Our Experts Discuss...

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Question: ***I have just become involved*** **with the inspection of gears in a production operation and wonder why the procedure specifies that four involute checks must be made on each side of the tooth of the gear being produced, where one tooth is checked and charted in each quadrant of the gear. Why is this done? These particular gears are checked in the pre-shaved, finish-shaved, and after-heat-treat condition, so a lot of profile checking must be done.**

Answer: The involute or profile check is one of the elemental checks made during the process of inspecting gears. The others include lead or parallelism, tooth spacing, and runout. In this case, reference is made only to the element of profile, which is usually based on a modified involute curve, where the modifications may include tip relief or both tip and root flank relief, called involute crowning. Routinely, the results of this check are recorded as a trace on a chart, and the results are verified by reference to a profile diagram or "K" chart, usually supported by some additional written dimensional limits, such as profile inclination, form inclination averaging, form reversals, holes, or steps.

Ordinarily, the profile check is made in the center plane of the gear tooth face, and this only shows the conditions in a very narrow band traced by the sensing stylus. In other words, the check only examines a very narrow slice of the entire tooth flank. Consider that usually many teeth in the gear are tested. Then checking only one trace on one tooth is a poor way of judging the profile merits *of the entire gear. Checking four teeth* approximately 90° apart yields a better sampling of what might exist on the gear, but is still not a good sample size if the gear comes from an unknown source. But in this case at least, different teeth are examined in four separately removed regions on the gear circumference.

One does not freely accept the use of such a small sampling on the profile until there is some evidence that the process is consistent and is under control. At least a few gears must be checked for profile in a number of positions across the face, as well as many teeth around the gear perimeter, to assure this. The shaving process, for example, does have a consistency in its process, and the four profile checks are reasonably sufficient once some historical data is developed, and the gear is in production.

On gears with smaller numbers of teeth, the runout error can cause a scattering of the involute traces for the four quadrants checked. Frequently the overall profile error from tip to root, taken from the four checks, is averaged, cancelling the runout effect.

Then, of course, the same inspection procedure must be done for the opposite tooth flank, usually working to the same tolerances. Planet gears and idler gears must work on both flanks, while other gears may be identified as to driving or following flanks and might be toleranced separately.

The quality demands made on gears specifically for involute or profile control are usually related primarily to the final quality level required and secondarily to the manufacturing methods employed. When the gear shaving process is used to finish-machine a gear, then considerations of certain interim quality levels between the pre-shave cutting of the gear and the shaving process are essential, because in the shaving process, no external rotational control is present, and the gear being shaved is its own steering or guiding element, and its pre-shaved accuracy will affect the final shaved accuracy level. In other words, pre-shaved accuracy can control the results after shaving. The better the gear before shaving, the better the gear after shaving.

If a gear is subjected to a heat treating process after the shaving operation, then the gear must be again inspected to assure the final quality level is met. Obviously this means some adjustments and

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allowances must be prescribed in the dimensioning of the shaved profile in anticipation of changes during the thermal processing.

Today some of the monotony associated with manual profile inspection, recording, and analysis can be reduced with the use of programmable computer controlled gear inspection equipment. It can also be highly useful when extensive checking must be done when doing developmental work or doing troubleshooting work.

Question: **As we monitor the wear occurring on hobs in our gear cutting operation, we notice that some different wear patterns develop. Most of the time they appear as edge wear where a definite wear land on the hob tooth side flank develops. At other times, the edge wear seems less, but a definite wear gouge occurs on the hob tooth cutting face. What causes the differences?**

Answer: Factors involved in the development of wear patterns on rotary cutting tools, such as gear hobs, include the work material, hardness and microstructure, tool material, hardness, surface finish, surface treatment and special coatings, machine-tool-work rigidity and guidance, hob shifting methods, cutting speeds, feed rates, and coolants. Even things, such as climb or conventional cutting, and gear part geometry, such as helix angle or pressure angle, can have an influence.

In spite of all these variables, we can make some observations of average results seen on the cutting of typical carburizing gear steels being cut in the 180 BHN hardness range using uncoated hobs made of M-2 or M-3 high-speed steels. Usually the wear patterns observed can be divided into four categories. First, edge wear; second, face gouging or cratering; third, edge chipping; and last, peel back.

Edge wear alone is frequently found on single start or single thread hobs, where feeding the hob fast enough to utilize available machine power is possible. Because of the many available hob flutes and a limited feed rate, the tool cutting edge flank is abraded. This is due to a light chip load per tooth and is caused by skating or rubbing. This condition can be seen on any hob being applied with a light chip load per tooth.

Cratering is usually the result of substantial feed rates coupled with the use of high production, multiple-start hobs. The available power of the hobbing machine can be utilized, and substantially heavy chip loads are imposed on the hob tooth face, abrading away a pocket or crater area near the cutting edge where the chip impinges. Edge or flank wear, although also present, usually appears less severe when compared with the amount of cratering. If the crater wear approaches the cutting edge, it is probable that edge chipping will ultimately occur.

Chipping can also be caused by brittleness at the cutting edge from higher hardness, higher alloyed, high-speed steels, or from a surface treatment, such as nitriding. If a chip does occur, and the tool continues running, further edge damage can be seen as a washed out area nucleating at the chip. This is called peel back, and usually the evidence of the originating problem, such as a microchip, is gone. Peel back can progress very quickly when a tool is operating at high production speeds and feeds.

The use of titanium nitride as a tool coating has proven successful at deterring tool wear on hobs used in cutting steel materials. A single coating which remains on the side flanks of the hob, even after the face sharpening operation, is helpful when flank wear is predominant. If cratering occurs, then the recoating of the tools may be necessary after each sharpening to protect the tooth face. ■

Address your gearing questions to Gear Technology, P.O. Box 1426, Elk Grove, IL, 60009, or call (708) 437-6604.