June 4, 1946. E. WILDHABER 2,401,446

METHOD OF GRINDING CLUTCHES, GEARS, AND OTHER TOOTHED PARTS

Filed March 31, 1944 2 Sheets-Sheet 1

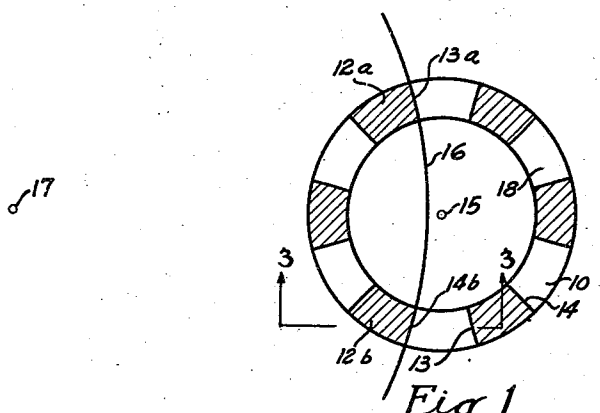


Fig. 1

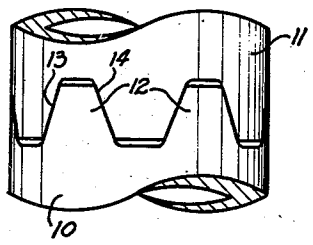


Fig. 2

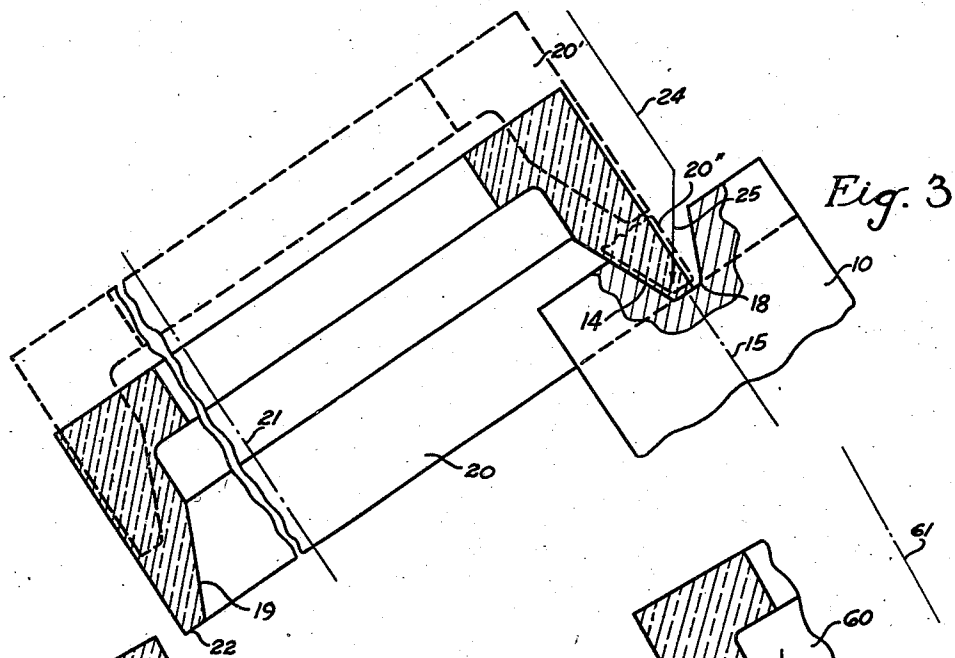


Fig. 3

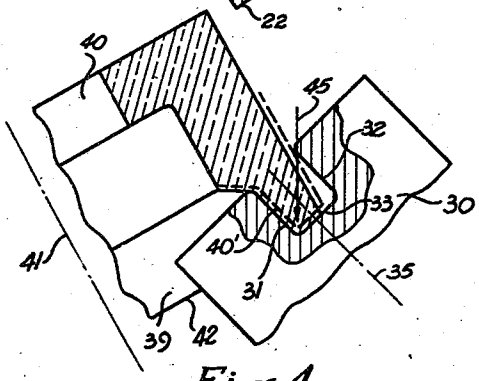


Fig. 4

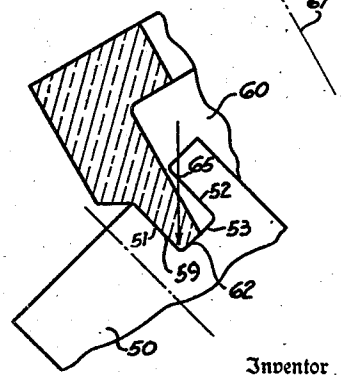


Fig. 5

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June 4, 1946. E. WILDHABER 2,401,446

METHOD OF GRINDING CLUTCHES, GEARS, AND OTHER TOOTHED PARTS

Filed March 31, 1944 2 Sheets-Sheet 2

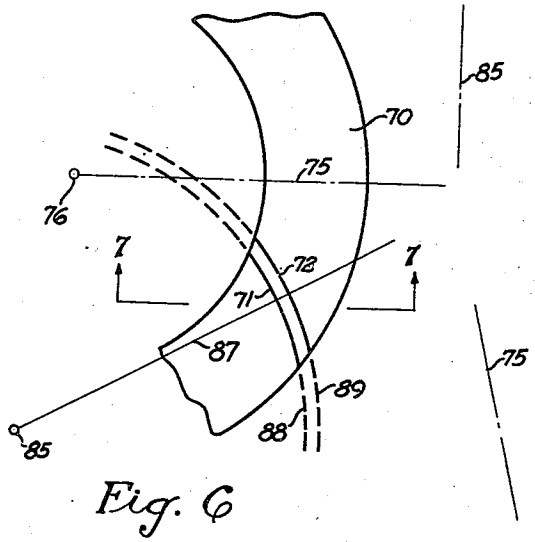


Fig. 6

