Helical vs. Straight Cut Gears

Bert Baker,
Baker Drivetrain

In my youth I was fascinated with my Erector Set. The nuts, bolts, beams, plates, wheels, pulleys, axles and motors included in the Erector Set kit allowed me to construct anything my imagination could cipher. Legos never really did it for me because the snap-together plastic components were for sissies. Erector Sets had the fundamental building blocks for any industrial society because the components were steel and bolted together with nuts and bolts. The stuff I was constructing needed to be tough enough for an Oldsmobile Vista Cruiser to run over it.

In recent years I figured out my childhood obsession with Erector Sets. That is, the Erector Set gave me all the necessary components to construct mechanical assemblies from the ground-up. This is very much like what I do for a living today. I have a "kit" of hardware and design guidelines that I use to design new transmissions and drivetrains. Some of it is easy and some of it is more involved. For example, choosing bearings for a new product is easy because the choices are specified in the bearing catalog with performance perimeters and fitment tolerances all spelled out.

Gears and shafts are not standard catalog items and must be designed for the specific application by assessing three criteria: Noise/whine, strength, and efficiency. Based on the qualitative importance of the three criteria, a decision is made to utilize a straight cut (also called spur gear) or helical gear.

Noise/Whine

Gear noise can be prominently heard in a stock 5-speed in 4th gear on a 1980-93 Big Twin before the factory evolved the 5-speed to the HCR design in 1994 with some help from Porsche. Noise, or lack of noise, is very important in modern commercial motor vehicle manufacturing because of a government (USA, Europe, Japan, etc) imposed "noise pass-by test." Anything and everything is done from an engineering standpoint to minimize gear noise, valve train noise, piston slap, etc. to get a good score on the noise pass by test. Gear noise doesn't care about saving the whales or spotted owls and is of no concern to most racing applications like NHRA, Monster Truck, and NASCAR. In general, a transmission with helical gears shows intent (on the part of the manufacturer) to produce a quiet, government compliant motor vehicle.

Strength

For a given tooth size, spur gears are weaker than helical gears. I realize this blasphemous statement will purge me from the Christmas card lists of drag racers and weekend warriors but some explanation is required. There are hundreds of gear tooth parameters that are manipulated to design a gear, be it helical or spur. One very significant parameter is contact ratio, which represents an average of how many teeth are in mesh at any given time. A straight cut gear can only achieve practical contact ratios of 1.2-1.9. Above 1.9 the tooth cross-section gets spindly and the strength is compromised. Below 1.2 gets too close to 1.0, which is dangerously close to the point of flirting with gear failure as the gear teeth load-and-unload. Helical gears can achieve contact ratios of 2.2 to well over 4. So, a gear pair with a 3.0 contact ratio will have an average of 3.0 teeth in contact as the gears make their way around the circle of mesh with each other. A high contact ratio makes for a quiet gear mesh but the resultant axial thrust cashes in the noise-free operation for efficiency losses (see next paragraph). Generally, the tooth size in a helical will be smaller because of the multiplicative strength factor of the contact ratio. Generally, the tooth size in a straight cut gear will be larger because an increase in strength is desired given the contact ratio shortcoming.

Efficiency

When torque is transmitted across a gear pair, parasitic losses make the output torque less than the input torque. In other words, mechanical efficiency is lost as the torque is transferred across the gear pair. A helical gear pair is less efficient than a straight cut gear pair. The helix of the gear tooth generates axial thrusts that *waste* energy (in return for quiet operation). For this reason, a helical gear will never be found in any racing applications.

When considering noise, strength and efficiency, there is, unfortunately, no hybrid gear design that captures the best attributes of both types of gears. Today's motorcycle transmissions mix and match gear designs to achieve the best possible outcome. The BAKER DD6, introduced in 2003, and the modern factory 6-speed, AKA Cruise Drive, introduced in 2006, both have a mix of straight cut and helical gears to achieve a blend of performance and strength. Straight cut designs are used in the lower gears and helicals are used in the higher gears, including 6th. In 6th gear there is no powerflow through the helical 6th gear pair. Powerflow comes in from the clutch and goes right back out to the secondary drive pulley. This in-and-out power transfer (in 6th only) is more efficient than any helical or straight cut gear. This is specifically due to the arrangement of the gears within the transmission. It's really not much different than it was with my old Erector Set, the key is not just in choosing which pieces to use, it's in how you choose use them. IW