Hob Length Effects

Y. Kotlyar
American Pfauter
Elk Grove Village, IL

Hobbing is probably the most popular gear manufacturing process. Its inherent accuracy and productivity makes it a logical choice for a wide range of sizes. Hobbing is successfully used for both roughing and finishing processes, depending on the accuracy required. Recent developments in cutting tool technology, such as coatings and improved materials, have proven hobbing processes to be even more competitive.

Optimum selection and utilization of cutting tools is essential for successful and economical gear hobbing. Hob material, feed and speed rates, gear material and hardness all influence hob performance. Hob length selection and its proper utilization can have a greater effect on performance than is usually realized.

Hob utilization would be ideal, if all hob cutting edges undergo an even cutting load, and consequently even wear. Unfortunately, in reality, only part of the hob is engaged in hobbing at a time, and even along this engagement zone cutting load is distributed unevenly. This causes some hob cutting edges to wear out more quickly than others. Hob shifting is used to offset this phenomenon. Hob wear distribution analysis helps to determine the benefit from utilizing the entire hob length, as well as the advantages from using longer hobs.

Cutting action divides hob length into four specific zones: non-usable, roughing, generating and shifting.

The non-usable zone is not suitable for metal removal, because the hob teeth in this area are not fully developed. This section is about one to one and a half pitches in length.

The roughing zone is the area where usually significant material removal occurs. Length of this zone is a function of gear-hob geometry, but depends primarily on the number of teeth on the gear. A relatively long roughing zone results in a more even distribution of cutting loads and creates a smoother cutting action. A very short roughing zone, occurring when hobbing gears with small numbers of teeth, creates excessive wear, due to the large amount of material removal per hob cutting edge. In this case, it is usually recommended to use a hob with a larger number of gashes.

The third region on the hob is designated the generating zone, as the involute is actually generated here. As such, it is critical that only sharp hob teeth operate in this area. The direction of shifting or movement of the hob, in relation to the workpiece, should be made so that the shift brings fresh hob teeth into the generating zone, and moves slightly worn teeth from the generating zone to the roughing zone. The generating zone represents the theoretical absolute minimum of hob length required to generate a gear. Locating this zone on the hob is essential for relative hob – workpiece positioning.

The remaining hob length, the "shifting zone", represents the amount of hob shift available. Availability of this zone makes it possible to offset the hob once part of it is worn out.

The so-called "engagement zone" is the sum of roughing and generating zones. The ratio between total hob length and length of engagement zone can be named "relative hob length". It is a more universal criteria to describe a real hob length value.

Fig. 1 shows wear distribution when the hob-workpiece relative position remains the same. Some of the hob cutting edges are worn out to the extent that further use may result in catastrophic breakage. Hob resharpening is necessary at this point, despite the fact that most of hob cutting edges are still suitable for hobbing.

If there is a provision for changing the hob-workpiece relative position (if hob length is greater than length of engagement zone) cutting load can be redistributed as some cutting edges wear out. Fig. 2 represents a wear pattern for longer hobs which are shifted at an optimum rate. Compar-

