GEAR FUNDAMENTALS

Hob Basics Part I

Keith Liston
Pfauter-Maag Cutting Tools, L.P.
Loves Park, IL

The Hobbing Process

The hobbing process involves a hob which is threaded with a lead and is rotated in conjunction with the gear blank at a ratio dependent upon the number of teeth to be cut. A single thread hob cutting a 40-tooth gear will make 40 revolutions for each revolution of the gear. The cutting action in hobbing is continuous, and the teeth are formed in one passage of the hob through the blank. See Fig. 1 for a drawing of a typical hob with some common nomenclature.

Fig. 2 shows the generating process of hobbing. This diagram shows the cutting action of consecutive teeth in a hob thread passing through the gear space as the gear space rotates past the hob. Each hob tooth cuts its own profile, which is straight-sided. It is the accumulation of these straight cuts that produces the involute form on the gear teeth. The gear profile is formed a little at a time in a series of cuts. This method is known as the generating process of cutting gears. As the number of flutes in a hob are increased, the number of cutting teeth also increases. Thus, given the same feeds and speeds, a hob with a higher number of flutes will generate a smoother profile.

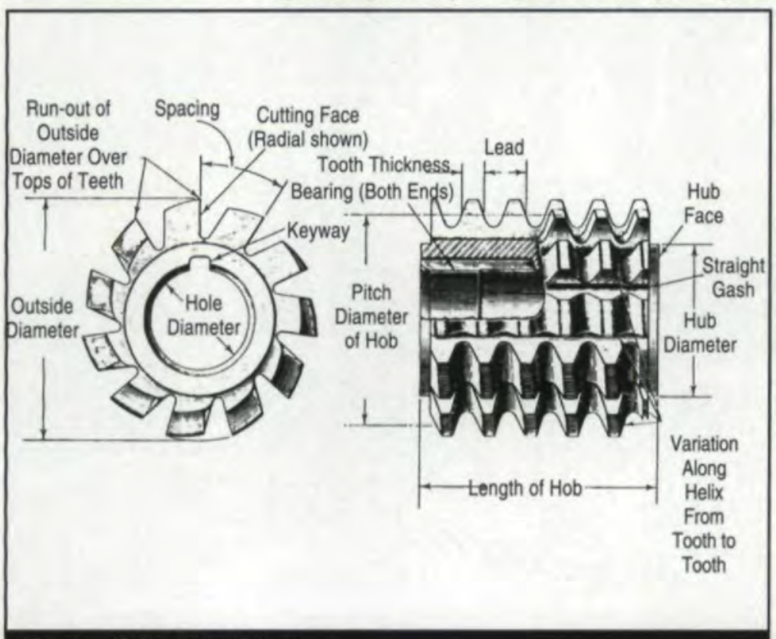

Fig. 1 — Hob nomenclature.

Selection of the Type of Hobbing Operation

The selection of the type of hobbing operation is dependent upon the class of gear required, the type of equipment available, the condition of the equipment, the experience of the work force or the personal preference of the gear designer. In some cases there may be more than one manufacturing method available to obtain the same end result.

Finish Hobbing. Finish hobs are used to put the final tooth form on a part. No secondary operations are performed on the tooth after hobbing, therefore, the hob cuts the part teeth to the finish tooth dimensions. Gears can be finish-hobbed if the quality level permits, and the machine and fixturing are accurate enough. See Fig. 3 for achievable gear qualities. Note that this chart is only a guideline, with actual results dependent upon the equipment and tooling available, the experience of the work force and the control of the heat treating process.

Semi-Finish Hobbing. Semi-finish hobbing differs from finish hobbing, since a secondary operation is performed on the tooth form after the hobbing operation. Secondary operations include shaving, grinding, rolling or skiving, to name the more common methods. Semi-finish hobs leave stock on the tooth form to be removed by the finishing tool. The stock remaining must be of a minimum and uniform amount; therefore, semi-finishing hobs must have the same accuracy as finishing tools. Hobs of ground accuracy are frequently used as semi-finishing hobs. This is especially true if multiple-thread hobs are used, because thread-to-thread inaccuracies in unground tools can deteriorate part quality.

