Gear Design and Manufacture

Bert Baker
Baker Drivetrain

Today, transmissions are everywhere in our lives. The obvious applications are cars, buses, and motorcycles. But there are many not so obvious transmissions, like in video cameras, PCs, and DVD players where rotary motion is translated into linear motion via a rack-and-pinion-type arrangement and a linkage system. Washing machines, casement window cranks, power tools, garage door openers, and military machines have speed reduction devices (transmissions). The focus of this article is to shed some light on transmissions in motorcycles. In future articles I'll discuss the off-center transmission mechanism in our new line of variable-speed adult sex toys.

Manufacturing Gears (The short version)

Willy Wonka had this groovy machine that made everlasting gobstoppers. A stoned oompa loompa would pour the ingredients in the hopper of the machine and out popped a gobstopper at the other end. One machine did the whole thing. Pretty cool. But making transmissions is a lot more involved.

The process to make a gear goes something like this: Bar stock is rough cut on a CNC saw. The gear blank then goes to a CNC lathe for rough turning. Next it goes to a CNC milling machine where the dog teeth are cut. Then it's sent to the hobbing, or shaping, machine to get the teeth cut after which it's sent to be heat-treated. When it comes back from heat-treat the inner bore is ground on an I.D. grinder and the teeth are reshaped by one of the methods listed below. Manufacturing capability is then checked on an M&M gear checker to establish and maintain a specific AGMA (American Gear Manufactures Association) standard.

Spur (straight cut) vs. Helical

Motorcycle transmissions generally use helical gears, spur gears, or a combination of both. Helical gears are used for applications where low/minimized gear noise is required. The negative side of helical gears is that they inherently lose some efficiency. As two helical gears roll together in a gearbox a percentage of the input torque is consumed via axial thrust, which is converted into heat in the ball bearing or thrust bearings. The higher the helix angle of the gear tooth, the quieter it will be but the more energy will be wasted. For this reason, racers prefer spur gears because they are trying to get every last giga-wump of power to the ground; racers don't give a rat's ass about noise. The flank of a spur gear generates an obvious slapping noise when it spanks the flank of the mating gear. But a helical gear rolls gently onto the flank of the mating gear in a point-loading manner rather than full-flank contact like a spur, which is why helical gears are quieter than spur gears.

Government-imposed noise restrictions have pretty much forced manufacturers to use helical gears to minimize noise these days. Gear noise, as it relates to the operator of the bike, will always seem worse to the guy with a fairing because the fairing acts like an acoustical chamber to contain transmission and engine noise, and bounce it back in the rider's face (and ears).

Heat-treat

Heat-treat is a necessary evil. Gear teeth and the gear bore need to be hardened for wear resistance. The evil part is when the perfectly formed gear teeth are heat-treated; they begin to curl like a potato chip and their contorting results in things like tooth-to-tooth spacing error, run-out, lead error, and involute profile deformation. The resultant tooth geometry errors generate noise and reduce strength. Correcting the tooth geometry after heat-treat is difficult and expensive, but it is necessary if strong and quiet gear teeth are desired.

Tooth Geometry Correction After Heat-treat

There are many different processes (such as grinding, honing, power honing, skiving and lapping) to correct the tooth geometry after heat-treat. Old 4-speed gears used no post-heat-treat tooth correction. Without a doubt, grinding is the most expensive method and the method that BAKER uses. It's also the only way to achieve the most perfect tooth correction (after heat-treat). Harley used grinding on their 5-speed transmission gears from 1994-2006 with a bank of Reishauer grinding machines. You can always recognize a ground gear by looking at the teeth under a bright light; they shimmer and twinkle like sequins on a stripper. To reduce manufacturing costs Harley migrated to power honing on their new Cruise Drive 6-speed. BAKER uses Liebherr grinding machines that cost about $1.5 million each and use tooling (called a CBN worm) that is coated with industrial diamonds that goes for $40,000. Grinding gears is a highly premium and expensive process, but we feel it pays off in the end.

I may not be the world's most qualified expert on transmissions and gear design; it is a very complicated subject. But I do know enough to get by and get the job done. The intent of this article is to give you a brief insight into the world of transmissions in the time it takes to take a dump. IW