

Face Milling or Face Hobbing

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American Gear Manufacturers Association



TECHNICAL PAPER

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ABSTRACT:

Face milling and face hobbing are the two principal processes used in the production of bevel and hypoid gears. A manufacturer must decide on one or the other. This paper defines the methods and the inherent characteristics they impose on the tooth design and manufacture. Geometric tooth design differences and the reasons for the differences are examined. TCA, finite element analysis and test results for the two processes are included. The cutting processes and cutting tools are compared. The advantages and disadvantages of each process are enumerated. Based on this information and the requirements of the application, a criteria for the selection of one process over the other is proposed.

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Most spiral bevel and hypoid gears are manufactured by either the face milling or the face hobbing process. A great deal of discussion has centered on which process is best for a given application. In the past the discussion was somewhat academic, in that it depended on which machines were available, since older machines generated by only one or the other method. Newer machines are capable of using either method.

Both face hobbing and face milling methods are discussed. Blank design, tooth geometry, contact pattern control, as well as the cutting processes and their respective tools, are examined. Comparisons are made and criteria for selecting the most appropriate process are presented based on geometric considerations.

FACE MILLING

Basic Generating Member

The tooth shape of a spiral bevel or hypoid gear is more easily understood by considering the basic generating gear. Face milling employs a circular face mill type cutter. The cutter is designed and set into position relative to the work, so that it cuts the correct pressure angle and spiral angle at the calculating point, and sweeps out the tooth form as it rotates about its axis. The lengthwise tooth form then is a circular arc with a curvature equal to the curvature of the cutter. Figure 1 shows a spread blade cutter and the generating gear it emulates. The

generating gear is rolled with the workpiece to produce tooth surfaces on one or both sides of a tooth slot. The part is indexed to the next tooth and the process is repeated.

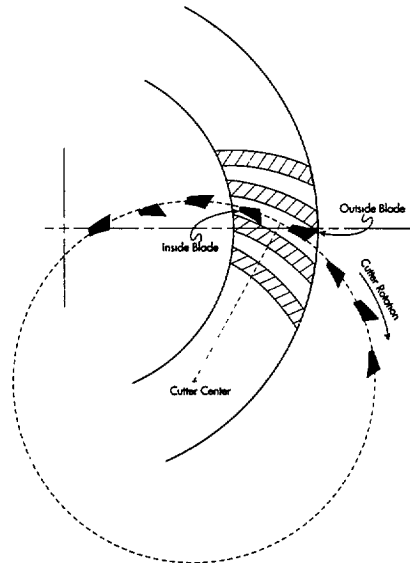


Fig. 1: Face Milling Method

Modifications of Generating Member

This simple generation concept is complicated by two factors. First, gear blanks are designed with tapering depth teeth, and second, in order to assemble the gear set in its final environment and for it to perform under load, regardless of the cutting method, mismatch is required between the mating tooth surfaces.

Blanks are designed with tapering depth for several reasons:

1. Since the pitch surfaces are cones, it is natural that tooth depth should be a function of the distance from the pitch apex. See Figure 2.
2. The normal pitch is greater at the outside of the blank than at the inside, which results in tapered toplands and slotwidths. By designing the teeth to be deeper at the outside, toplands and slotwidths are made optimum.

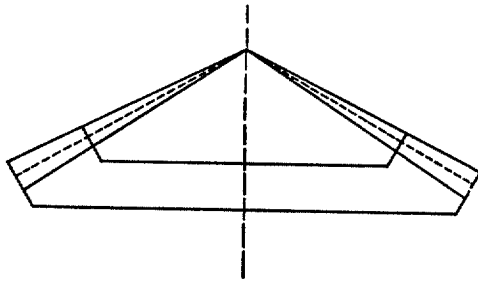


Fig. 2: Tapered Depth Tooth

In most cases the gear cutter is set to follow the root line of the gear, and the pinion cutter is set to follow the root line of the pinion. For tapering depth teeth these lines are not parallel. This results in a pressure angle change along the pitch cone from inside to outside of the blank. The change is opposite on the gear and pinion members producing generated mismatch. The change in pressure angle in the lengthwise direction produces a change in the direction of the path of contact, a second order change, which is referred to as a bias change. A schematic of the condition is shown in Figure 3.

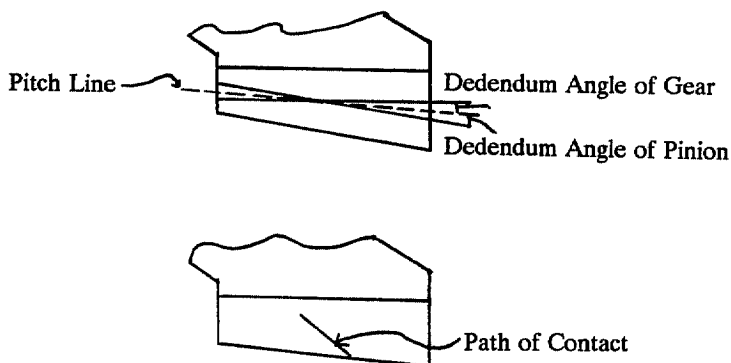


Fig. 3: Bias Path of Contact Resulting from Tapered Depth Teeth

Mismatch is deliberately designed into gear sets to compensate for manufacturing and assembly tolerances and for deflections under load. It is applied in both the lengthwise and

profile directions of the tooth flank and is parabolic in form. These mismatches are also second order. See Figure 4.

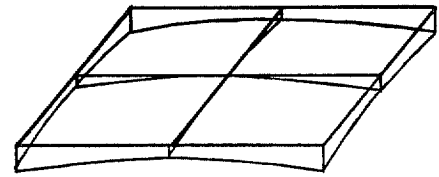


Fig. 4: Design Mismatch

The generating gear is modified to address the fact that generating mismatch exists due to the tapered depth, and that this mismatch is not necessarily the desired mismatch. When the pinion is generated with two setups the following changes are generally used to control second order tooth contact.

The cutter radius is adjusted to give the desired lengthwise mismatch. This is an obvious change which is shown in Figure 5.

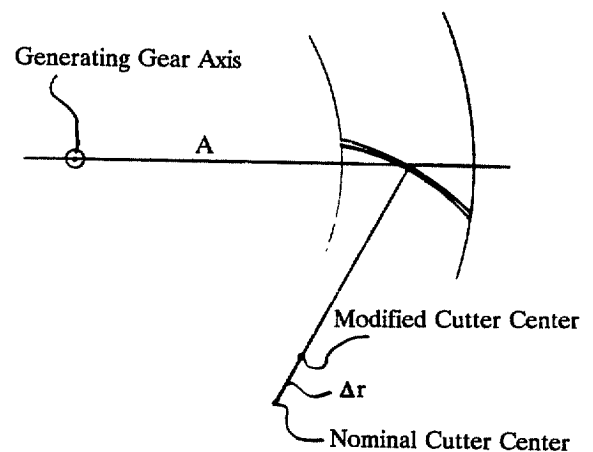


Fig. 5: Cutter Radius Change

The generating cone distance is changed to control the direction of the path of contact. Figure 6 shows the path of the cutter is changed during generation, producing a change in spiral angle from the top to the flank of the tooth, which is a bias change.

The generating pitch angle is adjusted to give the desired profile mismatch. The generating member becomes a tapered generating gear and tilt, or a simulation of tilt, is required in the generating machine. The change in profile curvature can be envisioned by considering the transverse plane layout shown in Figure 7. Of particular interest is the generating gear center, O_x . For crown gear generation the