The finishing operation can be performed on parts in the soft green state or can be performed after hardening the parts. Shaving and rolling are soft gear finishing methods, while grinding and skiving are used on hard gears.

Rough Hobbing. A rough hobbing operation is intended to remove metal stock quickly without concern for the final part tolerances. A second hobbing operation is always required. Roughing hobs are used on coarse pitch gears where a relatively large amount of metal removal is necessary. Roughing hobs are designed to remove metal faster with less tool wear and less machine strain. Higher production rates are obtained with lower overall tool cost.

Design Features

Topping. Topping hobs cut the outside diameter of the part to finish size (Fig. 4). The outside diameter is held concentric to the pitch diameter. The resulting tooth thickness is held to a constant relation to the outside diameter. The tooth thickness of the gears can be easily verified by measuring the outside diameter of the part. The use of topping hobs can often result in a cost savings for the user. Finish-hobbed gears can be chucked on the outside diameter in subsequent operations for hole finishing. Their use also eliminates the need for an accurate finish-turning operation on the gear blank prior to hobbing.

Semi-Topping. Semi-topping hobs have a ramp near the bottom of the hob tooth to provide a chamfer on the part tooth (Fig. 5). The purpose of this chamfer is to reduce the

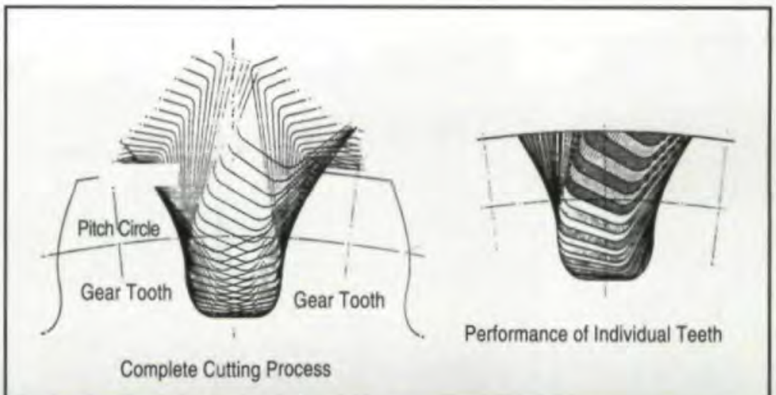

Fig. 2 — A) Generating action of a hob in cutting the profiles of gear teeth. B) Performance of an individual hob tooth.

