Cutting Low-Pitch-Angle Bevel Gears; Worm Gears & The Oil Entry Gap

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Quuestion: Do machines exist that are capable of cutting bevel gear teeth on a gear of the following specifications: 14 teeth, 1" circular pitch, 14.5° pressure angle, 4° pitch cone angle, 27.5" cone distance, and a 2.5" face width?

Bob Smith replies: Machines made by The Gleason Works in years past could cut such gears, except for the very low pitch angle. These machines were known as "planers" and "planing generators." Some of these machines are still being used today by gear jobbers.

The planers used an involute former and a single point tool to generate the conjugate tooth profiles. The planing generators also used a single point tool, but had a relative motion between cradle and work spindle that generated the tooth shape. The most common planers were the 37, 54, 77, 120, 144, and 192. These numbers represented the approximate workpiece diameter capacity of the machines. The most common planing generators were the 60, 70, and 90. Again, these numbers represented the approximate workpiece diameter capacity.

Investigation shows that these machines were typically able to get down to a pitch cone angle of approximately 7°. But the questioner requires an angle 3° smaller.

He has resorted to milling the teeth and has asked for guidance on how to select cutter sizes and machine settings in order to achieve a quality result.

For many years, *Machinery's Handbook,* available from Industrial Press, has had a section on the use of Brown & Sharpe form cutters for the milling of bevel gear teeth. It also has a lengthy discourse on how to calculate machine settings. However, this method is used primarily for replacement gearing when no other proper method is available. The method creates a compromise tooth form that is not very conjugate. The result may very well be noise and vibration that is intolerable.

A solution to the questioner's problem might be the use of a gear type that has been known for years, but not widely used. H. E. Merrit, in the third edition of his book *Gears,* published by Pitman & Sons, Ltd., and others referred to these as conical involute gears. A more recent AGMA technical paper by L. Smith (AGMA paper 89-FTM-10. *Gear Technology,* Vol. 7, No. 6, Nov/Dec, 1990.) refers to them as "taper gears." The taper gears have an involute helicoid tooth form that is generated from a cylindrical surface, the base cylinder. All sections normal to the axis have a common base circle diameter and, therefore, the same involutes. However, the tooth thickness at

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any diameter increases linearly from the front face to the back face. (See Figs. 1 and 2.) The gear has the appearance of a bevel gear, but each transverse section represents a spur gear. (See A. Beam, "Beveloid Gearing," *Machine Design*, Dec., 1954.) This tooth form will produce conjugate gears and can be made with very little transmission error. This type of gear has the additional benefit of being insensitive to mounting errors, as are spur gears.

Calculations for this tooth form can by found in *Involutometry and Trigonometry* by W. F. Vogel and in several technical papers by Mitome, ASME, and JSME.

The taper gear can be produced by any rack type tool generator or hobbing machine which has a means of tilting the work axis and/or coordinating simultaneous transverse and infeed motions. (See Smith.) In the past, mechanical machines of this type have been rare. This is the main reason that they have not come into common use. However, any CNC hobbing machine in common use today should be able to produce taper gears. CNC abrasive hobbing machines can also be used to grind them.

To address questions to Mr. Smith, circle Reader Service No. 78.

Question: What is meant by the term "oil entry gap," when referring to the mesh condition of a worm and worm wheel?

Bill Janninck replies: One of the requirements frequently specified, among the other geometric and dimensional values and tolerances for a worm gear set, is the one defining the area of contact. The driven flank of the gear is examined for the location and percentage of area of contact shown by the transfer of a color-

