June 23, 1931. G. L. BAYLEY 1,811,254

METHOD AND APPARATUS FOR GENERATING CURVED SURFACES ON GEAR TEETH

Filed Sept. 21, 1926 7 Sheets-Sheet 1

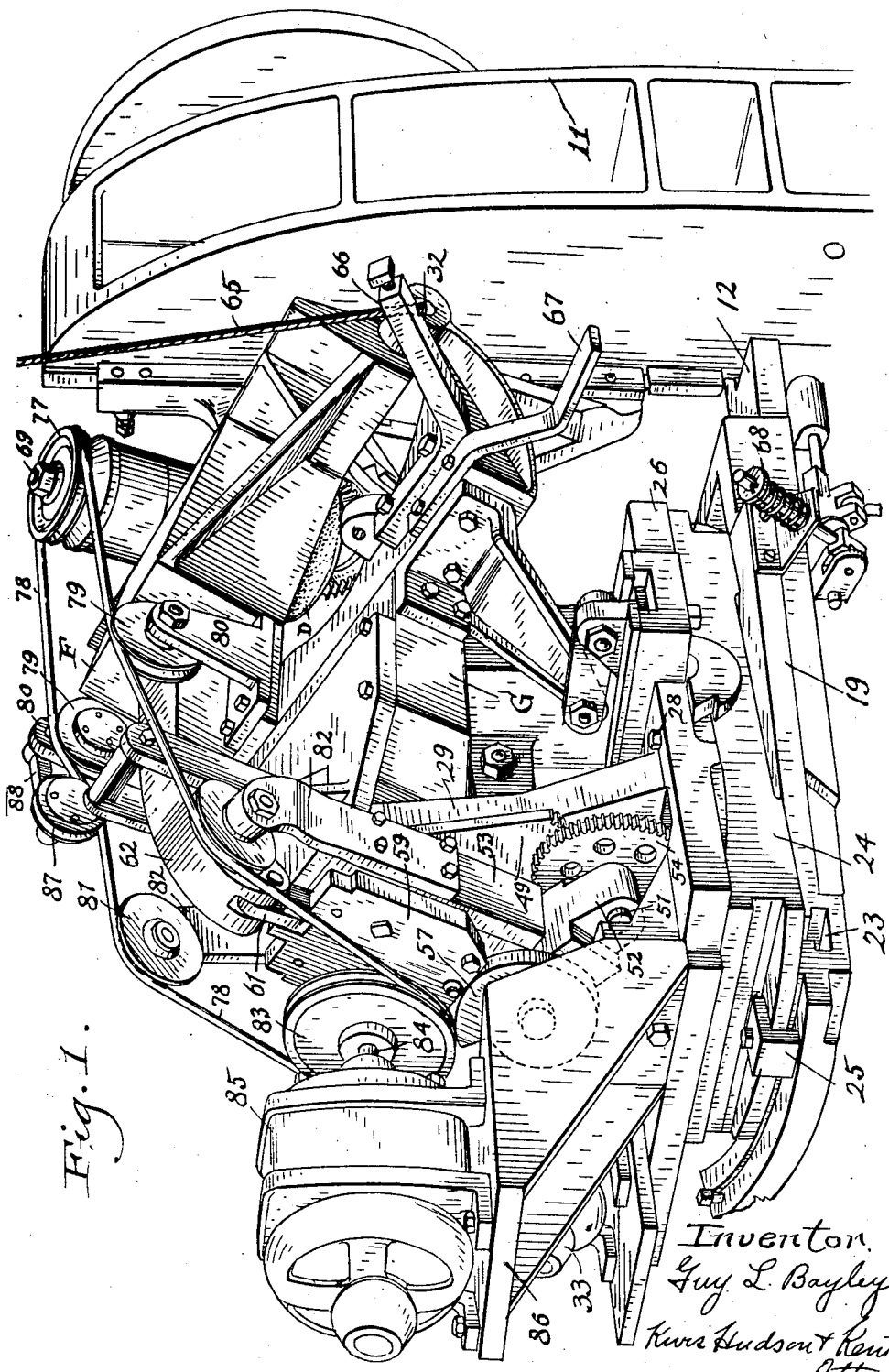


Fig. 1.

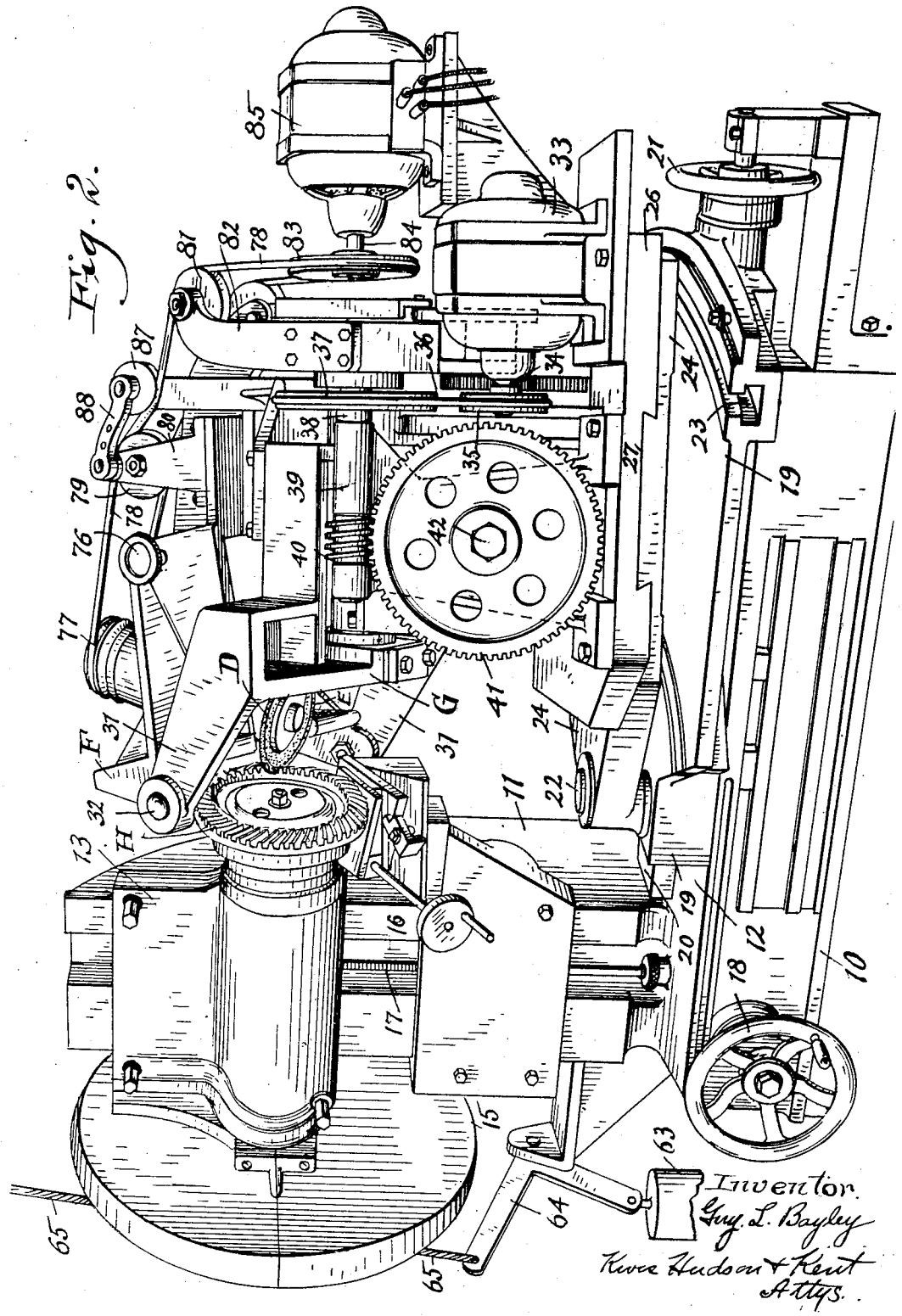
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Fig. 2.



