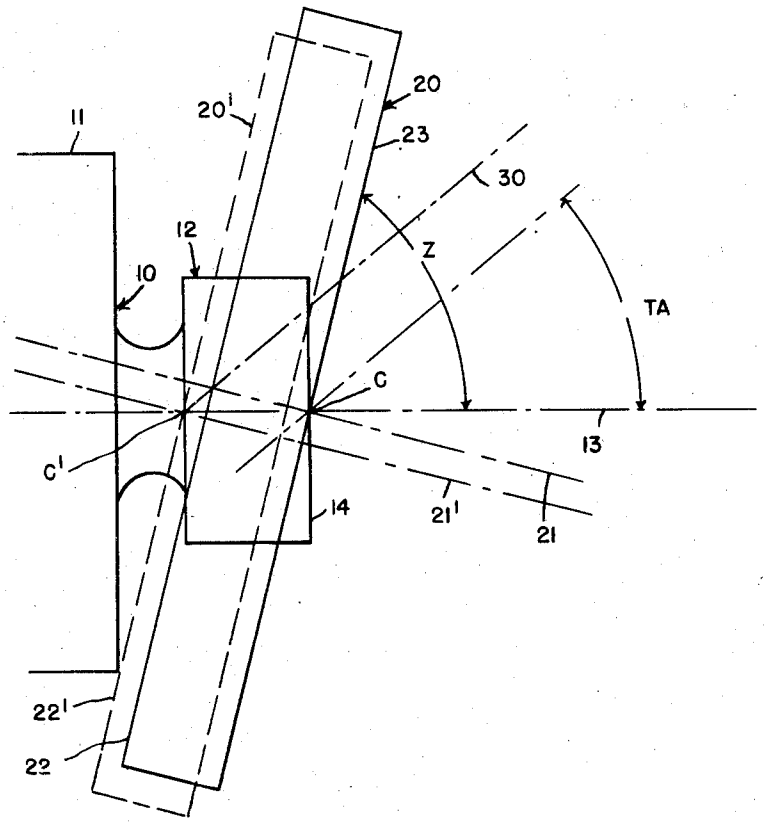
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METHOD OF SHAVING SHOULDER GEARS

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METHOD OF SHAVING SHOULDER GEARS

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The present invention relates to a method of shaving shoulder gears.

The finishing of gears to accurate dimensions by a method of crossed axes shaving has come into wide usage but it has been subject to certain limitations insofar as the final finishing of shoulder gears is concerned. By the term "shoulder gear" is meant a smaller one of a cluster of gears on the same shaft, the gears being of different diameter, or a gear next to a part of larger diameter on the same shaft. This leads to a problem of interference when attempting to shave a gear of relatively small diameter which is closely spaced from a gear or other part of larger diameter.

In the past, shoulder gears have been shaved by various modifications of the crossed axes shaving process, one of such methods being described in the patent to Mentley, 2,411,973, granted December 3, 1946.

It is found that if a gear and gear-like cutter are rotated in mesh at crossed axes and if a relative traverse between the gear and cutter is effected, the direction of which occupies a plane parallel to the axes of both gear and cutter and which direction is oblique to the axes of both gear and cutter, a superior shaving operation may be carried out on shoulder gears.

It is accordingly an object of the present invention to provide a new method of shaving shoulder gears characterized by the ability to shave gears of small diameter closer to larger gears without encountering interference between the cutter and the larger gear.

It is a further object of the present invention to provide a new method of shaving shoulder gears in which a smaller crossed axes relationship may be employed, thus reducing the effect of interference limitations.

More specifically, it is a feature of the present invention to shave a shoulder gear with a rotary shaving cutter by a method which comprises selecting a crossed axes relationship limited by minimum clearance conditions, meshing the gear and cutter at such crossed axes relationship, rotating said gear and cutter in mesh, and effecting a relative traverse between the gear and cutter in a plane which is parallel to the axes of both gear and cutter and in a direction oblique to the axes of both gear and cutter, which direction occupies an acute angular zone in said plane delimited by the projection in said plane of the axis of said gear on one side and the edge of said cutter on the other side.