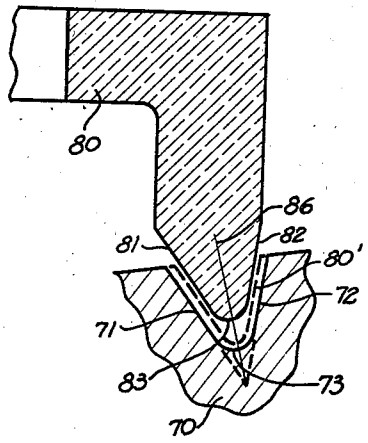


Fig. 7

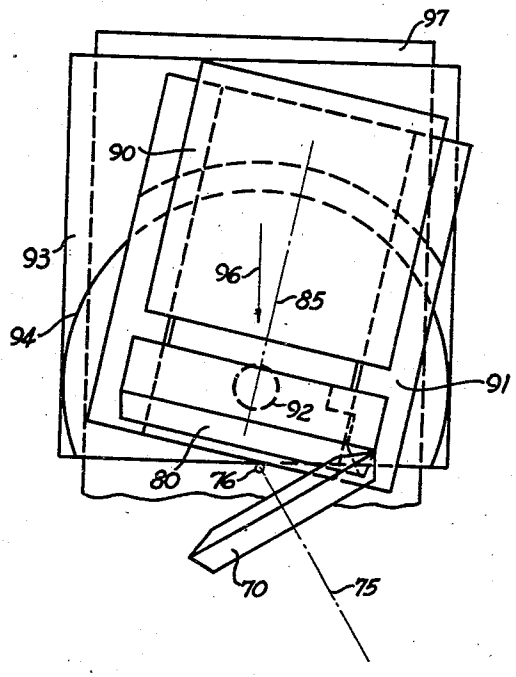


Fig. 8

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METHOD OF GRINDING CLUTCHES, GEARS, AND OTHER TOOTHED PARTS

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11 Claims. (Cl. 51—287)

1

The present invention relates to the grinding of the tooth surfaces of face clutches, spiral bevel and hypoid gears, and of other toothed members, especially where the grinding surface and the surface to be ground are counterparts of one another, as is the case in certain types of face clutches, and non-generated spiral bevel and hypoid gears.

