By Bert Baker, BAKER Drivetrain

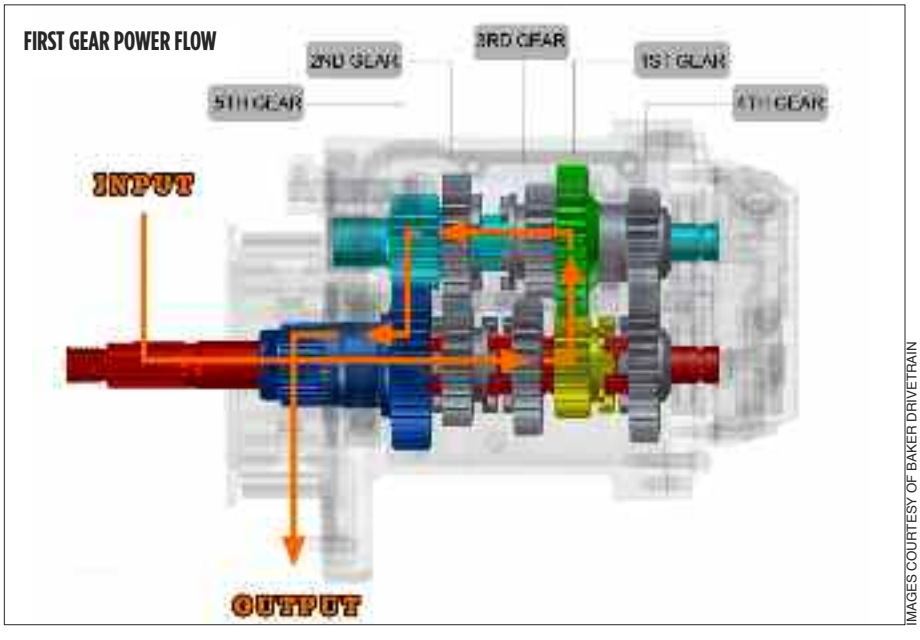
H-D FIVE-SPEED TRANSMISSION

Part II: Common glitches and their fixes

In this month's follow-up article, we'll finish up transmission function fundamentals, get into the field issues with the design, and give an overview of the aftermarket manifestations of the original Harley-Davidson five-speed design.

Constant Mesh

The Harley-Davidson Big Twin five-speed transmission is a constant mesh design, meaning all five gears on the mainshaft are always in mesh with their respective gears on the countershaft. Each gear pair has one gear that's splined (locked) to the shaft while its mating gear, called a speed gear or idler gear, on the other shaft rides on a needle bearing. For example, let's look at the power flow when first gear is engaged. First gear on the mainshaft is splined to the mainshaft and first gear on the countershaft spins freely on the countershaft on a needle bearing. Third gear on the countershaft is splined to the countershaft and is located adjacent to first gear on the countershaft. When the shift fork moves third gear over to first gear on the countershaft and engages the dog teeth, first gear on the countershaft is coupled to the countershaft and transmits the power flow through the first gear pair, as shown in the power flow illustration below.



IMAGES COURTESY OF BAKER DRIVETRAIN

There are five dog teeth, also known as drive lugs, on each gear. Each dog tooth has a 4-degree undercut on both sides. This undercut is necessary to hold the dogs in engagement with no chance of kicking out of gear. The H-D four-speed also uses 4-degree undercuts on the dog teeth; the successive Cruise Drive six-speed uses lesser degree undercuts to improve shift quality. Dog tooth undercuts, like most things in engineering, are a give and take. Racing transmissions have modified undercuts as high as 10 degrees to guarantee the gear doesn't kick out. However, shift quality suffers at that level, but racers generally aren't concerned about that. Foreign bikes generally have undercuts close to zero degrees for smooth shift quality, but it's a little more complicated than that: those in-line four-cylinder engines generate smoother torque pulses through the drivetrain than a gnarly big displacement V-twin.

Another factor in whether the transmission jumps out of gear is dog tooth gap. This is the distance, or air gap (like the air gap on a spark plug), between adjacent dog teeth when the transmission is in neutral. The dog tooth gaps on the five-speed, according to the Harley service manual, should be 0.035"-0.164", but this is a nonadjustable spec. From experience, a nominal dog tooth gap of 0.060" is a good target value for proper transmission performance. The dog tooth gaps are measured with the transmission in neutral. It's a tricky measurement to take because sliding a feeler gauge into the gap between dogs naturally pushes the dog teeth aside, thereby skewing the measurement. The story short is this: when dog tooth gaps wander above 0.080", missed shifts may occur. The way to correct this condition is to replace the suspect gears along with the adjacent retaining rings and thrust washers. In extreme cases, surface-ground thrust washers with modified thicknesses can be used, but you really have to have the big picture in focus to attempt this modification.

The H-D five-speed design underwent many improvements over the years to increase durability and quality. Over-

all, the design is sound and can be counted on for the long haul — with the exception of the following issues.

