March 24, 1936. J. S. LOEWUS 2,035,434

GEAR SHAPING MACHINE

Filed Jan. 12, 1933 5 Sheets-Sheet 1

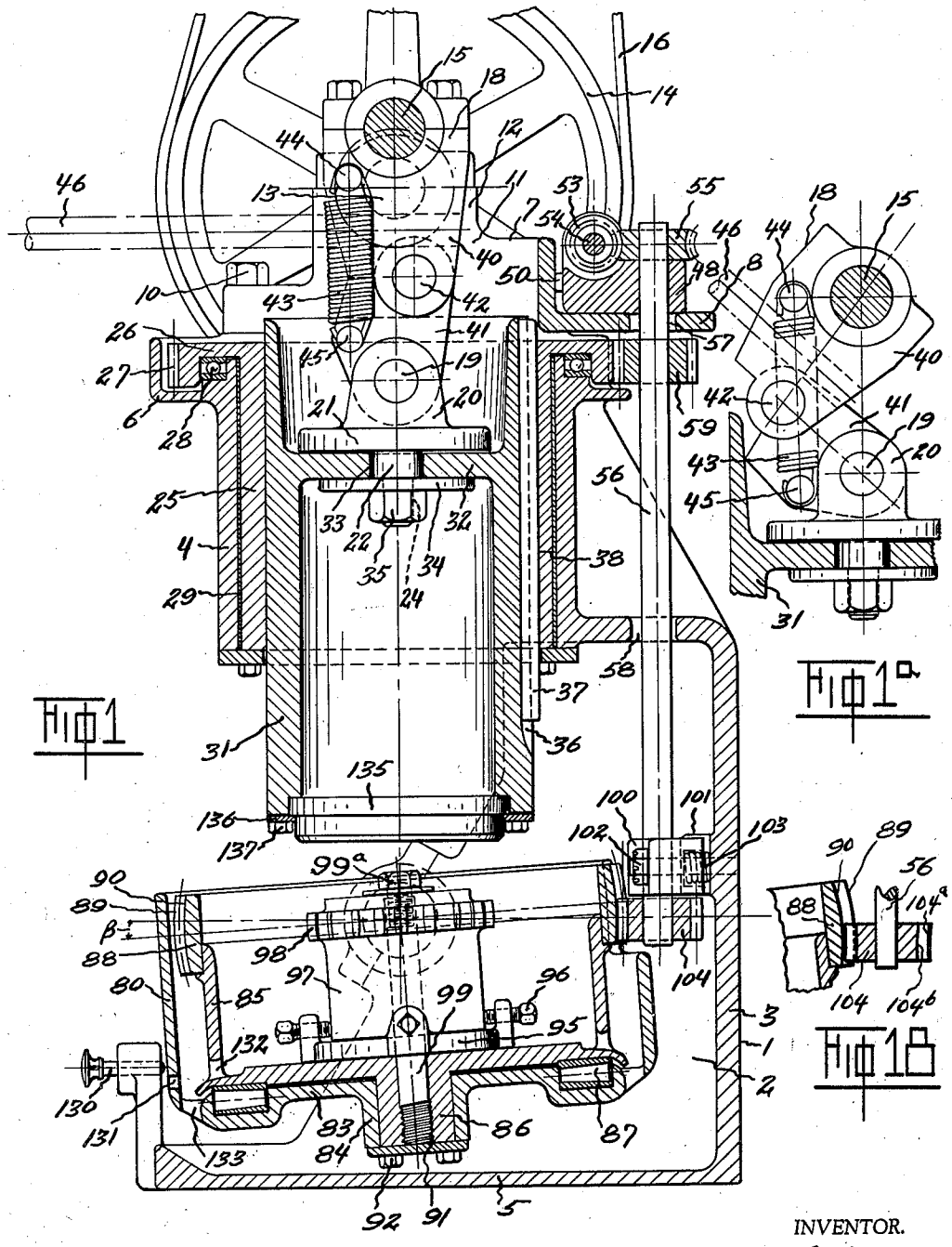


Fig 1

Fig 1a

Fig 1b

INVENTOR.