In the grinding of face clutches, it is the usual practice to grind both the sides and the bottoms of the tooth spaces. Ordinarily, a rotary annular grinding wheel is employed, and grinding is effected by rotating the wheel in engagement with the work while producing a relative feed movement between the wheel and work in the direction of the wheel axis. In such an operation, the rate of feed of the wheel is determined by the rate at which stock can be removed from the bottom of a tooth space, and the relative rates of feed in directions normal to the tip and sides of the wheel will, therefore, obviously be unequal, because the tip and sides of the wheel are differently inclined to the axis of the wheel. This causes unequal wear on the tip and sides of the wheel. Moreover, when the tooth spaces of the work have been previously cut, and the grinding operation is used only to remove very slight amounts of stock from the sides and bottoms of the tooth spaces, the wheel will contact the side of a tooth space long before it contacts the bottom of the tooth space, and, while the wheel may be fed into the work at a relatively fast rate while it is grinding only a side of a tooth surface, the feed has to be slowed down prior to engaging the tooth space bottom. Sometimes the rate of feed in a direction normal to the tooth side is then so reduced that danger of burning the tooth side arises through rubbing of the side of the wheel against the side of the tooth. These difficulties have all seriously hindered the development of clutch-grinding.

In grinding non-generated spiral bevel and hypoid gears, the usual practice is to grind both sides of a tooth space simultaneously, and frequently the bottom of the tooth space is also ground in the same operation with the sides. Here the difficulties arising from the differences in relative rates of feed on the sides and tip of the wheel have been recently aggravated by the fact that it has lately become the practice to grind non-generated spiral bevel and hypoid gears with wheels whose opposite sides have unequal pressure angles so as to obtain more favorable tooth shapes on the teeth of the mating pinion. The unequal pressure angles on the two

2

sides of the wheel mean that the relative rates of feed of the wheel are not only different between the tip and each side of the wheel but between the two sides of the wheel themselves.

A primary object of the present invention is to provide a method for grinding clutches, gears and other members having formed tooth surfaces in which the rate of feed may be equalized on the sides and tip of the grinding wheel.

A further object of the invention is to provide a method for grinding parts, such as mentioned, in which, because of equalization of the rates of feed and equalization of wheel-wear on the sides and tip of the wheel, the tooth surfaces may be ground at a faster rate than heretofore without danger of burning.

Other objects of the invention will be apparent hereinafter from the specification and from the recital of the appended claims.

In grinding a clutch or gear or other part according to the present invention, the wheel is fed relative to the work in a direction normal to the two sides of the work which are engaged by the wheel. In the case of clutches, this means that the feed employed is in a direction bisecting the angle between the side and the bottom of the tooth space being ground, and in the case of non-generated gears, whose opposite tooth sides are to be ground simultaneously, this means that the feed will be in a direction bisecting the angle between the two sides of the tooth space. There are two outstanding advantages obtained with the present invention. The two sides, or the side and bottom, of a tooth space may be engaged by the grinding wheel simultaneously, and the feed on the sides, or on the side and bottom, is balanced and can therefore be kept at a maximum on both sides or on both the side and bottom. Therefore, the feed motion is not limited, as in the past, by the maximum rate of feed possible on one side or on the tooth space bottom, but can proceed at top speed on both engaged surfaces, simultaneously.

