GEAR FUNDAMENTALS

Hob Basics Part II

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This is Part II of a two-part series on the basics of gear hobbing. Part I discussed selection of the correct type of hobbing operation, the design features of hobs and hob accuracy. This part will cover sharpening errors and finish hob design considerations.

Sharpening Errors

The hob errors which contribute to the profile error on a gear are the hob profile error and the hob lead error. A perfectly accurate hob with a proper setup, on an accurate machine with good tooling can cut a bad gear if the hob is improperly sharpened. Sharpening errors can contribute to both profile and lead errors since the hob profile is actually shifted from its true position by exposing the cutting edge in a different plane. The sharpening errors which affect the hob accuracy are as follows:

1. Rake angle error
2. Index error
3. Flute lead error

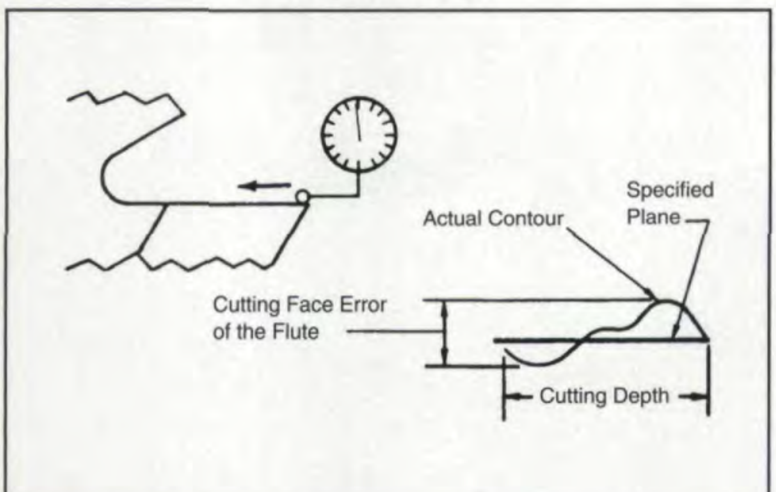

Fig. 1 — Method of measuring the cutting face error of the hob flute.

Rake angle error. The hob cutting face is designed to lie in a specified plane, and any variations of the actual hob flute cutting face from that plane are considered flute cutting face error. This error is measured from the outside diameter to the cutting depth. (See Fig. 1).

Negative rake error describes the condition when too much stock is removed from the upper portion of the tooth face. Negative rake decreases the depth and increases the pressure angle on the hob tooth. The result is cutting drag and a gear tooth that is thin at the top and thick at the bottom. The effect of negative rake is an involute chart that leans in the positive direction (Fig. 2).

Positive rake error describes the condition when too much stock is removed from the lower portion of the tooth face. Positive rake increases the depth and decreases the pressure angle on the hob tooth. The result is a gear tooth that is thick at the top and thin at the bottom. The effect of positive rake is an involute chart that leans in the negative direction (Fig. 3).

A belly or convex curve is produced at the tooth face when a straight line dresser is used to sharpen a helical fluted hob. This belly causes the hob tooth to be thin at the top and bottom. The resulting gear tooth will be thick at both the top and bottom. This will cause a bowed curve on the involute chart (Fig. 4).

Index Error. Hob flute indexing error is the deviations of the actual radial positions of the hob flutes from the theoretical positions (See Fig. 5). Index error occurs when stock is sharpened off the hob flutes unequally.

Hobs sharpened with unequally spaced

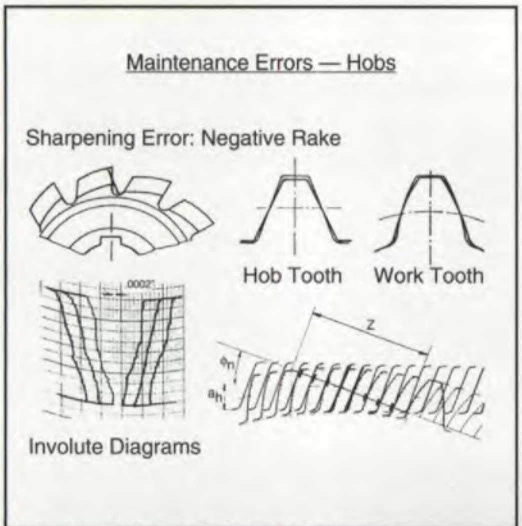

Fig. 2 — Effects of negative rake error.