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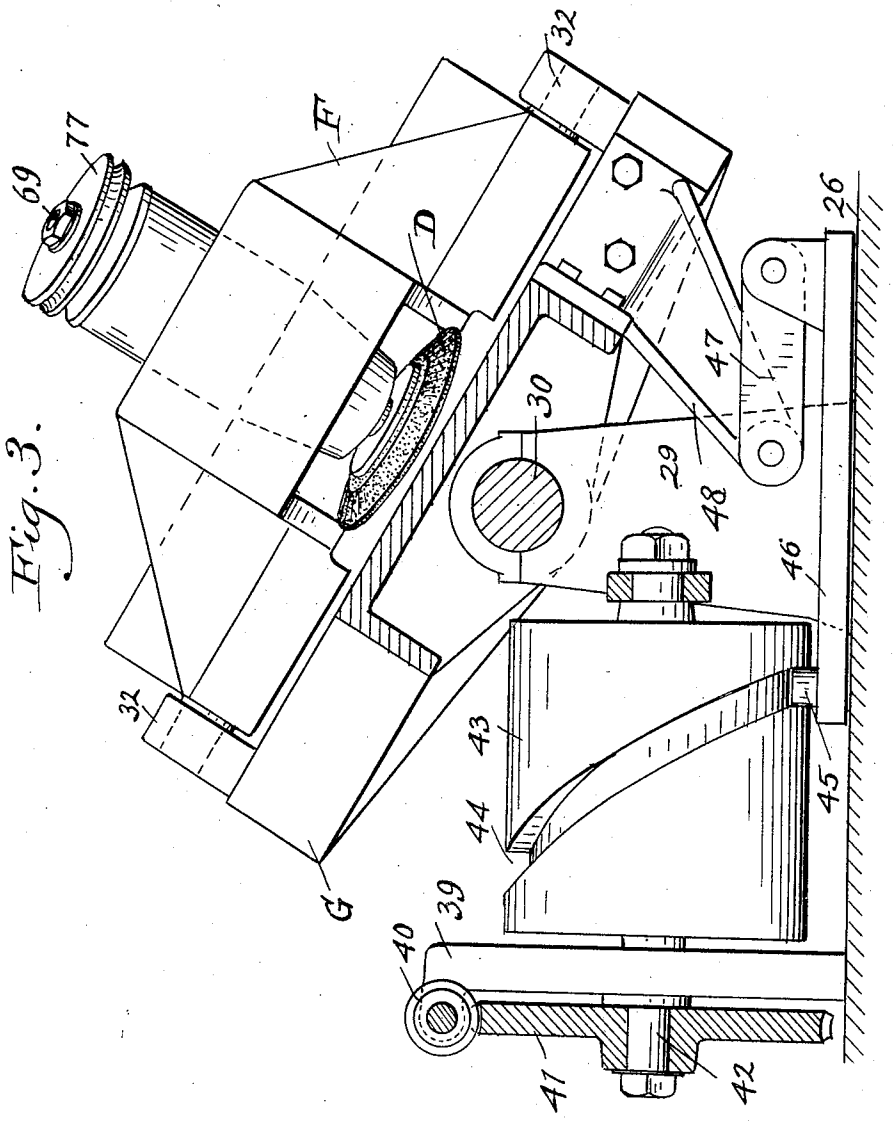


Fig. 3.

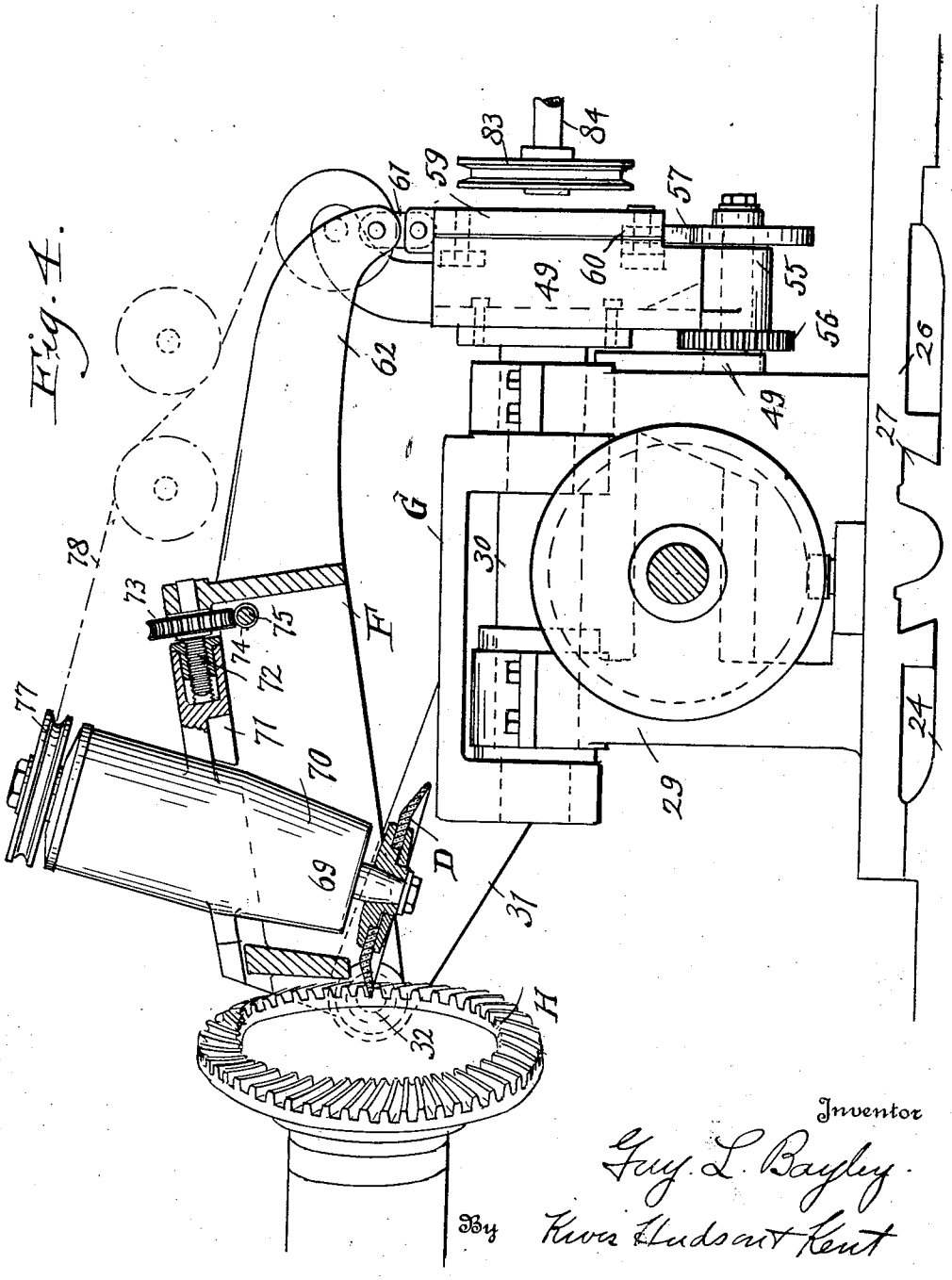
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METHOD AND APPARATUS FOR GENERATING CURVED SURFACES ON GEAR TEETH