Several different embodiments of the invention are illustrated in the accompanying drawings, in which:

Fig. 1 is a sectional view in a plane perpendicular to the axis, illustrating diagrammatically the method of grinding a clutch member according to the present invention;

Fig. 2 is a fragmentary side elevation showing two face clutch members made according to this invention in engagement;

Fig. 3 is a part elevational, part sectional view along the line 3—3 of Fig. 1, further illustrating

the principles of the invention as applied to the grinding of a face clutch member, which has side tooth surfaces of positive pressure angle;

Fig. 4 is a fragmentary sectional view illustrating one method of grinding according to this invention a face clutch member having side tooth surfaces of zero pressure angle;

Fig. 5 is a similar view illustrating one method of grinding the clutch member which is to mate with the clutch member of Fig. 4;

Figs. 6 and 7 are a fragmentary plan view and a fragmentary sectional view on the line 7—7 of Fig. 6, respectively, illustrating one method of grinding non-generated spiral bevel or hypoid gears according to this invention; and

Fig. 8 is a fragmentary plan view, illustrating diagrammatically the structure of a grinding machine which may be employed to practice the invention.

Fig. 2 shows a pair of mating clutch members 10 and 11 in engagement. The two clutch members may be of identical construction, or one may have longitudinally convex tooth sides and the other longitudinally concave tooth sides as described in my copending application Serial No. 444,031, filed May 22, 1942, and which matured as Patent No. 2,384,582, dated September 11, 1945. Each member has teeth 12 whose opposite side surfaces 13 and 14 are of positive pressure angle or inclination to the axis 15 of the clutch.

The present invention is herein specifically illustrated as applied to the production of the clutch member 10 whose opposite side tooth surfaces are of longitudinally convex shape, but it will be understood that the invention is equally applicable to the production of a clutch member whose opposite tooth surfaces are both longitudinally concave, or one longitudinally convex and the other longitudinally concave. In fact, the invention may be applied to the grinding of the tooth surfaces of a clutch member regardless of its lengthwise tooth shape.

The clutch member 10 shown is made according to the principles of my prior application Serial No. 444,031 above mentioned and has the opposite sides of spaced teeth formed as parts of a common surface of revolution. In the illustrated embodiment, they are parts of a common conical surface. Thus, the side 13*a* of a tooth 12*a* of the clutch member is a part of the same conical surface which contains the opposite side 14*b* of a spaced tooth 12*b* of the clutch member. This conical surface is denoted in Fig. 1 by the line 16. Its axis is at 17 parallel to the axis 15 of the clutch member.

The two tooth sides 13*a* and 14*b* and all other pairs of tooth sides can be ground simultaneously with the inside conical surface 19 of a rotary annular grinding wheel 20 whose inside surface is of the same pressure angle as the side tooth surfaces 13 and 14 and whose axis 21 in full depth position coincides with the axis 17 of the tooth surfaces. The inside surface of the grinding wheel, in other words, is the counterpart of the side surfaces to be ground.

Heretofore a clutch of the character shown has been ground by rotating the grinding wheel in engagement with the work while effecting a relative depthwise feed movement between the wheel and the work in the direction of the wheel axis until the engaged tooth sides and tooth bottom have been completely ground. Then the wheel is withdrawn from engagement with the work, and the work is indexed. With such feed, the inside surface 19 of the wheel contacts the tooth sides 13 and 14 of the tooth spaces long before the tip surface 22 of the wheel contacts the tooth space bottom 18, assuming that the same amount of grinding stock is left on the sides and bottoms of the tooth spaces which is the usual practice. With the previous method of grinding, then, the axial feed movement of the wheel may be at a relatively fast rate during the grinding of the sides of the teeth but has to be slowed down for the grinding of the tooth-space bottoms. It is this reduction in feed rate that in some cases, as previously stated, causes the feed movement normal to the sides of the tooth spaces to become so small that danger of burning the sides arises through rubbing.