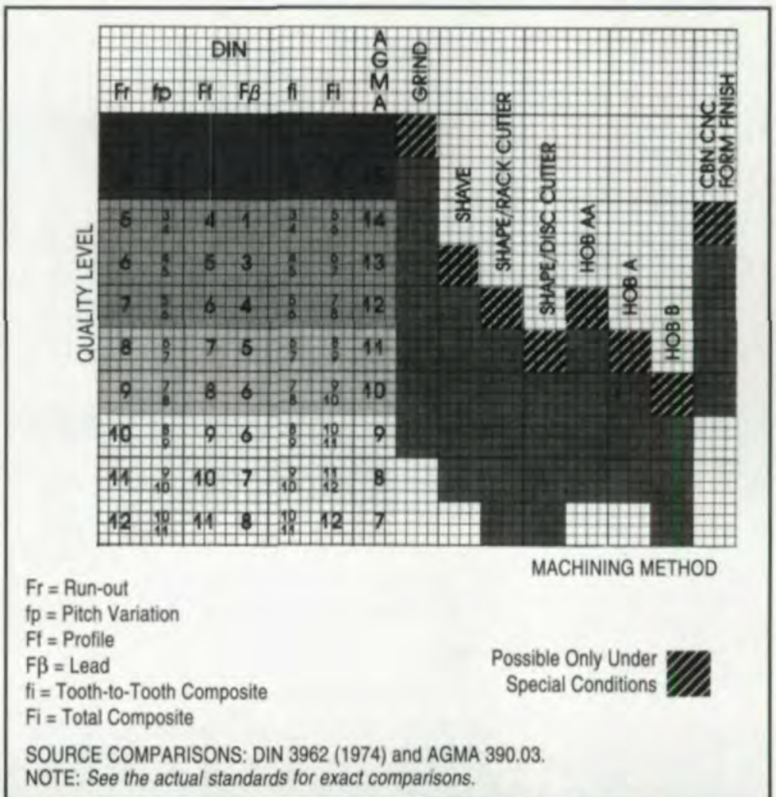

Fig. 3 — Obtainable gear qualities by machining methods.

Fig. 4 — Topping hob.

Keith Liston

is an Engineering Manager with Pfauter-Maag Cutting Tools, L. P. He holds a B.S. in Industrial Engineering from the University of Wisconsin — Platteville and an MBA from the University of Wisconsin — Whitewater.

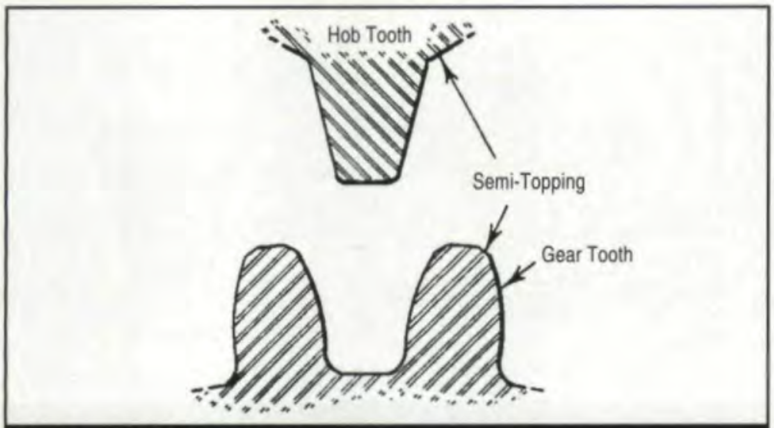

Fig. 5 — Semi-topping hob.

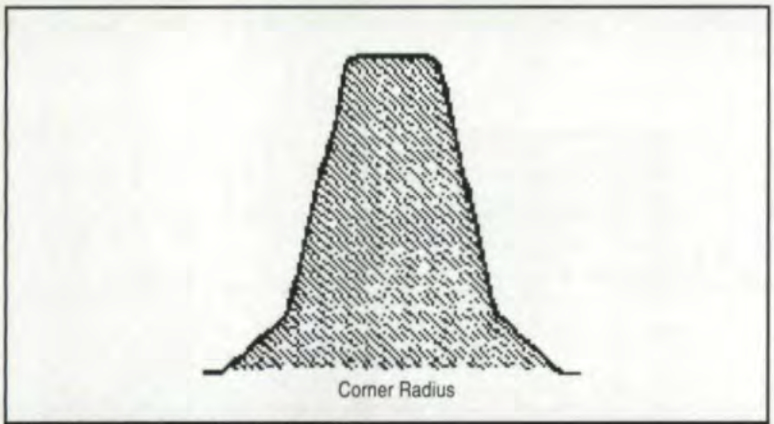

Fig. 6 — Corner radius hob tooth.

