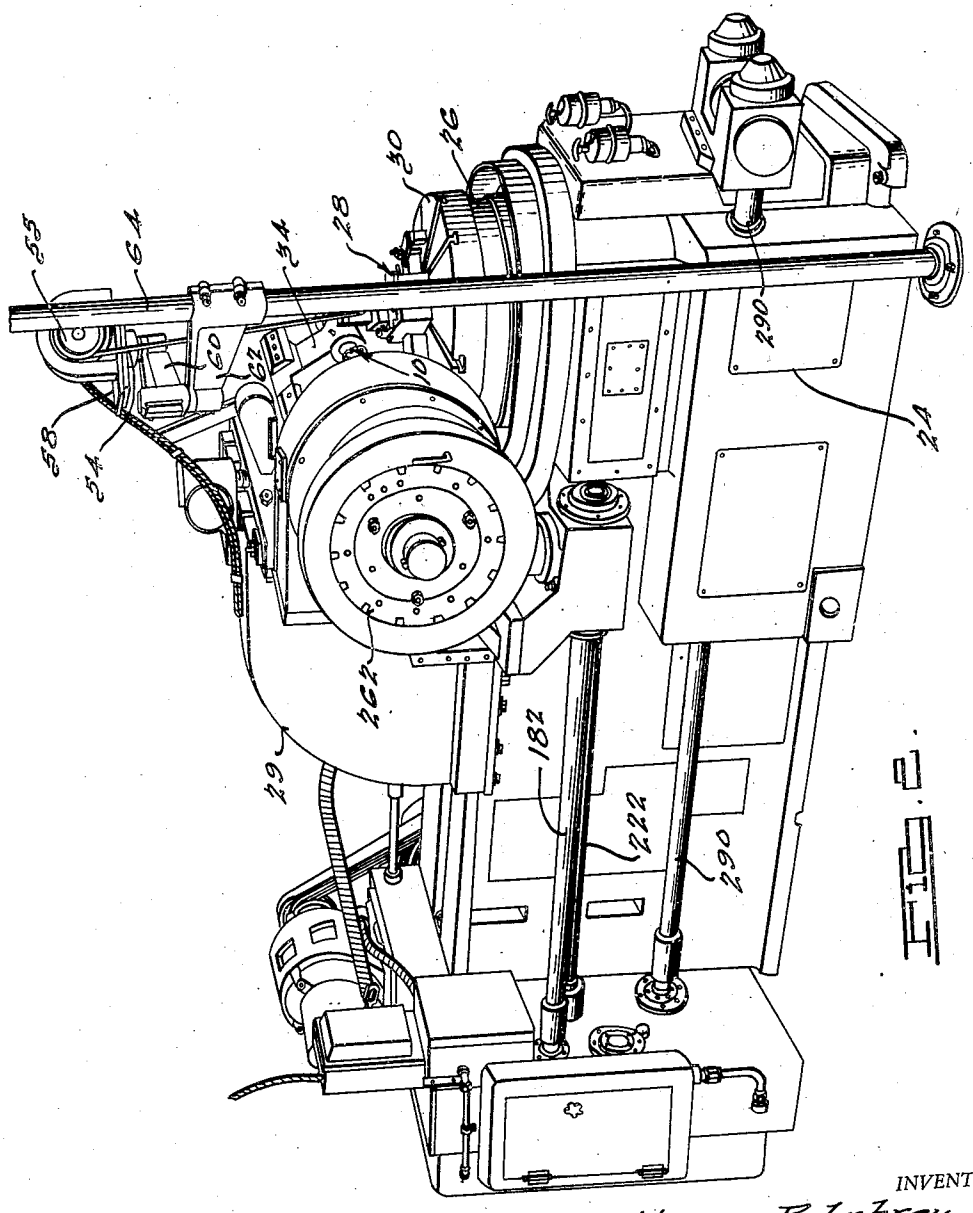


Fig. 1.

INVENTOR
Harry Pelphrey.
BY Harness, Dickey & Pierce.
ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 3