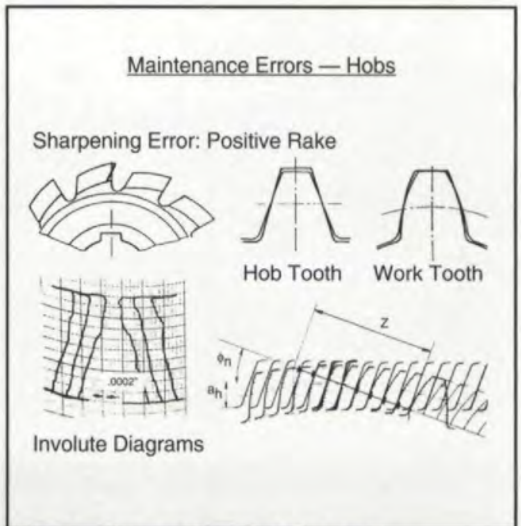

Fig. 3 — Effects of positive rake error.

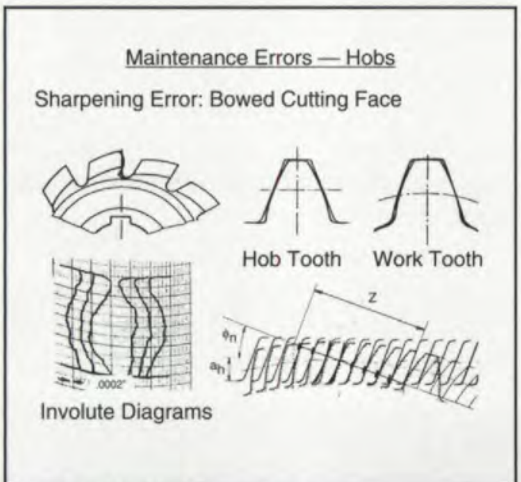

Fig. 4 — Effects of convex curve.

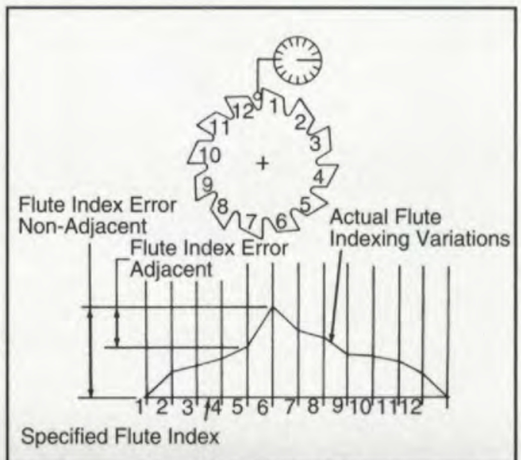

Fig. 5 — Method of measuring hob flute errors by use of an index mechanism.

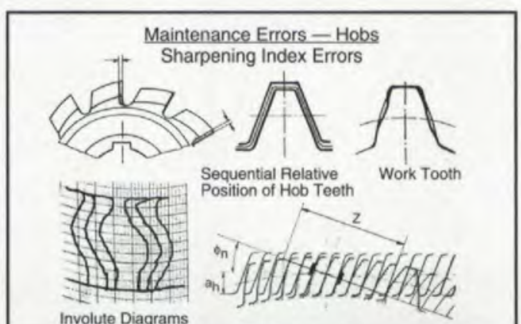

Fig. 6 — Effects of hob index error.