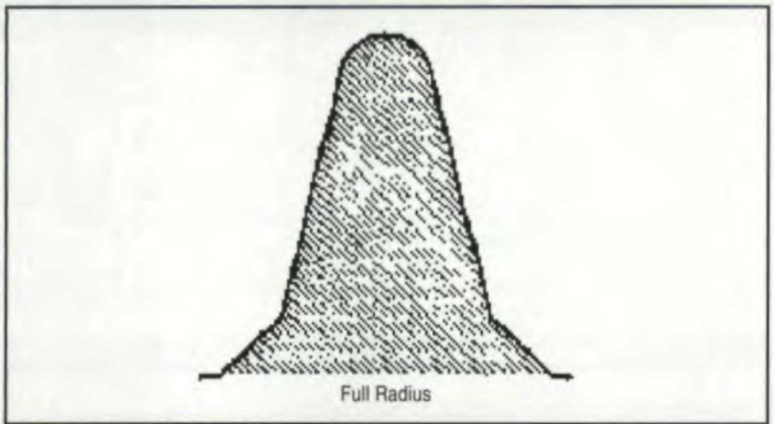

Fig. 7 — Full radius hob tooth.

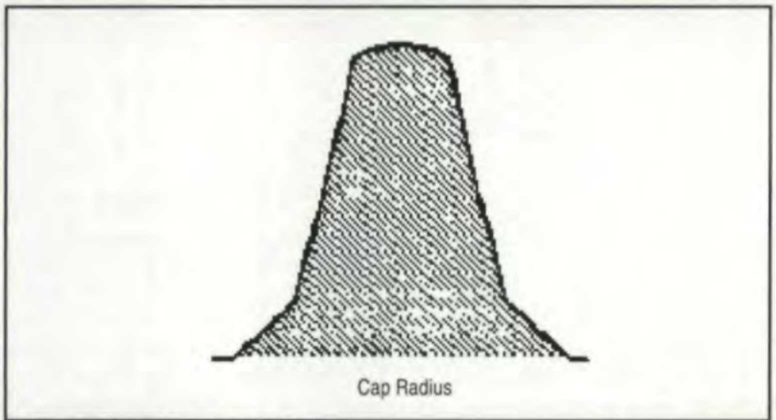

Fig. 8 — Cap radius hob tooth.

possibility of nicks on the involute profile when large numbers of gears are being handled. In addition, deburring operations are often eliminated or reduced because the burr is thrown away from the involute profile. The form of a semi-topping modification will vary with the number of teeth in the gear, just as the width of the top of the gear tooth varies.

Radius. The tops of hob teeth are designed with radii to help reduce the tip wear while providing greater strength to the gear teeth. The size of the radius is often dictated by the true involute form (T.I.F.) diameter and the root diameter. A standard finishing gear hob is designed with corner radii which are equal to 1/10 the tooth thickness. Semi-finishing hobs are usually given larger radii than finishing hobs. The deeper form is better able to accommodate a larger radius without violating the T.I.F. diameter.

Three types of radii are shown in Figs. 6-8. The corner radius (Fig. 6) is the most common type used on all standard hobs. The full radius (Fig. 7) provides the best wear characteristics, but is less likely to adhere to the root diameter and T.I.F. diameter constraints. The full cap radius (Fig. 8) is the poorest overall design because of its tendency to wear at the intersection points. This last option is only used when all other possibilities have failed.

Keep in mind that a true radius on a hob tooth does not generate a single radius in the gear fillet. Rather, a trochoid is produced. A trochoid is best described as a series of connecting fillet radii.

Hob Accuracies

Classes of Hob. Hobs are available in 5 different accuracy classes as follows:

- AA - Ultra Precision Ground
- A - Precision Ground
- B - Commercial Ground
- C - Accurate Unground
- D - Commercial Unground

The tolerances for classes A-D have been established by the Metal Cutting Tool Institute. Class AA tolerances were established by the Barber-Colman Company. The tolerances associated with these 5 classes are presented in Fig 9.

(Continued on p. 52.)

Fig. 9 – Single-Thread and Multi-Thread Gear Hob Tolerances
(All readings in tenths of a thousandth of an inch.)