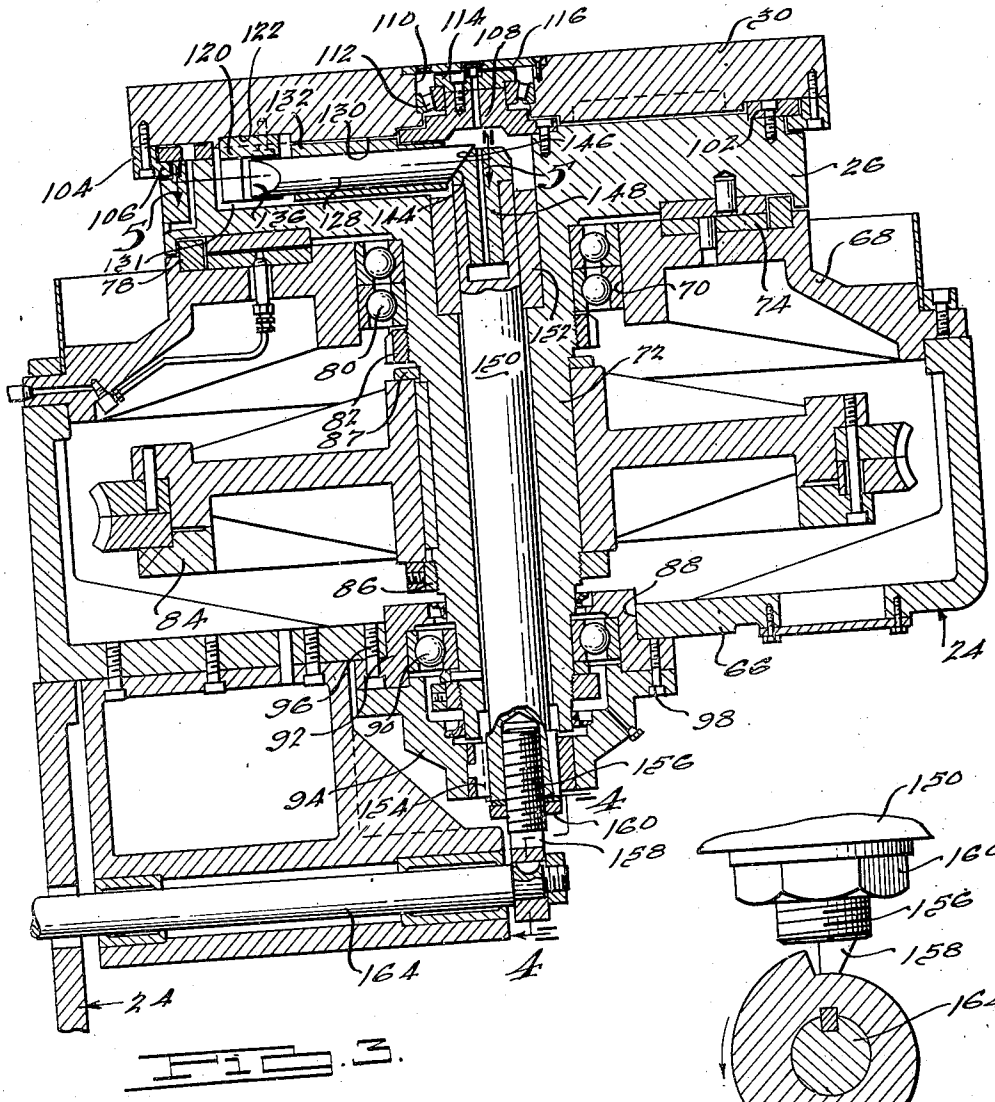


FIG. 3.

FIG. 4.

INVENTOR
Harry Pelphrey.
BY Harness, Dickey & Pierce.
ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 4

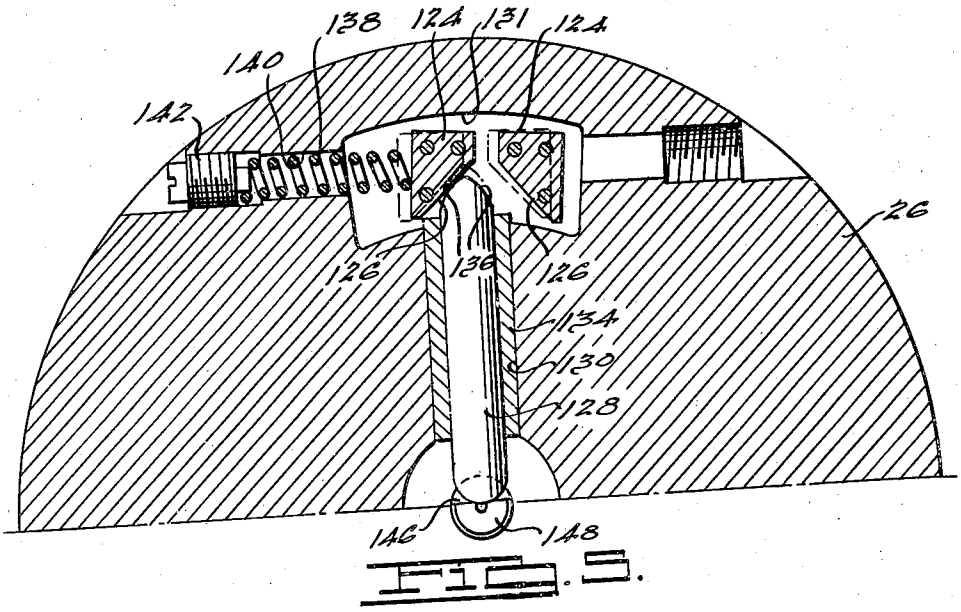


FIG. 5.

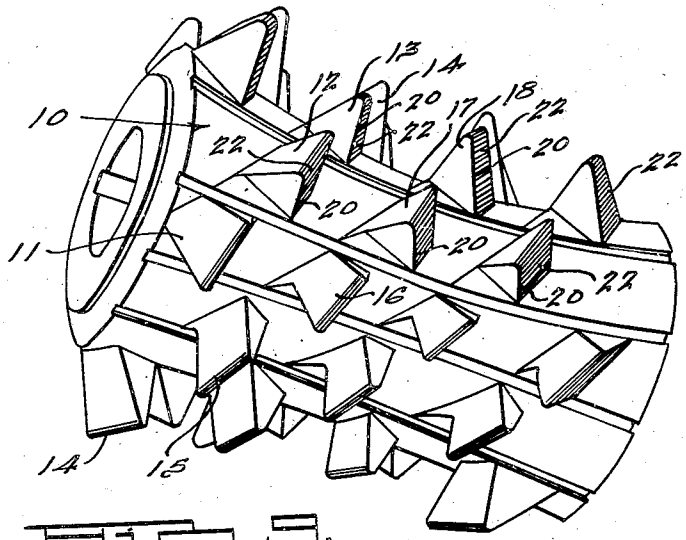


FIG. 3.

INVENTOR.
Harry Pelphrey.
BY
Harness, Dickey & Pierce
ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 5

