Hard Gear Processing with Skiving Hobs

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As we approach the problem of hard gear processing, it is well to take a look at the reason for discussing it at this time. In our present economic atmosphere throughout the world, more and more emphasis is being placed upon efficiency which is dictated by higher energy costs. We also see more regulations that encompass the personal environment for workers, which is being translated into more stringent requirements, as far as gear noise is concerned. As we see more activity in these areas, gear designers are being forced to consider the advantages of higher loads, lighter weights, and noise reductions.

The strength and wear resistance in gear teeth may be increased by hardening the tooth and roof fillet surfaces, thereby, making it possible to reduce gear size and increase transmitted load and speed. When going in this direction, there are normally three basic hardening processes that are used to obtain the strength and wear resistance needed in the gear teeth. This is through hardened alloy gears, case hardened gears, and carburized and hardened gears. In all instances, one is faced with either trying to predict the distortions that are to be expected in the hardening process, or to do something to the gears after the hardening process is completed. While it is possible to predict hardened distortions with some degree of succcess where you have large quantities of smaller gears, such a prediction process does not lend itself to larger gears, as they are usually produced in smaller quantities, where some additional work must be done on the gears after hardening.

When discussing skiving by the hobbing process, questions invariably arise as to the meaning of the word "skiving". The origin of the word, as described in Webster's unabridged dictionary, was applied to smoothing hides and removing flesh without gouging or cutting the surface of the hide. To quote Webster, skiving is "to slice, pare, to cut off in thin layers or pieces, shave, to form a smooth joint." This basically leads us to the derivation of the term skiving, and as it applies to skiving hobs, is attributed to the cutting geometry which enables one to cut hardened materials with a thin curled chip and produce a smooth finish.

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Fig. 1—High Negative Rake of Skiving Hob

One of the first questions asked about finished gears by the skiving hob process is, are the gears too hard? Normally within the range of the hardening processes being used, such is not the case, as the application of the skiving hob can satisfactorily be applied in the range of Rockwell C hardness 40 through 65. It is important to consider that this is a new technology of finish or semi-finishing hardened gears, and the economics of the process should not be compared to hobbing of gears in the soft condition, but rather to the other alternative which is gear grinding. As more distortion is present in the gears, the economics become more and more favorable to the skiving process. The skiving hob is to be used in a manner which allows the hob to cut only on the involute profile of the gear without cutting in the root fillet area of the gear. It is possible to cut the hardened gears in this manner because of a combination of the carbide used and the high negative rake in the hobs (See Fig. 1).

The high negative rake, which imparts a shear cut cutting geometry to the hob, lessens the cutting resistance and shock and decreases vibration. The spiral formation of chips typically insures a very smooth cutting operation. In Fig. 2, we are showing the comparison of the cutting action of a normal hob with zero degree rake and one with 30° negative rake which is the degree of negative rake normally applied to skiving hobs. (On very coarse pitch hobs, 1-1/4 DP and coarser, a negative rake of 25° is utilized.)

In reviewing Fig. 2, note that the cutting edge of the hob moves in an oblique line starts hobbing at the base cutting edge thus producing curled chips. Figs. 3, 4 and 5 show chips produced at various feed rates utilizing a 2-1/2 DP hob.

Why should one be concerned about the hob design and this new technology? It all resolves itself into one simple statement. "To remain competitive." To do this one must avail themselves of all new technology, and in so doing reduce part cost.