Julian S. Loewus

by Francis B. Leach,

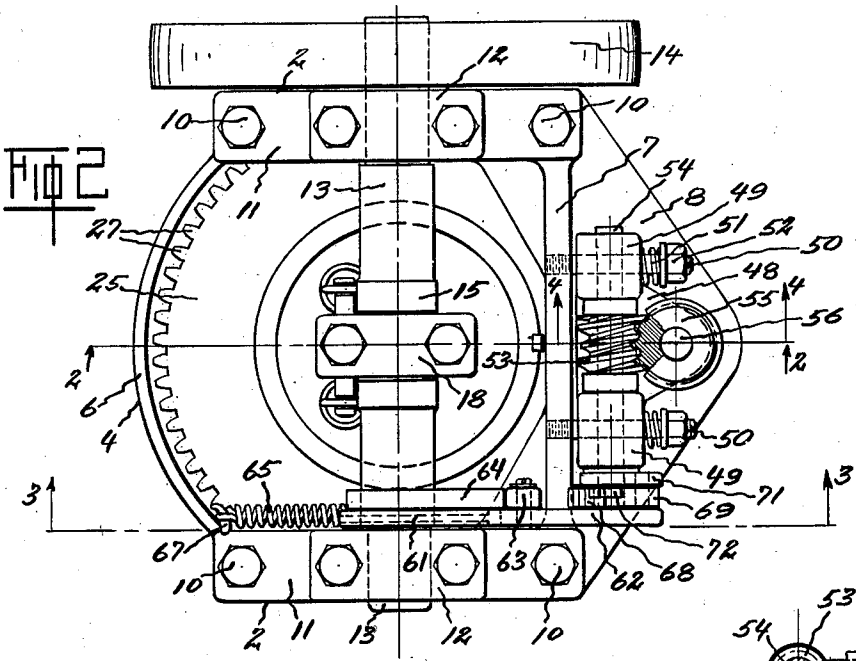
Attorney

March 24, 1936. J. S. LOEWUS 2,035,434

GEAR SHAPING MACHINE

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Fig 2



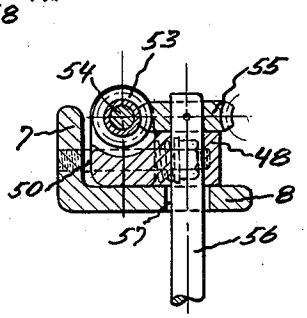


Fig 3

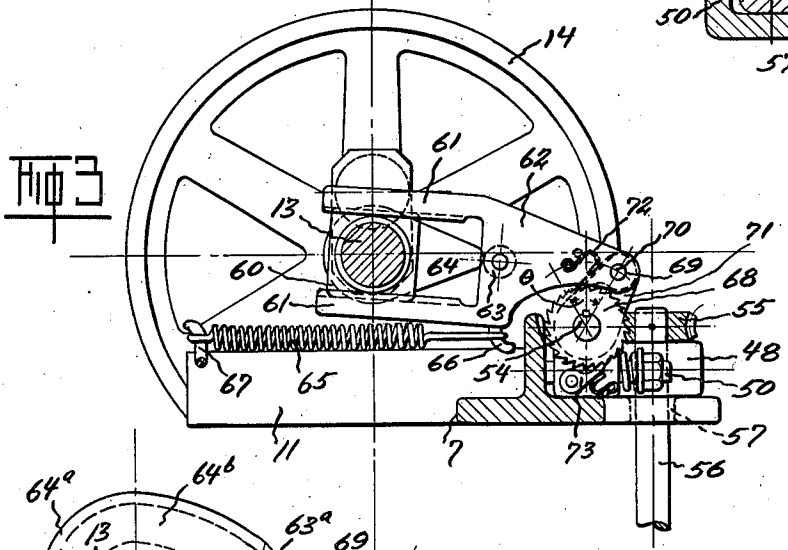
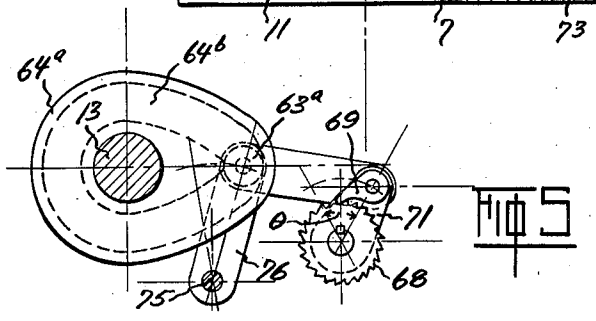


Fig 4

Fig 5



Inventor

Julian S. Loewus

by Francis B. Leech

Attorney.

March 24, 1936. J. S. LOEWUS 2,035,434

GEAR SHAPING MACHINE

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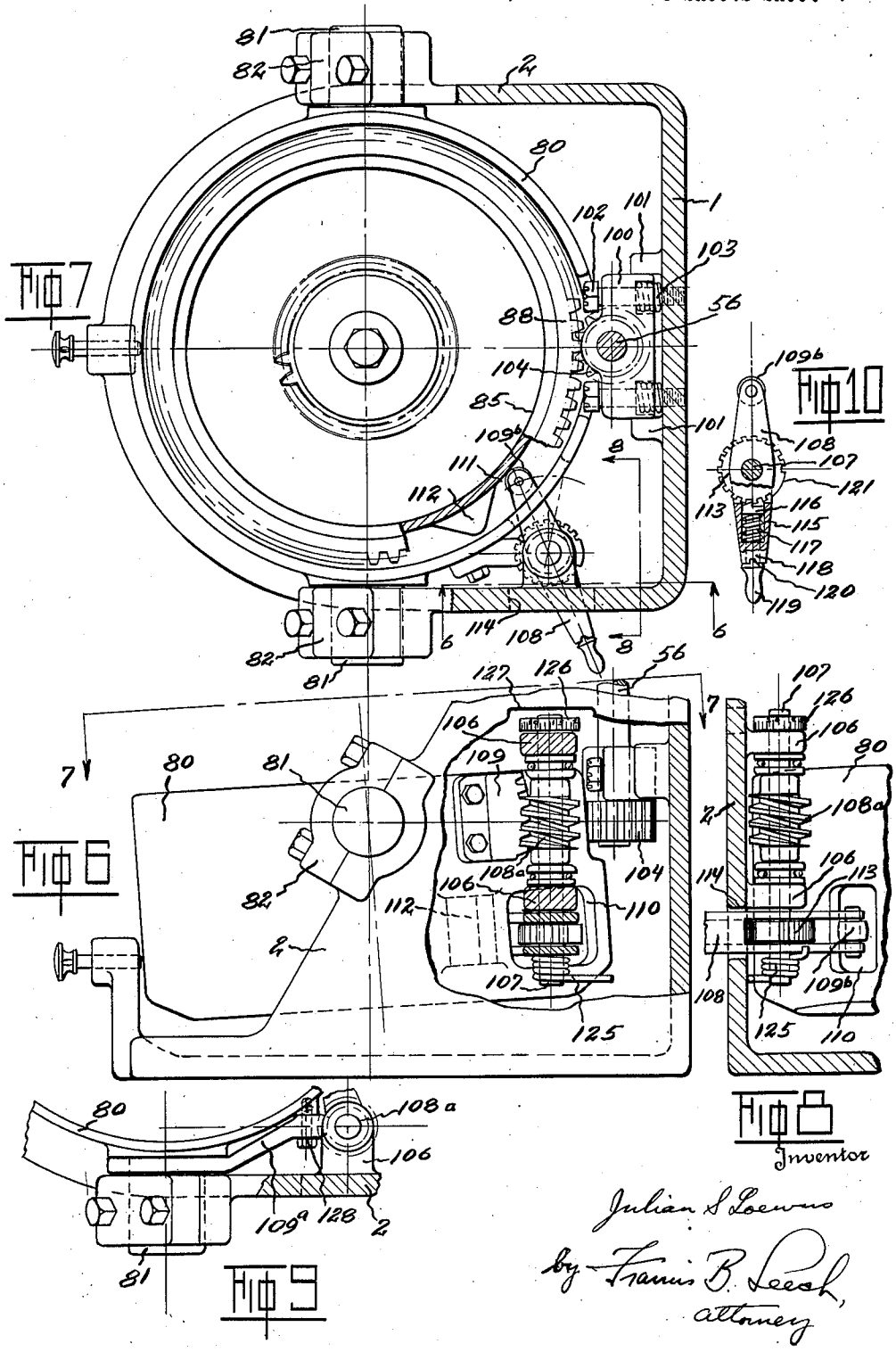