In the grinding method of the present invention, in at least the final stage of grinding, when the sides and bottoms of the tooth spaces are engaged by the sides and tip of the wheel, the feed movement is in a direction bisecting the engaged tooth surfaces. The grinding wheel may, however, during the first part of the feed movement, be advanced at a relatively rapid rate along its axis 21 from a position such as denoted in dotted lines at 20' Fig. 3, where the wheel is disengaged from the work, to a position such as denoted at 20'', where it has entered into two spaced tooth spaces of the work but where it is still out of grinding engagement with both the sides and the bottoms of the tooth spaces. The axial feed movement in fact is preferably continued to a point where the separation between the wheel surface and the work is at a practical minimum, and sometimes in the final stages of this axial feed movement, the active side surface of the wheel will then actually come into grinding engagement with the high teeth of the work. When this position is reached, the direction of the feed movement is changed in the method of the present invention, and the wheel is then fed, as already described, in a direction 25 which is inclined to the wheel axis 21 and which approximately bisects the angle between the side surface of a tooth space being ground and the bottom of that tooth space. In other words, in the final stage of the feed movement, the wheel is fed from position 20'' to the full line position 20.

Mathematically, the side profiles of the tooth surfaces being conical would appear as curved lines in the section of Fig. 3. They are, however, herein shown straight for the purposes of illustration. The shown straight lines can be considered as the mean tangents to the tooth surfaces.

In practicing the present invention, one pair of spaced tooth sides may be ground for their full depth, and then the work may be indexed, or one pair of tooth sides may be ground to a limited depth and then the work indexed, and, after all of the teeth have been ground to the same limited depth, the wheel may be fed further into the work and a second grind at a further limited depth taken on all the teeth, and this operation may be continued until the wheel has been fed in direction 25 into full depth and all of the tooth sides have been ground to full depth. In either method, the feed is first preferably in the direction of the wheel axis and only in its final stage in a direction inclined thereto and bisecting the angle between the side and the bottom surfaces to be ground.

An annular grinding wheel, such as the wheel 20, has, of course, surface contact with the work. To avoid burning of the work surfaces, it may be desirable to impart a series of rapid reciproca-

tions to the wheel during the grinding operation according to the principles of the method disclosed in Condon Patent No. 1,979,870 of November 6, 1934. With this method, the feed from the position 20'' to the full line position 20 in the direction of the arrow 25 is performed in an oscillatory manner, in other words, it is broken up into a series of miniature strokes whereby grinding engagement ceases part of the time. This permits of maintaining a suitably fast grinding speed during actual grinding contact even on a clutch member of large face width where continuous contact between the wheel and the work would be too much for the wheel to handle and where a mere reduction in the rate of feed might cause burning.

Fig. 4 illustrates the application of the process to the grinding of the sides and bottoms of the tooth spaces of a clutch member 30 whose tooth sides 31 and 32 are of zero pressure angle, that is, extend in the direction of the axis 35 of the clutch member. Here an annular grinding wheel 40 may be employed that has an inside active grinding surface 39 which is of positive pressure angle and inclined to the axis 41 of the wheel, and that has a tip surface 42 which is conical and inclined to the inside of the wheel at such an angle as to produce tooth space bottoms 33 in the work which are perpendicular to the tooth sides 31 and 32 of the work. The wheel 40 is positioned in engagement with the work so that the axis 41 of the wheel is inclined to the root surface of the work at substantially the pressure angle of the active side surface 39 of the wheel. Here, as in the previously described embodiment of the invention, the grinding wheel is first advanced axially and then the direction of feed is changed to follow the arrow 45 which bisects the angle between the side 31 or 32 of a tooth space and the bottom 33 of that tooth space. The active portion of the wheel is shown in dotted lines at 40' in the final position of its axial feed movement and in full lines at 40 in the final position of its inclined feed movement. Again opposite sides of spaced teeth of the work may be ground simultaneously to have longitudinally convex side surfaces which are parts of a common conical surface of revolution.

