GEAR FUNDAMENTALS

The Right and Wrong of Modern Hob Sharpening

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Precision gears play a vital role in today's economy. Through their application, automobile transmissions are more compact and efficient, ships sail faster, and diesel locomotives haul more freight. Today great emphasis is being placed upon the reduction of noise in all gear applications and, to be quiet, gears must be accurate.

For this reason, a great deal of engineering attention has been devoted to the various factors involved in precision gear production. The need for accurate machines and cutting tools, together with careful, precise set-up procedures, is well understood.

Not enough notice, however, has been given to hob sharpening, a necessary operation wherever gears are produced by hobbing and fully as important as original hob accuracy in its effect on gears produced. Even the finest class AA precision ground hob will produce poor gears if improperly sharpened.

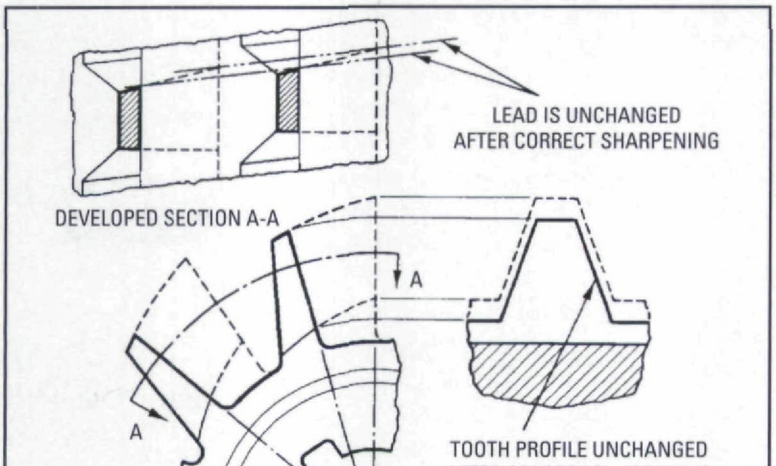

Fig. 1 - Correct tooth profile and lead are maintained with careful attention to sharpening methods and accuracy.

The purpose of this article is to discuss the various effects of hob sharpening on hob performance and proper sharpening methods.

Hobbing is a generating process in which involute gear teeth are formed by a sequence of cuts made by successive hob teeth in a continuously rotating gear blank. In order for the gear tooth form to be accurate it is essential that:

1. The cutting edges of the hob teeth have the correct form or pressure angle.

2. The cutting edges of the hob teeth lie along a helix of the correct lead.

Hob manufacturers hold these important elements to very close tolerances, and it is possible to sharpen a hob repeatedly to the very end of its useful life without impairing the accuracy of the gear produced. (See Fig. 1.) But sharpening must be done properly - otherwise both pressure angle and lead will be adversely affected.

Hobs are sharpened by grinding the face of all flutes until no trace of a worn surface is visible on the tops or sides of the hob teeth. Grinding should extend deep enough to blend in with the bottom of the flute. The flute elements affected by sharpening are:

1. Adjacent spacing
2. Non-adjacent spacing
3. Rake (A radial flute has zero rake.)
4. Lead (A straight flute is parallel to axis and has an infinite lead.)

All of these elements must be held within the tolerances listed in Table 1 if the original accu-

The figures in the table represent total indicator variation in ten thousandths of an inch.												
Diametral Pitch		1 thru 1.99	2 thru 2.99	3 thru 3.99	4 thru 4.99	5 thru 5.99	6 thru 8.99	9 thru 12.99	13 thru 19.99	20 thru 29.99	30 thru 50.99	51 and finer
Adjacent Flute Spacing	AA Precision Ground*	—	—	20	15	10	8	8	6	6	6	6
	A Precision Ground	40	30	25	20	15	10	10	10	10	10	10
	B Commercial Ground	50	45	40	30	20	15	15	10	10	10	—
	C Certified Unground	50	45	40	30	20	15	15	10	10	10	10
	D Commercial Unground	60	60	50	50	30	25	25	20	17	17	—
Non-Adjacent Flute Spacing	AA Precision Ground*	—	—	40	35	25	15	15	15	15	15	15
	A Precision Ground	80	60	50	40	30	30	30	25	25	20	20
	B Commercial Ground	100	90	80	60	50	50	50	40	35	30	—
	C Certified Unground	100	90	80	60	50	50	50	40	35	30	30
	D Commercial Unground	120	120	100	100	80	80	70	60	50	40	—
Rake to Cutting Depth	AA Precision Ground*	—	—	10	8	6	5	5	3	3	3	3
	A Precision Ground	30	15	10	8	6	5	5	3	3	3	3
	B Commercial Ground	50	25	15	10	8	7	7	5	5	5	—
	C Certified Unground	50	25	15	10	8	7	7	5	5	5	5
	D Commercial Unground	100	75	50	40	30	20	20	15	15	10	—