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Fig. 4.



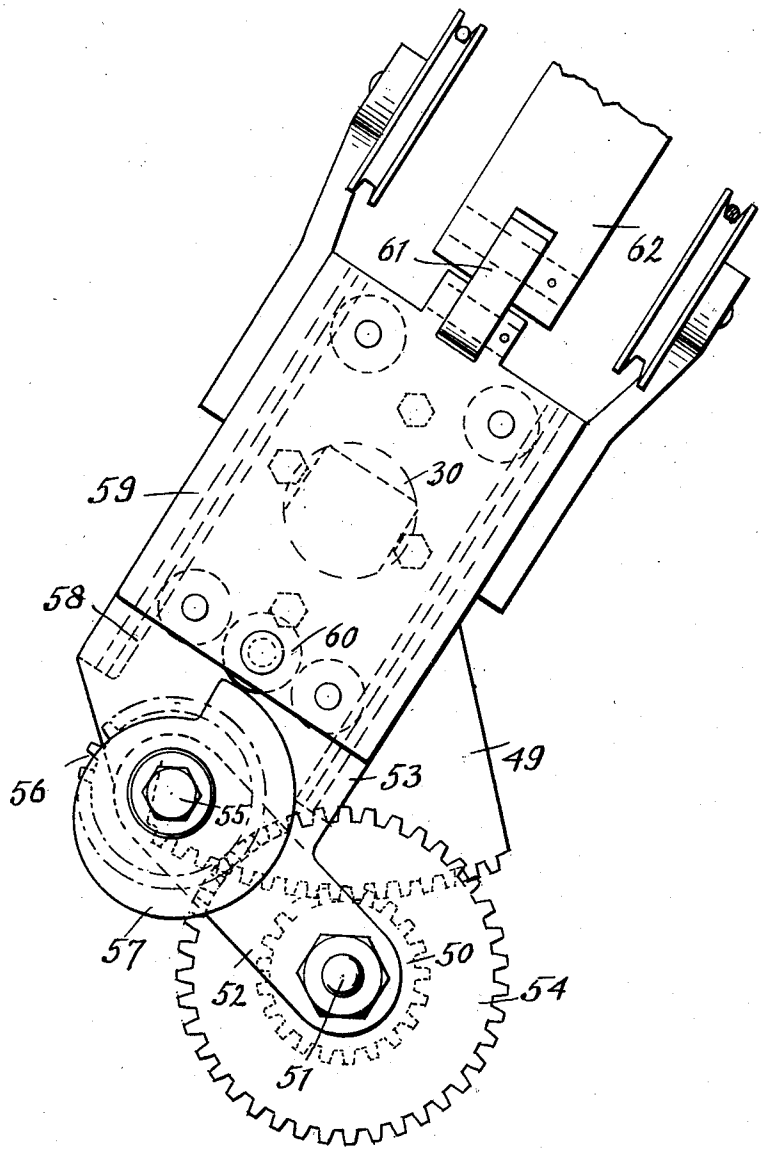
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METHOD AND APPARATUS FOR GENERATING CURVED SURFACES ON GEAR TEETH

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Fig. 5.



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METHOD AND APPARATUS FOR GENERATING CURVED SURFACES ON GEAR TEETH

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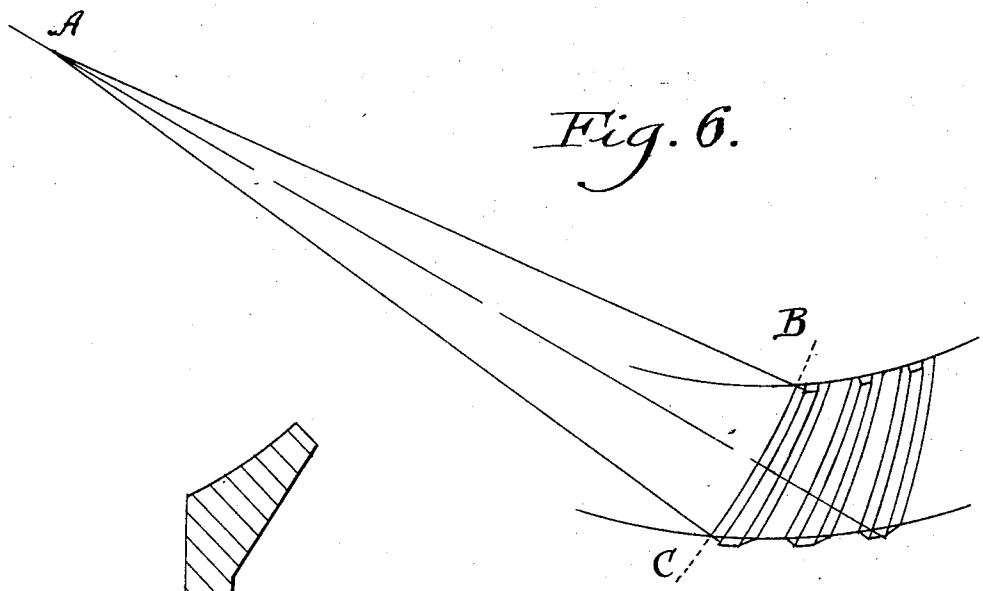


Fig. 6.

