By Bert Baker, BAKER Drivetrain

H-D FIVE-SPEED TRANSMISSION

How it does what it does, part by part

THE FOCUS OF THIS ARTICLE IS TO SHARE SOME fundamental knowledge of how a Big Twin five-speed transmission works and a little about the evolutional history of the design. Though there are a few small parts — like neutral switches and fasteners — that are common between them, the components of H-D's four-, five-, and six-speed Big Twin transmissions have little in common with the design preceding it. The gears, shafts, cases, and even specifications for each type are completely different, though they may appear alike to the untrained. For example, the center distance between the mainshaft and countershaft is 2.563" on the four-speed, 2.502" on the five-speed, and 2.835" (72mm) on the Cruise Drive six-speed, which, in itself, guarantees no interchangeability of gear and shafts between them. Just like a small-block Chevy crankshaft cannot, and will never, fit into a big block. Why is centerline distance so important? In general, the torque (power) capacity of a transmission is dictated by the center distance and gear widths just like the torque output of an engine is dictated by the bore of its cylinder(s) and the stroke of its flywheels (crank). Torque is the twisting force created by the engine and transforming torque into a usable force is what a transmission is all about.

A gear is basically a round lever. When you want to lift a large rock, you put the short end of the lever under the rock and push down on the much longer end. The ratio of the short end's length compared to the long end determines how much the force you're applying to the long end will be multiplied at the short end. A transmission does the same thing by mating different-sized gears — one on the mainshaft and one on the countershaft — together when you select a gear. The different sizes of the gears determine their ratios to each other, and this ratio determines how fast the gears will spin and how much force they will exert on the rest of the drivetrain. For example, to get your bike moving from a dead stop, you shift the transmission to first gear. Think of the two different-sized gears that make up first gear as the two ends of a lever. And as with a lever, though one end moves a lot, the other end, the one doing the heavy lifting, moves very little, but it does so with lots of force. Lots of force is just what you need to get that 700-pound bike moving. But, as with a lever, though there's lots of power at the short end, there's only a little bit of movement, which is why the engine revs up quickly in first gear even though the bike is not moving very fast.

Now that you know what a transmission does, let's go through how all the components work together, starting with when you move the shifter lever with your foot.

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This ghost image of a Harley-Davidson five-speed transmission shows the way the internal components are situated and interact with each other inside the case.

The Shifter Pawl

When the rider upshifts or downshifts the transmission, the external shift linkage translates this rotary motion (foot shift lever) into linear motion (shift rod), and then back into rotary motion on the external lever located on the left side of the transmission. The rotary motion of this external shift lever is transferred to the ratchet pawl located inside the transmission via a splined pawl shaft. The ratchet pawl is a neat widget that rotates (indexes) the shift drum to upshift or downshift the transmission by one gear each time the shifter lever is moved. On 2000 Softails and 2001 FLs and Dynas, H-D redesigned its late-style ratchet pawl and incorporated an anti-overshift feature on the arm of the ratchet pawl to prevent unintentional overshifts. On 1979-99 five-speeds, the ratchet pawl has no anti-overshift feature, so it is possible to inadvertently shift from first to third during an aggressive first-to-second upshift. The return spring on the ratchet pawl brings the ratchet pawl back to a "home" position each time an upshift or downshift is completed. On 1979-99 transmissions, the home position can be adjusted via an eccentric screw on the ratchet pawl, but the late-style ratchet pawl has no adjustment option. The eccentric screw is adjusted at the factory and anytime the transmission is disassembled. Sometimes, the eccentric screw has to be adjusted on a transmission subjected to heavy abuse or with high mileage. An adjustment is made by putting the transmission in third gear and then centering the pawl over the two pins on the shift drum. When the eccentric screw is out of adjustment, the transmission will do one of two things. It will upshift fine, but miss when downshifting or downshift fine but miss on upshifts. Which one occurs depends on which way the adjustment is skewed. An eccentric screw can be installed in place of the fixed screw on late-style 2000-06 shift systems if there's a missed upshift or downshift problem. The late-style ratchet pawl has a rectangular cross-sectional return spring that is durable. The 1979-99 ratchet pawl has a round cross-sectional scissor spring with cantilevered legs, but there are issues with the legs of the spring breaking off.