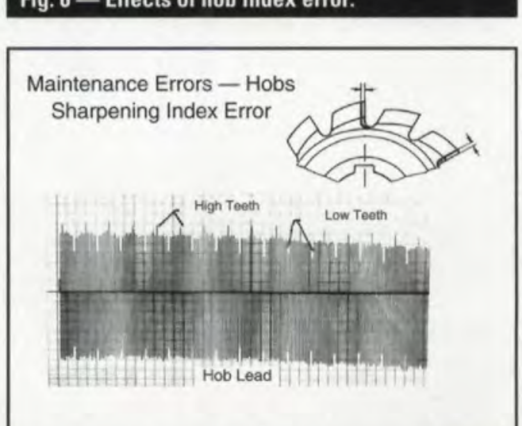

Fig. 7 — Lead chart of hob with index error.

flutes will not produce the correct involute form. The hob will have high and low teeth which will produce unequal generating flats on the gear teeth. High hob teeth will produce low flats or hollows on the gear profile. The resulting involute diagram will be wavy due to the high and low spots on the profile.

Hob runout during sharpening is a source for index error. It will result in unequal amounts of stock being ground from the face of the hob teeth (Figs. 6-7).

Flute lead error. Flute lead tolerance is the total allowable indicator variation when traversing the total face width of the hob in any one row of teeth following the specified lead of the flute. Hobs sharpened with flute lead errors have teeth which do not have the correct profile, and the profile differs on each side of the teeth. Due to the cam relief profile, the teeth on the end of the hob which has the most amount of stock removed will be at a smaller diameter than the teeth at the other end, making the hob

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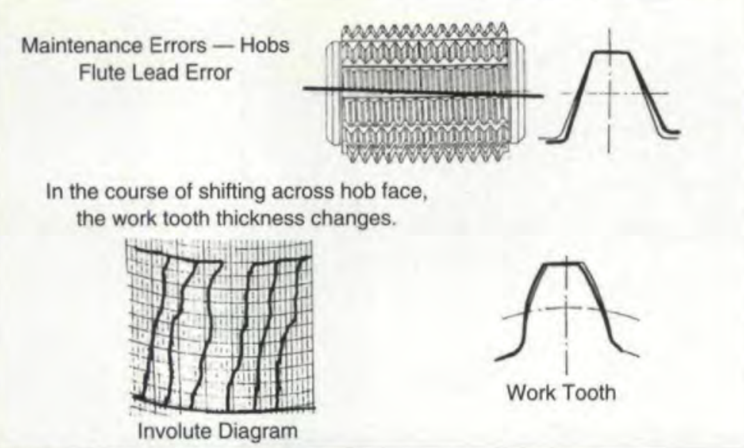

Fig. 8 — Effects of flute lead error.

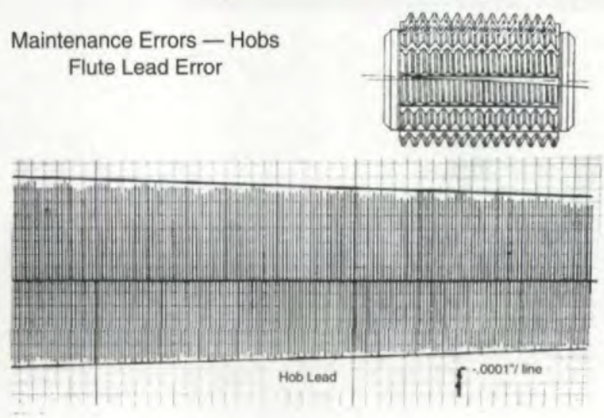

Fig. 9 — Lead chart of hob with lead error.

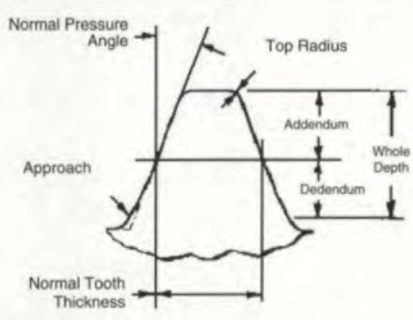

Fig. 10 — Hob nomenclature.