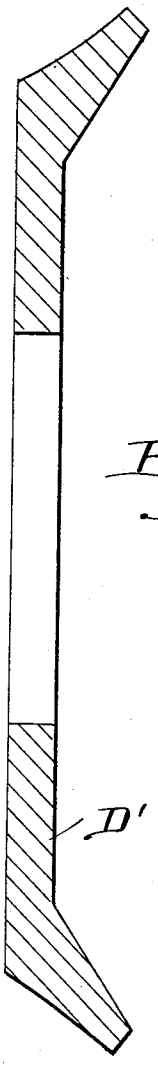


Fig. 8.

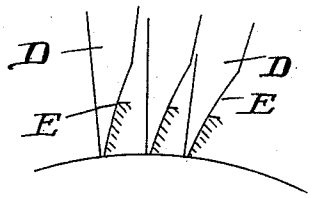


Fig. 7.

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Fig. 9.

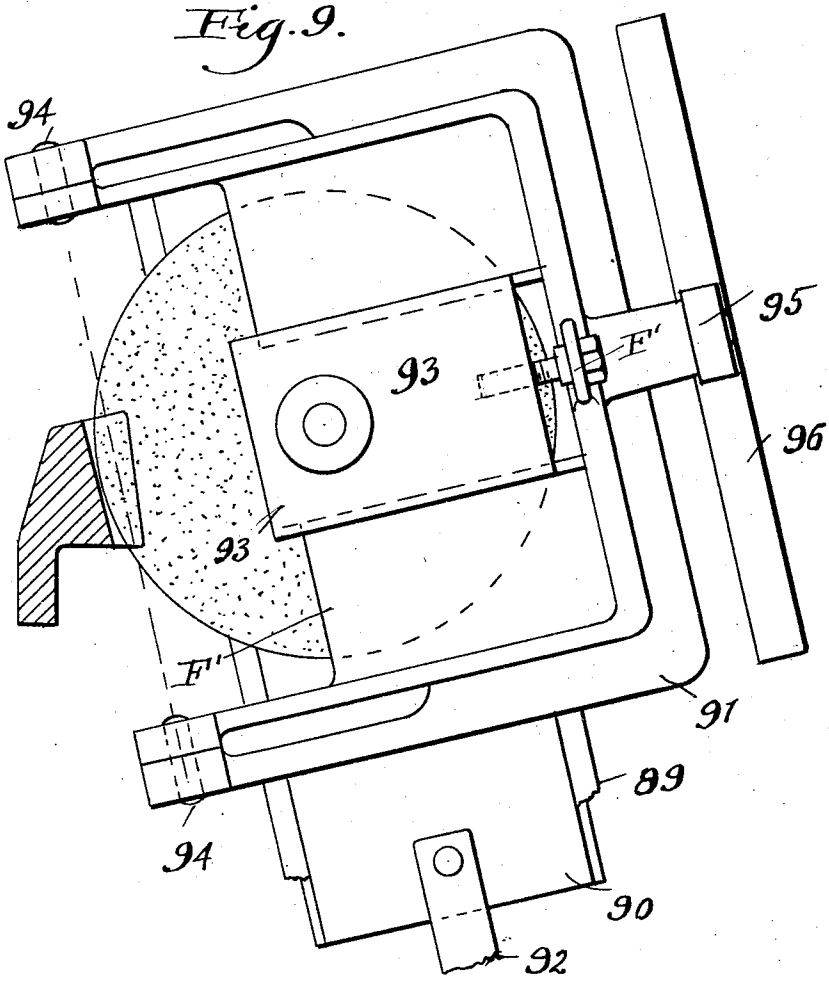
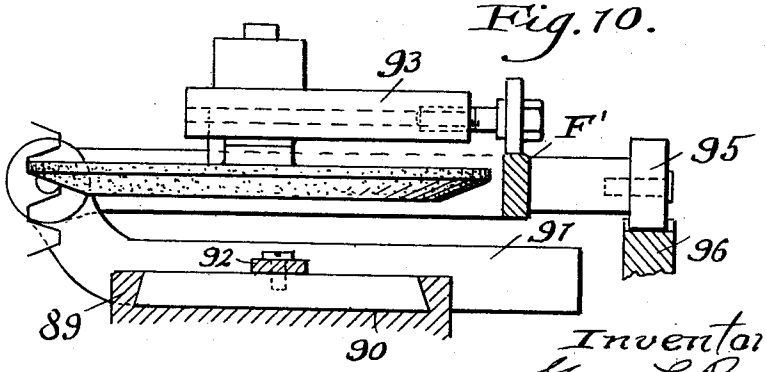


Fig. 10.



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR GENERATING CURVED SURFACES ON GEAR TEETH

Application filed September 21, 1926. Serial No. 136,803.

The present invention relates to a method and apparatus for generating the curved faces of gear teeth and more particularly to a method and apparatus for generating tooth faces in which the transverse form of the tooth surface varies between the opposite ends of the tooth, the principle of the present invention being applicable to bevel gears and to spur gears in which the teeth are so formed as to have a transverse form which varies between the ends of the teeth.

Many machines have heretofore been designed for generating involute and octoid curves upon the faces of spur and bevel gears by imparting relative movements to a cutter and a blank corresponding to the movement which would be produced by rolling the curved surface upon the plane of the cutter so that the face of the cutter is held, at all times, tangent to the curve to be generated. Assuming perfect accuracy of adjustment and perfect correlation of the various movements required, such machines would generate theoretically correct gear teeth. Perfect accuracy of adjustment, perfect machining of the pivot bearings and of the gearing by which the movements are effected is, of course, impossible and the curves generated are consequently only close approximations to the theoretically correct curve. The combined movements of rotation and translation required in geometrical methods of generation require complicated mechanisms, all parts of which must be machined with extreme accuracy and consequently such machines are very costly.

Furthermore, due to the complicated construction and the greater number of simultaneous and correlated movements required, the operation thereof is slow and the error in the work is increased in bevel gears, particularly bevel gears with curved teeth. The accurate finishing of gear tooth surfaces is very desirable but heretofore the accurate finishing operation has so greatly increased the cost of the gears that higher limits of error have been permitted than desirable, and often the finishing operation is omitted due to the excessive cost where greatly improved results could be obtained with accurately meshing gears.