CUTTING FACE WIDTH						
		Up to 1"	1.001 to 2	2.001 to 4	4.001 to 7	7.001 & up
Flute lead over Cutting Face Width	AA Precision Ground*	8	10	15	20	20
	A Precision Ground	10	15	25	30	50
	B Commercial Ground	10	15	25	30	50
	C Certified Unground	10	15	25	30	50
	D Commercial Unground	15	23	38	45	75

* Single thread only

Table 1 - Sharpening Tolerances for Single and Multiple Thread Hobs

racy of the hob tooth form and lead is to be maintained. These tolerances, standardized by the Metal Cutting Tool Institute, are maintained by all hob manufacturers. When a hob is sharpened within these tolerances, the gear tooth accuracy will not be impaired.

Flute Spacing Error

Fig. 2 shows the effect of sharpening with unequal angular spacing of the cutting faces. Every lead variation caused by such faulty sharpening shows up in approximately a one-to-one ratio as an error in the gear tooth profile. The lead variation is roughly 1/16 of the flute spacing error. A spacing error of .016 would produce about .001 error in the lead and in the gear tooth profile.

The most common reasons for excessive flute spacing errors in sharpened hobs are:

1. Excessive runout of the hob during the sharpening process. This may be caused by loose-fitting or eccentric arbors, non-parallel collars, excessive tightening of the nut, or runout of the machine work spindle.

2. Use of worn index plates or pawls in the sharpening machine.

3. Not "sparking out" the grinding wheel.

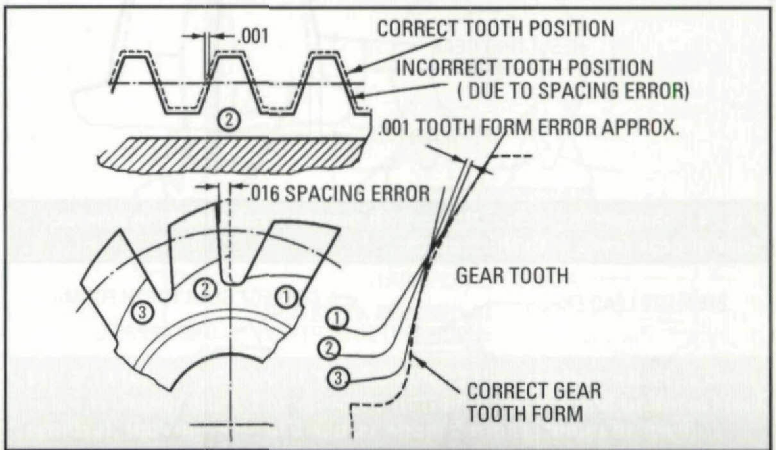

Fig. 2 - Serious hob lead errors result from sharpening with unequal spacing of cutting faces.

Under no circumstances should the tool sharpener remove more material from any one flute just because it shows greater wear. This would create a large flute spacing error and inaccurate gear tooth profile. All cutting faces must be ground back the same amount that is needed to sharpen those showing the greatest amount of wear.