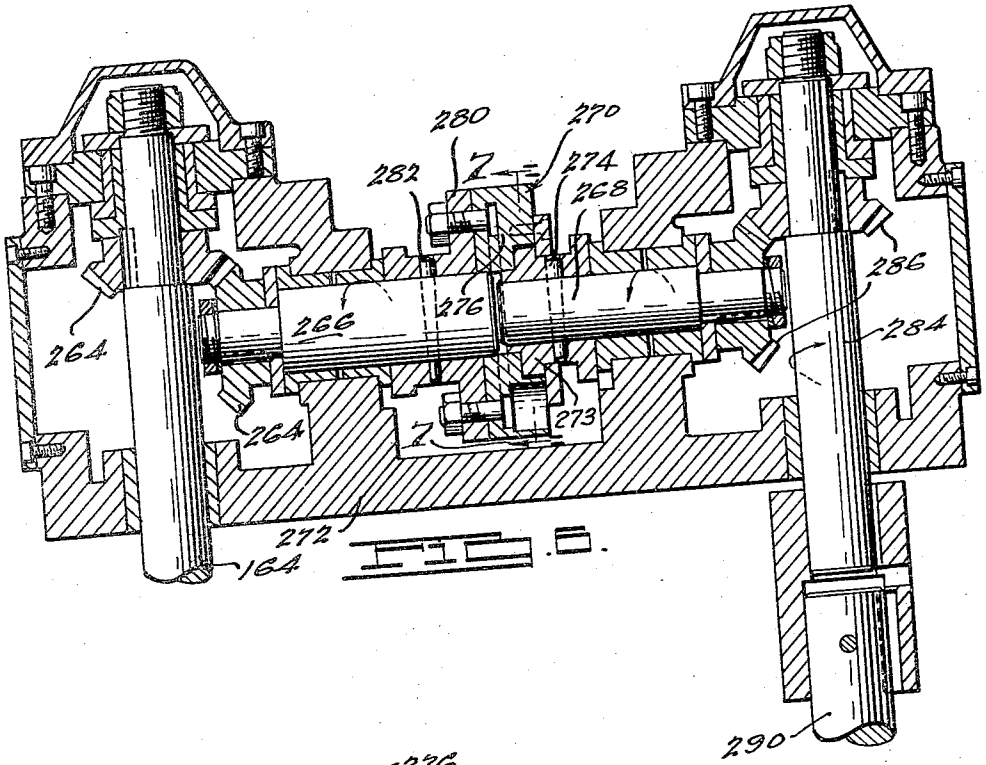


FIG. 5.

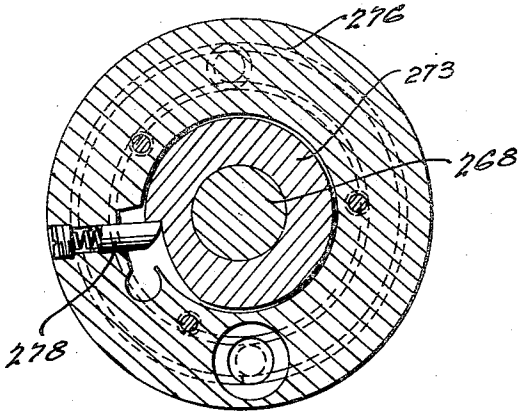


FIG. 7.

INVENTOR

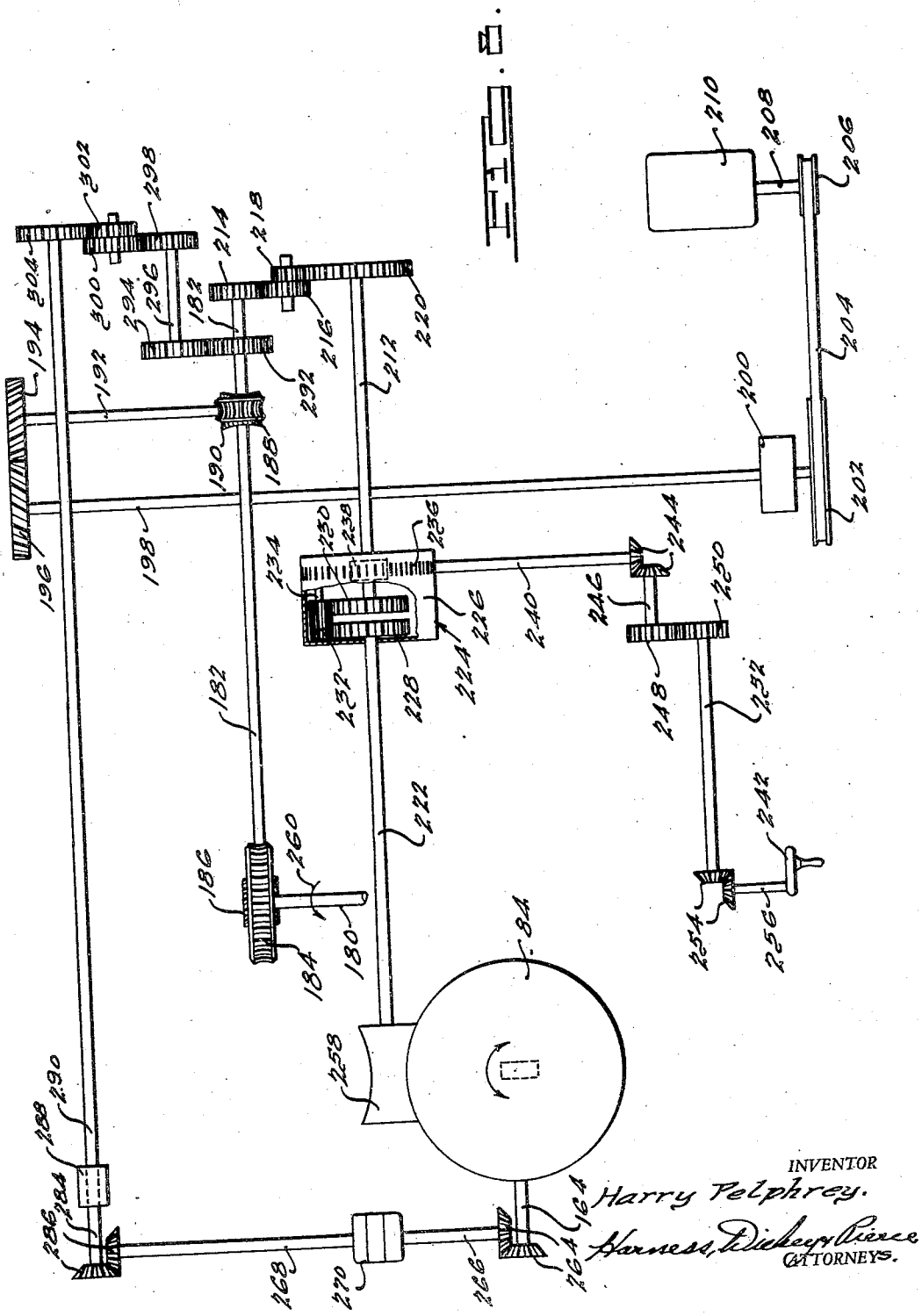
Harry Pelphrey.

