Our Experts Discuss Hobbing Ridges, Crooked Gear Teeth, and Crown Shaving

Question: When cutting worm gears with multiple lead stock hobs we find the surface is "ridged". What can be done to eliminate this appearance or is it unavoidable?

Bill Janninck replies: We examined the sample worm gear you submitted as an example of the ridging problem. To illustrate it we show a scale graphical diagram of the gear tooth flank in Fig. 1. The lines on the flank show the ridges or high points on the profile surface representing a surplus of material. In the gear cutting trade the flats causing this are called generating flats and are similar to facets. These flats are a function of the number of flutes in the worm gear hob used in cutting the gear by the infeed process. In this process changes in feed or speed have no effect on the flats, as the hob and gear are locked together by the machine gearing. Unless the flutes in the hob are changed, these flats are unavoidable.

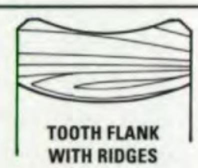

Fig. 1 Sketch of ridges on tooth flank.

In the hobbing process all parts cut, whether gears, splines, sprockets, serrations, etc., are formed by generating flats on the profile. Normally on finish-cut parts, the flats must be narrow enough to be inconspicuous and not cause a physical problem. This is easily accomplished using single-start or larger diameter hobs with more flutes.

We do not know the specific requirements for your gearing, but in most cases, if the flats are visible there may be a problem, both in smoothness of roll and in surface durability. On softer bronzes some ridging can be accepted with the peaks being smoothed down plastically in operation with the mating worm. But on the harder bronzes or with iron-based materials, such as yours, little ridging is tolerable.

Can one eliminate this appearance? Yes! The most direct and best way to do this is to use the tangential method of hobbing worm gears. Fig. 2 shows a comparison of infeed and tangential feed hobbing. The latter requires a special capability in the hobber which advances the hob axially at a rate which eliminates the ridges. Your current hob could probably be used in this mode.

Is this an expensive way to go? Yes! The infeed process is still the fastest way of cutting worm gears, and if one does not have a tangential hobber, there may not be much choice.

So let us ask another question. Could we improve the ridging using the infeed process? Yes! In your case the gear has 23 teeth and the hob has 4 starts. There are no common divisors in 4 and 23 so we have what is called a prime or hunting ratio. (If the numbers were 4 and 24, the ratio would be even or non-prime.)

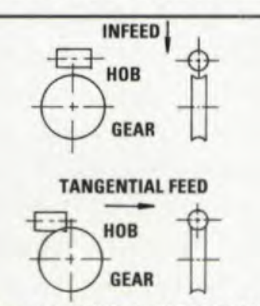

Fig. 2 Comparison of infeed and tangential feed hobbing.

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Address your gearing question to our panel of experts. Write to them care of Shop Floor, Gear Technology, P.O. Box 1426, Elk Grove Village, IL 60009, or call our editorial staff at (708) 437-6604.

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With hob makers the usual rule is to make the flutes prime to the number of hob starts when the gear teeth and hob starts are prime. In your case the hob should have 9 flutes, which geometrically produce about 13 flats. We suspect your present hob has 10 flutes, and it will produce some 7 flats as was seen on the sample. Ten flutes in the hob with 4 starts have a common factor of 2, so one-half of the hob teeth will always track through the same path, reducing the possible flats generated by half. With 9 flutes there is no hob tooth tracking, and every tooth in the generating zone can cut a flat.

A single-thread hob is always prime, so all of the hob teeth available within the generating zone can cut. Hence, worm gears cut with single star hobs seldom have a problem.

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Different rules for fluting are used for infeed and tangential feed hobs because of different geometrical needs, and the rules must sometimes be modified to suit available space for flutes in the hob blank.

The generating flat problem occurs more with low numbers of gear teeth, with higher numbers of hob starts, with lower pressure angles, and with higher hob lead angles. There are some parts with even ratios, such as the 4 and 24 mentioned above, where only tangential hobbing can do the job. There is definitely a place and need for tangential feed hobbing.

Question: We use a Gauthier hobber for cutting gears. What could be causing us to get crooked teeth on the parts cut?

Bill Janninck replies: It has been many years since I have heard anyone mention the Gauthier hobber. I believe it is of Swiss origin and is usually used to cut small gears of fine diametral pitch.

Usually a complaint of crooked teeth refers to what is seen in the plane of the profile. This crookedness, which some call lopsided or unsymmetrical teeth, can refer to involute or cycloidal form, but is more apparent on the latter.