Other objects and features of the invention will become apparent as the description proceeds,

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especially when considered in conjunction with the accompanying drawing, wherein:

The single figure is a diagrammatic view illustrating the meshed relationship between a cutter and shoulder gear in accordance with the present invention.

Referring now to the figure, there is illustrated at 10 a shoulder gear comprising a relatively large gear 11 and a relatively small shoulder gear 12 which is to be machined by a crossed axes shaving operation. The axis of the cluster gear 11 is indicated at 13.

In order to finish the teeth of the shoulder gear 12 completely across the length thereof and particularly to the ends thereof adjacent the larger gear 11, it is necessary for a cutter 20 to reach a limiting position indicated by dotted lines 20', at which time the axis 21 of the cutter occupies a position 21' and crosses with the axis 13 of the shoulder gear 12 at a point designated C'. It will be observed that the inner edge 22 of the cutter at this time is in the position 22' closely adjacent to a corner of the larger gear 11. In the figure, the edge 22 is shown diagrammatically as apparently contacting the corner of the larger gear 11, but it will be appreciated that in fact the cutter 20 and gear 11 are in different vertical planes so that the condition illustrated does not represent actual interference between the cutter and the larger gear 11. Assuming, however, that the dotted line position of the cutter 20 illustrates the limiting condition from minimum clearance considerations, it will be appreciated that this same condition determines the maximum crossed axes setting which may be employed.

In the diagram, the angle of crossed axes is illustrated as on the order of 15°. This is an exaggeration of the angular relationship between the axes of the gear and cutter which has been made for the purpose of clarifying the diagram. In practice it is found that the axes may be crossed at very small angles down to angles of 2° when the present method is employed.

In order to obtain the full benefit of the present shaving operation it is necessary that the cutter and gear have a relative traverse in a direction which is oblique to the axes of both gear and cutter and which traverse further is in a direction which occupies the angular zone Z delimited by the axis 13 of the gear on one side and the edge 23 of the cutter 20 on the other side.

In crossed axes shaving, theoretical contact between the teeth of the gear and the teeth of the cutter is located in a small zone which is deter-

mined by the instantaneous common normal to the axes of the gear and cutter, this zone being known in the art as the center of crossed axes. In order to distribute the finishing action of the shaving cutter across the teeth of the gear from one end thereof to the other, it is necessary to introduce a relative traverse between the gear and cutter, this trverse occupying a plane which is parallel to the axes of the gear and cutter and which may be in a number of different directions in such plane. If the relative traverse between the gear and cutter is in a direction parallel to the axis of the gear, the center of crossed axes remains fixed with respect to a definite zone of the cutter, thus causing excessive wear in the cutting zone without employing the full width of the cutter. On the other hand, if the relative traverse were in a direction parallel to the axis of the cutter, the center of crossed axes would remain fixed with respect to a definite zone on the gear and accordingly the teeth of the gear would not be machined uniformly from end to end. Instead, they would be provided with a hollow whose maximum depth coincided with the zone determined by the center of crossed axes.

Other directions of relative traverse have been suggested in the past. One such direction of traverse is perpendicular to the axis of the gear. This direction of traverse has the disadvantage that it tends to reproduce marks on the teeth of the gear corresponding to the cutting edges provided on the teeth of the cutter. In my prior copending application, Serial No. 694,477, filed September 3, 1946, there is suggested the possibility of effecting relative traverse in a direction oblique to the axes of both gear and cutter, which direction forms an angle of not more than 65° with the axis of the cutter. This traverse, which is termed "diagonal traverse," has certain definite advantages. Among these, it causes the center of crossed axes to shift simultaneously with respect both to the gear and the cutter, thus extending the finishing action of the cutter uniformly across the length of the gear teeth from one end to the other and also distributing the wear longitudinally across the width of the cutter.

