TOOTH TIPS

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THE ZEN OF GEAR DESIGN

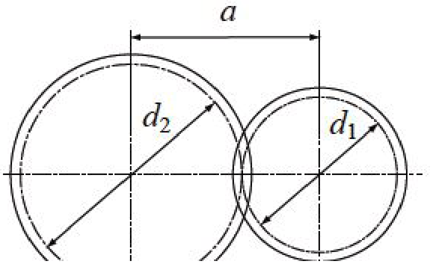
Exploring the ‘hows and whys’ of choosing the proper center distance for your gearing requirements.

THE FEELING OF ZEN IS ONE THAT WE ALL can aspire to. Through practice and self-reflection, we can work toward being centered and grounded. Unfortunately for gears, too many designers overlook the need for gears to be properly centered.

When set at the proper center distance, gears will mesh at the pitch point. In doing so, they will perform as designed. The proper center distance allows for the tooth of one gear to engage with the mating gear at the optimal intersection point; it allows for the proper flow of lubricant into the mesh; it allows for the gears to operate with the designed backlash allowance, and it minimizes gear noise.

The formula for calculating the center distance of two parallel axis gears is:

Center Distance = (Pitch Diameter of Gear A + Pitch Diameter of Gear B) / 2



Unit: μm

Center Distance (mm)		Accuracy Grade of Gears			
More than	Less than	N3,N4	N5,N6	N7,N8	N9,N10
5	20	6	10	16	26
20	50	8	12	20	31
50	125	12	20	32	50
125	280	16	26	40	65
280	560	22	35	55	88

This formula calculates the nominal value of the center distance. It does not reflect the tolerance of that value. For most parallel axis gear applications, a tolerance of ±25~30 µm is ideal. This range reflects the inherent variations in pitch through one rotation of each gear.

The accompanying table shows the center distance tolerance for parallel axis gears. The tolerance values in this table are quoted from JGMA1101-01 (2000), and are applicable for involute spur and helical gears made of iron and steel.

When designing a gear pair, the consideration of center distance is often one of the last values calculated. In some instances, the center distance between the parallel shafts is different than the optimum center distance of the gears. This situation can arise if you replace diametral pitch gearing with metric gearing. As these two systems are not 100-percent interchangeable, the center distance of standard metric gears would not fit an inch dimensioned shaft center distance. For example, a 10DP, 20-tooth spur gear mated with a 25-tooth spur gear would have a designed center distance of 2.25 inches. If these gears are replaced with a Module 2.5, 20-tooth spur gear mated with a 25-tooth spur gear, its design center distance is 56.25 mm (2.2146 inches).

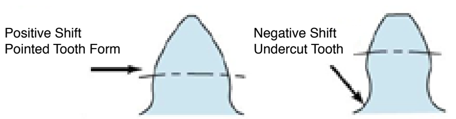
One of the ways in which these metric gears can be adjusted in order to match the shaft center distance is to design the pinion with an enlarged addendum. A modification factor, known as the coefficient of profile shift, can be applied to a gear during manufacture, which will increase the pitch point of the pinion such that its effective pitch diameter is larger than the nominal pitch diameter. By selecting a positive profile shift coefficient that increases the effective pitch diameter of the pinion by 1.8 mm, these gears would now fit the 2.25-inch center distance.

The second way for these gears to meet this center distance requirement would be to introduce a helix angle. Since the pitch diameter of a helical gear is calculated as:

Pitch Diameter = {(Module * Number of Teeth) / cos β}, where β is the helix angle, the pitch diameter increases as the helix angle increases.

For this example, if you make the pinion a left-hand gear with a helix angle of 10° 10’ 54” and make the mating gear a right-hand gear with a helix angle of 10° 10’ 54”, then these gears will have a center distance of 2.25 inches.

Although both of these manufacturing methods will achieve the desired operating center distance for the gear pair, both have their limitations. For gears with addendum modification, the maximum amount of shift is limited. The value for the coefficient of profile shift can vary from +1.0 to -1.0 where a value of +1.0 is equivalent to increasing the pitch diameter by one tooth and a value of -1.0 is equivalent to decreasing the pitch diameter by one tooth. When applying a positive profile shift, the pinion’s tooth tip becomes pointed and is weaker than a gear with a standard addendum. When applying a negative profile shift, the pinion’s tooth root is weakened due to undercutting.



For gears with a helix angle, there is a limitation on the helix angle, and there are additional forces on the gear tooth that are introduced due to the twist. A traditional spur gear has a helix angle of zero degrees. Once a helix angle greater than zero is applied, a thrust force is imparted by the gear mesh in the transverse direction. This thrust force requires the introduction of thrust bearings into the application.

One common issue with center distances is the use of undersized distances in order to reduce the backlash of two gears in mesh. In doing this, the assembler is forcing the gears to mesh at a point other than the pitch point. If the mesh is reduced to a point where the addendum of the pinion is hitting the tooth root of the mating gear, the results will be an increase in gear noise, premature wear, and a significant reduction in gear life. When properly centered, life is quiet and peaceful.

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