Diametral Pitch		1 thru 1.999	2 thru 2.999	3 thru 3.999	4 thru 4.999	5 thru 5.999	6 thru 8.999	9 thru 12.999	13 thru 19.999	20 thru 29.999	30 thru 50.999	51 and finer
Run-out (1-4 Thread)	**Class**											
Hub Face*	AA			2	2	2	1	1	1	1	1	1
	A	8	5	2	2	2	2	2	2	2	2	2
	B	10	8	4	4	3	3	2	2	2	2	
	C	10	8	4	4	3	3	2	2	2	2	2
	D	10	8	5	5	4	4	3	3	3	3	
Hub Diameter*	AA			2	2	2	1	1	1	1	1	1
	A	10	5	4	3	3	3	2	2	2	2	2
	B	12	8	6	5	4	4	3	2	2	2	
	C	12	8	6	5	4	4	3	2	2	2	2
	D	15	10	8	8	6	6	6	5	4	3	
Outside Diameter*	AA			5	4	3	3	3	3	2	2	2
	A	30	20	15	15	10	10	10	10	10	7	5
	B	40	30	25	20	15	15	15	10	10	7	
	C	50	45	40	25	20	17	17	12	12	10	8
	D	60	55	50	45	35	35	30	25	20	15	
Lead Variation												
Tooth to Tooth* 1 Thread	AA			4	3	2	1.7	1.7	1.7	1.7	1.5	1.5
	A	7	5	4	3	2	2	2	2	2	2	2
	B	10	8	6	4	3	3	3	3	3	2	
	C	15	12	8	6	5	4	4	4	4	3	3
	D	25	20	16	14	12	10	10	8	6	5	
2 Thread	A	8	6	5	4	3	3	3	3	2	2	2
	B	12	10	7	6	5	5	5	4	3	2	
	C	18	14	10	9	7	6	6	5	5	3	3
	D	27	22	18	16	14	12	11	9	8	6	
3 Thread	A	9	7	6	4	4	4	3	3	3	2	2
	B	14	12	8	7	6	6	5	5	4	3	
	C	21	16	12	10	8	7	6	5	5	4	3
	D	29	24	20	18	16	14	12	10	9	7	
4 Thread	A	10	7	6	5	4	4	4	3	3	3	2
	B	16	13	9	8	7	6	6	5	4	4	
	C	24	18	13	11	9	7	7	6	5	4	4
	D	31	26	22	20	18	16	13	11	10	8	
Any One Axial Pitch* 1 Thread	AA			8	6	4	3	3	2	2	1.5	1.5
	A	25	18	10	8	6	5	5	4	4	3	3
	B	35	25	17	11	9	7	7	6	6	4	
	C	45	35	22	14	11	9	9	8	8	8	6
	D	60	50	40	30	25	20	20	18	16	14	
2-4 Thread	A	25	20	10	8	6	5	5	4	4	3	3
	B	35	30	17	12	10	8	8	7	7	4	
	C	45	35	22	18	15	12	12	10	10	8	6
	D	60	50	40	30	25	20	20	18	16	14	
Any Three Axial Pitches* 1 Thread	AA			12	9	6	5	5	4	4	3	3
	A	38	26	15	12	9	8	8	7	7	5	5
	B	53	38	22	16	12	11	10	9	9	7	
	C	70	50	30	21	16	14	13	12	12	12	8
	D	120	100	80	60	50	40	35	25	20	16	

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Fig. 9 (cont.) – Single-Thread and Multi-Thread Gear Hob Tolerances
(All readings in tenths of a thousandth of an inch.)