The present invention has for an object to provide an inexpensive method and apparatus for accurately generating the curved faces of gear teeth thereby making possible the manufacture of accurately meshing gears at a relatively low cost.

The present invention has for a further object to provide a method for generating gear tooth surfaces which, while not theoretically perfect, enables the mechanism to be greatly simplified and reduces the errors due to complicated actuating mechanisms, producing gear teeth approximating the theoretically correct form within the very small limits of error which have been established for accurately finished gears by machines heretofore used.

A further object of the invention is to provide a machine which is simple and rugged in construction and which can be operated at a high speed.

A further object is to provide a method of generating curved tooth surfaces in which fewer relative movements between the cutting element and blank are required.

A further object is to provide a method of generating curved tooth surfaces, of bevel gears, in which the gear blank is held in a fixed position and all of the necessary movements are imparted to the cutting element.

One form of bevel gear now extensively used, particularly in automobile rear axles, is one in which the teeth are of arcuate form, such bevel gears are usually generated from a conical blank by a crown milling cutter having a circular row of teeth projecting from the face thereof at the periphery, the teeth being provided with inner and outer

cutting edges lying in concentric oppositely tapering surfaces of revolution. During the cutting operation, the gear blank has movements relative to the cutter about its own axis and about a second axis passing through the apex of the pitch cone, the movements about the two axes being so correlated that the movement of the blank relative to the cutter corresponds to the movement the finished gear would have in rolling on its conjugate crown gear, the cutter having a position relative to the blank corresponding to a tooth of the crown gear.

After a gear has been cut, it is hardened by suitable heat treatment and this heat treatment causes more or less distortion of the gear teeth making it desirable to subject the gear teeth to a grinding operation for the purpose of eliminating the inaccuracy introduced by the heat treatment. The grinding of arcuate bevel gear teeth has heretofore been an exceedingly difficult problem, since the tooth surfaces cannot be engaged by the plane face of a grinding disk in the ordinary methods of gear grinding, and even if this were possible, a very complicated combination of movements would be required to maintain the grinding surface tangent to the curve to be generated while moving from one end of the tooth to the other end across the face of the tooth.

Attempts have been made to grind the arcuate bevel gears in the same machine employed for cutting them, or in a similarly constructed machine, employing an emery wheel of substantially the same form as the crown milling cutter used for cutting teeth, the emery wheel being provided with a laterally projecting annular flange having conically oppositely inclined inner and outer faces. With this form of grinding, the wheel has a large arc of contact longitudinally with the tooth, and the grinding action is limited to a small width where the surface of the wheel is tangent to the tooth profile. Owing to these restrictions, it is impossible to remove metal from the tooth surface at a high rate, and a considerable time is required to grind progressively from the top to the bottom of the tooth.

A very important feature of the present invention is the provision of a method for grinding arcuate bevel gear teeth by means of a disk wheel, which is of such form that it makes line contact from the top to the bottom of the tooth and further to provide a method of giving such disk movements along the length of the tooth that the curved surface produced thereby will be a very close approximation to the theoretical correct tooth form.

With the above and other objects in view, the invention may be said to comprise the method and apparatus as illustrated in the accompanying drawings hereinafter described and particularly set forth in the appended claims, together with such variations and modifications thereof as will be apparent to one skilled in the art to which the invention appertains.

Reference should be had to the accompanying drawings forming a part of this specification, in which:

Fig. 1 is a perspective view looking toward the front side of the machine;

Fig. 2 is a perspective view looking toward the rear side of the machine;

Fig. 3 is a sectional detail view, showing the means for moving the support for the cutting element about its fixed axis;

Fig. 4 is a sectional detail view, showing the means for swinging the supporting member upon which the cutting element is mounted about its axis on the swinging support;

Fig. 5 is a detail view showing the mechanism for swing the cutter supporting member in end elevation;

Fig. 6 is a diagram showing the location of the fixed axis about which the cutter support swings relative to the arcuate root line of the tooth surface to be generated;

Fig. 7 is a diagrammatic view showing different angular positions of the grinding disk with respect to a tooth being ground;

Fig. 8 is a detail sectional view showing a grinding disk for finishing the sides of the arcuate gear tooth opposite those finished by the grinding disk shown in Figs. 1 to 5;

Fig. 9 is a diagrammatic plan view showing a modification of the machine for finishing straight bevel gear teeth; and

Fig. 10 is a side elevation of the mechanism shown in Fig. 9.

While the principle of the present invention is applicable generally to the generating of teeth having a transverse curvature, which varies between the ends of the teeth, the invention as illustrated in the accompanying drawings is embodied in a machine for grinding the surface of bevel gear teeth. The principle for the invention is also applicable generally to cutting and finishing operations, the grinding wheel shown being one of various well known types of generating cutting elements which may be employed in a generating machine of this character.

In generating tooth surfaces by the method of the present invention, a cutting element is employed which has a tooth engaging portion formed to have a line contact with the tooth surface to be generated transversely across the face of a tooth, and this cutting element is caused to transverse the blank lengthwise of the tooth, with the cutting portion in engagement with the face of the tooth. In addition to the traversing or feeding movement, the cutting element is caused to rock about an axis transverse to

and intersecting the line of contact between the cutter and tooth, while it is being moved across the blank, the rate of movement of the cutter about said axis being so correlated to the rate of movement of the cutting element along the blank that an exceedingly close approximation to a tooth of theoretically correct form is produced.

In generating the curved surfaces of arcuate bevel gear teeth, the cutting element is caused to swing about a fixed axis which passes through the center of curvature of the root line of the tooth face and is substantially perpendicular to the plane of the root line or, in other words, at the axis of rotation of a crown cutter, which could be employed to generate the surface of the arcuate tooth.

In the diagram shown in Fig. 6, this center is indicated by the letter A and the root line of the gear tooth is indicated by the arc BC. In the accompanying drawings, the cutting element which is shown as a grinding disk is indicated by the letter D and has a bevel peripheral face portion E, which is slightly concave and has a transverse curvature such that it will contact across the face of a theoretically correct octoid tooth at a point substantially midway between the ends of the tooth. Since the transversely octoid surface of a theoretically correct bevel gear tooth has its origin in a cone coaxial with the pitch cone and having the same apex angle, the tooth face along longitudinal lines, parallel with the pitch line, has a transverse curvature which increases toward the inner end of the tooth and decreases toward the outer end of the tooth. I have found that by imparting to a cutting element such as above described, a rocking movement about an axis moving with the cutter about the fixed axis and tangent to the face portion thereof, contacting with the tooth, a very close approximation to the theoretically correct form of the arcuate bevel gear tooth may be obtained. The latter axis is preferably tangent to the grinding disk at the point thereof which contacts with the pitch line of the tooth face. In Fig. 7 of the drawings, the position of the disk D relative to the inner central and outer portion of a tooth along which it is moved is shown.

