Gear Inspection Chart Evaluation; Specifying Unusual Worm Gear Sets

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Question: When evaluating charts from a gear inspection machine, it is sometimes found that the full length of the profile traces vary, and that sometimes they are less than the length of active profile (above start of active profile-SAP) by up to 20%. This condition could be caused by a concentricity error between tooth grinding and shaping, or by unequal stock removal when grinding. (See Fig. 1.) Is it possible that some of the variation is coming from the inspection machine? How can variation from the inspection machine be reduced?

When looking at Fig. 1, the minus stock shows near the start of active profile (SAP), sometimes above and sometimes below the line. This is an undercut of the teeth. When producing gears with a small number of teeth, this can be a natural result of the trochoid generated by the cutting tool. However, the gear we are discussing had 31 teeth, so the undercut must be from intentional protuberance built into the pregrind shaping tool. Theoretically, if the cutter were designed correctly, this would clean up to a nice blend in the grinding operation. From a practical standpoint, this probably will never happen. The amount of protuberance would have to be just right, stock division evenly balanced, and the tool would only work for cutting a given tooth number. Also if there were runout of the blank between the cutting and grinding operation, the height of the undercut would be different in each tooth. Some would clean up and others would not.

If everything were theoretically correct, but the operator didn't divide the stock equally between sides, the undercut would show on one set of flanks only (e.g., the right flanks). That is not the case in Fig. 1. Some teeth look good on both sides, and some look bad on both sides. Therefore, I must assume that the operator did divide stock the best he could, and that runout did exist some place in the process between cutting and grinding of the teeth. Also, given the fact that the tips all line up on the chart, I don't believe that the inspection machine is at fault in this case.

However, there are some problems with the data furnished by the gear maker, and there are some things that can happen on the inspection machine to make the data faulty. First, the gear maker supplied charts without any substantiating scale factors or reference marks on it. The buyer of the gear put the dotted SAP line on by counting down from the tips of the teeth. This would only be correct if the gear OD were correct. The chart maker should mark at least one reference point for

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degrees of roll or base tangent length, such as pitch diameter, SAP, etc. The chart maker should also put scale factors on a chart for profile deviations (X) and degrees of roll or base tangent length (Y). A chart that is unmarked is worthless to anyone the next day.

The inspection machine and recorder calibration could also be off as far as base tangent length is concerned. Another potential source of error in base tangent length (or degree of roll) evaluation would be a worn stylus. A worn stylus will give errors in the starting point of non-involute parts of a gear profile, such as tip modification and undercut. The best way to qualify a machine for this problem is to use a non-involute master as well as an involute master for calibration. Such masters are called pin masters or flank masters. They will quickly show a problem with stylus wear and placement relative to the master or theoretical base disk and tangent.

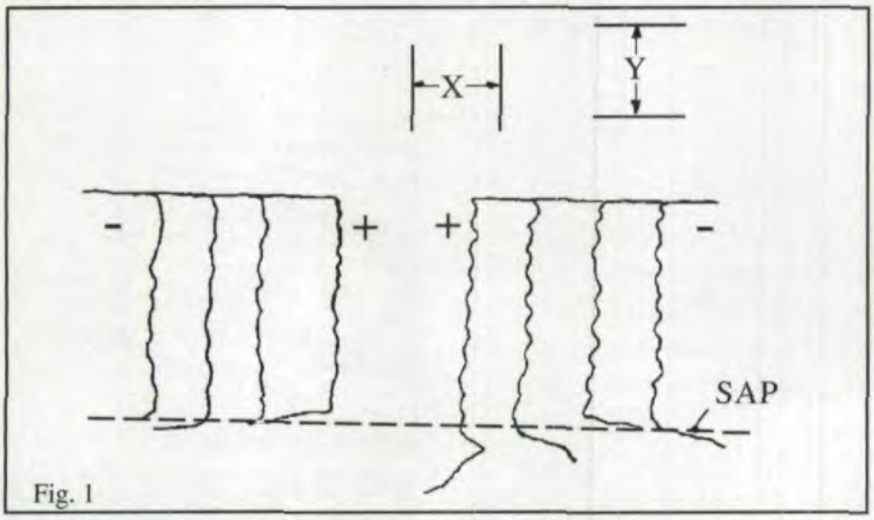

Fig. 1

Question: How should this undercut be evaluated in relation to performance and life?

Performance, in my mind, is related to noise or vibration (transmission error). If the undercut is severe and uses up 20% of the active profile as the questioner says, there could be loss of contact ratio and, therefore, loss of smooth motion. For the amount shown in Fig. 1, it should make only an insignificant difference.

Life of the gear set relates to surface durability and bending strength. Undercut will cause a reduction of bending strength. Whether this is serious or not depends on your design and application. If you have not experienced any breakages, it may not be a serious problem. If your design is borderline for strength, then it would be of concern.

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

Question: Many of the gear sets manufactured by gear shops are of very low quantity, even as little as only one set. These are used frequently as replacement gearing for equipment breakdown and repairs. Along with the usual spur, helical, and worm gear sets that are needed, there is also a demand for some of the rather unusual designs, such as dual lead worm gear sets, double enveloping worm gear sets, and barrelled coupling parts. How does one layout and specify these, and can they be cut on conventional gear shop equipment?