Diametral Pitch		1 thru 1.999	2 thru 2.999	3 thru 3.999	4 thru 4.999	5 thru 5.999	6 thru 8.999	9 thru 12.999	13 thru 19.999	20 thru 29.999	30 thru 50.999	51 and finer
Lead Variation (con't.)												
Any Three Axial Pitches* 2-4 Thread	A	38	30	15	12	9	8	8	7	7	5	5
	B	53	38	22	20	15	12	12	10	10	7	
	C	70	50	30	28	20	18	16	14	14	12	8
	D	120	100	80	60	50	40	35	25	22	18	
Adjacent Thread to Thread Spacing* 2 Thread	A	11	9	8	7	6	5	4	3	3	3	3
	B	14	12	11	10	9	8	6	5	5	5	
	C	20	17	15	13	11	10	9	8	7	6	5
	D	26	22	19	17	15	13	12	11	10	9	
3 Thread	A	13	11	10	8	7	6	5	4	4	4	3
	B	16	14	12	11	10	9	7	7	6	6	
	C	22	19	16	14	13	11	10	9	8	7	6
	D	28	24	20	18	16	15	13	12	11	10	
4 Thread	A	15	13	12	9	8	7	6	5	4	4	3
	B	18	16	14	12	11	10	8	7	7	6	
	C	24	21	18	15	14	12	11	10	9	8	7
	D	30	26	22	20	18	16	14	13	12	11	
Tooth Profile												
Pressure Angle or Profile* 1 Thread	AA			2	2	1.7	1.7	1.7	1.7	1.7	1.5	1.5
	A	10	5	3	3	2	2	2	2	2	2	2
	B	16	8	5	5	4	3	3	3	3	2	
	C	25	15	10	5	4	3	3	3	3	3	3
	D	80	55	30	18	12	8	8	6	5	4	
2 Thread	A	12	7	5	4	3	3	2	2	2	2	2
	B	18	10	7	5	5	4	3	3	3	2	
	C	27	16	11	7	5	4	3	3	3	3	3
	D	80	55	30	18	12	8	8	7	6	5	
3-4 Thread	A	15	8	5	4	3	3	3	2	2	2	2
	B	20	10	7	5	5	4	4	3	3	2	
	C	27	16	11	7	5	4	4	3	3	3	3
	D	80	55	30	18	12	8	8	7	6	5	
Start of Approach (Plus or Minus) 1 Thread	AA			100	80	70	60	60	40	40	30	
	A	200	180	160	140	120	100	80	60	40	30	
	B	220	200	180	160	140	120	100	80	50	40	
	C	220	200	180	160	140	120	100	80	60	50	
	D	260	240	220	200	180	160	140	120	100	80	
2-4 Thread	A	200	180	160	140	120	100	80	60	50	40	
	B	220	200	180	160	140	120	100	80	60	50	
	C	220	200	180	160	140	120	100	80	60	50	
	D	260	240	220	200	180	160	140	120	100	80	
Symmetry of Approach* 1 Thread	AA			70	60	50	40	40	25	25	25	
	A	150	130	120	100	90	80	60	50	35	25	
	B	180	150	130	120	100	90	80	70	45	35	
	C	180	150	130	120	100	90	80	70	55	45	
	D	200	180	160	140	120	110	100	90	80	60	
2-4 Thread	A	150	130	120	100	90	80	60	50	40	30	
	B	180	150	130	120	100	90	80	70	60	50	
	C	180	150	130	120	100	90	80	70	60	50	
	D	200	180	160	140	120	110	100	90	80	60	

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Fig. 9 (cont.) – Single-Thread and Multi-Thread Gear Hob Tolerances
(All readings in tenths of a thousandth of an inch.)

