METHOD OF CROWN FINISHING THE TEETH OF INTERNAL GEAR


Application November 8, 1954, Serial No. 467,279

4 Claims. (Cl. 99—1.6)

The present invention relates to a method of crown finishing the teeth of an internal gear.

It is an object of the present invention to provide a method of finishing the teeth of an internal gear which permits using a single cutter or tool to produce different amounts of crown on identical gears.

More specifically, it is an object of the present invention to provide a method of finishing internal gears to produce a crown on the teeth thereof by a method which comprises selecting a direction of relative traverse between the cutter and gear to produce the required crown.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a diagrammatic front elevational view with parts in section, illustrating the relationship between a ring and a small cylinder received therein.

Figure 2 is a sectional view on the line 2—2, Figure 1.

Figure 3 is a sectional view on the line 3—3, Figure 2.

Figure 4 is a sectional view on the line 4—4, Figure 2, the small cylinder being sectioned perpendicular to its axis.

Figure 5 is a fragmentary diagrammatic front elevational view showing successive positions of a thin cylinder moved with respect to a ring.

Figure 6 is a sectional view on the line 6—6, Figure 5.

Figure 7 is a fragmentary diagrammatic elevational view showing successive positions of a thin cylinder moved relative to a ring in a direction oblique to the axes of both the ring and small cylinder.

Figure 8 is a sectional view on the line 8—8, Figure 7.

Figure 9 is a sectional view on the line 9—9, Figure 8, showing the path traversed by the cylinder in its movement relative to the ring.

Figure 10 is a diagrammatic view illustrating the meshing relationship between the teeth of an internal and external gear meshed at crossed axes with unmodified teeth.

Figure 11 is a fragmentary diagrammatic plan view illustrating the configuration of crowned teeth provided on a cutting tool.

Figure 12 is a diagrammatic view illustrating the tooth contact relationship between teeth of an internal gear and the crowned teeth of a pinion in mesh therewith.

Figure 13 is a front elevational view of the gear shaving machine adapted to carry out the present method.

In order to describe the theoretical basis of the present invention, reference is made first to the surface contacting relationship between a ring and a small cylinder contained therein. It will of course be appreciated that this contact is analogous to the contact between an internally toothed ring member or a gear on the one hand and an externally toothed gear or pinion on the other hand.

Referring first to Figures 1—4 there is illustrated a ring having an internal surface of the illustrated configuration in contact with the external surface of a cylinder. It will be observed that the internal surface of the ring has a minimum diameter between the ends thereof, this diameter being designated by the reference numeral 14 in Figure 2. On the other hand, the cylinder is a true cylindrical body and in the present case it is assumed that it is in line contact with the surface 10 of the cylinder along the line designated by the numeral 16 in the figure. This line 16 is an axial element of the cylinder and is accordingly a straight line and represents the only instantaneous contact between the interior surface 10 of the ring and the exterior surface of the cylinder C.

It will of course be obvious that the surface might be produced at the interior of the ring by employing the cylinder as a tool, such as for example as a cutting or grinding tool, and moving it to the illustrated position from a position displaced inwardly toward the center of the ring from the illustrated position, while driving both the ring and the cutter in rotation.

It will further be apparent that having brought the ring and the cylinder into the relationship illustrated in these figures, the cylinder C might be reciprocated in the direction of its axis without disturbing the illustrated relationship. If, however, while the cylinder and ring were to continue to rotate, the ring R, were moved in the direction of its axis, further abrading or cutting thereof by the cylinder C would occur.

It will further be apparent that the curvature which would be imparted to the surface 10 by the cylinder without reciprocation is a direct function of the angle between the axes of the ring and the axis of the cylinder.

Referring now to Figures 5 and 6 there is illustrated the relationship between a ring R and an extremely thin cylinder C which may be considered simply as a circular disc. In these figures it will be observed that the cylinder C is moved from the full line position through the intermediate position to the final dotted line position it will in effect generate a surface equivalent to the surface of the cylinder C. Thus, if during movement of the cylinder C from the full line to the dotted line position the ring R is rotated, its interior surface 20 will be curved as illustrated in Figure 6 to have a minimum diameter in the plane 22 midway between the ends of the ring.

From the foregoing it will be apparent that a ring such as R or R may have an interior surface thereof finished to the shape illustrated in the figures by one of two methods. In the first place, this surface may be produced by employing a tool in the form of a small cylinder having its axis inclined to the axis of the ring and moved radially from the central portion of the ring into the material of the ring until full contact is established between the ring and cylinder from end to end of the ring or throughout the axially overlapping portions thereof. Alternatively, the same identical surface may be produced at the interior of the ring by employing a disc or extremely thin cylinder having its axis inclined to the axis of the ring at the same angle as the angle of inclination of the cylinder and by feeding the disc or thin cylinder C in the direction of its axis so that the axis occupies the position of the axis of the cylinder C.