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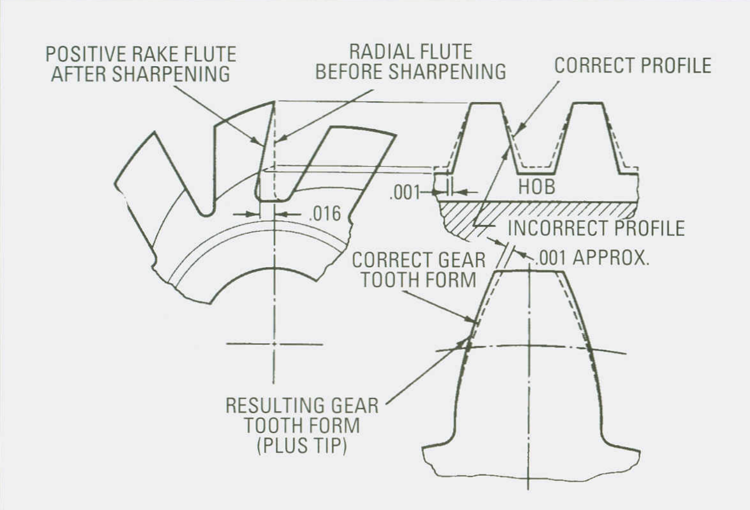

Fig. 3 - Sharpening radial flutes with a positive rake leads to production of gear teeth with thick tips.

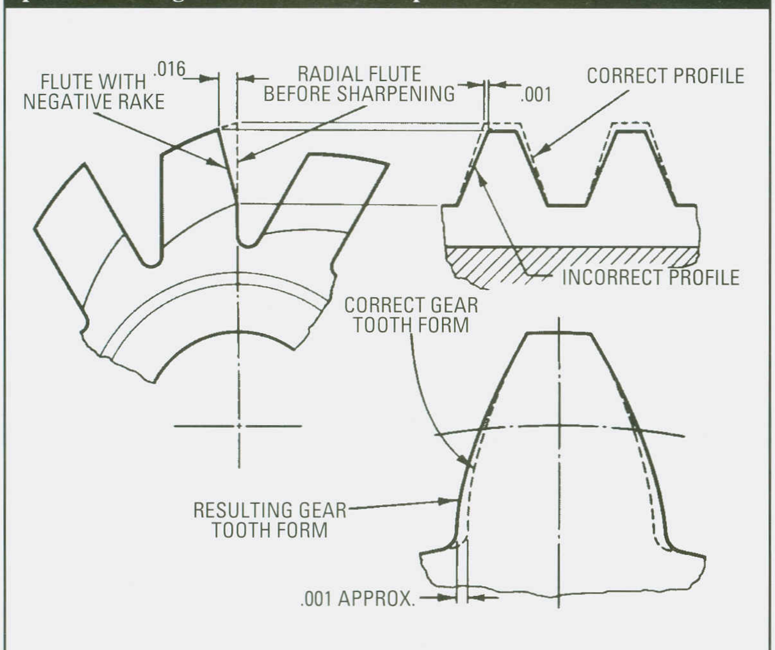

Fig. 4 - Sharpening radial flutes with negative rake leads to production of gear teeth with thick roots.

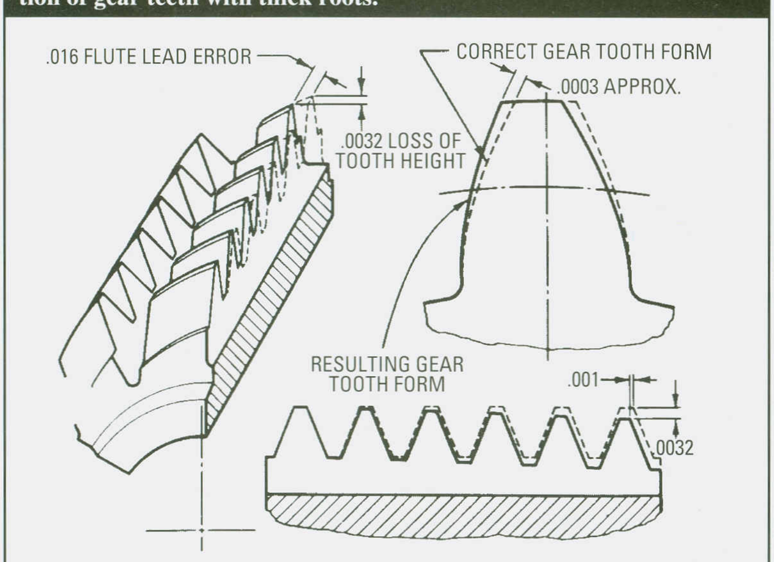

Fig. 5 - Lead errors in sharpening tend to produce distorted "leaning" teeth on the finished gear.