FIG 7

FIG 10

FIG 6

FIG 9

Inventor

Julian S Loewus

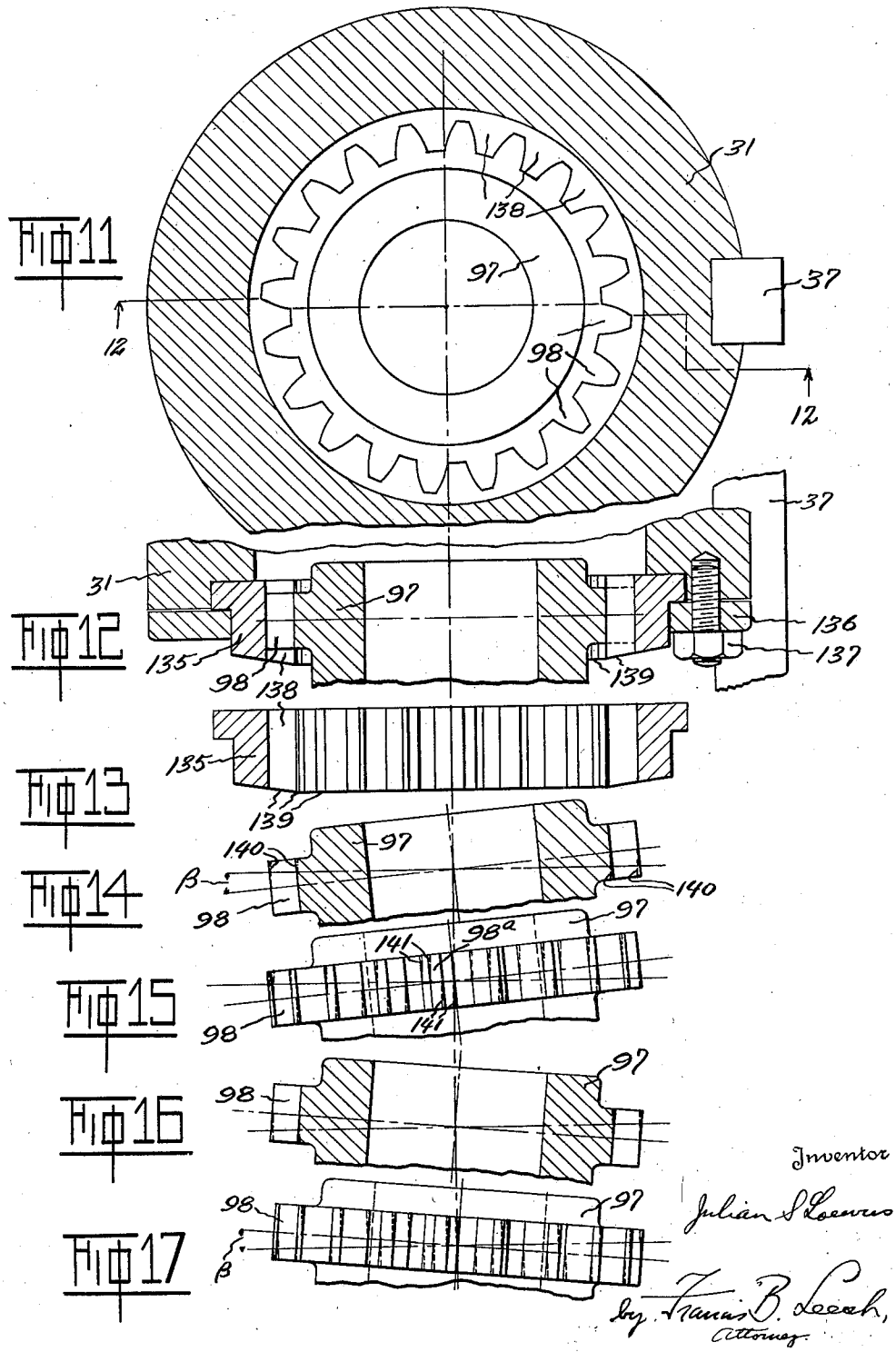
by Francis B. Leech,

attorney

March 24, 1936. J. S. LOEWUS 2,035,434

GEAR SHAPING MACHINE

Filed Jan. 12, 1933 5 Sheets-Sheet 4



Inventor
Julian S. Loewus
by Francis B. Leach,
Attorney

March 24, 1936. J. S. LOEWUS 2,035,434

GEAR SHAPING MACHINE

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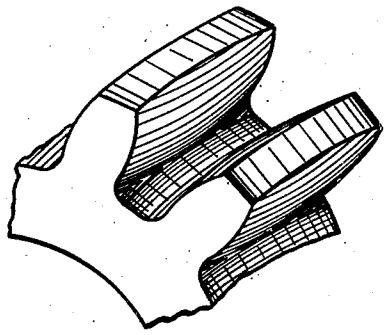


FIG. 19.

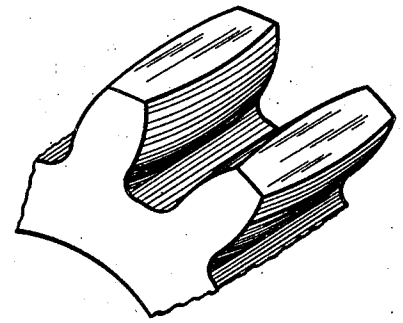


FIG. 20.

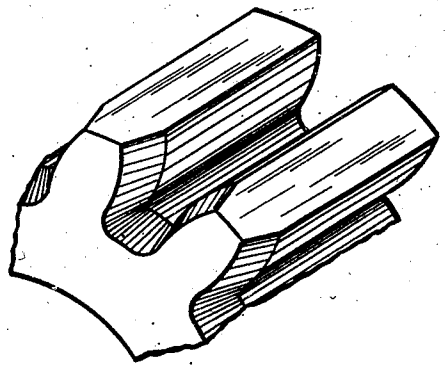


FIG. 21.

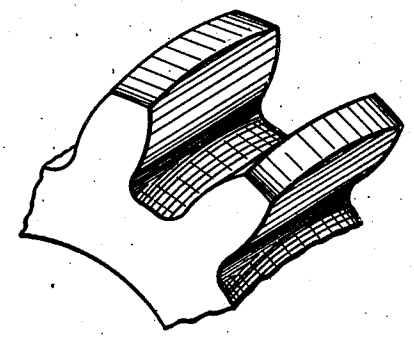


FIG. 22.

Inventor
Julian S. Loewus

Francis B. Leech,
attorney.

Patented Mar. 24, 1936

2,035,434

UNITED STATES PATENT OFFICE

2,035,434

GEAR SHAPING MACHINE

Julian S. Loewus, Baltimore, Md.

Application January 12, 1933, Serial No. 651,394

38 Claims. (Cl. 90—8)

This invention relates to the cutting or shaping of curved and plane surfaces on teeth as for example on gear blanks or on the toothed members of a flexible shaft coupling automotive gear and the like.

An object of this invention is the provision of a machine which is automatically operable to simultaneously cut a circumferential row of external or internal teeth formed on a suitable blank so as to shape or form each tooth of said row with curved convex surfaces either on the crown, side faces or the walls between the roots of adjacent teeth, or on all such surfaces or combination of surfaces at the same time.

Another object of this invention is to shape portions of the teeth with tapered ends, so that in mechanisms wherein one gear is shifted into mesh with another gear no fouling or undue noise results.

Further objects and advantages of the invention will be apparent from the following detailed description thereof.

While the invention is capable of numerous modifications, a preferred embodiment thereof is illustrated in the accompanying drawings, in which,—

Fig. 1 is an elevational sectional view of the machine taken on line 2—2 of Fig. 2.

Fig. 1ª is an elevational view partly in section showing the connecting rod of Fig. 1 in a collapsed position.

Fig. 2 is a plan view of the machine.

Fig. 3 is a detail elevational view partly in section taken on line 3—3 of Fig. 2.

Fig. 4 is a detail sectional view taken on line 4—4 of Fig. 2.

Fig. 5 is a modified form of cam operating mechanism shown in Fig. 3.

Fig. 6 is an elevational view with parts broken away of the lower part of the machine, parts in section being taken on line 6—6, Fig. 7.

Fig. 7 is a transverse sectional view of the lower part of the machine on line 7—7, Fig. 6.

Fig. 8 is a detail sectional view taken on line 8—8, of Fig. 7.

Fig. 9 shows a modified form of sector worm wheel that may be employed.