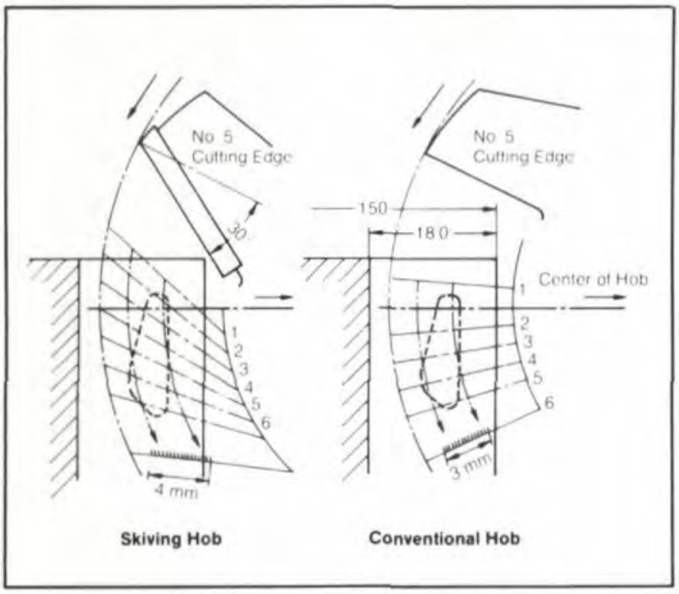

Fig. 2—Function of the Side Cutting Edge in Hobbing for the Finish

Fig. 3—.047" Feed/Revolution

Fig. 4—.063" Feed/Revolution

Fig. 5—.103" Feed/Revolution

Application of Hobs

The application of the skiving hobs should be applied as a pre-grind operation or as a finishing operation on carburized or through-hardened gears. Most of the applications are on through-hardened gears 54 to 58 Rockwell C and in carburized and hardened gears 58 to 63 Rockwell C. It is possible to satisfactorily cut gears with a hardness as high as Rockwell C 65. The composition of the material in the gear blank does not have as much bearing on the feeds and speeds to be utilized as does the hardness itself.

Gear Blank Preparation

The application of skiving hobs requires adequate preparation of the gear prior to skiving. When the gear is soft and cut to the proper pre-skive tooth form, it is one that is developed by a protuberance type hob. This is a hob that will adequately undercut the flank of the tooth at the gear root radius to insure that the skiving hob cuts on the involute portion of the tooth and not in the root. Normally such a pre-skiving protuberance hob will have a hob addendum of 1.250" or 1.350" ÷ D.P. *while the skiving hob has an addendum* of 1.15708" ÷ D.P. (See Fig. 6).

There is an alternative method which can be used, which for purposes of discussion, shall be identified as the "pressure angle increment" method. This employs a hob with a pressure angle that is slightly less than the finished specified pressure angle. Extra depth is required and care must be taken to insure that the hob tip radius on the skiving hob is large enough to accommodate the stock left at the last point of contact. Normally such a "pressure angle increment" hob has an addendum of 1.350" ÷ D.P. while the skiving hob has an addendum of 1.15708" ÷ D.P. (See Fig. 6A).

To obtain desired accuracies, the gear blank should be finished after hardening to insure that the locating face and the running bore or shaft are concentric one with the other.

Suggested Feeds and Speeds

As in any type of cutting operation, there are a multitude

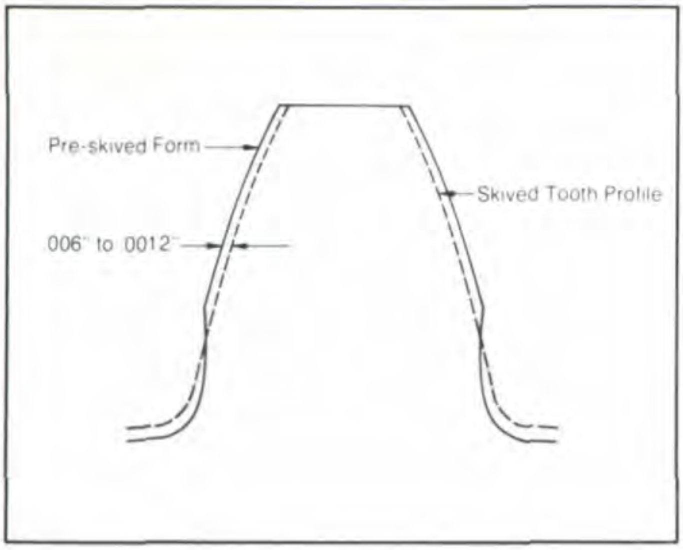

Fig. 6 – Protuberance Pre-skived Hob

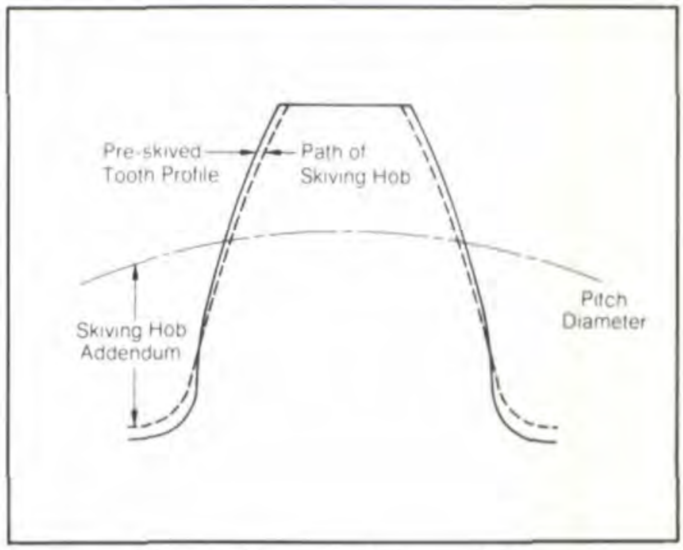

Fig. 6A – Pressure Angle Increment Hob

of factors which must be considered when establishing feeds and speeds so that one might optimize the operation as much as possible. The essential factors to consider are: rigidity of the machine, finish and accuracy requirements in the gear, gear blank preparation, work holding fixture, and condition of the machine to be used.

