Computerized Recycling of Used Gear Shaver Cutters

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Most gear cutting shops have shelves full of expensive tooling used in the past for cutting gears which are no longer in production. It is anticipated that these cutters will be used again in the future. While this may take place if the cutters are "standard," and the gears to be cut are "standard," most of the design work done today involves high pressure angle gears for strength, or designs for high contact ratio to reduce noise. The re-use of a cutter under these conditions requires a tedious mathematical analysis, which is no problem if a computer with the right software is available. This article describes a computerized graphical display which provides a quick analysis of the potential for the re-use of shaving cutters stored in a computer file.

Shaving cutters are very expensive and their re-use offers considerable savings. Other benefits are the reduced inventory of cutters and minimum delay in gear processing if some way can be found to evaluate these cutters' potential for re-use. Computer software is available to facilitate the search of existing cutters to learn if any are useable as is, or if they can be modified to be used. Every cutter is a candidate for being selected. An obsolete cutter may be useable or possibly modified to become useable. An existing active cutter may be modified, and after meeting an immediate need, be returned to its assigned activity by being resharpened to its original curve. This will sacrifice some of the life of the cutter, but may be justified to minimize the delay of producing parts or the cost of purchasing a new shaver.

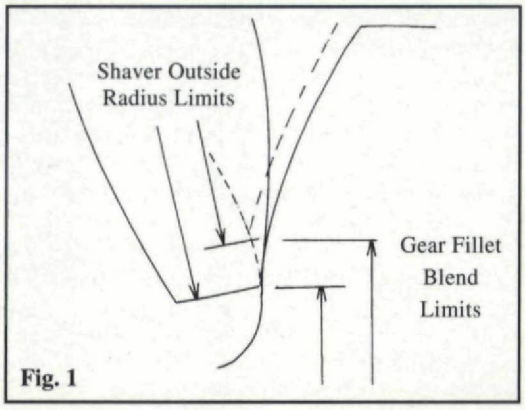

Fig. 1

For a shaving cutter to be useable, it must have the right base pitch, hand, and the proper helix angle to provide good shaving action. It is not obvious if the tooth length will permit shaving to the proper point in the fillet of the gear. If the tooth is too long, it will interfere in the root of the gear. If it is too short, it may not shave in the area where the mating gear tooth tip will make contact.

There are two approaches to assessing a shaving cutter's potential use in gear finishing. The first approach is to explore the fillet of the gear when a protuberance hob is used as a preshave cutter. The purpose of this study is to select a shaving cutter which will blend smoothly in the fillet of the gear. The second approach is to study the path of a candidate shaving cutter when a nonprotuberance cutter has been used as a preshave cutter. In this case the purpose is to select a shaving cutter which will penetrate to shave the flank of the tooth deeply enough to provide a shaved surface for the contact of the mating gear and may or may not reach the fillet. This second approach requires the "pairing" of gears, and caution must be used in designing a gear to match one which has been shaved in this manner.

The initial step in the first approach is to

study the action of the pre-shave cutter to determine two unique radii of the gear. The first radius is the point of maximum relief in the fillet formed by the protuberance of the pre-shave cutter. The second is the radius where the cutter protuberance has left the involute profile with adequate finishing stock for "cleanup." This does not need to be the full amount of finishing stock on the gear flank. If less than full stock is specified, it allows a greater outside diameter on the mating gear and a possible higher contact ratio. Ideally the outside diameter of the shaving cutter will finish the tooth to between these two unique radii with a nearly perfect blend in the fillet (Fig. 1).

To find the desired shaver cutter outside diameter it is necessary to compute the tight mesh center distance of the shaver and gear using an iterative procedure. Then calculate the working line of action, the radius that the tip of the cutter will have to be to reach the maximum relief in the fillet, and the radius to the point of required shaving stock for cleanup. The candidate shaving cutter must have an outside radius between these two values to be useful. The closer it is to the maximum relief value, the better. If the outside radius of the shaver is too large, it may be reduced to make it useable.

Shaving cutters may be sharpened a number of times. In so doing, the tooth thickness is reduced, which results in the shaver penetrating deeper into the gear. Therefore, the outside diameter must be reduced as well. The amount of outside reduction depends upon the involute angle when tight meshed with the gear being shaved. The suppliers of shaving cutters provide blueprint dimensions of the shaver outside diameter and tooth thickness when "new" and at "life." These dimensions are unique for a certain gear and are used for establishing a "sharpening curve" for the shaving cutter. These data can be plotted to show a curve of tooth thickness versus outside diameter throughout the life of the cutter.

While tooth thickness and outside diameter are the basic criteria, it is a common practice to use the terms "HOP" and "HOD." These terms stand for "height of pins" and "height of (outside) diameter," with measurements made from the circumference of the precision bore of the shaving cutter (Fig. 2). The HOP dimension is the distance from the closest circumference of the bore to the top of the pin placed between the teeth of the shaver, a process similar to measuring tooth thickness of gear teeth with "dimension over pins." The HOD dimension is the distance from the closest circumference of the bore to the top of the shaver tooth.