Referring again to Figure 1, considering the two limiting sides of the angular zone Z separately, it will be appreciated that relative traverse in the direction of the axis **13** of the gear is what has come to be known as conventional shaving. Traverse in this direction results in the center of crossed axes remaining fixed with respect to the cutter so that in order for the cutter to machine the inner ends of the teeth of the smaller or shoulder gear **12**, the initial set-up must be such that the center of crossed axes is at the left-hand edge of the cutter **20** at all times. This requires the stroke or traverse to be relatively long and further leads to undesirable unbalanced conditions. These conditions may be overcome in part by imposing a corrective angular displacement of the cutter relative to the gear as disclosed in the patent identified above, but if possible it would be preferable to avoid the necessity for imposing such corrective angular displacement.

The other boundary of the angular zone Z is determined by the side **23** of the cutter **20**. If traverse were in the direction of the side **23**, or perpendicular to the cutter axis, the result would be the formation of cutter marks on the teeth of the gear which would not be wiped out and which would render the gear unacceptable to the industry. However, if the direction of traverse is oblique to the axis **13** of the gear and the side **23** of the cutter and occupies the zone Z, by a judicious selection of the precise angle of traverse it is possible to avoid the necessity for excessive traverse, the corrective angular displacement between the gear and cutter, and the formation of undesirable cutter marks on the teeth of the gear. The direction of traverse may be varied substantially so long as it does not approach too closely to a direction parallel to the axis **13** of the gear on the side **23** of the cutter, and further so long as it does not exceed an angle of 65° with respect to the cutter axis, as fully set forth in my prior copending application, identified above.

In the diagram of Figure 1, the direction of traverse is illustrated as parallel to the lines **30**, which may be taken to indicate the trace of the ends of the axis **21** of the cutter **20**. It will be observed that when the cutter **20** is in the full line position the center of crossed axes is at the point C, at which time the cutting action is along the side **23** of the cutter and along the side **14** of the gear **12**. As traverse takes place in the direction of the lines **30**, the axis **21** of the cutter moves to the dotted line position indicated at **21'**, at which time the center of crossed axes C' has shifted to the opposite side of the cutter and to the side of the gear **12** which is closer to the larger gear **11**. This means that the finishing action has been distributed uniformly from one end to the other of the gear teeth and at the same time the cutting action has been performed by the entire length of the cutter teeth.

In the diagram the width of the cutter **20** is illustrated as just sufficient to finish the width of the gear **12**, although in practice it may be somewhat wider if desired. It will further be appreciated that the theoretical width of cutter necessary to finish a definite width of gear varies in accordance with the traverse angle selected. In the illustrated diagram the traverse angle TA, which is the angle between the direction of traverse and the axis of the gear, is illustrated as about 40°.

In prior conventional shaving, that is, crossed axes shaving in which the direction of relative traverse is parallel to the axis of the gear, the minimum crossed axes setting has been said to be about 3°. However, in practice it is found that at angles less than about 6° the cutting action has not been entirely satisfactory and instead of removing metal in a free cutting operation there has been a tendency for the cutter to burnish the teeth of the gear. When employing the present method of shaving shoulder gears, a crossed axes setting of as low as 2° has been employed and the cutting action has been observed to be exceedingly free and accurate. The reason for this free cutting employing the diagonal traverse disclosed herein is not entirely clear from a theoretical point of view, but it has been amply demonstrated in practice.

It is thus possible by employing diagonal traverse to reduce the crossed axes setting to an angle much smaller than previously thought practical, thereby making it possible to shave shoulder gears in which the smaller gear being shaved is closer to the adjacent larger gear than has previously been possible.

It may be pointed out that one of the objections to finishing a shoulder gear with the conventional process which involves relative traverse in a direction parallel to the axis of the gear is that all of the cutting done by the cutter is per-

formed by the ends of the cutter teeth. When the present invention is practiced the cutting action is initiated at one end of the cutter teeth and terminates at the opposite end thereof so that at no time is end cutting by the cutter teeth being performed.