The Shift Drum

The shift drum is the mechanical brains of the transmission; it is rotated (indexed) each time the ratchet pawl is rotated via the external shift linkage. The ratchet pawl rotates the drum by grabbing the pawl pins on the end of the drum and completing a shift. The pawl pins on the end of a 1979-99 drum are 1/4" thick and 4mm thick on 2000 and later versions. The number of pawl pins also changed in 2000, going from four to five. The addition of another pawl pin is why the late-style shift system deadheads in first and fifth gears. By that I mean, when the tranny is already in first gear, if you tap down on the shifter, there's no play or lever movement; ditto for fifth gear when upshifting. The 4mm pins were prone to breaking off, but Harley corrected this shortcoming by adding an outside support ring after 2001.

With the transmission in third gear, the shifter pawl should be centered over the two pins on the shift drum or shifting problems will occur.

The pawl pins on the end of a 1979-99 drum (left) are 1/4" thick and 4mm on 2000 and later versions. The number of pawl pins also changed in 2000, going from four to five.

The tracks in the drum guide the shift forks (via their fork pins) that, in turn, moves gears on both the mainshaft and countershaft to engage and disengage them. The drum has a detent that holds it in position (in gear) each time the drum is indexed. The detent is a spring-loaded device that rides on a star-shaped pattern on the drum. In 2000 Softail models and 2001 Dyna and FL models, the detent was upgraded from a plunger type to a roller detent type. This is the equivalent of a flat tappet being replaced by a roller tappet in a valvetrain. As you would expect, the roller detent shifts much smoother that the plunger type.

There are three primary features on the shift drum: the pawl pins, fork pin grooves, and detent provision. These components are precisely located relative to each other and repeat every 64 degrees. In other words, the pawl pins are 64 degrees apart, the fork pin grooves are 64 degrees apart, and the lobes of the detent are 64 degrees apart. If one aspect of one of these features is incorrectly machined, the transmission's mechanical brains (the shift drum) will not operate the transmission correctly. It's like having one line of code in a 10,000-line software program being wrong: the whole program will not work.

There's another feature that's also timed to the other three: the neutral switch trigger. On 1979-97 five-speeds, the single-pole neutral switch (a carry-over from the four-speed) is used to ground the negative side of the neutral light so it will light and let the rider know the transmission is in neutral. The spring-loaded plunger on this neutral switch physically makes contact with a bump or feature on the drum to complete the neutral light circuit. In 1998, Harley changed to a silver-bodied, automotive-style, two-pole switch with internal switching that is normally closed. Internal switching is a much more reliable way to activate the neutral light. The neutral light activates when the spring-loaded ball of the switch falls into a divot on the shift drum. On the 2000 Softails and the 2001 FLs and Dynas, H-D upgraded to a normally open, two-pole, black-bodied switch. On this version, a bump on the drum depresses the spring-loaded ball of the switch, which internally closes the switch to complete the ground side of the neutral light.

The shift drum rotates on two bearings, each of which is mounted in a pillow block on both ends of the drum. The 1979-99 shift drum is suspended by two drawn cup needle bearings, and the axial thrust is controlled by a thrust washer on the right side of the right pillow block. The 2000 and later-style drum is suspended by two radial ball bearings. The pillow block/drum assembly is positioned on the top of the transmission case via four hollow dowel pins, which positively locate both pillow blocks; they are secured using four bolts.

The Shifter Forks

When the shift drum rotates to make an up or downshift, the shifter forks are guided axially back and forth to move the gears they control. The forks move a gear to engage its shift dogs and, therefore, transfer power through the gearset. From 1979 to the mid-1980s, the five-speed had bronze shift forks. These

The shift drum has a spring-loaded detent that holds it in gear each time the drum is moved. Here are a 1979–99 plunger detent (top) and a 2000 and later roller detent.

were then replaced by powdered metal forks, which have good anti-wear properties but are prone to breaking. In the late-1980s, these powdered metal forks were replaced with forged steel forks that are reasonably strong with good anti-wear characteristics.