Ratchet Pawl Return Spring

In 2000, the Twin Cam Softail was introduced with a new ratchet pawl, which completely corrected the problematic shortcoming of the previous ratchet pawl spring and also provided overshift protection. To prevent an overshift, a beak was integrated with the new-style ratchet pawl arm, which guaranteed that a first-to-third gear upshift didn't occur when an aggressive first-to-second shift was attempted. In 2001, the new ratchet pawl was used on all Big Twins.

Generally, it's not a matter of if the 1979-2000 style return spring will break; it's a matter of when. The rider will know when the spring breaks because the foot shift lever will not return after a shift is made, and the lever will be floppy as if something in the shift system came loose. When this occurs, do not ride the bike any farther because the broken piece of spring will be migrating around in the transmission waiting for a chance to get churned between a gear pair, destroying the transmission. The H-D new-style ratchet pawl is not easily retrofitted into the older bikes because a longer case sleeve bushing, top cover, shift drum, and pillow block are required for that transformation. And the new-style detent spring has shortcomings as well, as we will discuss later. However, if you take preventative maintenance seriously, the aftermarket offers a ratchet pawl that incorporates the new-style return spring, with overshift protection, that retrofits into the existing 1979-2000 transmission without the need to change any other parts.

1985-93 Tranny Pulley

By 1985, all Big Twins were using the belt-driven, secondary drive system. The rear belt drive is clean and maintenance-free compared to the conventional chain drive. The pulley that mounts to the maindrive gear (output) of the transmission via a 33-tooth spline has a spline width of 0.500" (1/2"). Over time, the softer female spline teeth on the pulley lose the battle against the hardened male spline teeth of the maindrive gear, and the pulley splines strip out. Though this may never occur on a stock engine, on an enhanced engine, the probability increases in proportion to how much more power the engine puts out and how hard the bike is ridden. You'll know when this happens because a complete loss of drive occurs, and you'll find yourself stuck on the side of the road. In 1994, the factory introduced a new pulley with a spline width of 0.750" and the problem was solved. This configuration was used through 2006. The factory offers a 1994-style retrofit kit for 1985-93 bikes, which includes a new pulley, sprocket spacer, seal, nut, and nut anchor plate. All aftermarket pulleys are based on the 0.750" spline width.

The question is not if the stock 1979-2000 return spring will break; it's a matter of when. The left arm of the spring on the left has broken off.

A shift drum with unsupported 4mm pawl pins is on the left; a supported drum is on the right.

1979-98 Door Bearings

All 1979-98 Big Twin transmissions have two 20mm by 47mm by 14mm radial ball bearings in the trapdoor. When torque from the engine is transmitted through the transmission, the gears push away from each other like one positive magnet repelling another positive magnet. It's the job of the door bearings and the bearings in the left side of the case to keep the gears and shafts accurately located to each other. With a stock engine, the early door bearing was generally durable. On a modified engine, the door bearings work harder and may fail over time and miles. In 1999, all Big Twins were upgraded to the 20mm by 52mm by 15mm radial ball bearing. This upgrade positively corrected the shortcoming of the smaller, early bearings. Early models can be directly upgraded with the new-style die-casted door and bearings. Aftermarket trapdoors, in general, utilize the larger bearing and billet door construction.

Main Drive Gear Needle Bearings

The H-D four-speed has one long bronze bushing in the bore of the maindrive gear. Over time, the bronze will wear and cause leaks and other problems. The five-speed was upgraded to two caged needle shell bearings that remedied the wear problems of the bronze bushings. On a stock engine, the bearings performed well. However, on a modified engine, or if the secondary drive belt is kept excessively tight, the bearings have a tendency to move (walk) in the maindrive gear's bore. When the bearings move away from their intended design positions, they will be overloaded and fail, often maiming the mainshaft. The factory did not correct this shortcoming until the introduction of the Cruise Drive six-speed. The aftermarket addressed this problem by applying green Loctite to the bearings during installation into the maindrive gear and installing a spacer in between the bearings.

Shift Forks

The five-speed was introduced in 1979 with bronze shift forks. Bronze is a naturally self-lubricating alloy that has good wear properties, but it's not as strong as advanced steel alloys given the same design. In 1986, the bronze forks were replaced with powdered metal forks. Powered metal has great wear characteristics and is inexpensive to produce, but can be fragile if the design does not address the fragility of powdered metal. This led to one of the biggest transmission-related recalls in the Motor Company's history. When the forks fracture and break, sudden loss of transmission function will occur, and the transmission will be destroyed. According to the National Highway Traffic Safety administration, 43,058 Big Twin models (from 1986 to 1988) were recalled for this issue. The remedy was to

replace the powdered metal forks with forged steel forks. The forged steel forks used from 1989 to 2006 are durable and strong. Any 1986-88 Big Twin with the original transmission should be inspected to make 100 percent sure the powdered metal forks have been replaced with forged steel forks. The aftermarket offers thick section, billet steel forks with hard chrome plating for absolute wear resistance.

