Helical Gear Systems

QUESTION

In terms of the tooth thickness, should we use the formulation with respect to normal or transverse coordinate system? When normalizing this thickness in order to normalize the backlash (backlash parameter), we should divide by the circular pitch. Thus, when normalizing, should this circular pitch be defined in the normal or traverse coordinate system, depending on which formulation has been used? Is the backlash parameter always defined with respect to the tangential plane or normal plane for helical gears?

Expert response provided by Dr. Hermann J. Stadtfeld, Gleason Corp. A given helical gear is defined e.g. with a certain outer diameter, a pitch diameter and a root diameter. Regarding the number of teeth, the helix angle and the face width, it is important to define their basic dimensions. The transverse module can be calculated by dividing the pitch diameter by the number of teeth. The transverse module, multiplied with the cosine of the helix angle delivers the normal module. Figure 1 shows the difference between the directions of the normal plane and the transverse plane in a top view onto the generating rack.

This brings us to the normal plane, which is used to observe the tooth profile and relate it to a generating rack profile. The generating rack profile describes the active part of the tool profile without taking the backlash into consideration. In order to describe the point width of the tool (in case of zero profile shift), the slot width angle (in the transverse plane) is calculated from 180° divided by the number of teeth. In connection with the pitch radius, the theoretical chordal slot width in the transverse plane (without backlash consideration) can be calculated with:

Chordal slot width (in transverse plane without backlash) = pitch diameter × sin((slot width angle)/2)

Figure 2 explains the relationship between circular slot width and chordal slot width. In order to convert this value into the normal plane the formula changes to:

Chordal slot width (in normal plane without backlash) = pitch diameter × sin((slot width angle)/2) × cos(helix angle)

If the desired backlash normal to the flank surfaces is known, then this value can be divided by the cosine of the pressure angle to obtain the chordal backlash in the normal plane (Fig. 3):

Normal chordal backlash = (backlash normal to flank surfaces)/cos(pressure angle)

It is customary practice to add 50% of this value to the chordal slot width (without backlash) to obtain the chordal slot width at the reference circle (= pitch circle in case of zero profile shift). The chordal slot width is used to calculate the point width of the tool. 50% of the backlash is considered in the pinion tool and 50% in the tool of the mating gear.

In the normal plane, a standard profile has an addendum, which is 1.0 × normal module. The dedendum is 1.0 × normal module plus the clearance. A customary clearance is e.g. 0.2 × normal module. As a result, the whole depth of the example helical gear teeth is 2.2 × module. If there is a profile shift factor X unequal to zero and/or a depth factor unequal to 1.0, then the addendum and dedendum are calculated using the formulae below:

Addendum = normal module × (depth factor + X)

Dedendum = normal module × (depth factor + clearance factor – X)

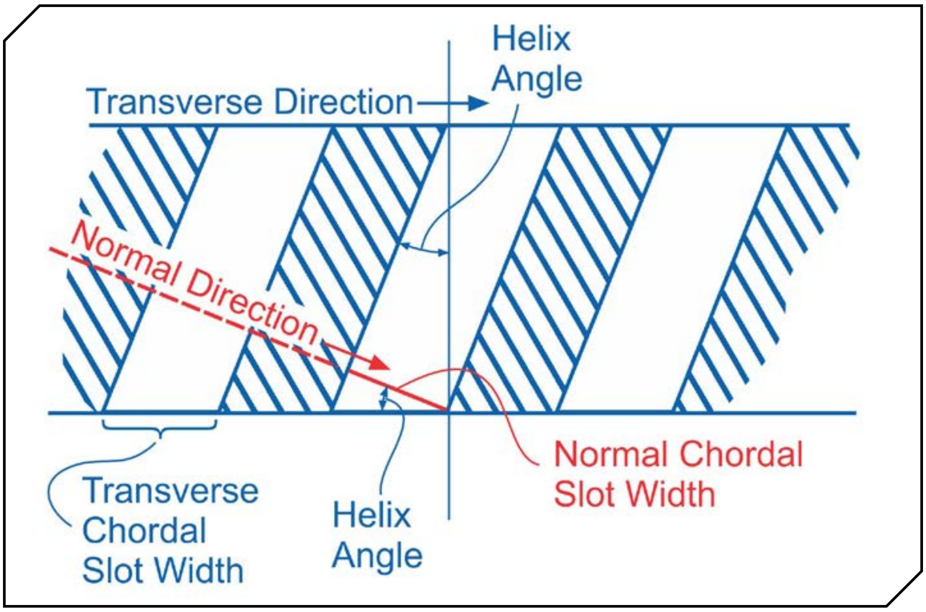

Figure 1 Transverse and normal direction.