This problem is not unique to the Gauthier machine, but is possible on all hobbers. The results are more obvious on small numbers of teeth and with the finer pitches.

There are several possible contributing factors which can be investigated. They include:

• *Hob wobble.* Hob wobble, which is a specific type of runout, can cause the hob teeth that finish-form that part to come into the cut out of proper position, and can cause an unsymmetrical form to be cut. The hob spindle can be checked for runout from end to end as a possible source for wobble. A bent spindle can be the cause of your trouble. But it is more important that the hob itself be checked while fully clamped down in the machine. The cantilever arbor used in some fine pitch hobbers is easily sprung if the nut face is not square.

•*Hob accuracy.* If the hob itself has been poorly formed or if the hob has been badly sharpened, the resulting errors can be directly transferred to the work.

•*The machine condition.* All machine parts are subject to wear or possible damage during routine use. In a gear hobber, the heart of the gear machine is the index drive worm and gear, and these have to examined particularly closely. If too much backlash or looseness exists, the part being cut can be randomly moving out of proper track, causing malformed teeth. Visual and mechanical inspection of the entire machine, including the gears, bearings, and ways, should be done.

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

Question: We have a gear of the following dimensions: 28 teeth, 6 D.P., 20° P.A., Pitch Diameter, 4.666. It runs against a bull gear with the following dimensions: 67 teeth, 6 D.P., 20° P.A., pitch diameter 11.166. These gears are carburized to a minimum hardness of 58 RC. The case depth is .040-.045". The parts are solid disks with a hub on one side. The material is #8620, with no pre-machining heat treatment under our control (machined as purchased). These are spur gears. The lot size is 20 pieces, run once a month. They are quenched in open baskets, hub side down - no racking or controlled loading. Heat treatment is in-house. Distortion is a .015 to .030 "potato chip" measured on side of blank. There is heat treat distortion on the larger gear. We wish to correct this with crown shaving. Should the shaving be done on the larger or the smaller gear?

Don McVittie replies: The pinion is usually crown shaved, because it is smaller and because wide face solid pinions tend to distort in an "hourglass" form. The barrel-shaped crown that results from shaving tends to distort back to a more cylindrical form during heat treatment.

In many shops, shaving is cheaper than finish hobbing, improves finish, and makes a more accurate part. In that case, either or both gears can be crowned during the shaving operation.

Parts can also be tapered to compensate for conical distortion or shaft bending deflection. Crowning is also used to compensate for mounting problems, like variations in shaft alignment due to tolerances on bore locations and parallelism. The book, *Modern Methods of Gear Manufacture*, is no longer "modern", but it's still a good practical reference on gear shaving. The AGMA Gear Symposium to be held in Indianapolis on April 5-6 will also have discussions on both shaving and heat treatment.

The amount of crown is critical, since too much total crown in the pair of gears will concentrate the contact into a narrow area of the face and lead to premature pitting failures. A reasonable rule of thumb is "no more than .0003 to .0005" of crown per inch of face". (The tolerance is necessary to control shaving cost.) In other words, if only one member were crowned, the tooth thickness of a two-inch face width gear would be .0012 to .0020 less at the ends than in the center of the face.

This limits the amount of distortion which can be compensated by crowning. If the part distorts irregularly, if the distortion is more than .0003" per inch, or if the distortion varies much between parts, crowning won't be able to compensate enough to give good contact between the gear teeth. In that case distortion must be reduced by better heat treating practice or by a post-heat-treatment machining operation. Even post-heat-treatment grinding or hard cutting can have problems with badly distorted parts because of excessive stock removal on some teeth. Grinding steps in the root, shallow case depth, and excessive grinding times are examples of these difficulties.

The most likely areas for process improvement to reduce distortion are:

•Uniform pre-machining heat treatment and stress relief of the parts, so that the carburizing process doesn't act as a stress relief.

•Control of part loading and racking to assure uniform heating and cooling of all parts in each load. Each part in the rack should see the same heating and cooling rates. Crowded parts will be more likely to distort, since the quenchant can't flow uniformly between them.

•Slow, uniform heating, so that the thin sections of each part don't heat much faster than the thick sections.

•Slow, uniform, quenchant circulation. Dead spots in the quench medium will cause differential cooling, promoting distortion. Use the slowest quench which will give the required root hardness and microstructure.

•Part orientation during the quench to promote symmetrical cooling. Stem pinions usually quench better with their axes vertical, but some gears seem to do better with their axes horizontal.

It takes some experimentation to get the right recipe for each part. ■

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