Fig. 10 is a plan view partly in section of the control arm shown in Fig. 7.

Fig. 11 is a plan view and Fig. 12 a sectional view on line 12—12, Fig. 11, of the cutter and blank in operative engagement, the axis of both coinciding.

Figs. 1 to 17, inclusive, show in section and in elevation various angular positions of the blank relative to the vertical position of the cutter, shown in Fig. 13.

Fig. 18 is a modified form of gear drive employed in Fig. 1.

Figs. 19 to 22 inclusive illustrate several forms of gear teeth generated by the gear shaping machine.

Referring to the drawings, 1 designates the stationary machine base or frame which comprises vertical side walls 2 and a vertical back wall 3. Integrally formed with the side walls 2 and back wall 3 is a cylindrical portion 4 open at both ends and which centrally overhangs the base 5 of the machine in the manner clearly shown in Fig. 1. The cylindrical portion 4 is provided with an integral concentric flange 6 which merges with the side walls 2. Seated on the top edges of the side walls 2 is a substantially U-shaped support 7 provided with a rearwardly horizontally extending shelf 8, said U-support being securely fastened to the side walls 2 by bolts 10, best shown in Fig. 2. Formed on each of the arms 11 of the U-support 7 are bearing housings 12 of conventional design adapted to have rotatably mounted therein a crank shaft 13, one end of which carries the pulley 14, the crank 15 of the crank shaft 13 being positioned between the arms 11 of the U-support 7. A belt 16 delivers power to the pulley 14 from a motor or any other source of power (not shown).

Secured to the crank 15 is a depending connecting rod 18, the lower end of which is pivotally connected as at 19 to a yoke 20 which is provided with a flange 21 and stud 22, the function of which is to be hereinafter described.

Mounted for rotative movement within the cylindrical portion 4 is a sleeve 25 provided with a radically extending flange 26 having teeth 27 formed thereon, the weight of said sleeve being carried by the anti-friction bearings 28 positioned between the flange 6 of the cylindrical portion 4 and the flange 26 of the sleeve 25. If desired a liner of bearing metal 29 may be placed between the cylindrical portion 4 and sleeve 25. Positioned within the sleeve 25 is a hollow cylindrical cutter bar 31 formed in the interior thereof adjacent its upper end with an integral partition 32. The partition 32 is provided with a central opening 33 through which the stud 22 freely extends. The stud 22 is formed with a threaded portion 24 of reduced diameter the stud portion 22 being of a slightly greater length than the thickness of the partition 32. A washer plate 34 is securely clamped against the shoulder of the stud 22 by the nut 35. It is thus apparent that the yoke 20 carries the cutter bar 31 which is free to rotate on the

stud 22 in the manner to be hereinafter described.

Mounted rigidly in the key way 36 provided in the cutter bar 31 is a guide key 37 which is adapted to have reciprocating movement in a suitable guide groove 38 formed in the sleeve 25. The cutter bar 31 while having a reciprocating movement by virtue of its connection to the connecting rod 18 is locked to the sleeve 25 by the guide key 37 so as to have rotative movement therewith, the cutter bar 31 being freely rotatable on the stud 22.

As shown in Fig. 1, the cutter bar 31 is in its uppermost position, the crank 15 being shown on its upper dead center position. In view of the fact that it is necessary to raise the cutter bar 31 still higher for the reason to be hereinafter explained, the connecting rod 18 is formed so that the same may be folded thus permitting further upward movement of said cutter bar. This is accomplished by forming the connecting rod 18 into two sections 40 and 41 pivoted together at one side of their longitudinal axis by the pivot 42. The section 40 is bifurcated to receive therebetween the section 41 at the point where the pivot 42 joins the same in the manner well known. Tension coil springs 43 at each side of the connecting rod 18 secured at their ends to the pins 44—45, function to hold the sections 40—41 in alignment in the manner shown in Fig. 1. To fold or bend the connecting rod 18 at its pivot 42 a bar 46 shown in dotted lines in Fig. 1, is inserted in the bifurcated section 40, an upward movement of the same about the pin 44 as a fulcrum will force the pivot pin 42 to the left (see Fig. 1a) with a bringing together of the sections 40—41 and a consequent upward movement of the cutter bar 31.

Seated on the shelf 8 of the U-support 7 is a bearing bracket 48 formed with spaced bearing housings 49 slidably mounted on the horizontal bolts 50 which are rigid with the back of the U-support 7, see Fig. 2. Springs 51 on the bolts 50 are positioned between the bearing housings 49 and nuts 52 on the ends of said bolts, the bearing bracket 48 thus being capable of slight movement on said bolts. Positioned between the bearing housings 49 is a worm 53 on the drive shaft 54 the ends of which are rotatably mounted in said bearing housings. Meshing with the worm 53 is a worm wheel 55 fixed on the end of the vertical driven shaft 56 which extends through a slotted opening 57 in the shelf 8 and a similar slotted opening 58 in the back wall 3 of the frame 1. Fast to the shaft 56 and directly beneath the shelf 8 is a pinion 59 meshing with the teeth 27 on the flange 26 of the sleeve 25.

Rotary movement of the worm 53 is accomplished through a cam and ratchet mechanism now to be described.

Mounted rotatably on the end of the shaft 13 inwardly of the arm 11 is a guide 60, on which is fitted for sliding engagement the parallel arms 61 (see Fig. 3) of a slide member 62, on the inner face of which is rotatably mounted a cam follower 63. A cam 64 rigid with the shaft 13 is provided with an edge surface upon which the follower 63 is adapted to roll. In the relative position of the parts shown in Fig. 3, the follower 63 is shown at the apex of the cam 64, the slide 62 being at its maximum outer position. To move the slide 62 inwardly and to maintain the follower 63 in engagement with the cam 64 a tension coil spring 65 is provided, one end of which is secured to the slide 62 as at 66 and the other end to the rigid arm 11 as at 67. Secured to the end of the drive shaft 54 beneath the slide 62 is a ratchet 68. A pawl 69 pivoted on the pin 70 carried on the end of the slide 62 engages the teeth of the ratchet to rotate the same in a counterclockwise direction. A link 71 pivoted at one end to the pin 70 is freely mounted on the shaft 54 and serves to hold the slide 62 in its proper relation to the shaft 54. The pawl 69 is always retained in positive engagement with the ratchet by virtue of the spring 72. In addition to the pawl 69, a spring pressed pawl 73 is provided to hold the ratchet 68 in position.

A modified form of cam and ratchet actuating means is shown in Fig. 5. The cam 64a is rigidly mounted on the shaft 13 said cam being provided with a grooved cam surface 64b. Pivoted on a pin 75 rigid with the support 7 is one end of a bell crank lever 76, the other end thereof being pivotally connected to the link 71 and carrying the spring pressed pawl 68 for engagement with the ratchet 68. At the juncture of the bell crank lever 76 is pivotally mounted the follower 63a which rides in the cam groove 64b. In each case the return movement of the cam and its associated parts will cause the pawl to rotate the ratchet a definite amount indicated in each case by the angle θ. This rotative movement is transmitted by the shaft 54 and worm drive 53, 55 to the vertical driven shaft 56, the exact function of which is to be hereinafter described.