BY Harness, Dickey & Pierce. ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 6



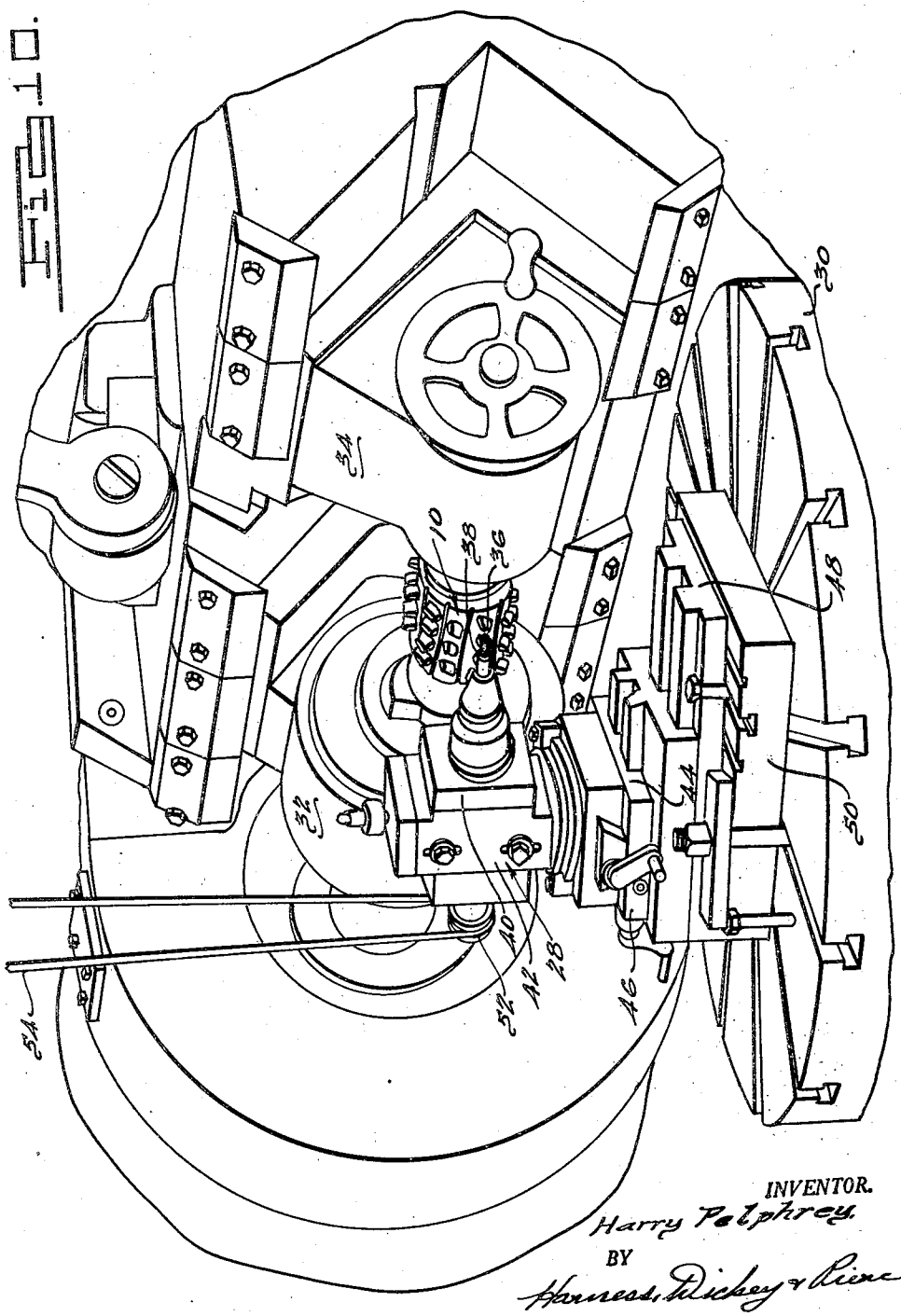
INVENTOR
Harry Pelphrey.
Harness, Dickey & Pierce
ATTORNEYS.

Oct. 8, 1946. H. PELPHREY 2,408,949

HOB GRINDER

Filed Nov. 26, 1943 7 Sheets-Sheet 7

Fig. 10.



INVENTOR.
Harry Pelphrey.
BY
Harness, Dickey & Pierce.
ATTORNEYS

Patented Oct. 8, 1946

2,408,949

UNITED STATES PATENT OFFICE

2,408,949

HOB GRINDER

Harry Pelphrey, Detroit, Mich., assignor to Michigan Tool Company, Detroit, Mich., a corporation of Delaware

Application November 26, 1943, Serial No. 511,788

9 Claims. (Cl. 51—33)

1

The present invention relates to a machine for producing cutting tools and particularly relates to a machine for grinding side relief on the teeth of hobs of the enveloping type, that is, hobs designed for use in cutting the worm wheel or worm gears of gear sets embodying the Hindley or globoidal principle.

In particular, the machine of the present invention is an improvement over the side relief grinding embodiment disclosed in Scott Patent No. 1,980,444.

In providing the side relief, the sides of the hob teeth are relieved from the front cutting edges away from the normal lead of the thread or tooth side in order to relieve the side from contact with the flanks on the worm wheel to be cut. The tool, or grinding element, is located at a normal position at the cutting edge of the teeth, and as the hob and main tool carriage are rotated in normal synchronism a relative rotative movement, with respect to the main tool carriage, is imparted to the tool to retract the tool with respect to its normal position as it engages the sides of each tooth. The tool returns to its normal position at the cutting edge of each tooth.

The primary object of the present invention is to provide an improved means for imparting the retraction to the tool from its normal lead so that there is a uniform, synchronous drive between the hob spindle and the mass of the main tool carriage. A further object of the present invention is to provide an improved means of the type mentioned which is independent of the main drive between the hob spindle and the mass of the main tool carriage so that there is no shock load on the drive worm during the shifting of the tool from its normal lead.