In both the foregoing cases the crowned or curved interior surface of the cylinder depends upon the angle between the axes of the ring and cylinder. This angle is designated XA in the figures and is referred to as the crossed axes angle.

Referring now to Figures 7—9 there is illustrated a ring R having an internal surface 30 which is presumed to be generated by a disc or thin cylinder C. In this
case it is assumed that the cylinder \( C_0 \) is positioned in space with its axis extending at an angle \( XA \) with respect to the axis of the ring \( R_n \). In this case however, traversal of the small cylinder \( C_n \) relative to the ring \( R_n \) is not in the direction of the axis of the cylinder \( C_n \). But instead, is along a line designated \( T \) which in this instance is oblique with respect both to the axis of the ring \( R_n \) and the axis of the cylinder \( C_n \). It will be apparent that the relative traverse along the line \( T \) between the cylinder \( C_n \) and the ring \( R_n \), considering the cylinder \( C_n \) to be operating as a tool, and considering the ring \( R_n \) to be rotating sufficiently to produce a uniform machining action over its entire inner surface 30 by the cylinder \( C_n \), will produce a crowned surface having a diameter in the plane 32 intermediate the ends of the cylinder. In this case however, the amount of curvature of the surface 30 as measured by deviation from a line 34 parallel to the axis of the ring \( R_n \) is a function of the angle between the line of relative traverse \( T \) and the axis of the ring \( R_n \). This angle is designated in Figure 8 as \( TA \) and is referred to herein as the traverse angle.

In the foregoing simplified examples reference is made to smooth surfaced rings and cylinders, whereas the present invention relates to the finishing of the teeth of an internal gear. To continue the analogy: the small cylinder \( C_n \) to \( C_0 \) according to the present invention is a small toothed pinion having teeth shaped to mesh with the internal teeth of the internal gear. Accordingly, for any particular gear, the crossed axes angle \( XA \) which is the angle in space between the axis of the gear and the axis of the cutter, is determined by the helix angle of the teeth of the cutter. Thus for example, if the internal gear is a spur gear and if a cutter is employed having its external teeth extending at a 5 degrees' helix angle, the cutter and gear can be brought into proper mesh only with their axes crossed at an angle of 5 degrees.

The type of tool employed in the present invention may be an abrasive tool, but preferably is in the form of a gear shaving cutter of the type disclosed in Drummond Patent 2,126,178 in which the teeth of the gear-like tool are provided with serrations or grooves extending up and down the sides of the teeth providing cutting edges. The cutting action between a gear shaving cutter of this type and the surface of the gear teeth engaged is essentially due to a relative sliding action longitudinally of the teeth of the gear which is a function of the angle between the axes of the gear and tool. If this angle is zero, or in other words, if the axes of the gear and tool are parallel, no crossed axes slippage is introduced but instead, the relative slippage between the teeth of the gear and the teeth of the cutter occupies planes perpendicular to the axes thereof. As a result of this it is desirable to provide a certain angle between the axes of the gear and cutter which is selected in accordance with the cutting action desired. Accordingly, it is not possible to select the angle between the axes of the gear and cutter in accordance with a crown formation or configuration required on the teeth of the work gear.

Even if it were possible by coincidence to obtain the desired cutting action and the required crowned configuration on the gear teeth by a particular crossed axes setting, it would be impossible to make minor changes in crossed axes setting to produce minor corrections or variations in the amount of crown and hence as a practical matter, it would not provide a satisfactory and efficient method of properly crowned internal gear teeth.

Also, it must be considered that to produce crowned internal gear teeth by providing a cutter in mesh with the teeth of the gear and by feeding it radially, initial contact between the teeth of the gear and cutter would be at one or both ends of the teeth of the cutter, unless the cutter were wider than the gear, in which case initial contact would be at the ends of the teeth of the gear. In either case, the cutting action obtained would be undesirable. The most efficient cutting action is obtained when initial contact is between intermediate portions of the gear and cutter and in which the cutting action may be extended continuously and progressively from the midpoint to either end of the teeth of the gear and employing a contact with the teeth of the cutter which is thereafter in contact at the extreme end of the teeth of the cutter.

Applying these considerations to the crown finishing or shaving of the teeth of an internal gear, reference is now made to Figures 10-12. In Figure 10 there is a diagrammatical showing of an internal gear G receiving a tooth space 40 therein. A tool in the form of an external gear or pinion P is provided having teeth 42 designed to enter into tooth spaces 40 when the axes of the gear G and tool P are at a certain crossed axes relationship. If the teeth of the gear and pinion are unmolded from end to end, the contacting relationship between the teeth is as illustrated in Figure 10, this contact taking place at the corners of the teeth 42 of the tool.

