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Unintended gear failures

How simple design flaws cause gears to fail prematurely, and what you should know to avoid failure.

At some point in your life, you had the opportunity to meet a set of twins. Maybe they were fraternal twins, or maybe they were identical twins. Fraternal twins are not usually obvious, but seeing two identical people is hard to miss. Some styles of gearing have twins. Miter gears are the closest gear pair to identical twins, since they have the same number of teeth, the same pitch, the same pressure angle, the same face width, and sometimes the same bore size. Regardless of style, a gear will always require another gear to transmit the torque desired.

When each gear in a system is independently designed, based on the performance criteria and without consideration of the other gears in the gear system, unintended failures can occur. For example, a design calls for a rack and pinion. When selecting the rack, it is determined that in order to assemble the rack to the base, the ideal face width of the rack must be 35 millimeters or wider. Concurrently, it is determined that the minimum face width for the pinion is 28 millimeters. In order to minimize weight and momentum, the engineer designs the pinion with a 30-millimeter face width instead of the 35 millimeters that the rack will be. Although the rack and the pinion have the same module and pressure angle, the difference in face width can result in an uneven wear pattern on the rack.

A similar wear issue can occur with spur gears in a compound geartrain. If the pinion shown in green in Figure 1 is designed such that it is wider than the gear it mates with, then the resulting wear will look like Figure 2.

Another cause of unintended failure is fracture of a gear at the corner of the keyway. This could occur if the torque applied to the gear is less than the bending strength torque of the gear, but the key is allowed to move within the key slot. These oscillating stresses applied by the key to the slot can cause the gear to fail as shown in Figure 3.

When selecting worm gears, one design flaw that is regularly overlooked is to mate a single lead worm wheel with a dual lead worm. The lead angle is the angle between the helix of the worm thread and a line perpendicular to the axis of rotation. In order to add additional thread starts to a worm, the lead angle of the threads must be increased. For a single lead worm, the typical lead angle is approximately three degrees. For a dual lead worm, the typical lead angle is approximately seven degrees. If you assemble a worm wheel with a three-degree lead angle with a seven-degree lead angle worm, the mating pair will be off-axis by approximately four degrees. If the assembly is set such that the worm pair is forced to operate at 90 degrees, then the resulting misalignment will cause the worm to produce an unintended wear failure of the worm wheel.

Another design flaw with worm gearing is in the selection of lubrication. In high-speed gearboxes, it is typical to use an EP gear oil to lubricate the system. These gear oils and greases are designated

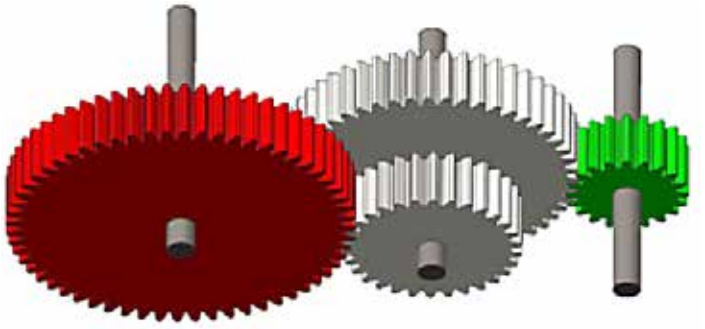

Figure 1.

Figure 2.

Figure 3.

as EP due to their Extreme Pressure additives. These additives are excellent for use with steel gears, but they are not suitable for worm wheels made from bronze. The sulfur additives in some of the EP gear oils react with the bronze causing corrosion and unintended failure of the gearbox.

One final design flaw that can occur will cause the gear pair to be non-operational. The flaw occurs when the spiral angle of individual spiral bevel gears or individual helical gears is not considered. For each set, one of the gears must be left handed and the other right handed in order for the pair to operate. If you select a helical gear with 40 teeth and the helix is left hand, then the mating gear must be right-handed regardless of the number of teeth.

In each of the examples detailed in this article, the unintended failure can be avoided. The designer must take a whole system approach to the design in order to eliminate the introduction of these design flaws. When designed properly, gears will make the world go around.

ABOUT THE AUTHOR

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