A further object of the invention is to provide an improved machine of the type mentioned by which the side relief may be accurately imparted to the sides of the hob teeth and in which the machine will maintain its accuracy over a long life.

Other objects of the invention will become apparent from the following specification, the drawings relating thereto and from the claims hereinafter set forth.

In the drawings in which like numerals are used to designate like parts in the several views throughout:

Figure 1 is a perspective view taken from the front right side of a machine embodying features of the present invention;

Fig. 2 is a view similar to Fig. 1 taken from the left front side of the machine;

2

Fig. 3 is a vertical cross-sectional view through the center of the tool carrying table and the main table, and showing the mechanism for imparting the retraction of the tool from its normal lead;

Fig. 4 is a cross-sectional and elevational view taken substantially along the lines 4—4 of Fig. 3;

Fig. 5 is a fragmentary cross-sectional view taken substantially along the lines 5—5 of Fig. 3;

Fig. 6 is a cross-sectional view illustrating the ratchet means for driving the retracting cam in one direction;

Fig. 7 is a cross-sectional view taken substantially along the lines 7—7 of Fig. 6;

Fig. 8 is a diagrammatic view of the driving means for the machine of the present invention;

Fig. 9 is a perspective view of a hob of the type to be worked upon by the machine of the present invention;

Fig. 10 is an enlarged partial view of the structure shown in Fig. 1.

Referring to Fig. 9 a hob of the type disclosed in Cone Patent 2,026,215 is illustrated and is generally indicated at 10. As shown, the hob teeth are formed from a thread having a normal lead, and in the embodiment illustrated there are a plurality of such threads. Several of the teeth of one thread are indicated at 11, 12, 13, and 14; and several of the teeth of an adjacent thread are indicated at 14, 15, 16, 17, and 18. Each of the teeth is provided with a cutting edge, 20, and it will be understood that such cutting edge 20 is located in the position described in the above mentioned Cone patent. The side relief is provided on the sides of each of these teeth indicated at 22, and it is the provision of this side relief to which the present invention is directed.

Referring to Figs. 1 through 8, an embodiment of the present invention is illustrated by which the side relief above mentioned is provided. The machine is automatically controlled and comprises a base 24, which serves to mount a vertical spindle having a main, rotatable work table 26 fixed thereto for rotation therewith. The forming means, in the form of a grinder, is generally indicated at 28 and is mounted on an auxiliary table 30 for rotation therewith. The table 30 is mounted on table 26 and is moved relative thereto to impart the retractive movement above mentioned, which will be described in greater detail hereinafter.

The hob 10, to be relieved, is mounted to a horizontal slide 29, which is mounted on horizontal, parallel ways 31, formed on the top surface of the base 24, so that such slide 29 is slid-

able on parallel lines toward and away from the table 26 and in a direction normal to the axis of table 26. The slide 29 serves to mount a head stock 32 and an adjustable tail stock 34 so that the hob 10 may be removably mounted therein with its axis horizontal and at a right angle to the direction of movement of the slide 29.

The head stock 32 and tail stock 34 are mounted on a vertically adjustable slide 33 which is mounted on parallel ways formed on the front vertical face of slide 29 so that the vertical position of the hob axis may be varied. A hand wheel 35 is operatively connected to the slide 29, and a hand crank 37 is operatively connected to the slide 33 for varying the positions of such slides. The particular mechanisms for operatively connecting the hand wheel and crank to their slides will be apparent to those skilled in the art.

In the forming means generally indicated at 28, the tool employed to impart the side relief comprises a small, cylindrical pencil grinding element 36 which is secured to a spindle 38 and rotatably mounted in bearing blocks 40. Such bearing blocks 40 are adjustably mounted in a frame 42, for vertical adjustment therein, which is mounted on a mounting block 44. The mounting block 44 is slidably mounted on the top surface of another block 46 having guideways formed thereon which are received in complementary guideways on the under side of block 44 and which are substantially parallel to the axis of the grinding element 36 so that block 44 may be adjustably fixed on block 46. The block 46 is slidably connected to another slide block 48 having parallel ways formed on the top surface thereof which cooperates with complementary ways on the under surface of block 46. Block 46 may be adjustably fixed to block 48. Block 48 is supported on another block 50 having parallel ways formed in the top surface thereof which are perpendicular to the ways formed in blocks 44, 46, and 48, and block 48 may be adjustably fixed with respect thereto. Block 50 may be adjustably fixed to the top surface of auxiliary table 30. The various slide blocks are employed so that the pencil grinding element 36 may be properly positioned with respect to the hob 10. That is, as disclosed in the above mentioned Scott patent, the grinding element is so positioned that the engaging portion of the grinding element is at all times tangent to a predetermined base circle having as its center the center of rotation of tables 26 and 30 and so that it lies in a plane at a right angle thereto and passing through the axis of the hob. The bearing block 40 is vertically adjusted in the frame 42 so as to place the engaging portion of the grinding element in the proper plane.

Spindle 38 has a pulley 52 fixed to the rear end thereof about which a drive belt 54 is trained. The upper end of the drive belt 54 is trained about another pulley 55 mounted on the shaft of drive motor 56. In order that the motor may generally follow the pivotal movement of the spindle 38, so that the belt 54 will properly engage pulley 52, the motor 56 is mounted on an overhanging platform 58. The platform 58 is mounted on a vertical pivot about the outer end of an arm 60 and the inner end of arm 60 is pivotally connected, through a vertical pivot pin to the outer end of another arm 62. The arm 62 may be adjustably fixed to a standard 64. The platform 58 may thus pivot with respect to arm 60 and arm 60 may pivot with respect to arm 62 so that a free following movement of the belt 54 with the pivotal movement of the spindle 38 is obtained. The pivot pins between the arms and the platform 58 are preferably mounted in ball bearing so as to provide for ease in movement.