In Figure 10 the shape of the tooth 42 as shown by the portion in section, may be considered as developed from a cylinder concentric with the axis of the gear G, and extended to the axis of another complementary cylinder C. The crown height of the gear teeth is thereafter angularly adjusted to the required crossed axes angle. It may be mentioned at this time that the crossed axes
angle will normally be between 2 and 20 degrees and the traverse angle may be any angle dependent upon the amount of crown to be imparted to the teeth of the gear.

In operation, either the gear member or the cutter member is driven in rotation and the other member rotated solely by the meshed engagement between said members. In the present case means are illustrated for directly rotating the gear and for rotating the cutter through its meshed engagement with the gear. Speed of rotation is relatively high, as for example at a surface speed of approximately 500 feet per minute, and this is referred to herein as rotation of the gear and cutter at cutting speeds. On the other hand, relative traverse, which in the illustrated apparatus is accomplished by moving the cutter in a horizontal plane and in a direction selected to produce the required crown, is relatively slow on the order of 12 inches per minute.

Referring now to Figures 13 and 14 the gear shaving machine is illustrated as comprising a main frame 59 provided with a vertically extending column 52 having a forwardly extending portion 54 at its top. Mounted in the forwardly extending portion 54 is a motor indicated in dotted lines at 56 which is adapted to drive a work support 58 in rotation. The work support 58 is carried by a head 59 which is angularly adjustable about a vertical axis to the angle required to bring about proper meshing between the cutter 70 and an integral gear carried by the work support 58 as determined by the helix angle of the teeth of the work and cutter. This adjustment is dependent solely on the helix angle of the parts and is entirely independent of the direction of relative traverse which as described has not as yet been determined. As previously described, the cutter has its teeth crowned so as to limit contact between the teeth of the cutter and the teeth of the internal gear to a narrow zone adjacent the high point of the crown of the teeth of the cutter. In order to determine the amount of crown to be imparted to the teeth of the internal gear, the sandwich 72 is now adjusted to the proper angular setting. If the direction of the ways is brought into parallelism with the axis of the gear, traverse of the cutter will produce a shaving action between the teeth of the gear and cutter but will not produce a crown on the teeth. If however, the sandwich 72 is adjusted so that the ways extend at an angle to the axis of the gear, traverse of the slide 66 will produce crowned teeth and the amount of the crown can be controlled by setting a desired angle between the direction of the ways and the axis of the work.

As a result of the foregoing the crossed axes angle of the gear and cutter may be selected as desired for most efficient cutting or for other considerations and the amount of crown may be predetermined by selecting the angularity between the direction of relative traverse and the axis of the cutter.

Thus, accurately controlled crowning may be produced in an operation characterized by the most efficient cutting action.

The drawings and the foregoing specification constitute a description of the improved method of crown finishing the teeth of internal gears in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. The method of crown finishing the teeth of an internal gear member which comprises running a gear-like finishing tool member in mesh at cutting speed with the internal gear member with the axes of said members crossed at an angle of between 2 degrees and 20 degrees, the tool member having its teeth crowned to an extent sufficient to limit the contact with the teeth of the gear member to narrow zones adjacent the thickest portion of the teeth of said tool member and producing a crowned configuration to the teeth of the gear member by effecting relative traverse between said members in a plane parallel to the axes of both of said members and in a direction in such plane oblique to the axis of said gear member and selected in accordance with required crowned configuration.

2. The method defined in claim 1 in which the direction of traverse occupies a zone in said plane between the projections of the axes of the gear and tool members thereon.

3. The method of producing a required crowned configuration on the teeth of an internal gear member which comprises placing it in mesh with a cutting tool member in the form of an external pinion with the teeth of the tool member having a helix angle differing from that of the internal gear member by an amount to result in a crossed 72 angular relationship between the axes of the members of between 2 degrees and 20 degrees, the teeth of said tool member being crowned sufficiently to limit contact with the teeth of said gear member to a narrow zone adjacent the diameter of the tool member intersecting the high point of the crown, driving one of said members in rotation at cutting speed and driving the other member solely through the meshing relation of said members, and relatively traversing said members in a plane parallel to the axes of both of said members and in a direction in said
plane oblique to the axis of said gear member and selected independently of the helix angles of the crossed axes angle of said members to produce the required crowned configuration on the teeth of said gear member.

4. The method defined in claim 3 in which the direction of traverse occupies a zone in said plane between the projections of the axes of the gear and tool members thereon.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,228,965</td>
<td>Miller</td>
<td>Jan. 14, 1941</td>
</tr>
<tr>
<td>2,228,967</td>
<td>Miller</td>
<td>Jan. 14, 1941</td>
</tr>
<tr>
<td>2,228,968</td>
<td>Miller</td>
<td>Jan. 14, 1941</td>
</tr>
<tr>
<td>2,280,045</td>
<td>Miller</td>
<td>Apr. 14, 1942</td>
</tr>
<tr>
<td>2,561,706</td>
<td>Miller</td>
<td>July 24, 1951</td>
</tr>
</tbody>
</table>