Placed directly beneath the cutter bar 31 is a rocking cradle 80 of substantially tub like form. This cradle 80 is provided with diametrically aligned trunnions 81 which are rotatably mounted in suitable pillow block bearings 82 provided on the side walls 2 of the machine frame 1, as most clearly shown in Fig. 6. The bottom 83 of the cradle is provided with a central downwardly extending cylindrical sleeve extension 84. A blank or work holder 85 of the same substantial form as the cradle 80 is placed within said cradle and centered therein by an extension 86 on the blank holder 85 fitted within the cylindrical sleeve extension 84. Anti-friction bearings 87 are provided between the bottoms of the cradle 80 and blank holder 85 to facilitate easy turning of the blank holder relative to the cradle. Secured to the outer edge of the blank holder 85 is an external ring gear 88 the teeth of which have convexly curved crowns 89, the walls 90 between the roots of said teeth being similarly convexly curved, as clearly shown in Fig. 1. To lock the blank holder 85 to the cradle 80, there is provided a plate 91 which is secured by bolts 92 to the exposed end of the extension 86, said plate abutting the edge of the sleeve extension 84 in the manner readily apparent.

Seated centrally on the bottom of the blank holder 85 and secured thereto in any desired manner (not shown) is a platen 95 provided with radially movable centering screws 96. Shown mounted on the platen 95 by way of example is a hub blank 97 provided with a row of teeth 98, of the type commonly employed in flexible shaft couplings. The blank is centered on the platen 95 by the screws 96 and is furthermore rigidly clamped in place by the vertical center bolt 99, the threaded portion of which is threadedly engaged in the extension 86 of the blank holder 85, in the upper end is a hole threaded to receive the stud 98a, as is readily apparent from an inspection of Fig. 1.

The lower end of the vertical shaft 56 passes through a bearing housing 100 positioned horizontally between spaced guide lugs 101 integral with the back wall 3 of the machine frame, and slidably mounted on the supporting bolts 102. Coil springs

103 are positioned on the bolts 102 between the bearing housing 100 and the back wall 3 and function to urge the bearing housing away from said wall. Rigid with the end of the shaft 56 is a pinion 104 adapted to mesh with the curved teeth of the ring gear 88 on the blank holder 85. Due to the action of the coil springs 103 against the bearing housing 100, the pinion 104 will always be in intimate engagement with the ring gear 88, thus reducing back lash to a minimum and automatically taking up all wear. It is thus seen by virtue of the pinions 59 and 104 on the shaft 56, that rotation of said shaft will result in a simultaneous rotation in the same direction of the sleeve 25 and blank holder 85, the purpose of this simultaneous movement to be described hereinafter.

To increase the efficiency of the drive between the pinion 104 and the ring gear 88 it may be desirable to form the crowns and the walls between the roots of the teeth on the pinion 104 with concave surfaces 104a and 104b which surfaces are to have the same radius of curvature about the same center as the convex curved surfaces 89 and 90 on the teeth of the ring gear 88, as shown in Fig. 18. With such a construction there will be line contact between the meshing teeth instead of point contact.

In the shaping of the teeth 98 on the hub blank 97 it is necessary that the same assume an angular position relative to the stroke of the cutter bar 31. The mechanism for effecting this angular movement will now be described.

Formed on one of the side walls 2, see Fig. 7–8, and to the rear of the pillow blocks 82 are vertically spaced brackets 106 in which through the medium of suitable bearings is rotatably mounted a worm shaft 107 provided with a worm 108a. Bolted to the side of the cradle 80 is a worm wheel sector 109 adapted to mesh with the worm 108a. Pivotally attached to the lower end of the worm shaft 107 is a bifurcated control arm 108, which carries at its inner end the cam follower 109b; that portion of the bifurcated control arm 108 carrying the follower 109b projects through a suitable opening 110 in the cradle 80, the follower 109b being adapted to ride on a suitable circular runway 111 prepared on the cylindrical surface of the blank holder 85. Positioned on the runway 111 is a projecting cam 112 which is so designed as to impart through the follower 109 and control arm 108 upon the completion of one revolution of the blank holder 80, a definite rotary movement to the worm shaft 107. To transmit the swinging movement of the control arm 108 to the worm shaft 107 there is provided a ratchet 113 placed between the spaced sections of the bifurcated control arm 108 and rigidly secured to the shaft 107. The outer portion of the control arm 108 extends through a suitable opening 114 in the side wall 2 and is formed with a longitudinal bore 115. Placed within the bore 115 is a pawl 116 and coil spring 117. The pawl 116 being on the end of a plunger rod 118 extending through the bore and terminating in a handle 119. A toothed clutch joint 120 is provided between the plunger rod 118 and the outer end of the control arm 108. When in the locked position of the clutch 120 shown in Fig. 10, the pawl 116 is in operative engagement with the teeth of the ratchet for rotation of the same and the shaft 107 upon a swinging movement of the control arm 108 in the proper direction, the pawl 116 being maintained in such operative position by the action of the spring 117. To reverse the position of the pawl 116 relative to the ratchet 113 in order to impart a reverse movement to the ratchet, all that is necessary is to pull the plunger rod 118 outwardly and rotate the same through half a turn. In case it is necessary to maintain the pawl 116 out of engagement with the ratchet 113 such may be effected by merely pulling the plunger rod 118 outwardly and giving the same a quarter turn. The ratchet 113 is provided for a portion of its periphery with a plain circular portion 121, the purpose of which will be hereinafter described. In order that the control arm 108 be kept in engagement with the runway 111 on the blank holder 85, there is provided a torsion spring 125 on the bottom of the worm shaft 107, one end of which engages a section of the arm 108 and the other end the side wall 2 as most clearly shown in Fig. 8.

Mounted on the upper end of the worm shaft 107 is a vernier 126 calibrated to show the angular position of the cradle 80 resulting from the rotation of the worm 108a and worm wheel sector 109. This vernier is rendered visible by an opening 127 formed in the side wall 2, part of which is shown in Fig. 6.

A modified form of worm wheel sector 109a is shown in Fig. 9 wherein the same is shown rigidly mounted on the trunnion 81 of the cradle 80, and also bolted to said cradle wall by the bolts 128.

Prior to the positioning of the blank 97 on the platen 95 it is necessary for the cradle 80 to be in a horizontal position, the axis of the same to coincide with the axis of the cutter bar 31. To insure the maintenance of this position there is provided a lock bolt 130 on the base of the machine frame 1 adapted to be positioned in the opening 131 in the cradle 80. When everything is set for the machine to operate the lock bolt 130 is withdrawn thus permitting the necessary angular movement of the cradle 80.

Formed in the bottom edges of the blank holder 85 and cradle 80 are ports 132 and 133 which function to permit the escape of oil or cutting fluid into a suitable drip pan or container not shown.

The cutter bar 31 is provided at its lower end with a cutter member 135 which is secured to said cutter bar by means of the ring plate 136 and bolts 137.