As shown in Figs. 1 to 5, the grinding disk D is carried by a supporting member F which is pivoted to swing upon a support G, which is mounted to swing about the fixed axis, passing through the center point A, above referred to. A gear blank H is supported in a fixed position with the tooth to be operated upon in a position with respect to the center A, corresponding to the arc BC in Fig. 6. The surface of the arcuate tooth is generated by a combined rocking movement of the disk D about the two axes, the simultaneous movements of the disk about the two axes being due to simultaneous movements imparted to the supporting member F and support G by means which will be hereinafter described.

Referring to Figs. 1 to 5 of the drawings, the grinding machine is provided with a supporting frame 10 which has an upwardly extending standard 11, at the forward end thereof, and a horizontal bed 12 extending rearwardly from the standard. The standard 11 serves as a support for a blank spindle carriage 13 in which is journaled a suitable spindle 14 to which the gear blank to be operated upon is attached. The rear end of the spindle 14 extends into an indexing mechanism housing, attached to the rear end of the spindle carriage 13 and having suitable mechanism by which the spindle may be turned through an angle corresponding exactly to the annular space between successive teeth of the gear to be generated. The indexing mechanism may be one of the many indexing mechanisms commonly employed in gear cutting and grinding machines and this mechanism is not herein illustrated. The spindle carriage 13 is mounted in a vertical guideway 16 in the front face of the standard 11 and is adapted to be adjusted to different heights above the bed 12 by means of a suitable lead screw 17 which is operated by a hand wheel 18 at the front of the frame 10.

Upon the bed 12 there is mounted a carriage 19 which is slidable lengthwise of the bed toward and from the standard 11 on a suitable slideway 20, the adjustment of the carriage 19 on the slideway 20 being effected by a suitable lead screw operated by a hand wheel 21 at the rear end of the frame. At the forward end thereof, the carriage 19 has an upwardly projecting vertical pivot post 22, and, at the rear end thereof, an arcuate undercut slot 23 concentric with the pivot post 22. Mounted upon the carriage 19 there is a laterally swinging supporting plate 24 which is pivoted at its forward end on the post 22 and provided at its rear end with a clamping member 25, sliding in the groove 23 and adapted to clamp the plate 24 in different positions of lateral adjustment on the carriage 19. On the support 24 there is mounted a mechanism supporting plate 26 which is movable laterally of the plate 24 on a suitable slideway 27 extending across the plate 24, the mechanism support 26 being secured in adjusted position by suitable clamping bolts 28. Adjacent the rear side thereof, the supporting plate 26 has fixed thereto a vertical standard 29 which has bearings at its upper end supporting a pivot shaft 30 which may be so positioned with respect to the gear blank that its axis intersects the center point A of the gear tooth to be ground and forms the pivot

of the support G for the grinding mechanism. The support G has forwardly extending spaced arms 31 which have aligned bearing portions at the outer end thereof adapted to receive trunnions 32 fixed to the member F upon which the grinding disk is mounted.

In the operation of the grinding disk, movements will be imparted simultaneously to the supporting member F and to the support G, upon which the member F is mounted, as will now be explained. Upon the rear end of the supporting plate 26, there is mounted an electric motor 33 which has a shaft 34, to which is attached a belt pulley 35, over which runs a belt 36 which drives a pulley 37 fixed to a horizontal shaft 38 journaled in the upper end of a standard 39, secured to the plate 26 adjacent the front edge thereof. The shaft 38 carries a worm 40 which meshes with a worm gear 41 fixed to a transverse shaft 42 journaled in the standards 29 and 39. Between the standards, a cylindrical cam member 43 is fixed to the shaft 42 and this cylindrical member is provided with a helical groove 44 which receives a pin 45, which projects upwardly from a slide 46 mounted on the base plate 26. The slide 46 is connected by a link 47 with an arm 48 rigidly secured to the pivoted support G and extending downwardly therefrom. Rotation of the cam member 43 causes the slide 46 to be reciprocated and the support G to be oscillated upon the horizontal pivot shaft 30. Means is also provided for causing an oscillating movement of the supporting member F about its trunnions simultaneously with the rocking movement of the support G. For effecting this movement of the supporting member F, a segment plate 49 is fixed to the standard with its toothed periphery concentric with the axis of the shaft 30, and, meshing with the teeth of this segment plate, there is a gear 50 fixed to a shaft 51 which is journaled in a laterally extending arm 52 at the lower end of an extension 53, rigidly secured to the support G at the rear end thereof and extending downwardly therefrom. A large gear 54 is fixed to the shaft 51 beside the gear 50, and in the lower end of the extension 53 there is journaled a shaft 55 parallel with the shaft 51 and having fixed thereto a gear 56 which meshes with the large gear 54. Fixed to the shaft 55 alongside the gear 56, there is a cam 57 which serves to impart the rocking movements to the supporting member F. The vertical extension 53, at the rear end of the rocking support G, has a slideway 58 on the outer side thereof, and in this slideway there is mounted a plate 59 which carries a roller 60 at its lower end which rests upon the cam 57. The upper end of the slide is connected by a link 61 with an arm 62 fixed to the supporting member F and extending rearwardly therefrom.

As the support G rocks upon the shaft 30, the gear 50 is caused to travel over the fixed segment 49 whereby it is rotated, turning the large gear 54 and driving the shaft 55 to which the cam 57 is attached through the gear 56. As the support G is rocked back and forth upon the shaft 30, the cam 57 is oscillated, swinging the rear end of the supporting member F upwardly during movement of the support G in one direction and permitting the rear end of the supporting member F to swing downwardly, during movement of the support G, in the opposite direction.

In order that less power may be required to rock the support G about its pivot, the support G may be counterbalanced by a suitable weight 63, attached to a bell crank 64, pivoted to the forward end of the frame, the bell crank 64 being connected by a cable 65 extending over suitable guide sheaves above the support G and attached at its opposite end to an arm 66 rigidly secured to the support G.

As well understood in the art, the indexing mechanism should be operated automatically at intervals to successively position teeth of the gear blank for engagement with the grinding disk. This is ordinarily accomplished by means of a trip mechanism controlling the operation of the indexing mechanism and operated by a movable part of the machine to cause the indexing mechanism to operate while the grinding disk or other cutting elements is out of contact with the blank. As shown herein, the rocking support G has rigidly attached thereto a rearwardly extending arm 67 which, when the rear side of the support has reached its lowermost position of movement with the cutting disk clear of the gear blank, engages with a suitable trip mechanism, indicated generally at 68, to cause an operation of the indexing mechanism. Since the indexing mechanism and the trip control for the indexing mechanism are old and well known, these parts are not shown in detail.