Diametral Pitch	Class	1 thru 1.999	2 thru 2.999	3 thru 3.999	4 thru 4.999	5 thru 5.999	6 thru 8.999	9 thru 12.999	13 thru 19.999	20 thru 29.999	30 thru 50.999	51 and finer
Tooth Profile (con't.)												
Tooth Thickness (Minus Only) 1-4 Thread	AA			15	15	10	10	10	10	10	5	5
	A	30	20	15	15	10	10	10	10	10	5	5
	B	30	20	15	15	10	10	10	10	10	5	
	C	35	25	20	20	15	15	15	15	15	10	10
	D	40	35	30	25	20	20	20	20	20	15	
Sharpening (1-4 Thread.)												
Spacing Between Adjacent Flutes*	AA			20	15	10	8	8	6	6	6	6
	A	40	30	25	20	15	10	10	10	10	10	10
	B	50	45	40	30	20	15	15	10	10	10	
	C	50	45	40	30	20	15	15	10	10	10	10
	D	60	60	50	50	30	25	25	20	17	17	
Spacing Between Non-Adjacent Flutes*	AA			40	35	25	15	15	15	15	15	15
	A	80	60	50	40	30	30	30	25	25	20	20
	B	100	90	80	60	50	50	50	40	35	30	
	C	100	90	80	60	50	50	50	40	35	30	30
	D	120	120	100	100	80	80	70	60	50	40	
Cutting Faces Radial To Cutting Depth*	AA			10	8	6	5	5	3	3	3	3
	A	30	15	10	8	6	5	5	3	3	3	3
	B	50	25	15	10	8	7	7	5	5	5	
	C	50	25	15	10	8	7	7	5	5	5	5
	D	100	75	50	40	30	20	20	15	15	10	

	Class	Face Width 0-1"	1"-2"	2"-4"	4"-7"	7" & up
Accuracy of Flutes, Straight And Helical*	AA	8	10	15	20	20
	A	10	15	25	30	50
	B	10	15	25	30	50
	C	10	15	25	30	50
	D	15	23	38	45	75

Bore (1-4 Thread.)

	Class	Bore Diameter 2.500"	2.000"	1.500"	1.250"	.750"	.500" & smaller
Diameter, Stright Bore (Plus Only)	AA				2	2	2
	A	8	8	5	2	2	2
	B	10	10	8	3	2	2
	C	10	10	8	3	2	2
	D	10	10	8	5	4	3

	Class	All Diameters Length
Percent of Bearing Contact, Straight Bore	AA	75
	A	75
	B	75
	C	60
	D	50

	Class	All Tapers Circumference	Length
Percent of Bearing Contact, Taper Bore	AA	95	75
	A	90	60
	B	90	60
	C	90	60

*Total indicator variation.
Class AA Ultra Precision Hobs are made single thread only.
Tolerances apply only to standard or recommended hob diameters.

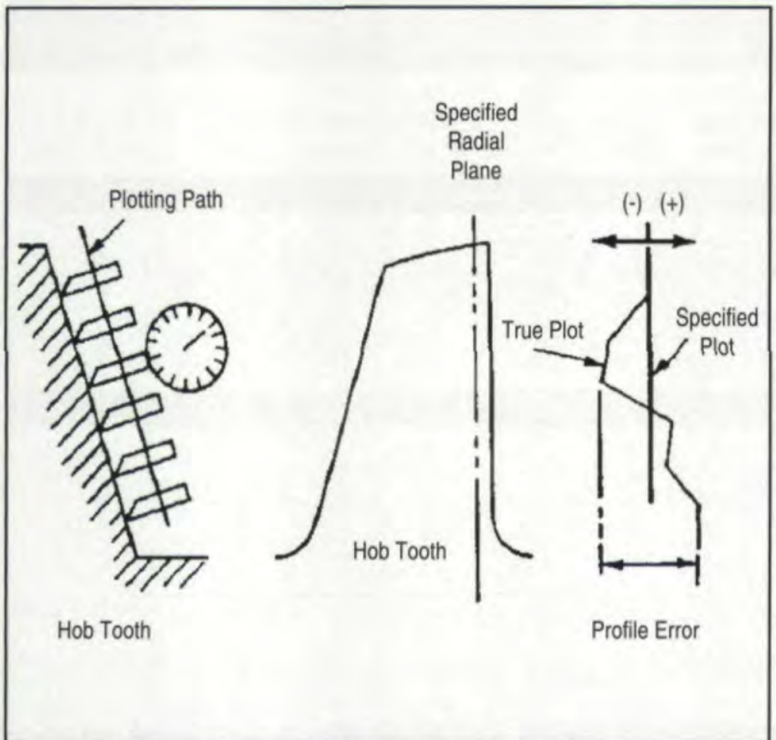

Fig. 10 — Method of measuring profile error of the hob.