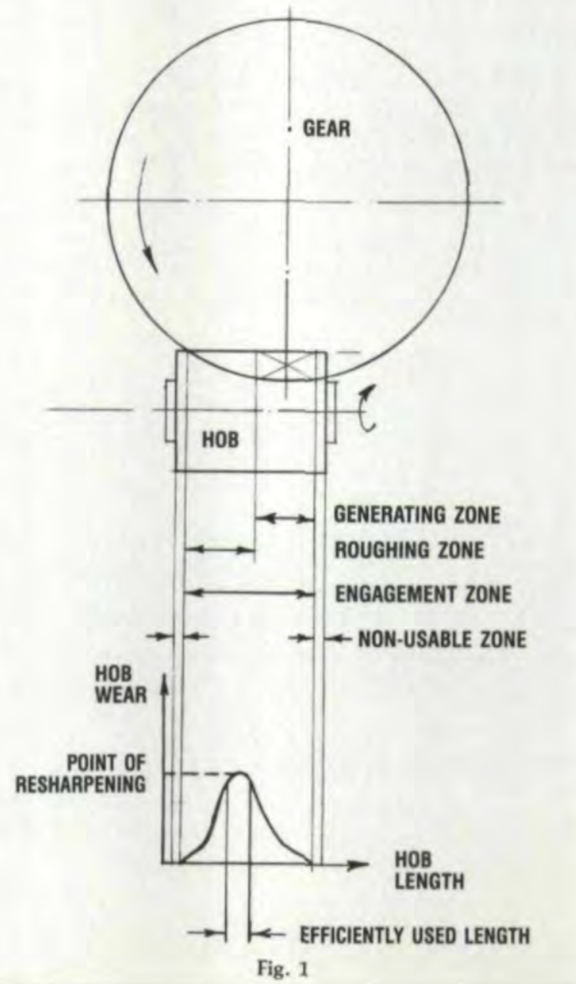

Fig. 1

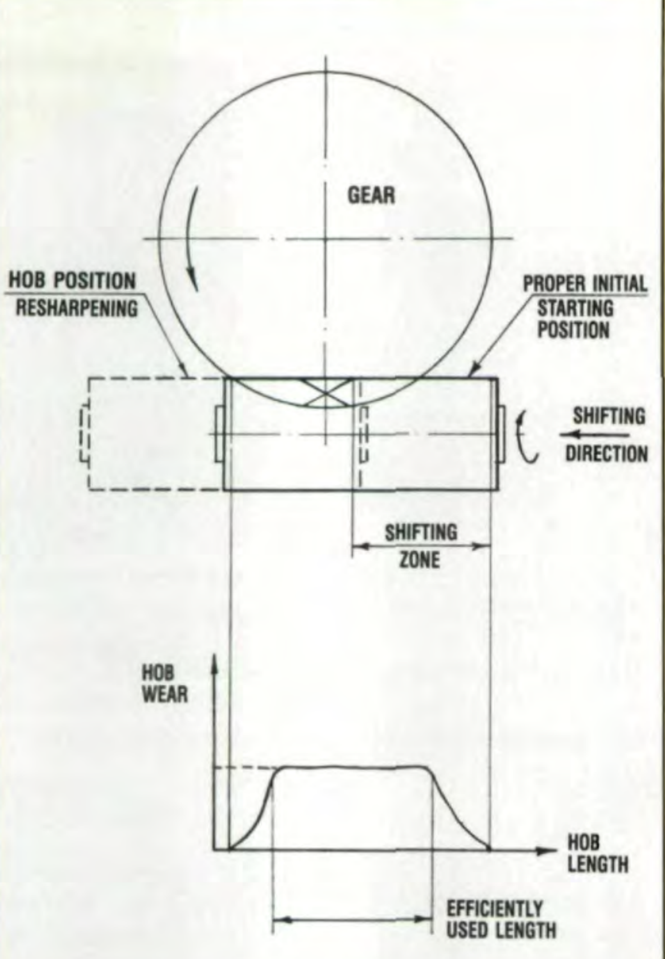

Fig. 2

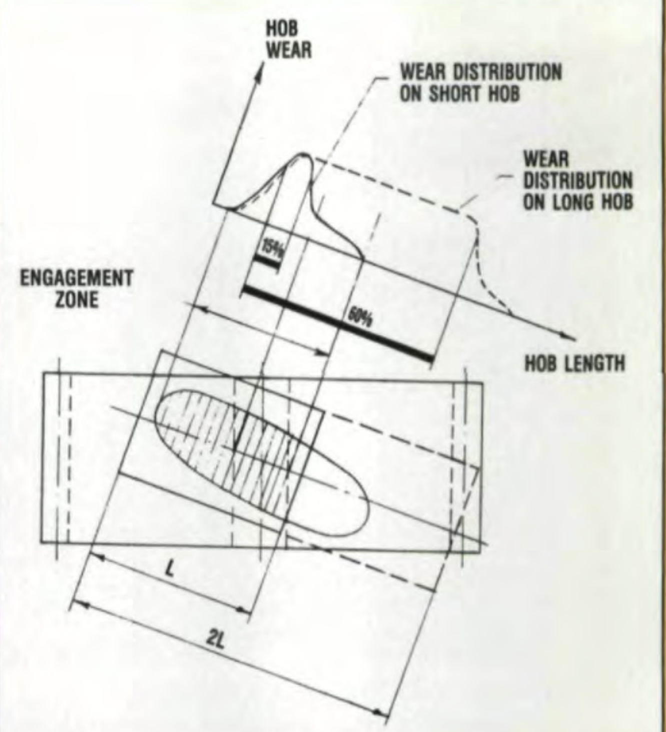

Fig. 3

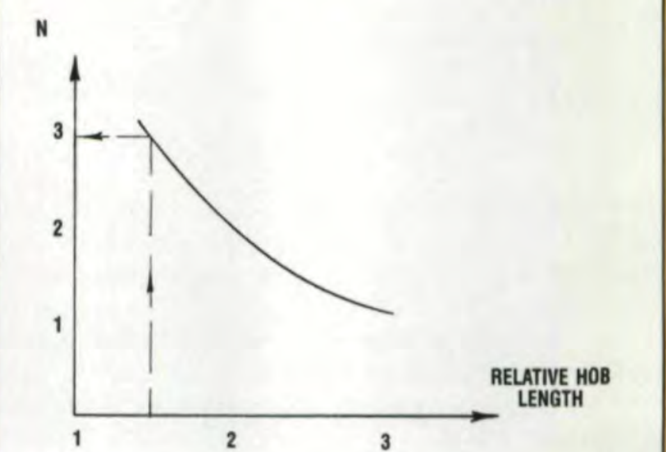

Fig. 4

ing Fig. 1 and Fig. 2, one can see that a greater percentage of hob length is being utilized in the latter case.

As an example, compare the performance of two hobs, one short and one long (Fig. 3). The length of the "short" hob is the sum of the engagement and non usable zones. The long hob is twice as long as the short hob. Reviewing the wear distribution charts, one can see that the short hob should be resharpened when approximately fifteen percent of the total hob length has been efficiently used. On the other hand, the long hob should be resharpened when approximately sixty percent of the total hob length is efficiently used.

Let's assume that the length of the short hob is equal to L, and the length of the long hob equals 2L. Then the efficiently used hob length is as follows:

small hob . . . . 15% × L
long hob . . . . 60% × 2L

The ratio of efficiently used long and short hob lengths or the actual gain from using the longer hob:

$$\frac{60\% \times 2L}{15\% \times L} = 8$$

This particular example indicates that 800% more gears can be cut by using a hob twice as long. Generally, the gain from using a longer hob can be calculated by:

Gain = $[(\text{length of longer hob}) / (\text{length of shorter hob})]^n$

where n is obtained from Fig. 4 as a function of relative hob length. It can be noted that after the relative hob length exceeds a value of three, additional gain is almost proportional to hob length.

The above method can also be used to estimate the loss when the initial hob placement, in relation to the workpiece, is incorrect. For example, take the case of a hob, five inches in length, mispositioned by 0.5 inch, (a ten percent error). This gives the five inch long hob a working length of four and a half inches. Assuming that one and one half times the engagement zone of this hob is equal to 4.5 inches, in the above equation, n would be set equal to three (see Fig. 4). Plugging in the numbers, one can see that the loss from using a five inch long hob, with an effective length of four and