It will be appreciated that the head stock spindle, carrying the hob 10, is disposed on an axis perpendicular to the axis of rotation of the main table 26 and that the hob is driven in synchronism with the main table. The drive for the table and the hob is reversible so that the pencil grinder 36 passes along one side of the teeth of one of the threads of the hob from one end thereof to the other and the drive is then reversed to return the grinding element 36 back to its original position between adjacent threads. When moving in one, or the first, direction, the grinding wheel engages the cutting edge 20 of each of the hob teeth. Since the sides 22 are relieved from the cutting edge 20 to the back edge of each of the teeth, and since such relief is gradual, it will be appreciated that the grinding element 36 must be given a retractive movement relative to the hob for each tooth. In passing from one end of the thread to the other, the grinding element follows a staggered path.

Such variation in relative movement of the grinding element with respect to the hob teeth is obtained by imparting a relative, rotative movement between tables 26 and 30 in the one direction of rotation of the tables only. Such relative movement is imparted to table 30 independently of the drive between table 26 and the hob so that the shock load of providing the retraction and return to normal lead is taken off the main drive. The main drive is uniform for the mass of the main tool carriage and the retraction is imparted to a relatively small mass made up of the auxiliary table 30 and the forming means 28.

Referring to Figs. 3, 4 and 5, the means by which the relative rotative movement between tables 26 and 30 is imparted is shown in detail. A stationary, cylindrical member 66, is mounted on the base 24 and fixed thereto and may be considered as an integral part thereof. An annular top plate 68 having a central opening 70 therethrough is mounted to the top of member 66 and fixed thereto. The main table 26 has a depending, integral hollow shaft portion 72 which passes through opening 70 with the table 26 supported on the top surface of member 68. A pair of cooperating bearing rings 74 and 76 are fixed to the top surface of member 68 and the under surface of table 26, respectively, to provide a bearing for the relative rotation of table 26 with respect to member 68. A ring member 78 embraces the bearings 74 and 76 and is received within the annular shoulders provided in members 68 and 26 to provide for axial alignment of the table 26. A ball bearing assembly indicated at 80 is disposed between the shaft portion 72 adjacent to table and the surface of opening 70. Such ball bearing assembly may be held in place by a lock nut 82 which is threadably received over a threaded portion of shaft portion 72 adjacent to the inner race of bearing assembly 80.

A drive gear 84 is keyed to shaft 72 for driving the main table 26. A lock nut 86 holds the gear 84 against a lock ring 87 in its proper axial position.

The lower end of shaft portion 72 projects through an axial opening 88 provided in the horizontal portion of member 66 and is rotatively

mounted with respect thereto by means of a ball bearing assembly 90 which is mounted within annular ball bearing mounting members 92 and 94. The member 92 is fixed to member 66 by means of screws 96 and the member 94 is fixed to member 92 by means of screws 98 so that the member 94 is stationary with respect to the base.

The table 30 is mounted on table 26 for movement therewith and for relative rotative movement with respect thereto. An annular bearing ring 102 is fixed to the top surface of table 26 and engages the under surface of table 30. The outer edge of ring 102 overhangs the edge of table 26; and a bearing ring 104 having an inwardly directed annular shoulder 106 is fixed to the under edge of table 30 so that the top surface of shoulder 106 bears against the under surface of ring 102. An axial bearing mount 108 is fixed to the top surface of member 26 and projects upwardly within an axial opening 110 in table 30. A thrust bearing assembly 112 is disposed between member 108 and opening 110 with the outer race thereof bearing against a shoulder provided in opening 110 and with the inner race thereof held in place by an overhanging plate member 114 fixed to the top surface of 108. A cover plate 116 may be removedly fixed to table 30 over opening 110 and flush with the surface thereof.

The relative movement between tables 26 and 30, or the retraction of grinding element 36 from its normal lead, is imparted through the drive connection between tables 26 and 30. Such drive connection includes a plate member 120 which is fixed to the under surface of table 30 within a recess 122. A pair of depending members 124 is fixed to the plate member 120 and each of the members 124 is formed with a sloping cam edge 126, such cam edges 126 being disposed to face inwardly and toward each other. A rod member 128 is disposed within a cylindrical, radial opening 130 provided in table 26 and projects outwardly within a space 131 in table 26 within which the members 124 extend. The space 131 is of such extent as to permit limited movement of members 124 therein.

A bearing sleeve 134 is received within the opening 130 and slidably receives therein the rod member 128. The outer end of member 128 is formed with tapering flats or cam edges 136 which are adapted to bear against the adjacent surfaces 126. For rotation of the main tables 26 and 30 in one direction, a spring 138 is disposed in an opening 140 provided in table 26 and may be adjustably held therein by means of a screw plug 142. The inner end of spring 138 bears against the adjacent face of one of the members 124 and resiliently urges it into engagement with the adjacent cam edge 136 of member 128. An opening similar to 140 is provided in the opposite side of table 26, so that when the machine is reversibly operated the spring 138 is placed in the opposite opening and the bearing is then between the opposite member 124 and the opposite edge 136.

The inner end of member 128 is formed with a sloping flat 144 which is adapted to bear against a complementary, sloping flat 146 formed on the top portion of a rotatable cam pad 148. The depending stem of the cam pad 148 is rotatably received within an axial opening formed in the top end of an actuator rod 150. The actuator rod 150 is received through the axial opening in shaft portion 72 and a bearing sleeve 152 is disposed between the upper end of member 150 and shaft portion 72. Such member 152 is received

within an enlarged portion of the axial opening. The lower end of member 150 is keyed to member 94 by means of key 154 so that the member 150 is rotatably stationary with respect to table 26 but may be vertically moved with respect thereto.

The lower end of member 150 has a tapped axial opening formed therein which receives a screw 156 having a depending cam follower 158 formed on the end thereof. The screw 156 may be adjusted to adjust the follower 158 and may be held in position by means of a jamb nut 160.

The cam 158 is adapted to engage the periphery of a rotatable cam 162 which is keyed to shaft 164. It will be appreciated that as the shaft 164 is turned in the direction of the arrow in Fig. 4, the cam follower 158 will cause member 150 to move upwardly. This occurs during rotation of tables 26 and 30 in one direction; and as the member 150 moves upwardly surface 146 slides along surface 144 and moves member 128 radially outwardly. The cam pad 148 rotates with the tables. As member 128 moves outwardly, surface 136 slides outwardly against surface 126, in the relationship shown in Fig. 5, thereby causing a relative retraction of table 30 with respect to table 26. This causes a corresponding relative retraction of the grinding element 36. The surface of cam 162 is such that there is one complete revolution of cam 162 for each tooth and the retraction is gradual to provide the gradual relief and the grinding element is returned to its normal position for the next tooth.