Dual Lead Worm Gear Sets

Dual lead worm gear sets are somewhat special, since the worm has a different lead for the right and left flank. A conventional worm has the same lead on both flanks. The name dual lead is preferred, but we have seen part prints labelled as "tapered lead worm", yet the configuration is identical. The outside diameters and root diameters are cylindrical, and the worm thread thickness increases progressively from one end to the other. The purpose of these worm gear sets is to control or minimize backlash by axially advancing the worm relative to the wheel. The increasing thickness of the thread displaces the lash. Subsequent wear, which gradually increases lash, can periodically be adjusted out. These sets are typically used in indexing applications, including the main indexing drive in gear hobbing machines.

One method for specifying this type of set is to first establish the dimensions for a normal worm and gear pair, all dimensions being set according to the standard procedure and proportions. The basic lead established for the worm then becomes the helix that passes through the middle of the worm thread, and each flank lead is then made slightly longer and shorter than the basic by an equal amount. This is determined to suit the amount of thinning required from the thin to the thick end of the worm. Holding the worm pitch diameter and the adjusted lead for each flank, the right side and left side lead angles are determined. Each flank has separate dimensions, and the worm can be produced by thread milling, thread grinding, or thread chasing using two separate setups and passes, one for each flank, verifying thread thickness from end to end to complete the worm. All the operations use conventional cutting equipment.

The mating worm gear is also different in specification from flank to flank, with each being conjugate to its mating worm flank. If desired, a special dual lead worm gear hob can be used, and the gear is cut by the usual infeeding process. Each flank of the hob, which simulates the dual lead worm, generates each mating flank. As is usual in worm and gear cutting, the set should be run together on a tester or fixture or tried in a gear box to assure a proper match. The gear and worm must be properly oriented, and the worm axially located for proper fitting.

If one is making only a set or two, they can also be fly-cut using a tangential-feed-equipped hobber. Again the machine must be geared separately for each flank, making a separate pass for each one. Final fitting must again be checked on a tester or fixture.

Double Enveloping Worm Gear Sets

Double enveloping worm gears, that is, those sets where the worm has an hourglass form or throat, as well as a throat on the mating worm gear, are not readily duplicated using conventional gear cutting machines. Their primary purpose is increased load capacity or compactness. They can by layed out for specifications by duplicating the geometric shape of the parts to be replaced, maintaining center distance and part diameters and holding the number of starts and teeth.

Hourglass worms can be machined on a regular hobber by putting a cutter or bladed cutter assembly on the usual work gear location on the hobber and mounting the worm blank in the hob arbor location. The cutter is then fed radially into the worm blank producing an hourglass form. The cutter may be of solid construction in high-speed steel with straight-sided teeth spaced around, or may be made of an assembly of tool points locked in a supporting body. Proper blade location is essential whether cutting single or multiple start worms. Grinding an hourglass worm does require special machines and cannot be done on conventional hobbing machinery.

Cutting the gear is another matter, and even if an hourglass shaped hob were available, some additional machine motions are essential. After the hob is fed to proper depth, the gear blank must be rotationally advanced

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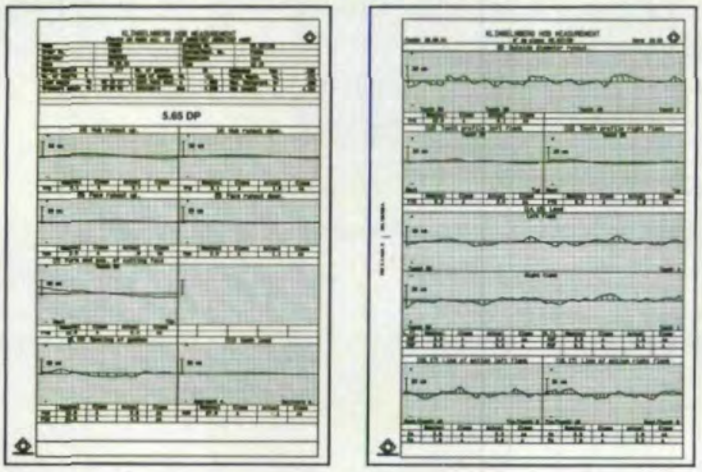

and retarded for a trimming cut on each flank. If this operation is neglected, the extra benefits and increased capacity of the double enveloping set may be completely negated. All of my personal efforts to cut the mating worm gear by conventional hobbing, even on single start sets, has been unsuccessful.

It may be a better choice to go to the original manufacturer of the gears and procure a proper replacement. They have the necessary special worm and gear cutting and grinding machines, the hob manufacturing capability, and the technology to produce these sets.

Under certain circumstances, a temporary or interim fix may be to replace the double enveloping set with a conventional cylindrical worm set.

Barrelled or Crowned Coupling Splines

Barrelled or crowned coupling splines also can be dimensioned by copying the damaged parts, but cannot be produced

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on a standard, conventional hobber without making some substantial modifications. It is necessary to make the hob change center distance with the part as it is fed along the part axis. This can be done by using a cam and follower mechanism or, if using a numerically controlled machine, by programming a rise and fall of the hob on the machine, such as is done in crown hobbing gear parts. We have seen some of these parts made first by hobbing the spline and then clearing away each end by form milling, leaving a small narrow tooth land. Functionally short term results were good.

If at all possible, it is best to try to procure these parts from the original source, where they have the special tooling and machinery to produce the parts properly. ■

To address questions to Mr. William L. Janninck, please circle Reader Service No. 79.