The machine as above described operates in the following manner:

The cutter bar 31 is raised to its maximum uppermost position by the folding of the connecting rod 18 as above set forth. This will permit the placing of the hub blank 97 on the platen 95 to which it is secured in the manner shown in Fig. 1, it being understood that the cradle 80 is in its initial horizontal position. As above described the hub blank 97 is provided with a row of external preformed teeth 98 of any suitable form. The cutter 135 is in effect an annular gear provided with internal teeth 138, see Figs. 11 and 12 which when the axis of the blank 97 and cutter 135 are in alignment will more or less snugly mesh with the blank teeth 98, the cutter bar 31 being then in its lowermost position. This relationship of cutter and blank is shown in Fig. 12. However, it is to be understood that to form an internal gear, the cutter is to be an external gear or cutter.

In the type of cutter shown it is desired to so cut the teeth of the blank that the same will ultimately be formed with convexly curved crowns and side faces, the walls between the roots of the teeth to be similarly curved. Fur-

thermore, any combination, portion or portions on these surfaces may be similarly cut with a cutting element extending around the entire periphery of the blank or only a portion thereof. The cutting edges of the cutter 135 are thus formed on the bottom profile edge of the teeth 138 around the entire peripheral circuit thereof as at 139, shown in Figs. 12 and 13. Or the cutter may be of the stepped type for abrading or cutting the teeth to shape so that solid blanks may be used. In Figs. 19, 20, 21 and 22 are shown various preferred structural forms of teeth that may be shaped from a solid blank. In Fig. 19, the teeth are shown formed with curved side wall surfaces, the tops or crests and roots of the teeth being also curved. In Fig. 20, the teeth are formed with similarly curved side wall surfaces, but in this case the crests and roots are formed as substantially flat or straight surfaces. In Fig. 21, the teeth are of conventional design, that is, formed with straight walls, crests and roots, but with the walls at one end of the teeth converging to form tapered ends on said teeth. In Fig. 22, the teeth are shown formed with straight side walls, and with the tops or crests and roots curved. It is to be understood that the above forms of the teeth are merely examples of the types of teeth and curved surfaces that can be formed by the machine, as other forms of surfaces may be shaped by the machine embodying various combinations of curved and straight surfaces.

With the axis of the cutter 135 and blank 97 in alignment the down stroke of the cutter on the blank will bring the cutter teeth 138 and blank teeth 98 into engagement with each other as shown in Fig. 12. In most cases this down stroke will be the initial cutting stroke removing any irregularities that may possibly appear on the bearing surfaces of the blank teeth 98. Attention at this point is called to the fact that each cutter tooth bears a definite relationship to each of the adjacent blank teeth which relationship must be maintained at all times in all subsequent cutting strokes.

After the above initial meshing and possible initial cut of the cutter and blank the cutter bar 31 is moved upwardly the cutter 135 being brought out of engagement with the blank 97. The cradle 80 is then placed at an angular position of predetermined amount as indicated by the angle β the plane of the blank teeth 98 assuming a similar angular position, see Fig. 14. This angular movement is initially accomplished by a suitable angular swinging movement of the control arm 108 the extent of this angular movement being indicated by the vernier 126. Actuation of the control arm 108 will partially rotate the worm shaft 107 which will operate the worm drive 108a and 109 to impart the necessary angular movement to the cradle 80. For this angular position of the cradle as well as the hub blank 97, it is obvious that the down or cutting stroke of the cutter 135 will remove those portions of the surface of the teeth 98 which are brought into the cutting path of the cutter teeth 138, indicated in Figs. 14 and 15 by the dotted lines 140 and 141. From an inspection of Figs. 14 and 15 it will be noted that the teeth 98 on the blank will each be differently cut, that is the teeth 98 in Fig. 14 shown 180° apart are cut on the crowns and on the roots between the walls of the teeth, while the teeth at right angles thereto and also 180° apart, are cut on their side faces as shown by the dotted lines 141 on the teeth 98a, Fig. 15, which is an elevational view of the teeth 98 on the blank 97, the intervening teeth being similarly cut on varied portions of their surfaces.

To have each tooth 98 on the blank similarly cut for the given angular position of the same it is necessary that each tooth be brought into the same angular position relative to the cutter 135, it being apparent that each tooth bears a different angular relationship to said cutter. This is accomplished by the action of the cam 54 on the slide 62 which through the pawl 69 and ratchet 68 will operate the worm drive 53—55 to turn the shaft 56. The pinions 59 and 104 which are of the same size will simultaneously rotate the sleeve 25 which carries the cutter bar 31, and the blank holder 85, the teeth 27 of the sleeve and the teeth of the ring gear 88 on the blank holder 85 being also of the same size though varying in form as shown. The amount of rotation of the sleeve and blank holder is such as to move the blank 97 and cutter 135 a tooth at a time or a small angular movement, which movement occurs prior to each cutting stroke of the cutter 135. Figs. 16 and 17 show the position of the blank teeth when the blank 97 is turned through 180° from the position shown in Figs. 14 and 15.

Upon the completion of an entire revolution of the blank 97 it is necessary to increase the angle of inclination of the cradle 80 with a consequent increase in the angular relationship of the blank 97 to the cutter 135. This is automatically accomplished by the action of the cam projection 112 on the control arm 108, see Figs. 6 and 7. The position of the cam 112 shown therein is at the beginning of a revolution. Upon the completion of a revolution of the blank holder 85, the cam 112 will move the control arm to the right which movement through the ratchet mechanism 113 and worm drive 108a—109 will impart the necessary increase in the inclination of the cradle 80 carrying the blank holder 85. This inclination is increased until the plain portion 121 of the ratchet 113 is brought into the path of the pawl which thus renders the pawl and ratchet inoperative and as a result prevents further rotation of the worm 108a on the worm sector 109. It is of course obvious that this automatic movement may be optionally displaced by a manual operation of the control arm 108.

Upon the conclusion of the above set forth operations there will be formed convexly curved surfaces on the crowns, side faces and on the walls between the roots of the teeth of the hub blank, each tooth being similar in all respects to its adjacent tooth.

It is to be understood that the form of hub blank teeth and cutter shown are merely examples of the type of forming or shaping operations capable of being performed by the above described machine. That while the cutter is provided with cutting edges on all the teeth thereon the cutter nevertheless may be provided with any desired number of cutting teeth which may be variously positioned in any definitely designed arrangement. Furthermore the cutting edges on the teeth of the cutter may only be formed on certain of the edges of the teeth whereby only the corresponding surfaces of the teeth of the blank will be shaped or cut to the selected form.

In any case, the above referred to cuts while producing a plane or flat surface are so small, in most cases being only a few thousandths of an inch, that the succession of these cuts for in-

creasing angles of inclination of the blank will produce a finished surface that to all intents and purposes will be curved. It has also been discovered that for most cases the blank has to be inclined in increments of a fraction of a degree for each succeeding series of cuts, as above set forth. However, if rotary cutters are used even these small flat surfaces blend into a perfect curve.