As mentioned above, the spindle to which table 26 is attached is driven by gear wheel 84. Referring to Fig. 8, the drive for the main table, the hob and also the shaft 164, which rotates cam 162, is diagrammatically illustrated. The hob 10 is mounted to the head stock having a hob driving spindle 180 mounted therein. The hob spindle 180 and the gear 84 are driven in uniform synchronism at all times. The hob spindle 180 is connected to a drive shaft 182 through a worm gear 184 and a worm 186. The worm gear 184 and worm 186 are of the double enveloping type disclosed in Cone Patent No. 1,822,800. Shaft 182 has a warm gear 188 keyed thereto which meshes with a worm 190. This worm and gear set is also of the Cone type. Worm 190 is keyed to shaft 192 which also has gear 194 keyed thereon. Gear 194 meshes with gear 196 which is keyed to shaft 198. Shaft 198 is operably connected through a conventional clutch 200 with a drive pulley 202. The drive pulley 202 is driven by a suitable belt or chain 204 which is trained about a motor pulley 206 keyed to the outer end of motor shaft 208 of main drive motor 210. The main drive motor 210 is a variable speed reversible motor. It will thus be seen that the hob spindle 180 is driven by the motor 210 through the chain of shafts and gears just described.

The gear 84 is synchronously driven with the hob spindle 180. To accomplish this, shaft 182 is connected to shaft 212 through change gears 214, 216, 218 and 220. Shaft 212 is drivingly connected to shaft 222 through a matching differential, generally indicated at 224. Such matching differential may be of the same structure as the matching differential employed in the machine of Pelphrey application Serial No. 435,649, filed March 21, 1942. The matching differential 224 is employed for the purpose of providing relative side feed of the grinding element 36, which is driven by gear 84, with respect to the hob so that the grinding element may be

properly set for its initial engagement with the grinding edges.

The matching differential 224 includes a housing or rotatable drum 226 into which the aligned shafts 212 and 222 extend. The housing 226 is mounted for rotation within suitable bearings on the base 24 and may be revolved about the axis of shafts 212 and 222. A gear 228 is keyed to the inner end of shaft 222 and another gear 230 is keyed to the inner end of shaft 212. An idler gear 232 is mounted within the housing on a shaft 234 which is mounted on suitable bearings therein, and such gear 232 meshes with gears 228 and 230. The gear 232 is free to rotate about its own axis but revolves about the axis of gears 228 and 230 when the housing 226 is revolved. The gears 228 and 230 have the same outside diameter but gear 228 has less teeth than gear 230. For example, gear 230 may have 24 teeth, gear 232 may have 13 teeth, and gear 228 may have 23 teeth. The center distances for gears 228 and 230 with respect to gear 232 are the same. The 24-tooth gear may be made standard, while the 23-tooth gear is cut to mate with the 13-tooth gear. All geometrical laws of the involute curve are strictly observed in the formation of these gear teeth.

By rotating housing 226, it is possible to accomplish a relatively small side feed action directly through the main drive in a very accurate manner. The rotation of the housing 226 is accomplished by forming a ring of worm gear teeth 236 around the housing which mesh with a worm 238. The worm 238 is keyed to shaft 240 which is connected to a hand crank 242 through bevel gears 244, shaft 246, gears 248 and 250, shaft 252, bevel gears 254, and shaft 256, to which the hand crank is keyed.

The drive shaft 222 has a worm 258 keyed thereto which meshes with the gear 84. The gear 84 and worm 258 are a set of the Cone type mentioned above.

By driving the gear 84 and the hob spindle 180 in synchronism, it will be understood that the main table 26 and the hob are driven in synchronism. The motor 210 is reversible so that the gear 84 and hob spindle 180 are rotated first in one direction and then in another. The side relief, or grinding action on the sides of the teeth, takes place when the gear 84 is rotating in a clockwise direction, viewing Fig. 8, and when the hob spindle 180 is rotating in the direction of arrow 260. When the grinding element has passed through one thread, it then returns through the space between that thread and the adjacent thread, at which time the direction of rotation of gear 84 and hob spindle 180 is reversed. The hob spindle may then be indexed through a conventional indexing mechanism, indicated at 262 (Fig. 2), to move the hob for engagement with the teeth of the next thread.

The synchronous drive between the main table 26 and the hob spindle is uniform; and the relative motion imparted to table 30 to retract the grinding element is imparted independently of the synchronous drive between table 26 and the hob. This is accomplished by driving the cam shaft 164, and such shaft is driven during the clockwise rotation only of gear 84. The shaft 164 is driven through a bevel gear set 264 by shaft 266. The shaft 266 is driven by shaft 268 through a one-way drive or ratchet mechanism 270. Such ratchet mechanism is shown in detail in Figs. 6 and 7. It comprises a mounting frame 272 within which the bevel gear 264 and shafts 266 and 268 are mounted. Shaft 268 has a ratchet 273 pinned thereto by a pin 274. An index plate 276, having a spring-pressed detent 278 mounted therein, is provided and may be adjustably fixed to a collar plate 280. The collar plate 280 is pinned to shaft 266 by a pin 282. The members 276 and 280 may be rotatably adjusted with respect to each other so that the cam 162 may be adjusted for proper setup. The members 276 and 280 are fixed to each other after said adjustment so that the shaft 268 may be reversed but it will drive shaft 266 in one direction of rotation only. When the shaft 266 is driven in that one direction, as shown by the arrow in Fig. 7, the cam 162 will be rotated to cause the retraction of the grinding element mentioned above. This is in the same direction of rotation as when the gear 84 is rotated in a clockwise direction.