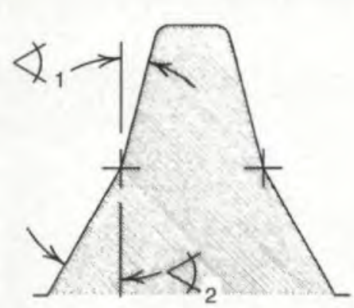
Fig. 11 — Dual pressure angle.

tapered. Gears cut by a hob with flute lead error will not have the correct involute form. The teeth are unsymmetrical, each side of the teeth having a different pressure angle. The teeth are said to be "leaning" or have cross bearing. The leaning of the teeth can be seen in the involute diagram (Figs. 8-9).

Mounting Errors. A hob which is mounted incorrectly can exhibit a condition known as runout. Traditional runout is in phase, while an out-of-phase condition is known as a wobble. A hob mounted with runout can destroy the accuracy of the hob. Hub runout causes errors in the part tooth form since the hob teeth are not in the proper position relative to the generating pitch line. In order to eliminate runout, hobs are designed with hubs which provide a qualifying surface. The hubs are used to true up the hob on the arbor. Since the hubs are held in relation to the form on the hob teeth, trueing the hubs makes the hob rotate about the proper axis.

Finish Hob Design Considerations

Depth System. The standard full depth system for 1-19.9 NDP is 2.25/DP with a gear addendum of 1.0/DP. The standard full depth system for 20 NDP and finer is 2.2/DP + .002, with a gear addendum of 1.0/DP.

The ASA stub-tooth depth system for 1-19.9 is 1.8/DP, with a gear addendum of .8/DP.

Modifications. Standard gear hobs with a full depth system have a standard modified tooth form. This consists of a corner radius, as mentioned previously, and an approach near the bottom of the hob tooth profile (See Fig. 10). The approach modifies the involute to prevent tip interference with the mating gear.

Hobs are sometimes ordered with special profile modifications. An example of a special double-angle profile can be seen in Fig. 11. The purpose of a double-angle profile is to provide tip relief much in the same manner as a standard approach. The double angle can also be used to provide relief in the root area.

Semi-Finish Hob Design Considerations

Depth System. The standard depth system for a pre-grind or pre-shave hob is 2.35/DP, with a gear addendum of 1.0/DP. This extra depth allows clearance in the root of the gear for the finishing tool. The depth also helps to maintain stock at the T.I.F. diameter which might otherwise be eliminated by undercut.

Protuberance. Protuberance is a modification of the hob tooth form at the top corner to produce undercut on the gear teeth (See Fig. 12). This undercut provides clearance for the shaving cutter or grinding wheel, and also prevents the formation of an abrupt change in profile with its resulting stress concentration. With small numbers of teeth, the tooth form cut with a hob without protuberance is often undercut enough, but a protuberance is required for larger numbers of teeth to eliminate contact between the tip of the shaving cutter or grinding wheel and the fillet of the gear tooth.

Undercut vs. the T.I.F. Diameter. Undercut is a condition in generated gear teeth when any part of the fillet curve lies inside of a line drawn tangent to the true involute form at its lowest point (Fig. 13).

Undercut occurs naturally and increases as the number of teeth cut decreases. It may also be deliberately introduced with the use of protuberance as discussed above.

Undercut, unless it is introduced to facilitate the finishing operations, may be a detriment to a gear designer. Undercut not only reduces the strength of the gear teeth, but may also reduce the contact ratio. A gear designer has two methods available for reducing undercut. These methods can be used separately or in combination with one another.