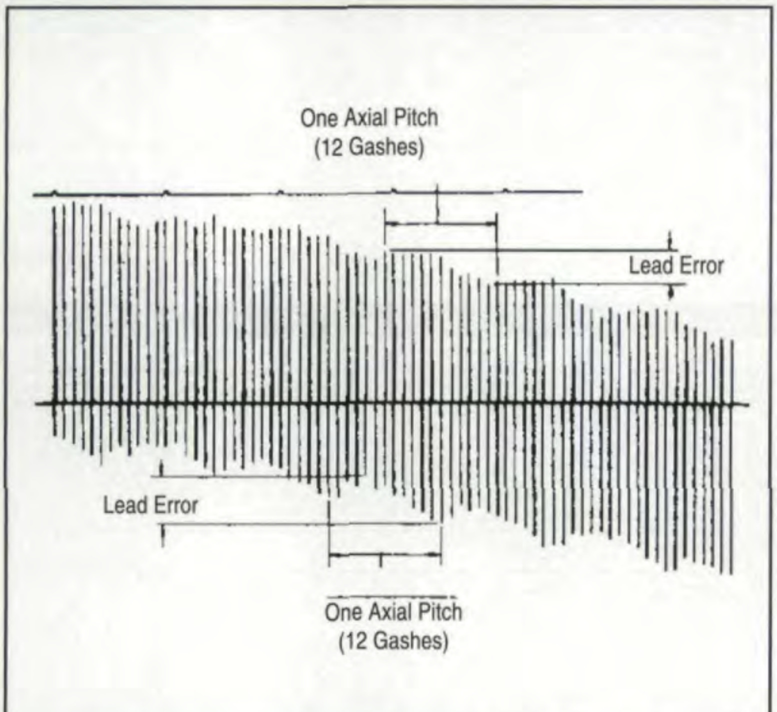

Fig. 11 — Hob lead chart measuring lead error in one axial pitch.

(Continued from p. 48.)

Hob Accuracy vs. Gear Accuracy. Hob accuracy has a direct relationship to the quality of the gears produced. It is generally accepted that the gear errors attributable to hob inaccuracies are the gear profile errors, and that gear profile errors are equal to the sum of the hob profile error and the hob lead error in one axial pitch. It should be noted that hob lead error is a composite of several elements.

Hob Profile Error. Pressure angle or profile error is the departure of the actual tooth profile from the correct tooth profile. The actual hob profile is allowed to vary from the specified hob profile entirely in the plus direction, entirely in the minus direction or split and divided in any ratio, provided the total deviation does not exceed the specified value. This maximum value can occur anywhere along the hob profile, and the variation of the profile on one side of the thread has no relationship to the variation on the other side of that same thread. The profile of either side can vary to the maximum positive or negative values independently. However, both must be within the specified tolerance. Fig. 10 is an illustration of the manner in which the hob profile error is measured by plotting. Hob tooth profile error is reproduced directly in the gear tooth profile.

Lead Error. Hob lead error (mispositioning of hob teeth along the thread) has varying effects. Tooth-to-tooth error produces small form or finish irregularities in a relatively localized spot. A hob lead error encompassing a whole axial pitch or more will change the gear tooth profile along the whole flank of the tooth from tip to root.

Lead error in one axial pitch is the maximum deviation from the theoretical thread helix in any group of hob teeth equal to the number of hob teeth in one axial pitch. This number of hob teeth may be selected anywhere in the length of the hob and is equal to the number of hob gashes divided by the number of threads. Fig. 11 illustrates the reading of the hob lead error in one axial pitch.

Part 2 of this article will appear in the next issue. It will cover sharpening errors and finish hob design considerations. ■

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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