The shaft 268 is connected to shaft 284 through bevel gear set 286. Shaft 284 is connected through a driving sleeve 288 with shaft 290. The shaft 290 is driven from the main motor 210 through shaft 182, gears 292 and 294, shaft 296, gears 298, 300, 302, and 304.

In the operation of the device above described, the hob to be ground is placed on the head and tail stock mountings and the slides 29 and 33 are then adjusted to place the axis of the hob on the proper center distance and in the proper plane with respect to the grinding element 36. The side feed may then be adjusted through the matching differential to properly position the grinding element with respect to the first cutting edge to be engaged. The cam 162 may be adjusted to its starting position by adjusting the index plate 276 with respect to member 280. When the motor is started, the gear 84 rotates in a clockwise direction, viewing Fig. 8, and the hob spindle 180 rotates in the direction of arrow 260. The shaft 164 is driven through the ratchet mechanism 270 so that the cam 162 turns through one complete revolution for each tooth. It thus causes a relative retraction of the grinding element for each tooth and returns the grinding element to its normal position on the normal lead for each succeeding tooth. After the grinding element has passed through one thread, the drive motor 210 is reversed so that the gear 84 and shaft 180 rotate in the opposite direction. The shaft 268 also rotates in the opposite direction but shaft 164 remains stationary. Where the worm has more than one thread, the index mechanism 262 may be turned to index the worm to the next thread.

The reversal of the above mechanism is controlled by limit switches operatively connected to an electric control panel which forms no part of the present invention but which will be understood by those familiar with this art.

What is claimed is:

1. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, means for rotating said hob support and main table in synchronism, another table mounted on said main table for rotation therewith and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means for causing said relative movement by retarding and advancing the relative rotative position between said tables

for effecting the relief on the teeth, said last-named means including means providing the driving connection between said tables.

2. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, driving means for rotating said hob support and main table in synchronism, another table mounted on said main table for rotation therewith and driven thereby, means mounting said tables for relative rotative movement therewith, and means separate from tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movementt herewith, and means separate from said driving means for causing said relative movement by retarding and advancing the relative rotative position between said tables for effecting the relief on the teeth, said last-named means including means providing the driving connection between said tables.

3. Apparatus for side-relieving the teeth of hobs having a plurality of cutting teeth from one end of the hob thread to the other, comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, means for rotating said hob support and main table in synchronism, another table mounted on said main table for rotation therewith and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables for effecting the relief on the teeth, said last-named means including a rotatable cam included in the driving connection between said tables, and means to effect such rotation of the cam relative to the travel of the tool from one end of the thread to the other that the relative rototive position between the tables is retarded and advanced a plurality of times in the travel from one end of the thread to the other dependent upon the number of teeth to be relieved between the ends of the thread for effecting the relief on said teeth.

4. Apparatus for side-relieving the teeth of hobs having a plurality of cutting teeth from one end of the hob thread to the other, comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, means for rotating said hob support and main table in synchronism, another table mounted on said main table for rotation therewith and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables for effecting the relief on the teeth, said last-named means including a rotatable cam included in the driving connection between said tables, and means to effect such rotation of the cam relative to the travel of the tool from one end of the thread to the other that the relative rotative position between the tables is retarded and advanced a plurality of times in the travel from one end of the thread to the other in one direction of travel only and dependent upon the number of teeth to be relieved between the ends of the thread for effecting the relief on said teeth.

5. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, reversible driving means for rotating said hob support and main table in synchronism first in one direction and then in the opposite direction, another table mounted on said main table for rotation therewith and for relative rotation with respect thereto and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means for causing said relative movement by retarding and advancing the relative rotative position between said tables in one direction only of rotation of said main table for effecting the relief on the teeth, said last-named means including means providing the driving connection between said tables.

6. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable, main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, driving means for rotating said hob support and main table in synchronism, another table mounted on said main table for rotation therewith and for relative rotation with respect thereto and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables for effecting the relief on the teeth, said last-named means including a resilient member mounted on one of said tables, a shiftable cam member engageable with said resilient member mounted on the other of said tables, said last two named members providing the driving connection between said tables, and means separate from said driving means to shift said cam member.

7. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, reversible driving means for rotating said hob support and main table in synchronism first in one direction and then in the opposite direction, another table mounted on said main table for rotation therewith and for relative rotation with respect thereto and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables in one direction only of rotation of said main table for effecting the relief on the teeth, said last-named means including a resilient member mounted on one of said tables, a shiftable cam member engageable with said resilient member mounted on the other of said tables, said last two named members providing the driving connection between said tables, and means separate from said

driving means to shift said cam member in one direction only of rotation of said main table.

8. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, reversible driving means for rotating said hob support and main table in synchronism first in one direction and then in the opposite direction, another table mounted on said main table for rotation therewith and for relative rotation with respect thereto and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables in one direction only of rotation of said main table for effecting the relief on the teeth, said last-named means including a member having a cam surface mounted on one of said tables, a shiftable cam member engageable with said cam surface mounted on the other of said tables, means resiliently urging said last two named members into engagement with each other, said last two named members providing the driving connection between said tables, and means separate from said driving means to shift said cam member in a linear direction during one direction only of rotation of said main table.

9. Apparatus for side-relieving the teeth of hobs comprising, in combination, a rotatable hob support, a rotatable main table adapted to rotate about an axis perpendicular to the axis of rotation of said hob support, reversible driving means for rotating said hob support and main table in synchronism first in one direction and then in the opposite direction, another table mounted on said main table for rotation therewith and for relative rotation with respect thereto and driven thereby, means mounting said tables for relative rotative movement with respect to each other, a forming tool positioned to engage the sides of the hob teeth mounted on said another table for rotary movement therewith, and means causing said relative movement by retarding and advancing the relative rotative position between said tables in one direction only of rotation of said main table for effecting the relief on the teeth, said last-named means including a member having a cam surface mounted on one of said tables, a shiftable cam member engageable with said cam surface radially mounted on the other of said tables, means resiliently urging said last two named members into engagement with each other, said last two named members providing the driving connection between said tables, and means separate from said driving means to radially shift said cam member during one direction only of rotation of said main table.

HARRY PELPHREY.