The Flow Of Power

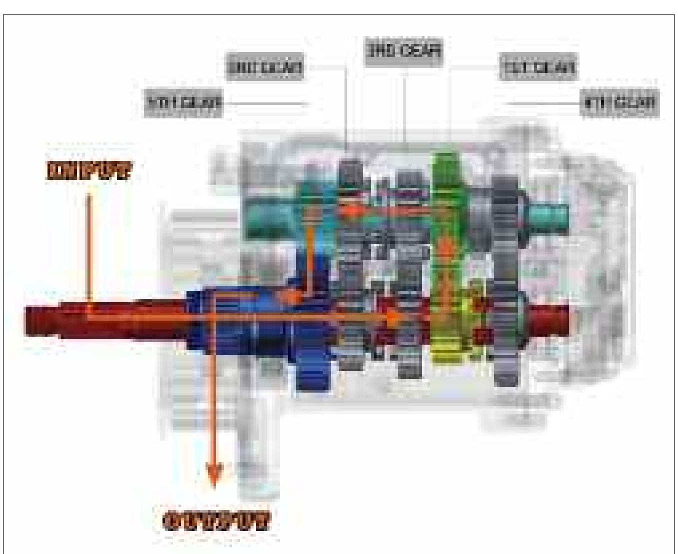
The illustration below left shows the flow of power through the transmission when first gear is selected. The flow of power is similar for second, third, and fourth gear in that power comes into first (or second, third, or fourth) gear on the mainshaft, gets transferred across to the countershaft first (or second, third, or fourth) gear, makes its way over to the countershaft fifth gear, and then on to mainshaft fifth gear, which is more commonly known as the main drive gear. Power then gets transferred to the rear wheel via the transmission pulley, which is directly mounted to the main drive gear.

As the illustration below right shows, when the transmission is in fifth gear power goes into the transmission via the mainshaft and then goes right back out through the main drive gear. This makes fifth gear a direct drive or a 1:1 ratio gearset. From a performance, fuel economy, and durability standpoint, having top gear be a 1:1 ratio is optimal because power loss, as well as wear and tear, are almost negligible.

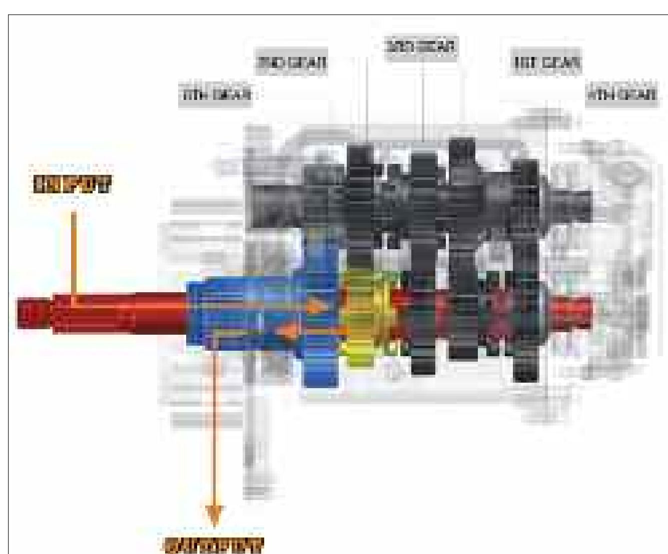
The Gearsets

Two gearset generations were used during the five-speed's 27-year run, but the basic layout is the same. The design is remarkably simple and easy to service, which makes it a brilliant one. The second and third gear pair are common. In other words, second gear on the mainshaft is the same as third gear on the countershaft, and second gear on the countershaft is the same as third gear on the mainshaft.

The first generation gearset design was used from 1979 to 1994, and it features stub tooth, straight-cut (spur) gear teeth that are basic but effective. In 1994-95, the high contact ratio (HCR) straight-cut (spur) gear tooth design was introduced to reduce gear noise in second, third, and fourth gears. The Motor Company commissioned Porsche to design the HCR gears because modern, high-contact-ratio tooth forms are complicated, geometrically speaking. Contact ratio is one of the primary gear



This illustration shows how power flows into, through, and out of the transmission when it's in first gear.