The grinding disk D is secured to the lower end of the spindle 69, which is journalled in a casing 70 mounted for sliding movement in guides 71 at the sides of the supporting member F. The casing 70, together with the spindle 69 and grinding disk D may be adjusted toward and from the trunnions 32 to properly position the grinding portion of the disk with respect to the axis of the trunnions by means of a screw 72 to which is fixed a worm gear 73 which meshes with a worm 74 on a transverse shaft 75 and which extends through the front side of the supporting member F and has a hand wheel 76 thereon, by means of which it may be turned to actuate the screw and shift the casing 70

toward or from the pivoted end of the member F. In gear grinding machines it is the usual practice to mount the grinding disk spindle for endwise movement to take up wear on the disk and to permit dressing of the engaging face, and it is to be understood that the spindle 69 may be so mounted in the casing 70.

The spindle 69 has a belt pulley 77 fixed to the upper end thereof and is driven by means of a suitable belt 78, which extends rearwardly from the pulley 77 over guide pulleys 79 mounted upon the upper ends of standards 80 fixed to the supporting member F and over guide pulleys 81 carried at the upper ends of standards 82 fixed to the rear end of the rocking support G to a driving pulley 83 secured to the shaft 84 of a motor 85 which is mounted upon a bracket secured to the rear end of the supporting plate 26. The motor shaft 84 is preferably in axial alignment with the fixed pivot shaft 30 so that the guide pulleys 81 carried by the rocking support G remain at the same distance from the periphery of the pulley 83. The pulleys 79, however, being mounted upon the pivoted supporting member F move upwardly and downwardly with respect to the pulleys 81, and in order to keep the belt 78 taut a gravity actuated tightener pulley 87 may be employed, the pulley 87 being carried upon the end of an arm 88 pivoted to one of the standards 80.

The adjustable mounting of the blank spindle casing and the adjustable mounting of the parts of the structure supporting the grinding disk permit the machine to be adjusted to operate upon bevel gears of different sizes, bevel gears of different bevel angles, and bevel gears having arcuate teeth of different longitudinal curvature. The vertical adjustment of the blank spindle casing permits the blank spindle to be positioned at the proper height above the fixed pivot 30 to enable the arcuate teeth of the gear to be properly positioned with respect to the axis of the pivot 30. The angular adjustment of the supporting plate 24 and the lateral adjustment of the supporting plate 26 carried by the plate 24 permits the pivot shaft 30 to be placed at the proper angle with respect to the axis of the blank spindle for bevel gears of different sizes and of different bevel angles. The longitudinal adjustment of the carriage 19 permits the cutter to be positioned properly with respect to root surfaces of the teeth regardless of the angular position of the cutter spindle supporting member.

After a blank has been fixed to the spindle and the grinding mechanism has been properly adjusted with respect to the tooth of the blank, the motors 33 and 85 are started into operation, the motor 85 driving the grinding disk D at a high speed and the motor 33 causing the support G to be rocked about the pivot 30 to move the cutter disk D from one end of the gear tooth with which it engages to the other. Simultaneously with the rocking movement of the support G, the supporting member F, upon which the spindle carrying the grinding disk is mounted, is rocked about the trunnions 32, the axis of which is tangent to the beveled cutting face E of the disk, the cam 57 being so formed as to impart to the supporting member F an angular movement at the proper rate to cause the grinding disk to generate approximately the exact tooth form desired. As the support G approaches its rearmost position, the disk D is moved out of engagement with the blank H and the trip arm 67 engages the index mechanism controlling trip 68, causing the index mechanism to be operated to turn the blank through an angle equal to one tooth space while the grinding disk D is out of engagement with the blank so that upon the return stroke the disk D engages with the corresponding face of the next tooth of the gear. When the blank has made one complete revolution the teeth will all have been finished upon one side.

To finish the opposite sides of the teeth a slightly different grinding wheel is required, this wheel D′ being shown in Fig. 8 of the drawings, and having a slightly offset peripheral beveled portion formed to engage the longitudinal convex sides of the teeth. While the disk D′ may be substituted for the disk D in the machine shown, and the necessary adjustments made to permit the disk D′ to operate upon the opposite faces of the teeth, it is found advantageous in practice to provide separate machines, one for finishing the longitudinally concave sides of the teeth and the other for finishing the longitudinally convex sides.

In Figs. 9 and 10 of the drawings there is shown diagrammatically a modification of the grinding device adapted to generate the faces of straight bevel gear teeth. The grinding mechanism, in this case, is mounted upon a suitable bed 89 which preferably corresponds to the supporting plate 26 in the machine shown in Figs. 1 to 5 of the drawings, the same adjustments being preferably provided for different sizes and angles of bevel gears. The bed 89 is provided with a transverse slideway 90 upon which is mounted a carriage 91 which is reciprocated during the operation of the machine by a suitable operating mechanism connected to the carriage 91 by a connecting rod 92. On the carriage 91 is mounted a spindle housing 93 corresponding to the housing 70 above described and similarly adjustable toward and from the gear blank on the carriage in a frame F′ connected to the carriage by trunnions 94 having a common axis tangent

to the tooth engaging portion of the grinding disk. During the reciprocating movement of the carriage 91, the supporting frame F′ is rocked about the trunnions 94 by means of a roller 95 mounted on the outer end of the frame F′ and rolling upon a fixed cam 96 which has the proper contour to impart to the supporting frame F′ a rocking movement properly correlated to the linear movement of the carriage.

Having thus described my invention, I claim:

1. The herein described method of generating the curved faces of gear teeth with a cutting element provided with a cutting portion formed complementary to the face of a gear tooth and adapted to contact with the gear tooth along a line extending transversely across the face thereof from substantially the top to the bottom of said tooth, which comprises engaging the cutting element with a gear blank, causing a relative movement between the cutter and blank longitudinally of the tooth face, and simultaneously causing a relative movement about an axis intersecting the line of contact between the cutter and blank.

2. The herein described method of generating the curved faces of gear teeth with a cutting element provided with a cutting portion formed complementary to the face of the tooth and adapted to contact with the gear tooth along a line extending transversely across the face thereof, which comprises engaging the cutting element with a gear blank, causing a relative movement between the cutter and blank longitudinally of the tooth face, and simultaneously causing a relative movement about an axis extending longitudinally of the gear tooth and intersecting the line of contact between the cutter and blank.