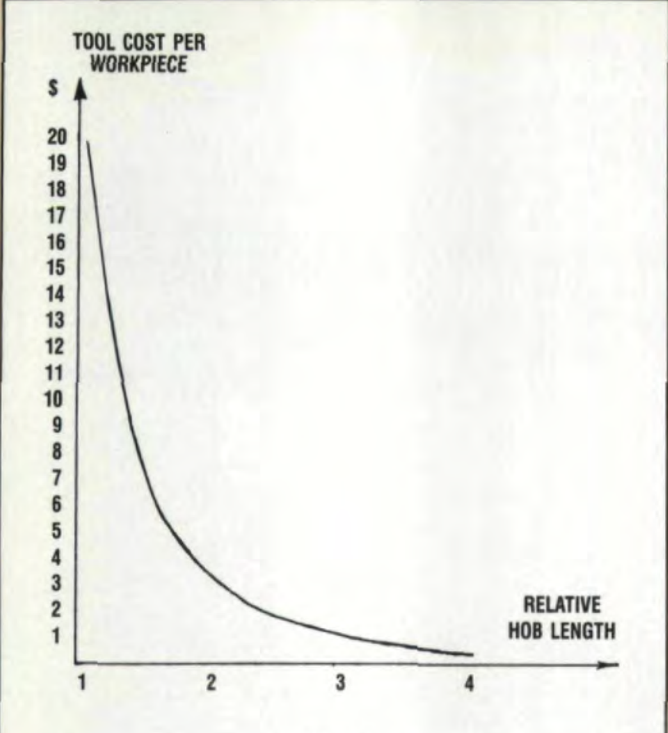

Fig. 5

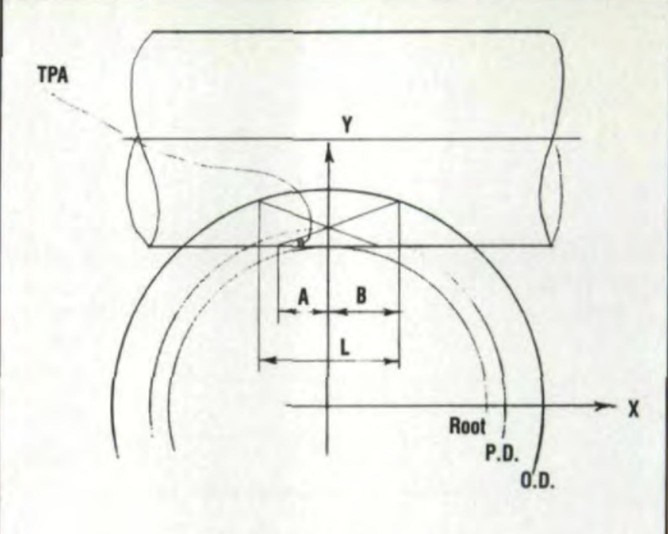

Fig. 6

a half inches, is 27.1%, almost three times as much as the initial error of 10%.

$$\text{Ratio} = \left(\frac{4.5}{5}\right)^3 = .729$$

$$\text{Loss} = (1 - 0.729) \times 100\% = 27.1\%$$

Fig. 5 shows the pattern of hob cost per workpiece as a function of relative hob length, considering that other cost influencing parameters remain the same. Cost figures are arbitrary and can be used only for comparison purposes.

Proper attention to hob length affects a substantial increase in hob life and time between resharpening. This leads to maximum tool and machine utilization, significantly reducing tool costs per workpiece while increasing productivity.

Obviously, close monitoring of hob wear distribution is necessary in order to benefit from the hob length effect. It is a rather easy task for mass production. For low quantity production, when the hob is frequently removed from the machine, it becomes a more difficult, but not impossible task, especially when utilizing hobbing machines with computerized controls.

APPENDIX

Method for calculating length of roughing, generating, and engagement zones:

1. GENERATING ZONE

Fig. 6 shows the generating zone in a transverse plane. The generating zone can be divided into two subzones:

A - length for generating dedendum
B - length for generating addendum

It is important to know the value of both of these lengths. Then, by doubling the greater length, one can determine the total engagement zone in the transverse plane.

$$A = Ded/\tan(TPA)$$

where: Ded- gear dedendum
TPA- transverse pressure angle

The length "B" can be determined as an X-coordinate of the intersection of the workpiece's outside diameter with the action line by utilizing formulas for a circle and a straight line.

