TOOTH TIPS

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PITCH-PERFECT GEAR DESIGN

Understanding the how and why of choosing the right pitch can make all the difference in the successful design of high-quality gears.

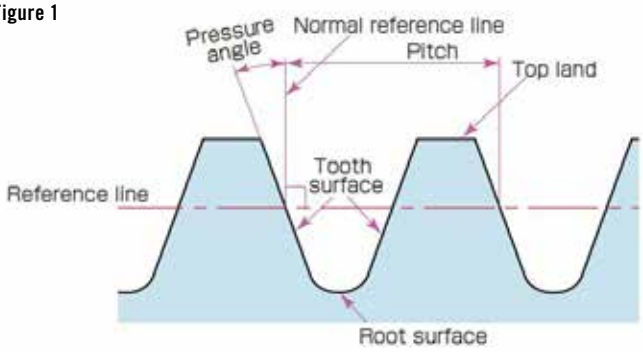
THE PITCH OF A GEAR IS DEFINED AS THE DISTANCE BETWEEN two identical points on two adjacent gear teeth. Ideally, it is measured at the pitch line, labeled in Figure 1 as the reference line.

There are three designators of pitch within gearing: gears can be produced to diametral pitch (DP), circular pitch (CP), or module, also known as metric pitch. The most commonly used designation of pitch in the United States is diametral pitch. This method of determining the size of the gear tooth is based on the unit circle. If you draw a circle that is one inch in diameter and equally space 16 teeth around this circle wherein the pitch diameter is overlaying the one-inch circle, then you have created a 16DP gear tooth form. If you continued to draw the same size teeth on a two-inch circle, then you would have 32 teeth, and the pitch would be 32/2, or 16DP.

The range of possible values within DP gearing could be infinite, and as such, certain set sizes have evolved. For course pitch, power transmission gearing, the typical values for diametral pitch gearing are 2DP, 4DP, 5DP, 6DP, and 8 DP. Medium pitch fractional horsepower gearing typically uses 10DP, 12DP, 16DP, and 20DP. For fine pitch instrument drive gearing, the typical values are 24DP, 32DP, 48DP, 64DP, 96DP, and 120DP. The advantage of these values is that each is highly divisible by many factors. A 48DP gear has factors of 2, 3, 4, 6, 8, 12, 16, and 24. This allows for multiple reduction ratios using common numbers of teeth.

One of the downsides to DP gearing is that, when the angular motion of a spur gear is transformed into linear motion along a gear rack, the translation along the rack is a fractional number. For example, if we are working with a 25-tooth, 5DP pinion traveling along a 5DP gear rack, the pinion will translate (5 x π) 15.708 inches per revolution. If the design calls for the pinion to travel 45 inches and then reverse, the designer would have to configure the mechanism to not complete the third revolution, or the pinion would travel too far. Thus, the concept of circular pitch, or CP, was born. This designation of pitch allows for linear translation that equates revolutions of the pinion to whole numbers. Within the family of circular pitch, there is both an inch CP and a metric CP. If we were to choose a value of 5/8 inch CP for this same 25-tooth gear but reduce the number of teeth to 24, each revolution of the resulting gear would translate 15 inches linearly along the rack. CP gearing is commonly found in "pick and place" applications, or gantry systems where frequent reversing and accurate positioning are required.

Figure 1



The third and most popular designator for pitch outside of the U.S. is module. To determine the value of module for a given gear, you measure the pitch length in millimeters and divide that value by π. For example, if the pitch length measured 9.425mm, this would be a module 3 gear. By incorporating π into the value of pitch, the metric dimensions of a spur gear are very simple to calculate. The pitch diameter of a module 3 spur gear with 25 teeth is equal to the module (3) multiplied by the number of teeth (25), 75mm. It also simplifies the calculation for addendum, dedendum, and whole depth. For a DP gear, the addendum is equal to 1/DP, the dedendum is equal to the whole depth minus the addendum, and the whole depth is equal to 2.157/DP. When dealing with module, the addendum is equal to the module, the dedendum is equal to 1.25 times the module, and the whole depth is equal to 2.25 times the module.

Similar to DP gearing, standardized module values have been established. For course pitch power transmission gearing, the typical values for module are 10, 8, 6, 5, 4, and 3. For medium pitch fractional horsepower gearing, the values for module are 2.5, 2, 1.5, and 1.25. For fine pitch instrument drive gearing, the typical values are 1, 0.8, 0.7, 0.5, 0.4, 0.3, and 0.2. Within metric gearing the concept of CP also exists. By subtracting the value of π, CP values of 2.5mm, 5mm, 10mm, 15mm, and 20mm are common.

Also common is the misunderstanding that two gears of a similar pitch will "find" their sweet spot if meshed together. This is not at all correct. The most common mix-up is using 5DP and module 5 gears together in the same mesh. Module 5 is comparable to a 5.08DP. This variance can cause tremendous headaches in assembly and will result in premature failure and excessive noise. The second most common pairing mistake is 16DP and 5mm CP. 16DP has a pitch length of 1.5875 inches, and 5mm CP has a pitch length of 1.59155 inches.

Although the interchange between DP and module is not exact, designers looking to internationalize their designs can do so by upgrading the gearing in their next design using the metric-to-inch conversion factor of 25.4:1. For example, if the current system is using a 12DP gear set, the next iteration of the design can use a module 2-gear set, and the performance expectations will be similar. Converting to metric gearing allows the designer to create a mechanism for which preventative maintenance can be performed anywhere in the world whereas diametral pitch gearing is only found in the U.S.

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