This illustration shows how power flows into, through, and out of the transmission when it's in fifth gear.

From left to right, an early stub tooth gear, a high-contact ratio gear, and a Cruise Drive six-speed helical gear.

Here are three of the four types of mainshafts used in a five-speed (bottom to top), from mid-1979 to early-1984, from mid-1984 to 1989, and from 1991 to 2006.

Here are three of the four types of main drive gears used (left to right): from 1979 to early-1984, from 1991 to 1993, and from 1994 to 2006.

tooth profile attributes that defines how many teeth are in mesh. Generally speaking, the higher the contact ratio, the quieter the gear. The stub tooth design has a contact ratio of roughly 1.4, which means 1.4 teeth are in mesh when the gear pair is rolling in mesh together. The HCR design has contact ratios of 1.8 or more. The HCR design has smaller gear teeth than its predecessor, but more of them are in mesh, which makes up for the loss in strength of the smaller tooth. As a point of reference, helical gears, like those on the Cruise Drive six-speed, generally have contact ratios over 2.0, which makes them quieter than any straight-cut or spur gear.

Post heat treat tooth grinding is another reason why the HCR gears are quieter. The gear tooth profile is cut by a gear manufacturing process called *hobbing*, which is done when the steel is soft, before heat treatment. After the gear profile is hobbed, the gear gets heat-treated (case-hardened) for wear resistance and long-term durability. The down side of heat treating is that the tooth profile gets deformed like a potato chip, and deformed gear teeth are noisy. To correct the distortion of the tooth profile, the gear is ground on an expensive machine made by Reishauer, which corrects the tooth profile within a range of 0.0002". When Harley-Davidson was producing its five-speed, it had a dedicated Reishauer machine for each gear part number. By comparison, the earlier stub tooth profiles were lapped after heat treating, which is a low-tech version of gear tooth grinding, and lapping doesn't do near as good a job correcting the tooth form profile.

There are four types of main drive gears used during those 27 years. The first was used from 1979 to early-1984. The mid-1984 to 1990 main drive gear looks just like the one that followed it, except it uses 1" bearings instead of the 25mm ones its replacement uses. This main drive gear was only used from 1991 to 1993, while the next gear version ran from 1994 to 2006.

There were four types of mainshafts used during the five-speed's run. The shortest one was used from mid-1979 to early-1984. The next one was used only from mid-1984 to 1989, while its replacement was used from 1991 to 2006. The 1990 shaft looks like the 1991-2006 shaft except it is a different diameter since its main drive gear uses a 1" bearing instead of a 25mm one. The biggest and most significant upgrade to the mainshaft was the change from the tapered clutch interface (end) to the splined clutch interface in 1990. The tapered interface worked fine until the clutch nut backed off a little, which would usually make a mess of the mainshaft and clutch hub.

The Bearings & Case

The bearings of the gears and shafts of the four-speed transmission are a combination of loose rollers and bronze bushings. These are durable, but they're also a service nightmare when a rebuild is needed. The bearings of the gears and shafts of the five-speed transmission are caged needle bearings and radial ball bearings. Servicing all the bearings in a five-speed takes a fraction of the time required for a four-speed.

The trapdoor radial ball bearings found in 1979-98 transmissions measure 20mm x 47mm x 14mm. In 1999, the door bearings were upgraded to larger 20mm x 52mm x 15mm ones with 25 percent more dynamic capacity to address premature door bearing failure issues. The left-side countershaft bearing was left unchanged from 1979 to 2006. The main drive gear bearing was upgraded from a 45mm x 75mm x 16mm bearing to a 45mm x 85mm x 19mm bearing in the mid-1980s to improve durability. The caged needle bearings located under the speed gears evolved from a two-piece metal cage design to a one-piece split cage design in the mid-1980s.

The venerable five-speed gearbox was used on FLT-FLH, Dyna, Softail, and FXR models. And though the transmission case is different from model to model, its internal architecture is the same for any given model year.

Conclusion

In next month's 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 five-speed design. **AIM**