The first method is to increase the pressure angle. An increase in the pressure angle of the gear will allow a decrease in the number of teeth without undercutting the tooth profile. See Fig. 14 for the relationship between the number of teeth which can be hobbed without undercut for the 2.157/DP and 2.350/DP systems.

The second gear design method is the use of long-short addendum design. This method is accomplished by increasing the addendum of the pinion and decreasing the addendum of the gear by an equal amount. Although the outside diameter of the pinion increases and the diameter of the mating gear decreases, the pitch and base circles remain the same. Thus they run together on the same center distance and have the same ratio as standard gears. See Fig. 15 for comparison of tooth forms using the long addendum approach.

Hob designs which produce excessive undercut conditions violating the T.I.F. diameter occur most frequently in semi-finishing

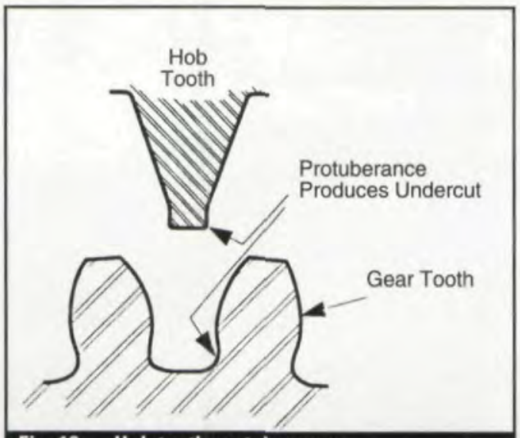

Fig. 12 — Hob tooth protuberance.

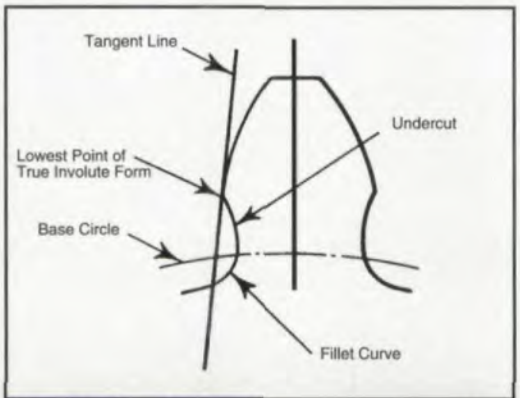

Fig. 13 — Gear tooth undercut.

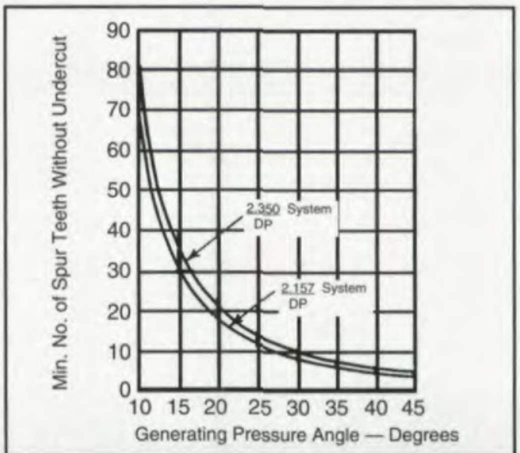

Fig. 14 — Hobbing without undercut.

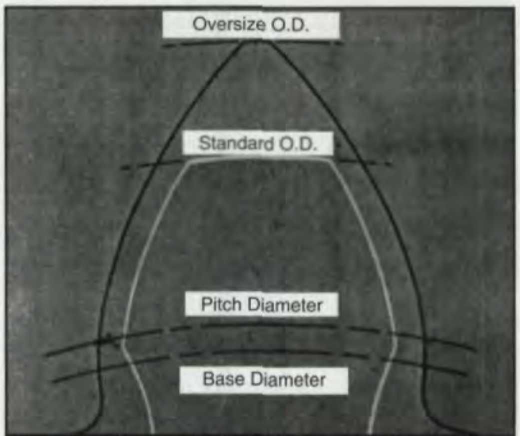

Fig. 15 — Comparison of a long addendum tooth with an undercut tooth.