Flute Rake Error

Fig. 3 shows the effect of sharpening the flute with a positive rake when it should be radial. Because of the side clearance, this sharpening error makes the base of the hob tooth narrower, and as a result, the gear tooth becomes thicker at the tip. Here again, an error of .016 from radial will cause approximately .001 of error in the gear tooth profile.

Occasionally hobs are designed with a positive rake. In such cases the hob tooth form (or pressure angle) is designed to correspond to the positive rake flute. Such hobs must be sharpened with the same positive rake. On such hobs the rake angle and rake off-set are marked on the end of the hob.

Error in the rake of the flute is caused by improper setup of the grinding wheel in relation to the hob axis.

Fig. 4 shows the effect of sharpening the flute with a negative rake. Because of the side clearance, this sharpening error makes the tip of the hob tooth thin, and as a result, the gear tooth is thicker at the root. Again, an error of .016 from radial will cause about a .001 error in the gear tooth profile.

This sharpening error is also usually caused by incorrect setting of the grinding wheel in relation to the hob axis.

Flute Parallelism or Lead Error

Fig. 5 shows the effect of sharpening helical flutes with incorrect lead or straight flutes non-parallel with the hob axis. The result is an error in the lead and form of the hob teeth. In fact the lead on one side of the teeth becomes longer than the theoretical lead, and the lead on the other side becomes shorter. This produces a "leaning" gear tooth; one side plus, the other minus on involute.

However, a flute lead or parallelism error would have to be much larger than a flute spacing or rake error in order to affect the gear tooth profile to the same degree. This is true because only about two convolutions of hob teeth finish the gear tooth profile. A .016 flute lead error would result in about .001 lead error over all convolutions of hob teeth. Assuming the hob had eight convolutions, the gear tooth would be affected by two over eight or one-fourth of the total lead error of .001. The resulting tooth profile error would then be about .00025.

It is interesting to note that a flute lead error, because of the cam relief on the hob teeth, creates a tapered hob. The flute lead error is approximately 2 1/2 times the amount of taper in the hob diameter. Since the taper can be easily measured, this affords a quick easy way of measuring the flute lead error.

A sharpening error in flute lead may be caused by an incorrect sine bar setting, excessive backlash, worn machine parts, misaligned centers, or failing to "spark out."

How Hobs Are Sharpened

Machines designed and built solely for hob sharpening are on the market. These machines have automatic indexing provisions and can sharpen hobs with helical as well as straight flutes.

Hobs can also be sharpened in a cutter sharpening machine. However, in this case, the backs of hob teeth in straight-fluted hobs must be ground to provide accurate indexing surfaces for a steel supporting finger, such as is commonly used in cutter sharpening. (See Fig. 6.)

Hobs and helical flutes that are to be sharpened in a cutter sharpener require a guide bar. This bar must have the same number of equally spaced grooves of the same lead as the flutes of the hob. This guide bar and the hob are mounted on the same arbor and placed between centers on the cutter sharpener table. A guide finger mounted on the machine and engaging a groove on the guide bar rotates the hob the correct amount in relation to the table travel past the grinding wheel. (See Fig. 7.)

A saucer-shaped grinding wheel is used for hob sharpening. For straight-fluted hobs, either the flat or cone side of the wheel may be used. However, the cone side is preferable because of more uniform pressures between the wheel and the hob. With a flat wheel the area of contact between the wheel and hob is small at each end, but large in the center. (See Fig. 8.) If a heavy cut is being taken, more stock is removed at the ends and less in the center. To correct this more passes must be made through each flute.

The flat side of the wheel cannot be used for helical flutes because of interference at the root and top of the flute, resulting in a convex, nonradial cutting face. (See Fig. 9.)