Table 1. Suggested Speed Ranges

Rockwell C Hardness	Surface Feet Per Minute
40-42	365-450
43-45	300-400
46-48	230-380
49-52	190-365
53-56	165-295
57-59	150-265
60-62	135-230
63-65	130-190

Table 1 lists speed ranges (surface feet per minute) depending upon hardness. The broad range of speeds for various hardnesses, is simply due to the various applications and requirements.

When the skiving hob was initially introduced, the normal surface feet per minute was about 150 in the Rockwell C 62 range. Laboratory testing has indicated that higher speeds are desirable when machine and cutting conditions warrant the same. This conclusion, reached under laboratory conditions, is being born out in the actual use on a commercial basis. Also, for the best life from the hobs, a heavier feed rate, rather than a lower feed rate should be used. This is, of course, dependent upon the accuracy and finish requirements that will serve to constraint the feed rate. Table 2 and Table 3 show the results of laboratory testing on the feeds and speeds.

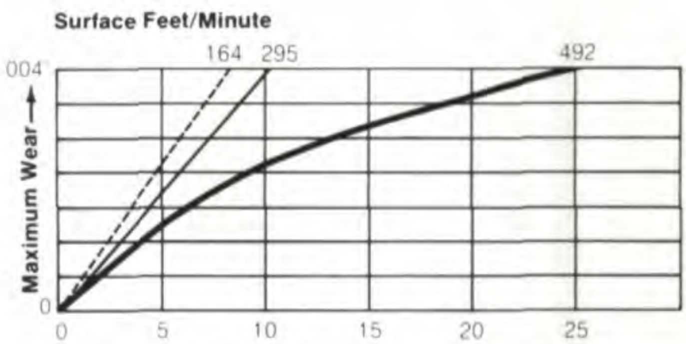

Table 2. Effect of Speed on Hob Life

Hob = 8 module (3.17 D.P.), R.H., 9 gashes, 20° P.A., 30° negative rake

Gear = 17 teeth, diameter 5.9", 1.968" face width, 55 Rc.

Feed Per Revolution = .236", wear land = .005"

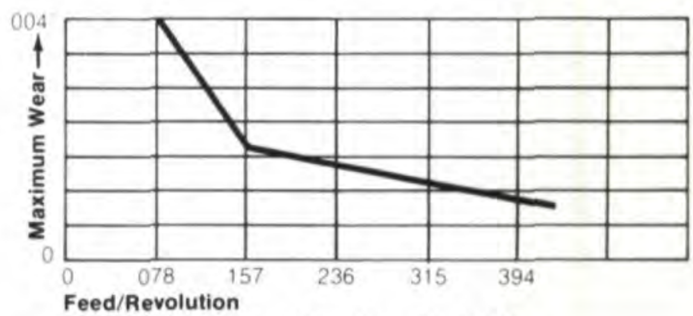

Table 3. Effect of Feed on Hob Life

Hob = 8 module (3.17 D.P.), R.H., 9 gashes, 20° P.A., 30° negative rake

Gear = 17 teeth, diameter 5.9", 1.968" face width, 55 Rc.

Cutting Speed = 328 SFM

Feed Rates

The suggested feed rates per revolution of the gear are as follows:

Table 4. Feed Rates

Pitch Range	Feed Rates IN/REV	
	Roughing	Finishing
2 DP & Coarser	120-.160	080-.120
2-1/4 DP & Finer	080-.140	060-.100

In application, it is essential to remove the same amount of stock from each flank of the gear tooth. This requires centering a hob tooth in the gear space, which can be done manually. In a production operation, a fixture to center the gear teeth, after the first gear has been set into the hob, would be helpful to the hobbing machine operator.