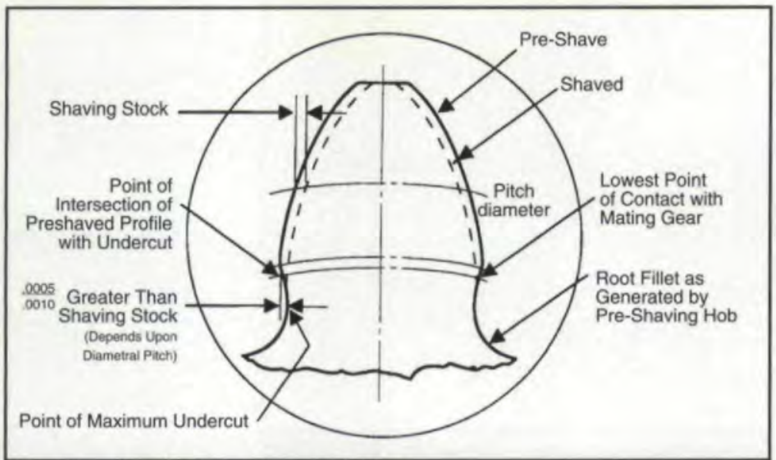

Fig. 16 — Standard pre-shave tooth form.

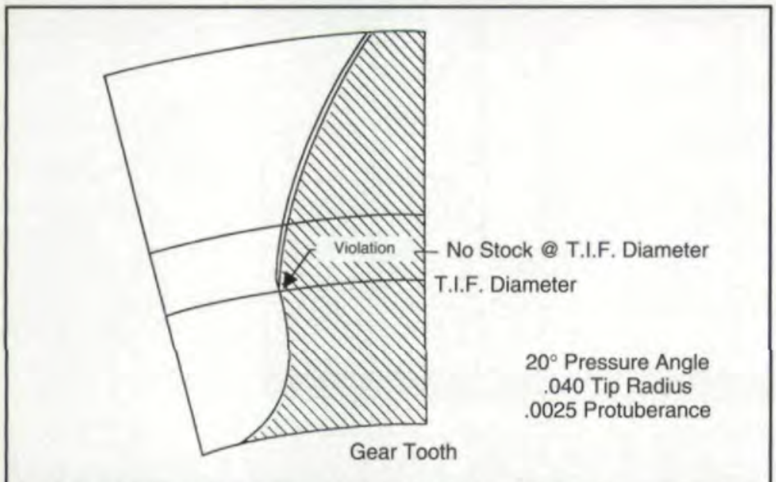

Fig. 17 — Gear tooth undercut which violates the T.I.F. diameter.

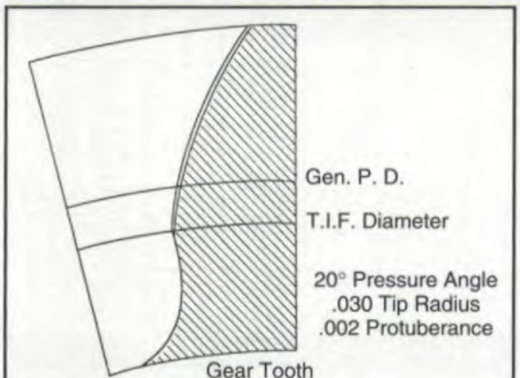

Fig. 18 — Acceptable gear tooth form.

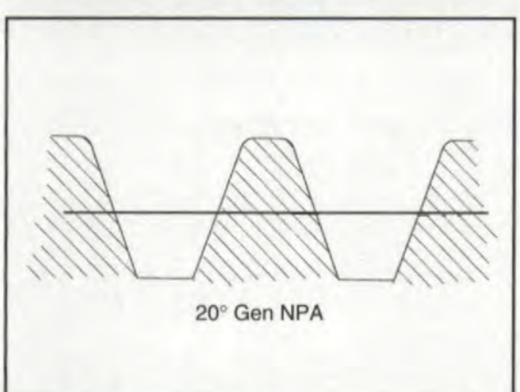

Fig. 19 — Hob rack form.

designs. When this condition is prevalent there are four options a designer has for eliminating the situation.

