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UNDER PRESSURE

Understand the choice of pressure angle in the design of spur or helical gearing.

THE PRESSURE ANGLE OF A GEAR IS DEFINED AS THE ANGLE formed by the radial line and the line tangent to the profile at the pitch point. As noted in the image in Figure 1, the pressure angle is the jump off angle of the characters.

In most cases, the pressure angle being referenced is the normal pressure angle, although the transverse pressure angle and the axial pressure angle are also considered when working with helical gearing.

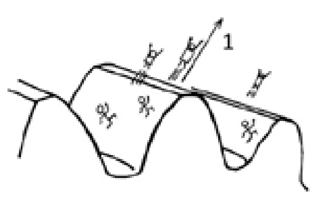

Figure 1

Looking at Figure 2, the line labeled "1" is normal to the tooth profile; the line labeled "2" is the tangent to the reference circle; the line labeled "3" is tangent to the profile, and the line labeled "4" is the radial line. In this image, the normal pressure angle is labeled α. Here $\alpha = \alpha'$. Therefore, α' is also the pressure angle.

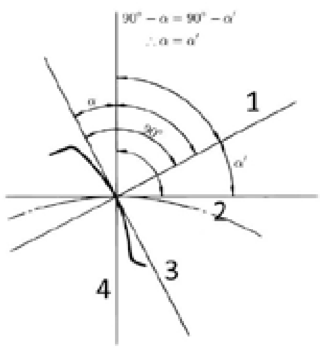

Figure 2

A common value of 14 degrees, 30 minutes was historically used in diametral pitch gearing. The basis for this selection was that this pressure angle allows for reduced noise in the gear mesh and exhibits a lower rate of wear. Mechanisms that did not need to transmit heavy power transmission were ideal for this pressure angle. However, it was recognized by AGMA that a 20-degree pressure angle was more suited for most applications and included this value as its preferred value for normal pressure angle beginning in the early 1980s.

The benefits of selecting a 20-degree pressure angle include additional power transmission capacity, better lubrication in the gear mesh, and reduced numbers of teeth for the pinion without undercutting. The 20-degree pressure angle gear tooth has a wider base that allows for additional load capacity, but it incurs additional wear on the tooth flank during interchange of teeth in and out of mesh. For some specialty applications where noise is not an issue but strength is, pressure angles of 22 degrees, 30 minutes; 25 degrees; or 30 degrees have been used.

When designing a pinion, one consideration that must be reviewed is the relationship between the number of teeth, the gear pitch, and the pressure angle. As each of these values decreases, the minimum number of teeth to prevent undercutting increases. For example, a module 1 spur gear with a 14-degree-30 minute pressure angle will begin to exhibit undercutting if it has less than 26 teeth. However, a module 1 spur gear with a 20-degree pressure angle would not exhibit undercutting until it has less than 15 teeth. This is significant when designing systems where a relatively large reduction ratio is required. For example, if one desired to use spur gears to reduce the speed from 1,200 rpm to 200 rpm and chose to design with 14-degree-30 minute pressure angle gears, the minimum number of teeth for the input would be 26, and the number of teeth for the output would be 156. These gears would have a very large footprint compared to a 20-degree pressure angle pair that could accomplish the same task with a combination of 16 teeth on the input and 96 teeth on the output. If designed with the same pitch, the 20-degree pressure angle output gear would be 38 percent smaller in diameter than the 14-degree-30-minute pressure angle gear. This would reduce both the space requirements for the gearing as well as reduce the weight of the gearing.

Gear racks are defined as a spur gear having a pitch radius of infinite size. For a 14-degree-30-minute pressure angle rack and for a 20-degree pressure angle rack, the racks both have the same straight-sided tooth form, but the sides of the teeth are at different angles. As such, the angle of the tooth profile and the pressure angle for the gear rack are the same.

For helical gearing, it is important to understand the action of the transverse pressure angle, and the axial pressure angle. The transverse pressure angle is defined as:

$$\alpha_t = \tan^{-1}\left(\frac{\tan \alpha_n}{\cos \beta}\right) \qquad \text{EQUATION 1}$$

where α_n is the normal pressure angle and β is the helix angle.

For example, if you design a helical gear with a 10-degree helix angle, a 14-degree-30-minute pressure angle, and 30 teeth, the resulting radial pressure angle will be 14 degrees, 42 minutes, 50 seconds. For a 10-degree helix angle but a 20-degree normal pressure angle, the resulting radial pressure angle will be 20 degrees, 17 minutes. This increase in pressure angle in the radial direction is due to the increase in the base circle. It permits an increase in power transmission proportional to the increase in the tooth width at the root.

One requirement for all gearing is that the pressure angle must be the same for both gears in mesh. A 20-degree pressure angle will not mesh properly with a 14-degree-30-minute gear, even if all of the other gear geometry is the same. For simplicity, metric spur gears as produced to JIS standards are always 20-degree pressure angle gears.

ABOUT THE AUTHOR: Brian Dengel is general manager of KHK USA Inc, a subsidiary of Kohara Gear Industry with a 24-year history of working in the industrial automation industry. He is skilled in assisting engineers with the selection of power-transmission components for use in industrial equipment and automation. Dengel is a member of PTDA and designated as an intern engineer by the state of New York. He is a graduate of Hofstra University with a Bachelor's of Science in Structural Engineering.