The maximum amount of stock that is normally recommended to be removed in one cut is as follows:

Table 5. Stock Removal

Pitch Range	Stock Removal on Tooth Thickness IN
1-1 4 DP	016-.024
1-1/2-2 DP	012-.020
2-1/4 DP & Finer	012-.016

Equipment

Any heavy-duty hobbing machine in good condition can be utilized for skiving. However, one should bear in mind not to overtax the machines; that is, do not go to the limit of the coarsest diametral pitch for which the machine is rated. There are two critical areas of any hobbing machine when it comes to the skiving operation. The first is the amount of backlash between the index worm wheel and the index worm. This should be maintained to the manufacturer's minimum tolerance. The hob spindle should be of the anti-friction type and should have no axial run-out in it. Among the popular machines which can be utilized for skiving are Barber-Colman, Liebherr, Module, Pfauter, and Shibaura.

Maintenance of Hobs

Resharpening of the hobs should take place where the wear of the hob has reached about .008" on the wear flank of the hob. The resharpening should be performed utilizing a cup-type diamond grinding wheel on a precision hob sharpening machine with high rigidity. This should be done using a wet grinding method to achieve the best possible surface quality on the cutting face of the hob. The axis of the grinding wheel should be offset about 10 minutes, so that the cup-type wheel is cutting only on its edge. A resin bonded diamond wheel with a mesh of 220 to 230 is recommended. A light hand lapping of the cutting edge (if done without influencing tooth profile accuracy) does help to prevent some chipping. This is especially important if one is cutting without coolant. A controlled edge honing operation may be beneficial. In all cases, the sharpening machine must have the capability of a large offset, the amount of which can be determined by the following formula:

$$\frac{\text{Hob O.D.}}{2} \times \text{Sine of the rake angle}$$

Economics

There are more items to consider than merely tool cost when reviewing the economics of this technology. The real criteria is the actual cost of gears. Example #1 shows a saving in skiving prior to a grinding operation. The other examples which will be given are finish skive examples and are being done in lieu of grinding.

One small part of the equation is an estimated life of the skiving hob. A "rule of thumb" estimate can be obtained by utilizing the factor of 165 lineal feet per position of the hob. This would be calculated first of all by establishing the generating length of the hob which is the working depth of the hob divided by the tangent of the pressure angle. This would be subtracted from the rest of the active face of the hob and shift, determined by 1/4 of the circular pitch minus 1, to be sure that you would always have sufficient generating length on the last position and/or to compensate for any slight errors in the positioning of hob which might occur. This would then translate itself into the number of pieces expected per sharpening of the hob, and the following is an example of the calculation of one such item:

Gear Data	Hob Data
4 D.P.	5.906 O.D.
20° P.A.	4.527 length
4-5/8" face width	3.740 active face
Spur* 17 teeth	2-1/2 bore

$$\text{Generating Length} = \frac{\text{Working Depth}}{\tan \text{P.A.}}$$

$$\text{G.L.} = \frac{.500}{\tan 20^\circ \text{ P.A.}} = 1.374''$$

$$\frac{17 \times 4.625}{12} = 6.55 \text{ lineal feet per gear}$$

$$\frac{165}{6.55} = 25 \text{ pcs. per position/per sharpening}$$

$$3.740 - 1.374 = 2.366''$$

$$\text{N.C.P.} = .7854''$$

$$\frac{2.366}{.7854} = 3.01 \times 4 = 12 \text{ shifts} - 1 = 11 + \text{initial position} = 12 \text{ positions}$$

$$12 \times 25 = 300 \text{ gears per sharpening} \times 20 \text{ sharpenings} = 6{,}000 \text{ pcs/life hob}$$

*If helical, divide face width by cosine of the helix angle.

Coolants

The normal high viscosity type coolants, used for cutting soft gears with high speed steel hobs, will simply not work.

The high viscosity film between the carbide hob and the work will tend to make the skiving hob slip or scuff, thus crushing the cutting edges and leading to severe cratering and chipping of the cutting edges. The gears should, therefore, be cut completely dry or by utilizing a special low viscosity cutting fluid, which was designed especially for skiving hobs. This cutting fluid has organic molybdenum as its active ingredient. When utilizing this oil, it is important that previous cutting oils be drained and the machine completely flushed with a solvent before the addition of the new cutting oil. If the machine is not cleaned in this manner, there will be residue that interacts with the new cutting oil which will cause stickiness and gumminess throughout the machine.

Through the utilization of this special cutting oil, skiving hob life is extended, thus providing for economical hobbing with the skiving hob.

The following are some examples of actual production runs utilizing skiving hobs.