3. The herein described method of generating the curved faces of bevel gear teeth with a cutting element having a cutting portion formed complementary to the face of the tooth from substantially the top to the bottom thereof and adapted to contact with a finished gear tooth along a line extending transversely across the face thereof substantially from the top to the bottom of the tooth, which comprises engaging the cutting element with a gear blank, causing a relative movement between the cutting element and blank longitudinally of a tooth, and simultaneously causing a relative movement between the cutting element and blank about an axis which remains substantially tangent to the pitch cone of the gear.

4. The herein described method of generating the curved faces of arcuate bevel gear teeth, which comprises bringing a cutting element having a cutting portion formed complementary to the face of the tooth to be formed and adapted to engage a tooth face along a line extending across the face thereof substantially from the top to the bottom of the tooth, causing a relative feeding movement between the cutter and blank about an axis passing through the center of curvature of the root line of the tooth face to be generated, and simultaneously causing a relative rocking movement between the cutter and blank about an axis intersecting the line of contact between the cutting element and tooth surface.

5. A machine for generating the curved faces of gear teeth varying in transverse form along the length thereof comprising means for supporting a gear blank, a rotary cutting element having a peripheral edge portion shaped complementary to the face of the tooth being formed and adapted to have a line contact across the face of a gear tooth, means for causing the cutting element to traverse the blank along the face of a tooth and for simultaneously causing a shifting movement of the cutting element relatively to the blank about an axis tangential to said peripheral portion engaging the tooth.

6. A machine for generating the curved faces of gear teeth varying in transverse form along the length thereof comprising means for supporting a gear blank in a fixed position, a rotary cutting disk having a peripheral edge portion formed complementary to the face of the tooth to be formed, means for moving the cutting element along the face of a tooth with its beveled edge in engagement with a tooth and means for simultaneously swinging the cutter about an axis tangential to the portion of the beveled edge engaging the tooth.

7. A machine for generating the faces of bevel gear teeth comprising means for supporting a bevel gear blank, a cutting element having a cutting portion conforming to the transverse curvature of the face of a tooth to be formed, means for causing the cutting element to traverse the blank in engagement with a face of a tooth, and means for simultaneously rocking the cutting element about an axis tangential to the cutter and in a plane substantially tangent to the pitch cone of the gear.

8. A machine for generating the curved faces of gear teeth varying in transverse form along the length thereof, comprising a supporting frame having means for supporting a gear blank in a fixed position, a rotary cutting element having a portion engageable with a tooth transversely across the face thereof, a support on the frame movable thereon in a direction parallel with a tooth, a supporting member upon which the cutter is mounted pivoted on said support and movable about an axis extending longitudinally of the tooth, means for simultaneously moving the support and swinging

said supporting member, and means for driving the cutting element.

9. A machine for generating the curved faces of gear teeth varying in transverse form along the length thereof, comprising a supporting frame having means for supporting a gear blank in a fixed position, a rotary cutting element having a portion engageable with a tooth transversely across the face thereof, a support on the frame movable thereon in a direction parallel with a tooth, a supporting member upon which the cutter is mounted pivoted on said support and movable about an axis extending longitudinally of the tooth, means for moving said support back and forth to cause the cutting element to traverse the blank, means operated by said support for swinging the cutter supporting member about its axis and means for driving the cutting element.

10. A machine for generating arcuate bevel gear teeth comprising a supporting frame having means for supporting a gear blank in a fixed position, a rotary cutting element having a portion formed to contact with a tooth across the face thereof, a support on the frame pivoted to swing about the center of longitudinal curvature of a tooth, a supporting member upon which the cutter is mounted pivoted to swing about an axis on said support tangent to the tooth engaging portion of the cutting element, means for swinging the support about its axis and for simultaneously swinging the cutter supporting member about its axis on the support, and means for driving the cutting element.

11. In a machine for generating the faces of arcuate bevel gear teeth comprising means for supporting a gear blank in a fixed position, a supporting member mounted for movement about a fixed axis perpendicular to a plane tangential to the root cone and intersecting the tooth surface to be generated, said axis being centrally disposed with respect to the arcuate tooth surface to be generated, a second supporting member mounted for movement about an axis on said first supporting member which lies in a plane tangent and extends longitudinally of the tooth surface to be generated, means for moving the supporting members simultaneously about their axes, a rotary cutting element carried by the second supporting member and engaging said tooth face, and means for driving said cutting element.

12. In a machine for generating the faces of arcuate bevel gear teeth comprising means for supporting a gear blank in a fixed position, a supporting member mounted for movement about a fixed axis perpendicular to a plane tangential to the root cone and intersecting the tooth surface to be generated, said axis being centrally disposed with respect to the arcuate tooth surface to be generated, a second supporting member mounted for movement about an axis on said first supporting member which lies in a plane tangent to the pitch cone at the center of the tooth and extends longitudinally of the tooth surface to be generated, means for moving the supporting members simultaneously about their axes, a rotary grinding disk carried by the second supporting member and having a concave bevelled peripheral portion engaging said tooth face, and means for driving said disk.

13. In a machine for generating the faces of arcuate bevel gear teeth comprising means for supporting a gear blank in a fixed position, a grinding disk having a peripheral edge portion adapted to enter the space between the teeth and having a bevelled face adapted to have a line contact with the tooth face to be ground, means for swinging said disk bodily about an axis centrally disposed with respect to the arcuate tooth to be ground, means for simultaneously swinging the disk about an axis tangent to its peripheral engaging face, and means for driving the disk.

14. In a gear generating machine, a supporting structure, a support mounted on said structure to swing about a fixed axis, a supporting member mounted on said support to swing about an axis thereon transverse to the first axis, a rotary cutting element carried by said supporting member, a fixed gear member concentric with said fixed axis, a second gear member mounted on said swinging support meshing with the first gear member, means for swinging said support, means operated by said second gear member for shifting the supporting member about its pivot, and means for driving the cutting element.

15. In a gear generating machine, a supporting structure, a support mounted on said structure to swing about a fixed axis, a supporting member mounted on said support to swing about an axis thereon transverse to the first axis, a rotary cutting element carried by said supporting member, a fixed gear member concentric with said fixed axis, a second gear member mounted on said swinging support meshing with the first gear member, means for swinging said support, a cam operated by said second gear member for shifting the supporting member about its pivot, and means for driving the cutting element.

16. In a gear generating machine, a supporting structure, a support mounted on said structure to swing about a fixed axis, a supporting member mounted on said support to swing about an axis thereon transverse to the first axis, a rotary cutting element carried by said supporting member, means for simultaneously moving said support and member about their pivots comprising a motor, a cam driven by said motor

and connected to the support for shifting the same, a rotatable cam mounted on said support for shifting said supporting member and means operated by said support in its movement about its pivot for rotating said cam, and means for driving said cutter.

In testimony whereof, I hereunto affix my signature.

GUY L. BAYLEY.