The tooth spaces of the clutch member 50, which is to engage with clutch member 30, may be ground with the outside conical surface 59 of a rotary grinding wheel 60 whose axis 61 is inclined to the root surface 53 of the work at substantially the pressure angle of the active side surface of the wheel. As before, the wheel may be advanced axially until it approaches grinding contact, and then the direction of feed is changed to follow the bisector 65 of the angle between a tooth side 51 or 52 of the work and the tooth-space bottom 53.

The invention is by no means limited to production of clutch members. Figs. 6 and 7 show how the principles of this invention may be applied to the production of spiral bevel and hypoid gears with grinding wheels whose opposite sides have different pressure angles.

70 denotes the gear which is to be ground. This gear has opposite side tooth surfaces 71 and 72 and rounded tooth space bottom surfaces 72. For grinding the gear, a rotary annular grinding wheel 80 is employed whose inside, outside, and tip surfaces 81, 82, and 83, respectively, are counterparts of the profiles of the side and bottom surfaces 71, 72, and 73, respectively, of the tooth spaces of the gear, but, whereas the side surfaces 71 and 72 of the gear are of equal pressure angle or inclination to the gear axis 75, the inside surface 81 of the wheel is of substantially greater pressure angle than the outside surface 82 of the wheel, being more inclined to the wheel axis 85.

When a wheel, such as the wheel 80, having unequal pressure angles on the outside and inside grinding surfaces, is fed axially, the side 82 of smaller pressure angle contacts the work ahead of the side 81 of larger pressure angle and the relative feed movements in directions normal to the active side surfaces of the wheel are vastly unequal. This means that the grinding action on one side of the gear teeth is inefficient.

With the present invention, the feed of the wheel into the work is in a direction inclined to the wheel axis 85 and along a line 86 which substantially bisects the angle between the two sides 71 and 72 of the tooth space being ground. Two different positions of the wheel during feed are shown in full lines at 80 and in dotted lines at 80', respectively. The wheel feed continues in the direction 86 until full depth position has been reached and the tooth space has been fully ground. Then the wheel is withdrawn from engagement with the work and the work indexed to bring the wheel into position to grind a new tooth space. As before, the wheel may be oscillated back and forth during the feed movement to avoid burning according to the principles of the Condon patent above mentioned. The two sides of the tooth space are ground as coaxial conical surfaces of revolution.

Fig. 6 represents a view along the axis 85 of the sides of a tooth space of a gear. 76 is the gear apex and 75 denotes the gear axis projected into the plane of the drawing. 88 and 89, respectively, denote the paths of points in opposite sides of the wheel during the grinding of opposite sides 71 and 72 of a tooth space of the work.

The invention may be practiced on any suitable type of grinding machine. Fig. 8 is a fragmentary plan view illustrating diagrammatically the structure of one such machine. 70 again denotes the gear to be ground, 75 its axis, and 76 its apex. The grinding wheel 80 is secured to a spindle (not shown) which may be driven by a motor or any other suitable means. The spindle may be journaled in a sleeve (not shown) which is movable in the direction of the axis 85 of the wheel to produce the axial feel movement of the wheel. This movement may be effected in known manner by a rotary cam. The sleeve is mounted on a slide 90 which is adjustable along the wheel axis 85 to permit of compensation for wear of the wheel. The slide 90 is mounted on a swivel plate 91 which is pivoted at 92 on a sliding base 93, a guide way 94 being provided on the upper face of the sliding base 93 for this purpose. The pivotal adjustment of the plate 91 permits of adjusting the axis of the grinding wheel at any desired angle to the direction 96 of motion of the sliding base 93 on the bed 97 of the machine. Motion of the sliding base 93 may be controlled by a cam or any other suitable means. The work piece 70 is mounted in a work head which is adjustable on the bed of the machine angularly about the apex 76 of the work, laterally, axially, and vertically, that is, parallel to the pivot axis 76.