Having in mind the fact that the traverse angle employed in diagonal traverse crossed axes shaving should be less than 65° (as disclosed in my prior copending application) and since the present method involves a relatively small crossed axes setting, it will be understood that the traverse direction will in all cases be between a direction parallel to the axis of the work, and a direction making an angle of not more than 65° with the cutter axis. However, traverse angles of less than about 5° to the work axis are so closely equivalent to conventional traverse parallel to the axis of the gear that in order to obtain the benefits of the present method the traverse angle should be greater than 5°. As a result, it is possible to define the traverse direction as a direction between a direction parallel to the axis of the work, and a direction making an angle of not more than 65° with the cutter axis.

Inasmuch as the dotted line position **20'** of the cutter represents the limiting condition under which the teeth of the gear **12** have been machined from end to end, it is necessary for the first traverse of the cutter to be toward the larger gear of the cluster, or in other words the first traverse must correspond to a movement of the cutter **20** from the full line position to the dotted line position **20'**. Normally the machining operation will include a reverse stroke during which the cutter moves relative to the gear from the dotted line position **20'** to or beyond the full line position.

If the direction of traverse between the gear and cutter were in a direction perpendicular to the axis of the gear, the dotted line position **20'** of the cutter would represent the positions of the gear and cutter at the beginning rather than the completion of a cutting stroke. In other words, to employ relative traverse in a direction perpendicular to the axis of the gear would necessitate a smaller crossed axes setting to avoid interference between the cutter and the corner of the larger gear **11**. Stated differently, the present method of diagonal traverse crossed axes shaving of shoulder gears permits the employment of larger crossed axes.

Where the direction of traverse has been referred to in the foregoing, and where it is recited in the claims, it is to be understood that this is a basic relative traverse which may if desired be modified by superimposing thereon additional relative motions, such for example as a relative rocking motion for producing crowned or otherwise modified gears. In such cases the relative traverse defined may then be merely a major component of a compound relative movement made up of two or more components.

While there is diagrammatically illustrated and fully described a specific method of shaving shoulder gears by diagonal traverse crossed axes gear shaving, it will be understood that this specific disclosure is made solely to enable those 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 shaving shoulder gears with a rotary gear-like cutter which comprises selecting a crossed axes setting determined by minimum clearance conditions when the common normal to the axes of the gear and cutter is adjacent the edges of the gear and cutter which are next to the shoulder of the gear, meshing the gear and cutter at such crossed axes setting with the common normal to the axes of the gear and cutter located adjacent the edge of the gear remote from its shoulder and with said common normal remote from the edge of the cutter next to the shoulder of the gear, rotating the gear and cutter in mesh, and effecting a slow relative traverse between the gear and cutter which occupies a plane parallel to the axes of both gear and cutter and which occupies the acute sector in the plane located between the axis of the gear and the side of the cutter, the direction and length of the traverse stroke being related to the crossed axes setting such that at the end of the stroke the common normal to the axes of the gear and cutter are closely adjacent the edges of the cutter and gear which are next to the shoulder of the gear.

2. The method of shaving shoulder gears with a rotary gear-like cutter which comprises selecting a crossed axes setting determined by minimum clearance conditions when the common normal to the axes of the gear and cutter is adjacent the edges of the gear and cutter which are next to the shoulder of the gear, meshing the gear and cutter at such crossed axes setting with the common normal to the axes of the gear and cutter located adjacent the edge of the gear remote from its shoulder and with said common normal remote from the edge of the cutter next to the shoulder of the gear, rotating the gear and cutter in mesh, and effecting a slow relative traverse between the gear and cutter which occupies a plane parallel to the axes of both gear and cutter and which occupies the acute sector in the plane located between the axis of the gear and the side of the cutter, the direction and length of the traverse stroke being related to the crossed axes setting such that at the end of the stroke the common normal to the axes of the gear and cutter are closely adjacent the edges of the cutter and gear which are next to the shoulder of the gear and thereafter reversing the relative traverse stroke to bring the gear and cutter to initial relative position.

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