The first thing he can do is to get approval from the customer to reduce the root diameter of the gear. As the root diameter is reduced, the undercut is moved lower on the tooth.

T.I.F. violations sometimes occur when trying to cut too large of a radius on the hob. The second method is used in this situation. This method consists of simply reducing the size of the radius.

The third method is to get customer approval to reduce the undercut in relation to the finishing stock. For example, our standard practice is to specify undercut to be .00005 to .001 more than the amount of shave or grind stock (See Fig. 16).

Gear designers will sometimes specify undercut in excess of this standard. When excessive undercut exists it may be possible to reduce the amount. Reduction of the hob tooth radius and/or the hob protuberance will reduce the undercut.

Fig. 17 shows a gear tooth generated by a 20° normal pressure angle pre-shave hob with a .040 tip radius and .0025 protuberance. This hob design is unacceptable since it produces a condition where there is no stock at the T.I.F. diameter. By reducing the radius to .030 and reducing the protuberance to .002, an acceptable gear tooth can be generated (See Fig. 18). This design leaves a full amount of shave stock at the T.I.F. while still allowing ample undercut. Fig. 19 shows the final hob tooth configuration in this case.

The last method for improving a condition where the T.I.F. diameter is violated is to short-pitch the hob design. When a hob is short-pitched, the pressure angle of the hob is reduced. This allows the hob to generate at a lower pitch diameter which reduces the sweep-out diameter of the generated undercut.

Fig. 20 shows the results from a short-pitched hob design. The hob was short-pitched to 14.5° normal pressure angle with a .0026 protuberance and a full .071 top radius. As a result stock is still left at the T.I.F. diameter and a much larger fillet trochoid form is generated. Fig. 21 shows the final short-pitched hob tooth form.

Fig. 22 shows a comparison of the two dif-

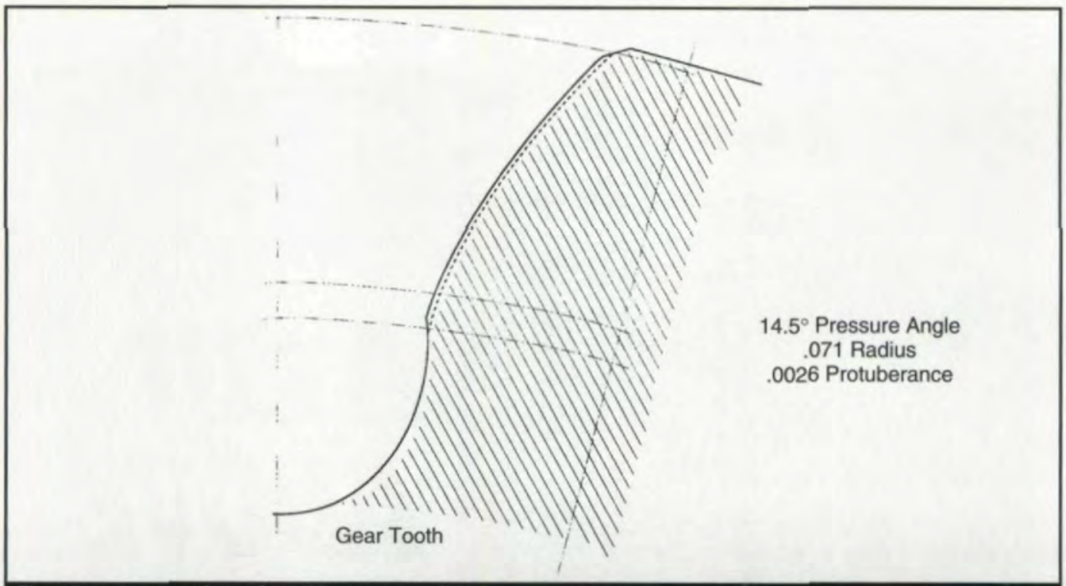

Fig. 20 — Gear tooth produced by short pitch hob.