In operation, the wheel is first moved axially by the cam on the sleeve to near grinding position and then is fed, by movement of the sliding base

93, in the direction 96 which bisects the sides of the tooth space being ground. The latter feed may be continuous or be a reciprocatory feed movement of the general type described in the Condon patent. Usually a plurality of cycles are performed in each tooth space of the work, the wheel being fed a limited distance during each cycle and then being withdrawn and the work indexed, the feed being preferably an intermittent feed movement taking place after a cycle of operation has been performed on each tooth space of the work.

The machine described with reference to Fig. 8 may be used for grinding clutches as well as gears. When a clutch is to be ground, the work is so set up that the direction 25 (Fig. 3), 45 (Fig. 4), or 65 (Fig. 5) of grinding feed proper coincides with the direction 96 of feed of the sliding base 93.

The invention can also be practiced, both in the grinding of non-generated gears and of clutches, on Gleason spiral bevel and hypoid generators of known construction which are provided with means for tilting the grinding wheel. In this case, a feed movement in a direction inclined to the wheel axis may be performed in the normal plane, such as the plane 87 of Fig. 6 which contains the wheel axis 85. Further than this, the feed in the direction inclined to the wheel axis may also be attained as the resultant of a plurality of feed motions, for instance, as a combination of feed along the wheel axis and feed angularly about the work axis. In other words, the grinding feed proper may consist of a feed along the wheel axis plus a simultaneous rotary motion about the work axis.

While the invention has been described in connection with the grinding of gears and clutches with an annular type of grinding wheel, it will be understood that it is also applicable where a cupped wheel is employed. It will further be understood that the invention is not limited to the production of clutches and of non-generated gears, but may be employed also in the production of other parts where there are two surfaces to be ground which are inclined at an angle to one another. It may thus be used, for instance, in the sharpening of blades of a milling cutter where the front face of a blade and the bottom of the space between successive blades have to be ground simultaneously. Again, the feed is in a direction bisecting the surfaces which are to be ground. In all cases, the surfaces ground are surfaces of revolution; such as conical or spherical surfaces, or planes; and ordinarily surface contact between the wheel and the work exists at least for an instant. In general it may be said that while certain embodiments of the invention have been illustrated, the invention is capable of further modification and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. A method of simultaneously grinding a side and the bottom of a tooth space of a toothed member, which comprises employing a rotary grinding wheel that has a side and a tip surface which are counterparts, in shape and in inclination to one another, of the side and bottom of the tooth space to be ground, and rotating the wheel in engagement with the work while effecting a relative depthwise feed movement between the wheel and work in a direction other than at right angles to the wheel axis and approximately bisecting the angle between the side and bottom of the tooth space.

2. A method of simultaneously grinding a side and the bottom of a tooth space of a toothed member, which comprises employing a rotary grinding wheel that has a side and a tip surface that are counterparts, in shape and in inclination to one another, of the side and bottom of the tooth space to be ground, and rotating the wheel on its axis while effecting a relative depthwise feed movement between the wheel and the work in a direction substantially normal to the bottom of the tooth space until the wheel and work are approximately in grinding contact, and then effecting a relative depthwise feed movement between the wheel and the work in a direction other than at right angles to the wheel axis and approximately bisecting the angle between the side and bottom of the tooth space until full depth position is reached.

3. A method of grinding simultaneously opposite sides and the bottoms of two spaced tooth spaces of a face clutch member which has side tooth surfaces of positive pressure angle, which comprises employing a rotary annular grinding wheel that has side and tip surfaces which are counterparts, in shape and inclination to one another, of the sides and bottoms of the tooth spaces, positioning said wheel with its axis parallel to the axis of the work and so that it will operate in two spaced tooth zones of the work simultaneously, and rotating the wheel in engagement with the work while effecting a relative depthwise feed movement between the wheel and work in a direction inclined to both the axis of the wheel and the axis of the work and bisecting the angle between a side and the bottom of a tooth space.