It is to be further understood that this invention is not limited to any specific construction, arrangement or form of the parts, or to the particular combinations illustrated, as numerous modifications and changes may be made without departing from the spirit of the claims.

I claim:—

1. The method of generating toothed elements having surfaces curved in two or more places on a blank which includes presenting said blank to a cutting element in successively varying axial positions.

2. The method of generating teeth on a blank wherein each tooth is curved in the direction of its length on at least two surfaces thereof which includes successively presenting said teeth to a cutting element in successively varying axial positions.

3. The method of generating teeth on a blank wherein each tooth is curved on a portion of its length on at least two of its surfaces which includes presenting the blank in varying positions to a cutting element.

4. The method of generating teeth on a blank wherein the teeth are curved in at least two planes which includes successively presenting said blank to a reciprocating cutting element while continuously rotating said blank and successively varying the position of its axis with relation to the cutting element.

5. The method of generating tapering toothed elements on a blank wherein vertical sides of the teeth are curved at least on one end which includes presenting a blank on which the teeth are to be generated to a cutting element in successively varying axial positions.

6. A method of shaping gears which consists in providing a cutter having teeth corresponding in contour to the teeth to be cut on a blank, producing a relative reciprocation between the cutter and the blank and inclining the blank axis relative to the cutter axis in successive increments whereby the cutter will act on different portions of the tooth surface on successive strokes.

7. The method of shaping gear teeth which consists in providing a member with a cutting edge having the same contour as the surface of the tooth to be shaped on a blank, imparting a relative reciprocation between the cutting member and the blank and inclining the surface of the tooth to be shaped into the path of movement of said member in successive increments whereby different portions of said tooth surface will be removed upon successive strokes.

8. The method of shaping gear teeth which consists in providing a cutter with teeth adapted to engage simultaneously all the teeth on a gear blank, producing a relative reciprocation between the cutter and the blank, and changing the angular position of the blank axis relative to the cutter axis whereby portions of said blank teeth will be removed upon a cutting stroke.

9. The method of shaping gear teeth which consists in providing a cutter with teeth adapted to engage simultaneously all the teeth on a gear blank, producing a relative reciprocation between the cutter and the blank, changing the angular position of the blank axis relative to the cutter axis and rotating in successive increments the blank in said angular position simultaneously with the cutter for a complete revolution.

10. The method as set forth in claim 9, and repeating the simultaneous rotation in successive increments of said blank and cutter for each increase by successive increments in the angular position of said blank.

11. The method of shaping external teeth on a gear blank which consists in providing a cutter with internal teeth adapted to engage simultaneously all the teeth on the gear blank, producing a relative reciprocation between the cutter and blank, changing the angular position of the blank axis relative to the cutter axis and rotating in successive increments the blank in said angular position simultaneously with the cutter for a complete revolution.

12. The method as set forth in claim 11, and repeating the simultaneous rotation in successive increments of said blank and cutter for each increase by successive increments in the angular position of said blank.

13. The method of shaping gear teeth on a blank which consists in inclining the blank axis by successive increments relative to the axis of a reciprocating cutter provided with teeth adapted to simultaneously cut the entire peripheral surface of said blank teeth, and for each successive angular increment simultaneously rotating the blank and cutter a tooth at a time so that for a complete revolution each blank tooth will have assumed the same angular relation to the cutter.

14. The method of shaping gear teeth on a blank which consists in providing a cutter having teeth corresponding in contour to the teeth to be cut on a blank, producing a relative reciprocation between the cutter and blank, rotating said blank by successive increments for a complete revolution and for each increment inclining in successive increments the blank axis relative to the cutter axis, and in the same plane repeating this inclination in successive increments in the opposite direction with respect to the cutter axis.

15. The method of shaping gear teeth on a blank which consists in providing a cutter having teeth corresponding in contour to the teeth to be cut on a blank, producing a relative reciprocation between the cutter and blank, rotating said blank by successive increments for a complete revolution and for each increment inclining the blank axis relative to the cutter axis for a cutting stroke and in the same plane swinging said blank in the opposite direction with the same inclination for an additional cutting stroke and repeating said swinging operation in the same plane for successive increments in the inclination of said blank.

16. A machine for shaping gear teeth comprising a cutter bar, means for reciprocating the same, a cradle, means for rockably supporting the same, a blank holder rotatably mounted in said cradle and movable therewith, selective manual and automatic means for inclining said cradle relative to said cutter bar and means for automatically and simultaneously rotating said cutter bar and said blank holder.

17. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a cutter bar rotatably mounted in said cylindrical portion, means

for reciprocating the same, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, selective manual and automatic means for inclining said cradle relative to said cutter bar and means for automatically and simultaneously rotating said cutter bar and said blank holder.

18. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a sleeve rotatably mounted within said cylindrical portion, a cutter bar within said sleeve reciprocating therein and connected to said sleeve for rotative movement therewith, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, selective manual and automatic means for inclining said cradle relative to said cutter bar and means for automatically and simultaneously rotating said cutter bar and said blank holder.

19. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a sleeve rotatably mounted within said cylindrical portion, a cutter bar within said sleeve reciprocating therein and connected to said sleeve for rotative movement therewith, means supported above said cylindrical portion and connected to said cutter bar for reciprocating the same, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, means for inclining said cradle relative to said cutter bar and means connected to said first mentioned means for automatically and simultaneously rotating said cutter bar and said blank holder.

20. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a sleeve rotatably mounted within said cylindrical portion, a cutter bar within said sleeve reciprocating therein and connected to said sleeve for rotative movement therewith, means supported above said cylindrical portion and connected to said cutter bar for reciprocating the same, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, means for inclining said cradle relative to said cutter bar and means operatively connected to said first mentioned means and to said sleeve and blank holder for automatically and simultaneously rotating said cutter bar and said blank holder.

21. A machine for shaping gear teeth comprising a reciprocating cutter bar, a blank holder adapted to have a gear blank rigidly secured thereto, means for inclining said blank holder relative to said cutter bar, and means for simultaneously rotating said blank holder with said cutter bar, and a single cutter attached to said cutter bar adapted to simultaneously produce a cut on all the gear blank teeth in a single cutting stroke.

22. A machine for shaping gear teeth comprising a reciprocating cutter bar, a blank holder adapted to have a gear blank rigidly secured thereto, a cutter attached to said cutter bar, means for inclining said gear blank teeth in the path of said cutter, and means for simultaneously rotating said blank holder with said cutter bar, said cutter upon a cutting stroke removing simultaneously portions on selected surfaces of each of said gear blank teeth.

23. A shaping machine comprising a cutter bar, means for reciprocating the same, a pivotally supported cradle, a blank holder rotatably mounted in said cradle, means for inclining said cradle about its pivotal axis relative to said cutter bar, a coaxial driving connection between said cutter bar and blank holder for simultaneously rotating the same, said cutter bar, cradle and blank holder being so arranged with respect to each other as to have the respective axes thereof intersect at a common point irrespective of their angular relationship.