The equation for the outside diameter of the workpiece:

$$X^2 + Y^2 = (WD/2)^2$$

where: WD- outside diameter of workpiece

The equation of the line of action:

$$Y = PD/2 + X \times \tan(TPA)$$

where: PD- pitch diameter of the workpiece

By solving this system of two equations, one determines the coordinates of the two intersections of the line of action with the outside diameter of the gear. Only one of the two intersections is to be considered.

$$B = X = \frac{-b + \sqrt{b^2 - 4 \times a \times c}}{2 \times a}$$

where: $a = 1 + \tan^2 (TPA)$
$b = PD \times \tan(TPA)$
$c = (PD/2)^2 - (WD/2)^2$

Thus, the total generating length "L" in the transverse plane *is as follows:*

$L = 2 \times A$ if $A > B$
$L = 2 \times B$ if $B > A$

To determine the actual hob generating zone, one can project the length "L" onto the axis of hob rotation:

Generating zone: $Lg = L/\cos(q)$

where: q - swivel angle of the hob

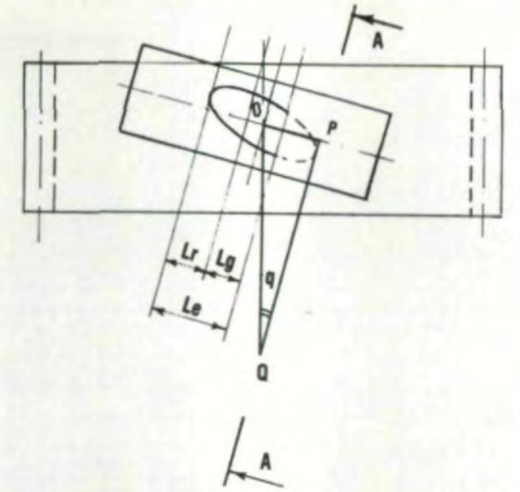

Fig. 7

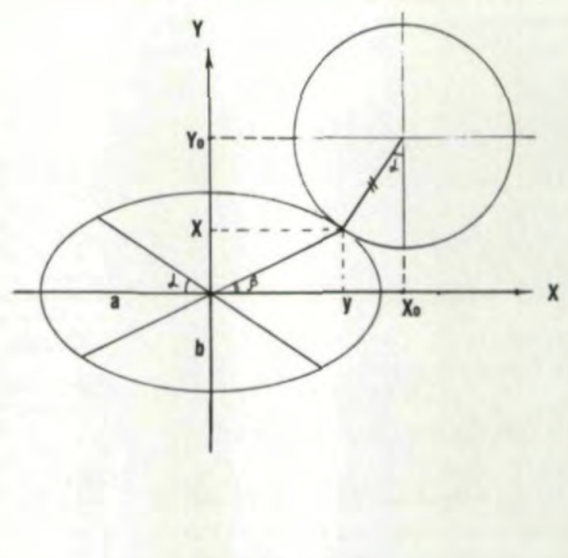

Fig. 8 View A-A

2. ROUGHING ZONE

The method shown below for determination of the roughing zone is valid for both spur and helical gears. The intersection of the O.D. of the hob with the O.D. of the workpiece is a 3-dimensional curve. The curve projection on a plane is an ellipse.

On Fig. 7 one can see that the distance from the pivot point to the start of roughing zone can be found from the triangle OPQ:

$$OP = QP \times \tan(q)$$

where QP can be determined by considering cross section AA perpendicular to the center line of the hob and tangent to the ellipse mentioned above.

This intersection is shown on Fig. 8, where the ellipse is the cross section of the gear, and the circle is the cross section of the hob. Placing a coordinate system at the ellipse center allows writing equations of the circle, the ellipse, and the line passes through the circle center and the common point of the circle and the ellipse.