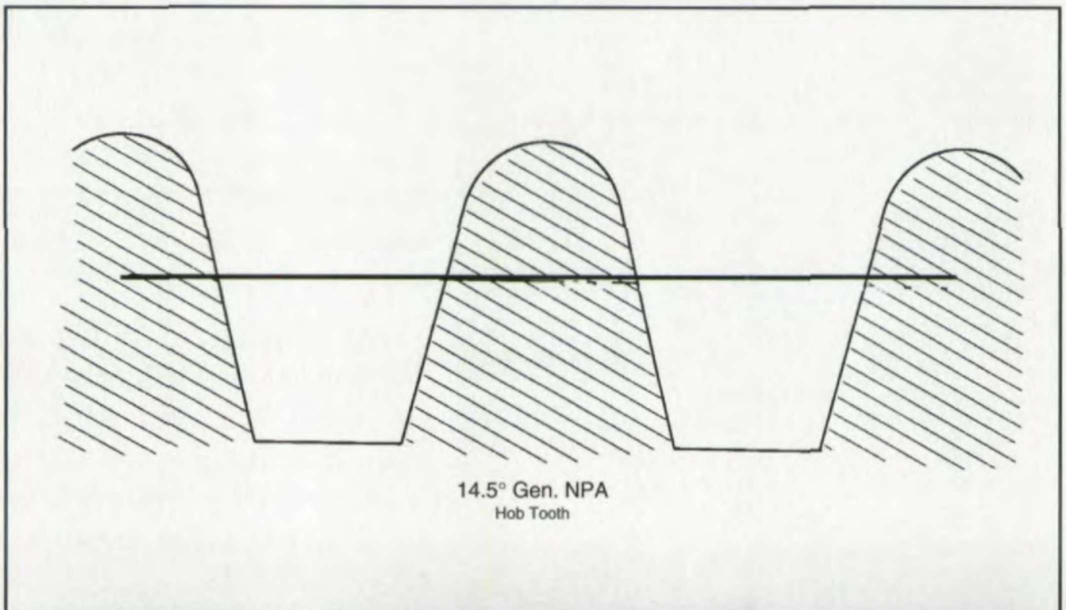

Fig. 21 — Short pitched hob tooth form.

ferent hob designs which both produced an acceptable gear tooth design. ■

References:

1. American Pfauter, L. P. *Gear Process Dynamics*, Malloy Lithography, Inc., 1985.

2. Barber Colman Company. *Hob Handbook*, Rockford, IL, 1954.

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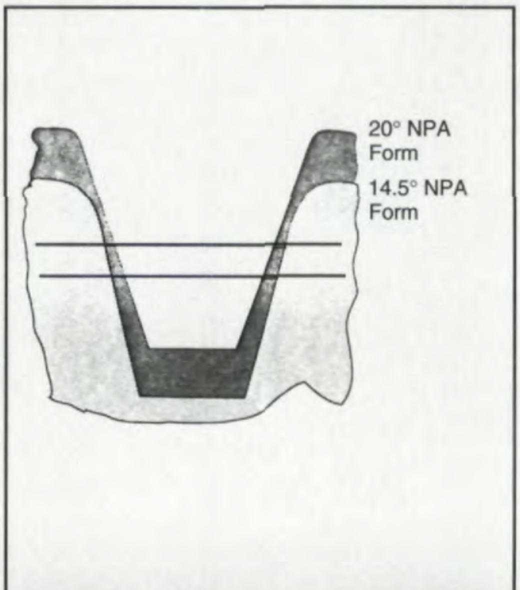

Fig. 22 — Comparison of hob tooth forms.