Examples

EXAMPLE 1
(Skiving prior to grinding)

Gear Data

Diametral pitch	6
Pressure angle	20°
Number of teeth	129
Face width	2-1/2"
Hardness	Rc58-62
Helix angle	15°

Application Data

Finishing stock on tooth thickness	.011"
Hob RPM	200
Surface ft/min	309
Feed/rev	.100"
Climb hobbed machine — Pfauter	P630

Results

Skive hobbed	= 31 min.
Finish ground	= 40 min.
Total hard processing time	= 71 min.
Previous grinding method	= 240 min.
Savings per gear	= 169 min.
Average hob wear	.006"
Estimated life of hob	1230 gears

Economic Justification

$35.00 hour × (169 min. ÷ 60)	= $ 98.58
Less tool cost/gear	= 3.02
Less sharpening cost/gear	= 1.00
	$ 94.56
Total savings 1230 × 94.56	= $116.308

EXAMPLE 2
(Finish Skiving)

Gear Data

Diametral pitch	8
Pressure angle	14-1/2°
Number of teeth	29
Helix angle — R.H.	27° 16'
Face width	1.250"
Hardness	Rc54-57

Application Data

Hob RPM	162
SFM	250
Feed/rev	.080"
Conventional hobbed machine — Barber-Colman	16-15
Cycle time	4.12 min

Results

Accuracy AGMA Class 12

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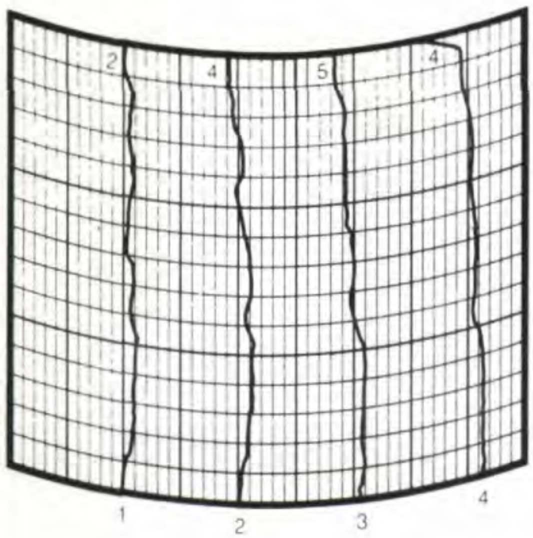
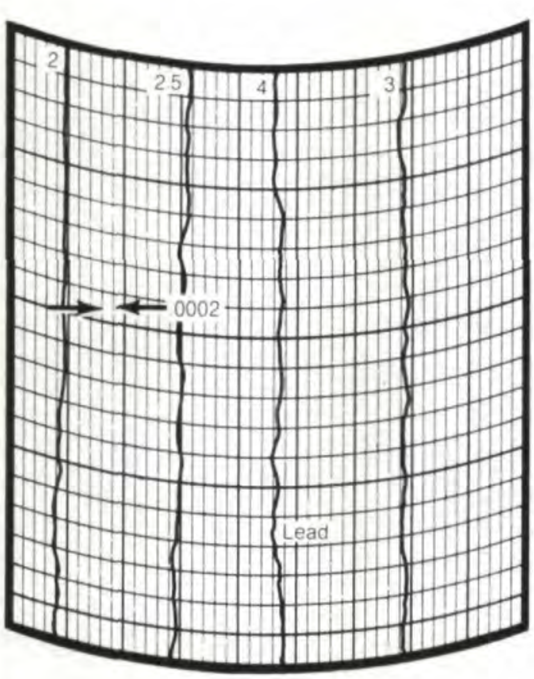


Example 2 – Involute Charts



Example 2 – Lead Charts

EXAMPLE 3

Gear Data

Diametral pitch	4
Pressure angle	20°
Number of spur teeth	100
Face width	4″
Hardness	Rc53-56

Application Data

Hob RPM	78
SFM	120
Feed/rev	.067″
Finishing stock on tooth thickness	.010″

Results

Finish smooth
Bearing pattern excellent (75% bearing required)

EXAMPLE 4

Gear Data

Diametral pitch	2.54
Pressure angle	25°
Number of spur teeth	70
Face width	4-5/8″
Hardness	Rc62

Application Data

Hob RPM	92
SFM	180
Feed/rev	.103″
Conventional hobbed machine — Barber-Colman	40-15
Cycle time	40 min.

Results (See Example 4 Charts)

(continued on page 33)