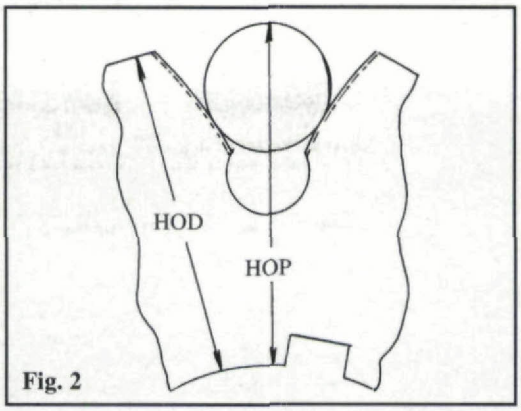

Fig. 2

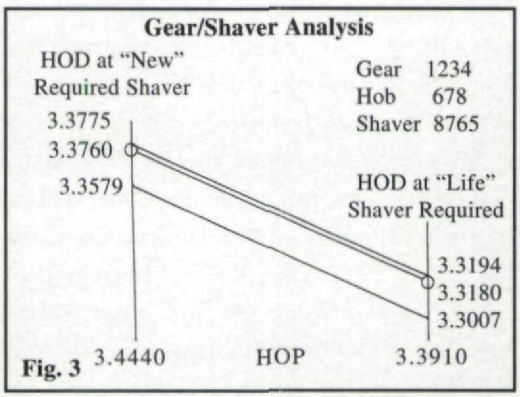

Fig. 3

A computer graphic display (Fig. 3) uses the HOP and HOD dimensions. The two vertical lines represent the tooth thickness (HOP) of the shaving cutter when new and at life. The circles on each of these lines represent the outside diameter (HOD) of a shaving cutter with tooth thickness (HOP) given at the bottom of the vertical lines. The line connecting the circles may be called the sharpening line. A shaver on the shelf may have a HOP and a HOD anywhere along this line, depending upon how many times it has been sharpened.

The two other sloping parallel lines on the computer screen are unique to the gear to be shaved. Taking the shaver's new tooth thickness (HOP) dimension, two shaver radii are calculated as described before, to meet the maximum relief and the desired shaving stock radii of the gear. The same is done for the "life" tooth thickness. These dimensions are placed on the two vertical lines and with the interconnecting lines form a parallelogram. If the shaver sharpening curve falls within this parallelogram, the shaver may be used to shave the gear.

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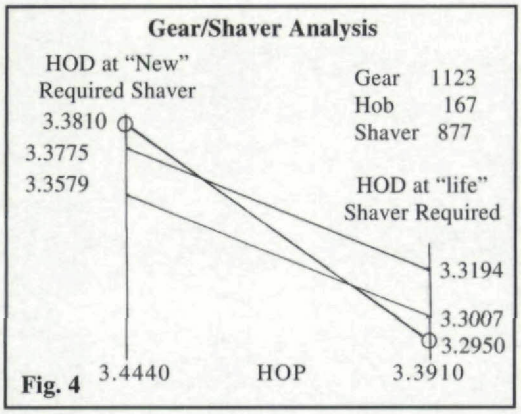

Fig. 4

If the shaver curve is outside the parallelogram, and the shaver has no prospect for other future use, it may be possible to modify it to get it into the parallelogram. If the sharpening curve is above the parallelogram, then by grinding the outside diameter, the sharpening curve will be moved downward and become useable. If the sharpening curve given is below the parallelogram, it may have only the tooth profile sharpened, and this will move the sharpening curve to the right and possibly enter the acceptable area.

The graphic display is a quick reference to the compatibility of a shaver/gear combination. The actual selection will require judgment of the urgency of getting the job done, number of gears to be shaved, and whether to modify obsolete cutters on the shelf. If the shaver is to be used for an application with long slender teeth, when it was originally designed for low contact ratio gears, there may be a problem with shaving the ends of the teeth. Shaver suppliers do not specify the depth of the tooth or root end of the shaving profile where it meets the drilled hole.

A shaver search computer program should have an option input so that if a particular shaver looks promising, an up-to-date measurement of the HOP and HOD can be input, and as a result the present capability known.

For the second approach, selecting a shaving cutter associated with a non-protuberance preshave cutter, the minimum radius on the workpiece gear where the mating gear tooth tip will touch is used instead of the previous two fillet radii discussed. This will occur at minimum gear center distance and maximum mating gear outside diameter. These values will establish a line with end points for new and life conditions. Since the shaving cutter now must have an outside diameter large enough to reach below the mating gear contact point, the same diagram requires that the sharpening curve of the shaver be above the line. A small margin of safety should be available to prevent any interference with the shaving stock remaining following the "rolling out" of the shaving cutter. This is especially true if the mating gear has more teeth than the shaving cutter. A calculation of the shaver tip/gear root clearance should be included in the display.

Two examples are shown on a computer screen. The first example is a "perfect" selection when using a protuberance cutter (Fig. 3). The shaving cutter sharpening curve, as indicated by the circles on each end, lies slightly below the top line of the parallelogram. This line represents the outside diameter of a shaving cutter which will reach the maximum relief of the gear fillet.

The second example (Fig. 4) shows a shaving cutter with the outside diameter (HOD) too large when new, but during its life it is reduced by the sharpening process, so that it enters the parallelogram of acceptance. However, near its life point of the sharpening curve, it again leaves the parallelogram of acceptance and cannot be used. Since it is very possible that a shaver on the shelf is in a "half-life" condition, it can be selected for use in this example.

Fig. 4 can also be used to show the situation corresponding to the second approach described above. If the top line of the parallelogram represents the outside diameter (HOD) of the shaving cutter required to reach the point where the mating gear tooth tip will make contact, then this shaving cutter will be useable when new to shave the gear. However, as the shaver is sharpened on the existing sharpening curve, it will go below the top line and will not shave deep enough to provide a good surface for the mating gear. If this shaving cutter is to be dedicated to this gear, than a new sharpening curve should be developed. As the shaver is sharpened, the amount removed from the outside diameter should be reduced so that the sharpening curve remains above the top line of this parallelogram.

The graphic display permits nearly instantaneous evaluation of the feasibility of using an existing shaving cutter to shave a new gear. If the computer has a file of shaving cutters, it is possible to evaluate a large inventory of cutters in a matter of minutes to learn whether any of the existing cutters are useable. A simple change of the pre-shave hob or shaper from a computer file will make possible a new search. ■