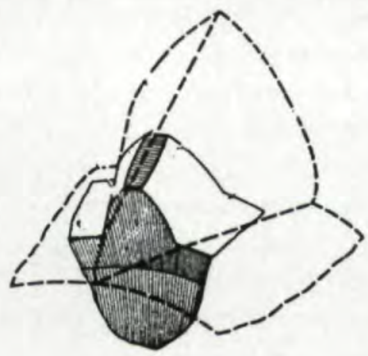

Fig. 1 - Spur taper gear tooth. Complex helicoid

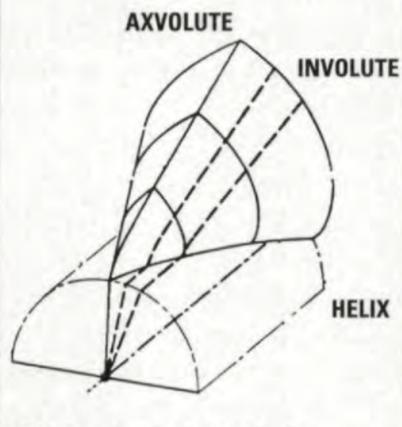

Fig. 2 - Taper gear tooth

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Fig. 3 - Ideal contact.

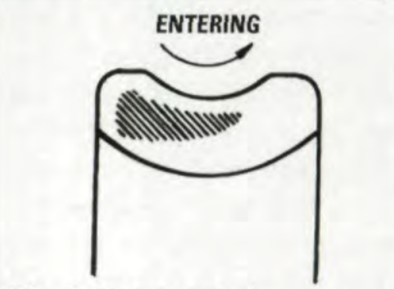

Fig. 4 - Entry contact.

Fig. 5 - Edge contact on entry.

ing medium from worm to gear while in rotation. The contact pattern can generally be described as high or low, leaving or entering, or edge, this last pattern being sure cause for concern or rejection. For some sets the contact patterns are checked at both low load and in the anticipated operating range to allow for possible deflections during use.

Since worm gear sets are classified as high sliding gearing, because the worm flank constantly slides across the gear teeth, lubrication is extremely important. The contact pattern is usually specified to be biased toward the leaving or outgoing side of the gear teeth. This is the ideal contact pattern and is shown in Fig. 3. That area of the gear flank which does not show contact is obviously in clearance, and as one proceeds across the gear face from entry edge toward the contact area, clearance diminishes. This tapering space forms a wedge or oil entry gap. It allows the oil to migrate or sweep into the mesh zone.

If the area of contact occurs near to the entry side, as is shown in Fig. 4, the oil film can be reduced or thinned out and may even be broken, possibly causing overheating and failure of the set. If a hard edge contact occurs, as is shown in Fig. 5, the oil can be substantially diverted from the mesh, and the oil film broken. Edge contact is immediate cause for rejection.

Question: How is this gap produced on the gear? Can it be produced with a standard hob? How can it be produced by the flycutting method?

The clearance gap is produced on the worm gear flank by the amount of oversize designed into the hob. The more the oversize, the more the clearance and the smaller the contact pattern. Standard worm gear hobs generally have ample oversize built in to form some gap clearance, but if a special specification is given on the contact pattern, the hob design might have to be reviewed. Actually hob oversize serves two purposes. It also permits some resharpening life when the hob becomes dulled. Every time a hob gets sharpened the diameter is reduced along with the oversize of the hob, and as the oversize is reduced, the contact pattern will change, slightly increasing in width. On a single start hob almost the entire hob can be consumed, resharpening gradually until the hob diameter is reduced to standard and no oversize remains. If the hob goes undersize, it is considered unusable. When the hob is new and has the largest oversize, the contact area is the smallest, and at the end of life, when the hob is a near match to the worm, the largest area of contact is seen. If there are strict limits on the contact pattern, then the hob oversize as well as sharpening life

may have to be restricted to suit.

During the worm gear cutting procedure, the contact pattern can be moved across the face of the gear by altering the hobbing machine, setting angle and observing the results, moving the contact into the ideal area.

The use of flycutting methods works in much the same manner. However, if the fly cutter is made of a radially adjustable blade inserted in a body, the oversize can be established by moving the blade out to the desired position. Once the pattern is accepted, the blade can be kept at the same oversize by resetting it after each sharpening. This gives consistent control on the contact pattern. If the flycutter is solid, then the same problems arise as experienced with conventional hobs. In any case the target oversize is usually selected by the hob designer or user based on experience and mathematical modelling. ■

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