4. A method of simultaneously grinding a side and the bottom of a tooth space of a toothed member which comprises employing a rotary annular grinding wheel that has a side and tip surface which are counterparts, in shape and inclination to one another, of the side and bottom of the tooth space, and rotating the wheel on its axis while effecting a relative feed movement axially of the wheel until the wheel and work are approximately in grinding contact, and then effecting a relative feed movement in a direction inclined to the wheel axis and approximately bisecting the angle between the side and bottom of the tooth space until full depth is reached.

5. A method of simultaneously grinding opposite sides of a tooth space of a toothed member whose opposite side tooth surfaces have different pressure angles, which comprises employing a rotary annular grinding wheel which has opposite side surfaces that are counterparts, in shape and inclination to one another, of the sides of the tooth space to be ground, and rotating the wheel in engagement with the work while effecting a relative depthwise feed movement between the wheel and work in a direction inclined to the axes of the wheel and the work and bisecting the angle between the sides of the tooth space.

6. A method of simultaneously grinding opposite sides of a tooth space of a toothed member whose opposite side tooth surfaces have different pressure angles, which comprises employing

a rotary annular grinding wheel which has opposite side surfaces that are counterparts, in shape and inclination to one another, of the sides of the tooth space to be ground, and rotating the wheel on its axis while effecting a relative depthwise feed movement between the wheel and the work in the direction of the axis of the wheel until the wheel and work are approximately in grinding engagement, and then effecting a relative depthwise feed movement between the wheel and work in a direction approximately bisecting the angle between the sides of the tooth space.

7. A method of simultaneously grinding on a toothed member two surfaces of a tooth space which are concentric surfaces of revolution and inclined to one another, which comprises rotating an annular grinding wheel on its axis while effecting a relative depthwise feed movement between the wheel and work axially of the wheel and thereafter effecting a relative depthwise feed movement between the wheel and work in a direction at an angle to the wheel axis.

8. A method of simultaneously grinding two surfaces of a tooth space which are inclined to one another, which comprises rotating a grinding wheel, which has active grinding surfaces that are counterparts of the surfaces to be ground, on its axis while effecting a relative depthwise feed movement between the wheel and work which is in one direction and at a relatively fast rate until the wheel and work are approximately in grinding contact and which is in a direction inclined thereto and at a relatively slower rate until full depth position is reached.

9. A method of simultaneously grinding two surfaces of a tooth space which are inclined to one another which comprises rotating a grinding wheel on its axis while effecting a relative depthwise feed movement between the wheel and

work in a direction substantially normal to the bottom of the tooth space, and thereafter effecting a relative depthwise feed movement between the wheel and work in a direction at an angle to the first described feed movement and substantially bisecting the angle between the two surfaces which are to be ground.

10. A method of grinding simultaneously opposite sides of a tooth space of a toothed member whose opposite side tooth surfaces have equal pressure angles or inclination to the axis of said member which comprises employing a rotary grinding wheel that has active side tooth surfaces at opposite sides of unequal inclination to its axis and that in shape and inclination to one another are counter parts of the side tooth surfaces to be ground, and rotating the wheel in engagement with the work while effecting a relative feed movement between the wheel and work in a direction inclined to the wheel axis and bisecting the angle between the opposite sides of the tooth space.

11. A method of grinding simultaneously a side and the bottom of a tooth space of a clutch member whose side tooth surfaces are of zero pressure angle and parallel to the axis of the clutch member which comprises employing a rotary grinding wheel that has an active side surface of positive pressure angle and inclined to its axis and whose side and tip surfaces, in shape and inclination to one another, are counter parts of the side and bottom of the tooth space to be ground, and rotating the wheel in engagement with the work, while effecting a relative feed movement between the wheel and work in a direction bisecting the angle between the side and bottom of the tooth space to be ground.

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