The cone side of the wheel works well for all helical flute hobs, excepting those with large thread angles, such as are found in multiple thread worm gear hobs. In such cases interference becomes noticeable, and the wheel must be

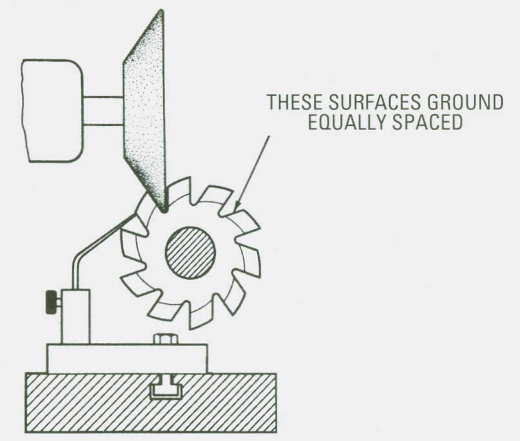

Fig. 6 - Backs of the teeth in straight-fluted hobs must be ground to provide an accurate indexing surface when sharpening is done on a cutter sharpener.

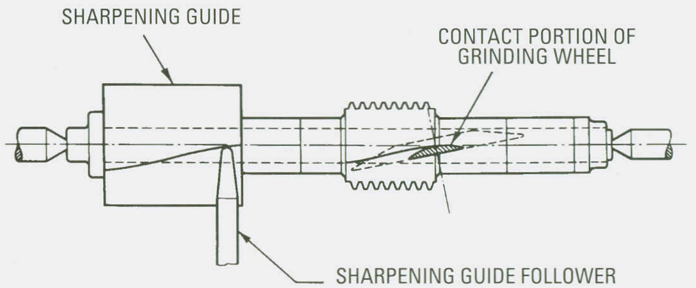

Fig. 7 - For sharpening hobs with helical flutes on a cutter sharpener, a guide bar with grooves of the same helical lead is required.

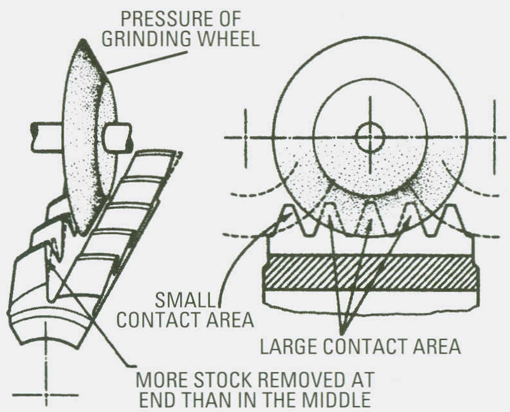

Fig. 8 - Flute grinding with the flat side of the grinding wheel as shown is not recommended. For uniform cutting pressures and uniform stock removal, the cone side of a saucer-shaped wheel should be used.

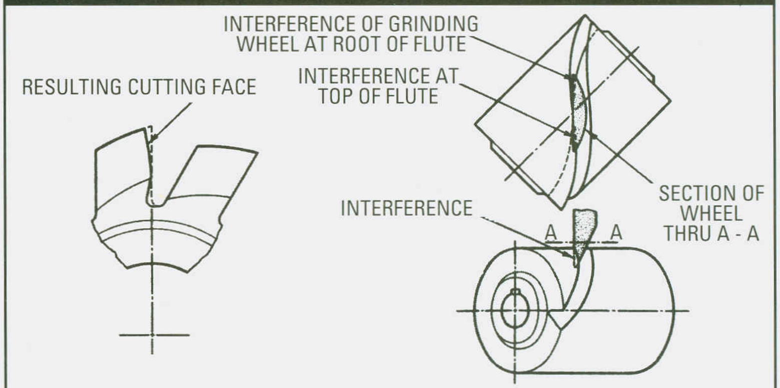

Fig. 9 - In sharpening hobs with helical flutes, the cone side of the wheel must be used to avoid interference.

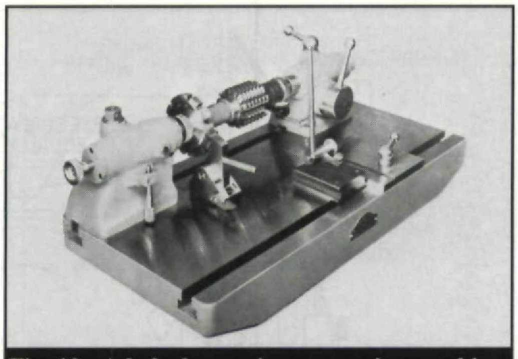

Fig. 10 - A hob sharpening measuring machine.

dressed to a curve that eliminates interference.