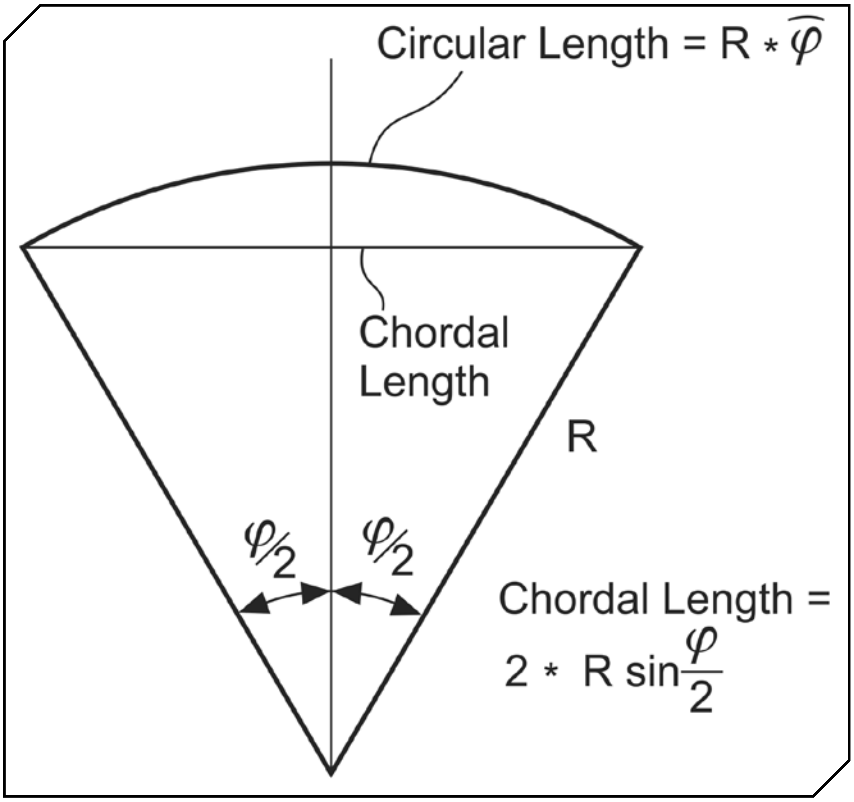

Figure 2 From circular and chordal dimension.

Whole depth = addendum + dedendum (= 2.2 in case of $X = 0$ and depth factor = 1)

The initial backlash number may be defined as a linear dimension normal to the flank surface (see above). If a tooth is in contact with a mating tooth, then the adjacent flank of the same tooth shows a gap to its mating tooth (Fig. 3). If a tooth is rolled from the beginning of meshing to the end, then the smallest gap is the smallest normal backlash. This backlash value is the normal distance between two flanks at the tight spot. Under no conditions during the operation of a gearset must the minimal backlash become zero. Zero backlash breaks up the lubrication film and can cause surface failure, depending on speed and load.

The minimal backlash is officially defined at the operating pitch circle of a gear. In case of no profile shift (or a $V0$ shift, where $X1 = -X2$) the operating pitch circle is equal the pitch circle. If not otherwise specified, the backlash of helical gears refers to the backlash measured in a transverse plane. While the initially desired normal backlash could be measured with feeler stock which is slid between the two mating flanks at the operating pitch lines, the transverse chordal backlash can only be measured with an encoder connected to the gear (angular backlash) or with an optical displacement measurement.

For general comparisons the normal backlash should be converted into the transverse plane to a transverse backlash, which is accomplished by multiplying the normal chordal backlash with the cosine of the helix angle:

Transverse chordal backlash = (backlash normal to flank surfaces)/cos(pressure angle)*cos(helix angle)

An interesting side bar is mentioning that the observation started in the transverse plane to obtain the generating rack dimensions for the tool design in the normal plane. Although numbers like module and backlash are different between transverse and normal plane, the addendum and dedendum will not change: A tooth profile which appears tall in the normal plane will show a stub tooth appearance in the transverse plane.

Summary

- Balanced slot width calculation begins in the transverse plane based on 360° divided by twice the number of teeth.
- The slot width arc is converted to a chordal width with the formula in Figure 2
- Then it is converted to the normal plane (Fig. 1)
- In the normal plane 50% of the backlash is added to the normal chordal slot width in order to define the tool proportions
- The normal chordal backlash is converted to the transverse plane for general comparisons with values from the standards or other gearsets.

Dr. Hermann J. Stadtfeld is vice president/ Bevel Gear Technology -R&D, Gleason Corporation, and longtime contributor to *Gear Technology* magazine.

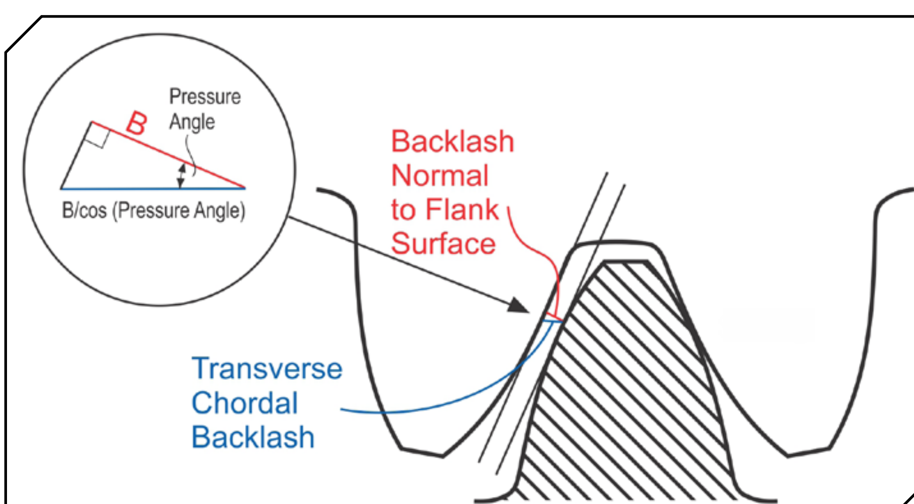

Figure 3 Backlash normal to flank and correlating transverse chordal backlash.