2.1 Hob circle: $$(X\text{-}Xo)^2 + (Y\text{-}Yo)^2 = (HD/2)^2$$

where: HD- hob outside diameter
Xo- coordinate of the circle center
$Yo = WD/2 + HD/2 - wd$ coordinate of the circle center

where: wd- whole depth of the tooth

2.2 Workpiece ellipse: $$(X/a)^2 + (Y/b)^2 = 1$$

where: $a = WD/2 \times \sin(q)$ major radius of the ellipse
$b = WD/2$ minor radius of the ellipse

2.3 Line: $$(Y\text{-}Yo) = (X\text{-}Xo)/\tan(\delta)$$

From the characteristics of an ellipse, $\tan(\delta)$ can be obtained as a function of known values:

$$\tan(\delta) \times \tan(\beta) = (b/a)^2$$
$$\tan(\beta) = Y/X$$

so $$\tan(\delta) = (b/a)^2 \times (X/Y)$$

Consequently the equation 2.3 can be rewritten as follows:

2.3 Line: $$(Y\text{-}Yo) = (X\text{-}Xo)/(\,(b/a)^2 \times (X/Y)\,)$$

To solve this system of three equations with three unknowns (X, Y, Xo), one can isolate Y and get an equation of the 4th degree as follows:

$$KA \times Y^4 + KB \times Y^3 + KC \times Y^2 + KD \times Y + KE = 0$$

where: $KA = (dr \times a)^2 - b^2$
$dr = \sin^2(q)$
$KB = (2 \times Yo \times b^2) - (2 \times Yo \times a^2 \times dr^2)$
$KC = (b \times rh)^2 - (Yo \times b)^2 + (Yo \times dr \times a)^2 - (dr \times a \times b)^2$
$rh = HD/2$
$KD = 2 \times Yo \times (dr \times a \times b)^2$
$KE = (-1)\,(Yo \times dr \times a \times b)^2$

This equation can be solved by Newton's approximation method, where each next iteration value is calculated by the formula:

$$Yn = Y_{n-1} - F(Y_{n-1})/F'(Y_{n-1})$$

where: $F(Y) = KA \times Y^4 + KB \times Y^3 + KC \times Y^2 + KD \times Y + KE$
F'(Y) is first derivative of the function F(Y)

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$$F'(Y) = 4 \times KA \times Y^3 + 3 \times KB \times Y^2 + 2 \times KC \times Y + KD$$

For first approximation Y can be set equal to PD/2

so $Y = PD/2$

This method allows fast and precise calculation with a small number of iterations.

Having Y, one can obtain X and Xo, by substitution.

Consulting Fig. 7, since QP=Xo, distance OP=Xo × tan(q) and roughing zone: Lr=OP - Lg/2

3. ENGAGEMENT ZONE

As mentioned above, the engagement zone is the sum of roughing and generating zones.

$$Le = Lg + Lr$$

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TECHNIQUES FOR ALIGNING & MAINTAINING . . .
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APPENDIX A
INSTRUMENTATION SPECIFICATIONS

Surface Contact Pyrometer

A digital type pyrometer having an accuracy of ±3°F and a response time of approximately five seconds or less was used. The contact probe was surrounded by ceramic type substance to shield it from the influence of ambient temperatures.

Fig. A-1 – Test Set-Up
Lens Type Infrared Radiation Thermometer

INFRARED

Instrumentation

There are basically two styles of infrared instruments. One focuses the infrared through a lens and the other reflects it from a mirror. The lens type can be aimed more precisely making it superior from an accuracy viewpoint. Unfortunately, lens type instruments are the least portable.

The specifications of each of these types of infrared instruments can vary widely. The following key specifications are recommended for this application:

Temperature	50°F to 300°F
Spectral Response	8-14 microns
Field of View	2° or less
Spot Size (max.)	1½" at 40" distance
Emissivity Range	.6-1.0 (min. range)

A digital readout or a meter readout with a meter hold feature (not peak) is recommended. Some mirror type instruments are available with laser optics to aid in aiming the instrument. This option makes them equivalent to the lens type.

Setup

Fig. A-1 illustrates the setup of the lens type infrared radiation thermometer. A fluorescent light is an aid for aiming the detector at selected measurement points. It has been determined that the heat emitted from this light does not influence the measurements. It is very important that the light be held horizontally to obtain a horizontal reflection from the pitch line of the mesh. The tripod is recommended.

Fig. A-2 illustrates the setup for a mirror type instrument. In this case, the fluorescent light and tripod are also recommended for instruments without laser sighting optics.

Fig. A-2 – Test Set-Up
Mirror Type Infrared Instrument

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