Effect of Sharpening Technique on Hob Life

In sharpening, care should be taken to avoid excessive heat. It is easily possible to create enough heat to soften the cutting edges and greatly increase the rate of hob wear. Another danger of excessive heat is the propagation of tiny cracks at the base of the hob teeth, which often results in tooth breakage. The "high" flute should be located and "kissed" before feeding in, or runout and unequal spacing conditions, when combined with the feed, may result in too heavy a grinding cut and excessive heat on one or more flutes.

It has been proved over and over again that more gears can be cut per sharpening when the grinding finish on the cutting faces of the hob teeth is good. It definitely pays to sharpen hobs with a good finish. The wheel should be dressed before the finish cut and should be allowed to "spark out", not only for accuracy's sake, but also for improved finish.

Need for Sharpening Inspection

It is obvious from the preceding that sharpening errors can result in gear tooth inaccuracies which prevent satisfactory gear performance. It is essential that hobs be sharpened accurately.

Sharpening errors, however, will occur. Mistakes will be made in the setup, machines will wear or become misaligned, worn arbors will be used, nuts will be tightened excessively, grinding wheels will not be allowed to "spark out", dirt and chips will get between collars, etc. And sharpening errors, even though large enough to cause intolerable gear errors, usually cannot be seen or measured with the naked eye.

Since it is only common sense that hobs with excessive sharpening errors be prevented from reaching the hobbing machine and cutting gears that have to be scrapped, the need for hob sharpening inspection is evident. Special measuring machines have been designed for this purpose, which measure directly, by means of a dial indicator, errors in flute spacing, rake, and parallelism of straight flutes. (See Fig. 10.) Flute lead errors are obtained indirectly through measurement of the taper in the hob diameter which results from an error in flute lead. The flute lead error is approximately 10 times the taper on diameter or approximately 5 times the difference in indicator readings, taken over the high points of the end teeth in the flute. These indicator readings can be obtained in the hob sharpening inspection machine.

All preceding remarks have been directed mainly to gear hobs, but they apply with equal force to all hobs, including sprocket hobs, spline hobs, and worm gear hobs. Fig. 11 shows the effect of sharpening errors on parallel key splines. Such inaccuracies may prevent proper fit.

In worm gear hobs, the high pressure angles and greater side clearance angles often used aggravate the bad effects of sharpening errors on the worm gear tooth form. Large lead angles are common in these hobs, and special wheel dressing is needed to avoid interference when sharpening.

Summary

1. Hobs sharpened outside of standard tolerances shown in Table 1 cut inaccurate gear teeth. This leads to unsatisfactory gear performance and often to early gear failure.

2. Sharpening with the cone side of the wheel is preferred for straight flute hobs and is essential on helical-flute hobs.

3. Excessive heat in sharpening and poor grinding finish shortens hob life.

4. Hob sharpening accuracy is easily checked with a hob sharpening measuring machine. ■

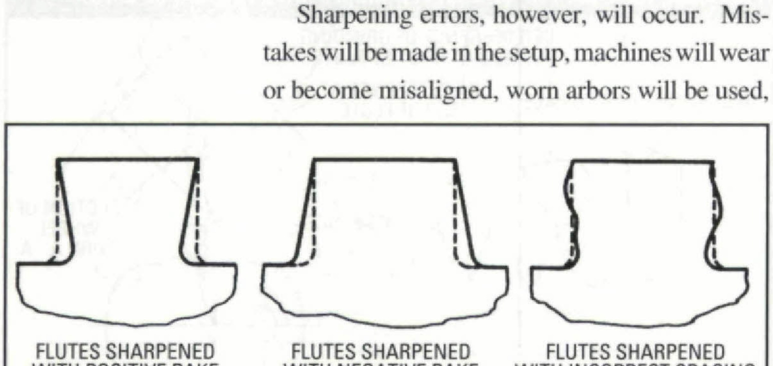

Fig. 11 - Parallel key spline profile inaccuracies resulting from improper spline hob sharpening.

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