2000-06 Pawl Pins

The new-style roller detent shift drum was introduced on the 2000 Softail. The unsupported 1/4" pawl pins of the previous design were replaced with smaller unsupported 4mm pawl pins, which were prone to breaking. Within that first year of production, the factory upgraded the design with an outside support for the 4mm pawl pins and the problem was solved.

2000-06 Detent Spring

Starting with the 2000 Softail, the factory replaced the plunger detent with a roller detent to improve shift quality and all 2001 models used this configuration. Unfortunately, the design of the detent spring, and the failure mode, is similar to the 1979-2000 ratchet pawl spring in that the cantilevered leg of the spring breaks off over time. The broken spring leg makes itself known when the foot lever lacks any detent feel. As with its predecessor, the broken piece of spring can cause transmission damage. The only solution for this is to replace the spring at 30,000-mile intervals or replace the whole shift drum detent assembly and ratchet pawl with an aftermarket version.

Inner Primary Bearing

The inner primary bearing race, which is pressed onto the mainshaft, was introduced on the 1985 five-speed models and remained part of the design through 2006. On a stock motor, it works fine. Modified motors and excessively tight secondary drive belts will cause the race to walk into the seal on the end of the maindrive gear and cause the transmission to leak. In 2008, the factory remedied the problem by necking down the diameter of the mainshaft, but no permanent fix was implemented for the five-speed models. The aftermarket offers a few different solutions to this problem, including Shovelhead-style inner primary bearings and inner primary bearing races with increased interference fit.

As you can see, the arm on the 2000-06 Softail detent spring on the left is broken. A complete spring is on the right.

Aftermarket Offerings

In 1955, Chevy introduced its 265 cubic-inch V-8. Over many decades, GM and the automotive aftermarket developed that basic design way beyond the imagination of those who conceived that first Chevy V-8. Similarly, the Big Twin five-speed has been the design basis for many aftermarket adaptations. All aftermarket variants of the factory design use the stock five-speed 2.502" center distance between shafts, fork rod location, ratchet pawl location, shift drum pillow block datum, and 7"-wide case.

One of the first significant transmission variants was the 5-into-4 transmission that gave four-speed Shovelheads one more gear. The design adapted the five-speed gearset into the four-speed-style transmission case and was revolutionary at the time. Since the five-speed center distance — we discussed this last month — is 2.502" and the four-speed is 2.5625", this transmission case is unique to the 5-into-4 tranny.

In 1998, two very different six-speed overdrives, by sheer coincidence, were introduced based on the factory five-speed design. These transmissions ushered in a new era of highway riding in that sixth gear reduced cruising engine speed by 400-500 rpm. The American-made version introduced by me had a lot of commonality with the factory five-speed in that the maindrive gear (fifth), second gear, and third gear, and the related shift forks are exactly the same as in the five-speed. The gearset of the other six-speed overdrive, made in Korea, had little in common with the H-D five-speed design, except that the same critical dimensions were used. There are at least three overseas copies of the American-made design available marketed under various names.

In 2001, a right-side-drive (RSD) five-speed variant of the factory design was introduced as a countermeasure to balance the powertrain on wide-tire bikes. The factory five-speed has a left-side input and left-side output. RSD transmissions have a left-side input and right-side output arrangement. The six-speed RSD tranny was introduced in 2002, and many copies from overseas followed.

In 2003, BAKER introduced a direct-drive, six-speed (DD6) transmission for touring riders. It features spur (straight-cut) gears in first through third gears, and helical gears in fourth through sixth to eliminate gear noise in the higher gears. It also features 1-degree dog tooth undercuts for improved shifting instead of the stock 4-degree variants. Since the DD6's sixth gear is the same ratio as fifth gear in the factory five-speed, the primary drive ratio is changed to get the needed rpm reduction in top gear. This means, effectively, the primary drive is overdriven with a larger compensating sprocket to achieve top gear rpm reduction. When the factory introduced its Cruise Drive six-speed in 2006 with a 1:1 top gear, it adjusted the stock primary drive ratio in the same manner.

In 2004, the BAKER 6-into-4 was introduced for Shovelheads, Panheads, and Knuckleheads. It has two significant differences from the earlier 5-into-4. First, a true 500 rpm reduction is achieved on the highway as installed. Second, it features a 1936-based kicker, which is an absolute requirement for most pre-Evo owners.

Conclusion

Since 1936, Harley-Davidson has had three transmission types for a reason: it's a big undertaking to design a clean-sheet-of-paper transmission. As a result, the product life of a transmission is measured in decades; the same applies in the automotive world. The current Cruise Drive six-speed that came out in 2006 will be around for many years to come, and no doubt will undergo many product improvements to make it better and more durable. **AIM**