24. A shaping machine comprising a cutter bar, means for reciprocating the same, a pivotally supported cradle, a blank holder rotatably mounted in said cradle and movable therewith, means for inclining said cradle relative to said cutter bar and driving means individual to said cutter bar and blank holder for automatically and simultaneously rotating the same, the driving means for said blank holder being in direct positive engagement therewith for all angular positions of the same.

25. In a machine for shaping gear teeth, an angularly movable blank holder, a ring gear fixedly secured to said blank holder, a power driven pinion meshing with said ring gear, said ring gear being provided with external teeth having convexly curved crowns and roots and said pinion teeth being provided with complemental concavely curved crowns and roots whereby line contact between said cooperating teeth is established for all angular positions of said blank holder.

26. In an apparatus, an angularly moving blank holder, a ring gear fixedly secured to said blank holder, a power driven pinion meshing with said ring gear, said ring gear being provided with external teeth convexly curved and said pinion being provided with complemental concavely curved teeth whereby line contact between said cooperating teeth is established for all angular positions of said blank holder.

27. An apparatus for simultaneously generating a plurality of different surfaces on a blank having, in combination, means for supporting and rotating said blank, means for supporting and rotating a reciprocating tool for operation on the blank, means for automatically inclining said blank in the path of movement of said tool in successive increments and means for simultaneously rotating said blank and tool for a complete revolution for each increment of inclination of said blank.

28. An apparatus for generating gear teeth including a cutter, a holder for a gear blank, means for angularly moving said blank holder in successive increments, means for giving relative movement to said cutter and said blank holder and for providing relative cutting motions therebetween while maintaining the point of intersection of the axes of the said cutter and said blank holder constant for all angular positions of said blank holder.

29. A shaping machine comprising a cutter bar, means for reciprocating the same, a blank holder arranged in the path of movement of said cutter bar, means for inclining said blank holder relative to said cutter bar, driving means individual to said cutter bar and blank holder for simultaneously rotating the same, the driving means for said blank holder being in direct positive engagement therewith for all angular positions of the same, and means automatically varying the angular position of the said blank holder for each revolution of the same.

30. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a sleeve rotatably mounted within said cylindrical portion, a cutter bar within said sleeve and connected to said sleeve for rotative movement therewith, a crank shaft supported above said cylindrical portion and connected to said cutter bar for reciprocating the same, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, manually and automatically operated means on one of said side walls operatively connected to said cradle for inclining the same relative to said cutter bar and a direct driving connection operatively connected to said crank shaft and to said sleeve and blank holder for automatically and simultaneously rotating said cutter bar and said blank holder.

31. In a machine for shaping gear teeth comprising a base, side and rear walls and an overhanging cylindrical portion, a sleeve mounted in said cylindrical portion, a cutter bar reciprocating therein and connected to said sleeve for rotative movement therewith, a power driven crank shaft supported above said cylindrical portion, a connecting rod on said crank and connected to said cutter bar for reciprocating the same, a cradle rockably supported on said side walls, a blank holder rotatably mounted in said cradle and movable therewith, means for inclining said cradle and means for simultaneously rotating said cutter bar and said blank holder.

32. The structure as specified in claim 31, and locking means on said base adapted to engage said cradle for locking the same in its normal horizontal inoperative position.

33. The structure as specified in claim 31, said connecting rod being formed in two sections pivotally connected together, said pivotal connection being offset with respect to the axis of said cutter bar and spring means on said connecting rod for maintaining the sections in alignment.

34. The structure as specified in claim 31, said cradle inclining means comprising a vertical shaft rotatably supported on one of said side walls adjacent said cradle, a worm on said shaft, a sector worm wheel rigid with said cradle and meshing with said worm, a manually operated lever attached to said shaft for rotating the same and cam actuated pawl and ratchet means associated with said cradle and shaft for automatically rotating said shaft by successive increments upon a complete revolution of said cradle.

35. The structure as specified in claim 31, said last mentioned means comprising spaced bearing brackets, a horizontal drive shaft rotatably mounted on the upper bearing bracket, a vertical shaft rotatably supported by said brackets, a worm drive between said drive shaft and said vertical shaft, a pinion on said vertical shaft meshing with teeth on said sleeve, a ring gear on said blank holder, a pinion on the lower end of said vertical shaft meshing with said ring gear, and a cam operated mechanism associated with said crankshaft and said drive shaft for automatically rotating said drive shaft and vertical shaft by successive increments for each revolution of said crankshaft.

36. The structure as specified in claim 31, said last mentioned means comprising spaced bearing brackets, a horizontal drive shaft rotatably mounted on the upper bearing bracket, a vertical shaft rotatably supported by said brackets, a worm drive between said drive shaft and said vertical shaft, a pinion on said vertical shaft meshing with teeth on said sleeve, a ring gear on said blank holder, a pinion on the lower end of said vertical shaft meshing with said ring gear, and a cam operated mechanism associated with said crankshaft and said drive shaft for automatically rotating said drive shaft and vertical shaft by successive increments for each revolution of said crankshaft, said spaced bearing brackets being movably supported on spaced guide means rigid respectively with said overhanging portion and said rear wall and resilient means on said guide means and acting on said bearing brackets for maintaining the pinions on said vertical shaft in intimate engagement with the cooperating teeth on said sleeve and blank holder whereby back-lash is reduced to a minimum.

37. The structure as specified in claim 31, said last mentioned means comprising spaced bearing brackets, a horizontal drive shaft rotatably mounted on the upper bearing bracket, a vertical shaft rotatably supported by said brackets, a worm drive between said drive shaft and said vertical shaft, a pinion on said vertical shaft meshing with teeth on said sleeve, a ring gear on said blank holder, a pinion on the lower end of said vertical shaft meshing with said ring gear, and a cam operated mechanism associated with said crankshaft and said drive shaft for automatically rotating said drive shaft and vertical shaft by successive increments for each revolution of said crankshaft, said ring gear being provided with external teeth having convexly curved crowns and the roots between the teeth being similarly curved whereby there will be the same driving connection at all times between said lower pinion and ring gear irrespective of the angular relation of the axis of said ring gear relative to the axis of said vertical shaft.

38. The structure as specified in claim 31, said last mentioned means comprising spaced bearing brackets, a horizontal drive shaft rotatably mounted on the upper bearing bracket, a vertical shaft rotatably supported by said brackets, a worm drive between said drive shaft and said vertical shaft, a pinion on said vertical shaft meshing with teeth on said sleeve, a ring gear on said blank holder, a pinion on the lower end of said vertical shaft meshing with said ring gear, and a cam operated mechanism associated with said crankshaft and said drive shaft for automatically rotating said drive shaft and vertical shaft by successive increments for each revolution of said crankshaft, said ring gear being provided with external teeth having convexly curved crowns and the roots between the teeth being similarly curved, the cooperating teeth on the lower pinion being formed with concave curved crowns the roots between said teeth being similarly curved whereby there will be the same driving connection at all times between said lower pinion and ring gear irrespective of the angular relation of the axis of said ring gear relative to the axis of said vertical shaft.

JULIAN S. LOEWUS.