The Science Of Synchronization

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Since the inception of the automobile, the quest to make the car more easily drivable has been unending. Early vehicles had relatively crude transmissions that were difficult to shift and were inefficient at making the power curve of the engine usable. Transmissions evolved from simple gearboxes to more-complex and smoother-operating units. Sliding-gear transmissions evolved into the first synchronized units. Typically the gearbox had an unsynchronized low gear with 2nd and 3rd speeds synchronized by using an internal cone-type clutch usually made of bronze. These early synchronizers were crude and relatively inefficient. The transmissions were slow shifting and required a much higher level of driver skill than is necessary with modern units. The saving grace for the gearbox was the low horsepower and low torque ratings of the powerplants of the time.

As engines developed higher horsepower and torque with the advent of the V-block designs, transmissions were created to carry the increased loads. Three- and four-speed units that were synchronized in all forward speeds evolved, and new types of synchronizers were produced. Pin-type synchronizers and the typical key, spring and brass-ring types we still see today were introduced. Late-model designs have developed into five- and six-speed units with multiple-cone synchronizers using state-of-the-art lined material and specifically formulated fluids for smooth shifting and the ability to carry very high horsepower and torque ratings.

As they have throughout the history of the standard transmission, synchronizers still cause many of the problems we deal with in our industry and remain one of the least-understood functions of the transmission. The function of the synchronizer is very similar to that of the common zipper in our clothing. Everyone knows how to use one, but few understand how it works.

A synchronizer is basically a cone-type clutch that equalizes the speed of the shaft to which it is splined with the rotation of the speed gear being selected. This used to be accomplished through "double-clutching," which requires a high level of coordination by the driver and a good "feel" for the transmission through the shift lever. Many race transmissions and heavy-duty-truck units still require double-clutching, but that may be an idea for a future article.

During a double-clutch shift, the clutch is depressed and the transmission is shifted into neutral.

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Synchronization Steps

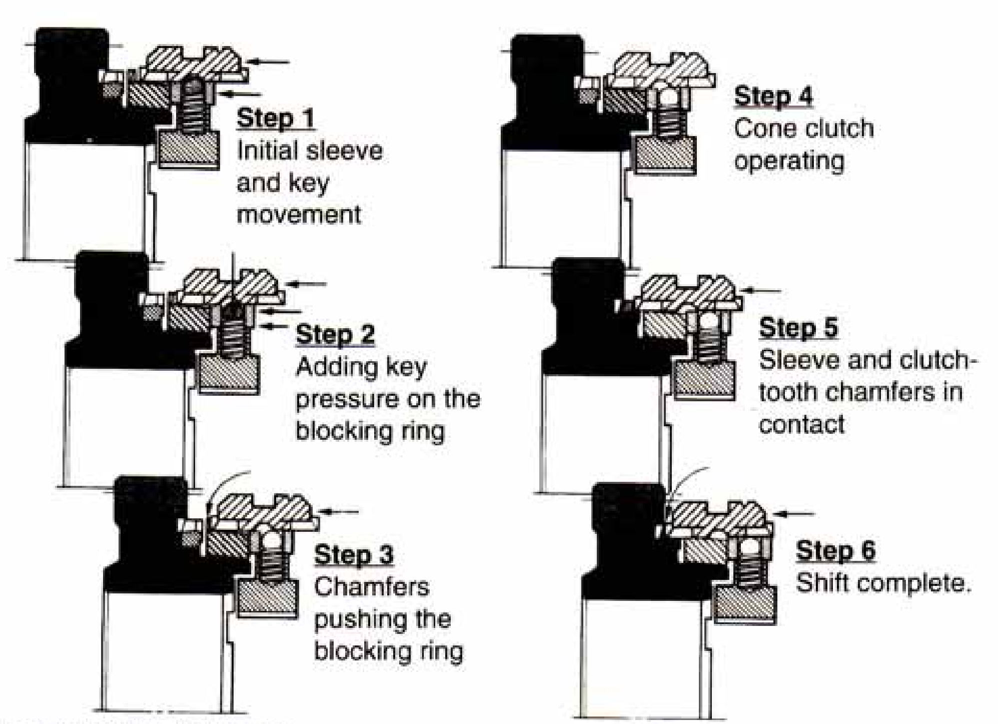


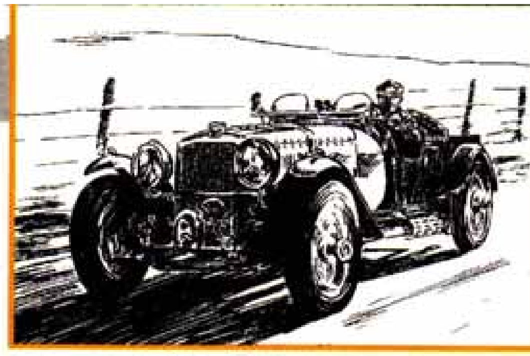
Illustration Courtesy GM Powertrain

The clutch then is engaged and the throttle is "blipped" to raise the engine speed several thousand rpm higher. The driver then depresses the clutch again and selects the speed gear desired by feel as the engine speed starts to drop and the shaft speeds equalize. The synchronizer accomplishes this without all the fancy footwork.

A typical synchronizer consists of a hub that is splined to the mainshaft and a sliding sleeve that is splined to the synchro hub and is moved by a shift fork. Grooves machined into the synchro hub contain keys or struts that are retained in position by circular or coil springs. The keys move with the slider as it slides over the hub toward the speed gears on either side of the hub. Between the hub and the speed gear is the synchro or "blocking" ring, which is a cone clutch that mates with a precisely tapered cone machined onto the speed gear.

Below the cone of the speed gear is a set of coupling teeth that match the splines on the inside of the sliding sleeve and the outer teeth of the synchro ring. The hub side of the blocking ring has slots machined to accept the synchro keys. As the sleeve moves toward the spring gear, the keys move with it, pushing the blocking ring onto the cone of the speed gear being selected. The pressure of the ring on the cone creates friction to increase or decrease the gear's speed to match that of the mainshaft.

While this is happening the teeth of the blocking ring are not lined up with the slider. This prevents the slider from contacting the coupling teeth of the speed gear; hence, the term blocking ring. When the shaft speed matches the gear speed, the friction drops on the blocking ring, permitting it to line up with the coupling teeth and enabling the slider to engage with the coupling teeth of the speed gear, completing the shift. This duration of the shift is very short, and clash-free shifting requires all the components to be in good working order. No matter what the design of the synchro assembly, the function remains the same.



Problems occur with engagement while shifting and with gear jump-out after a shift is completed. When gears grind during shifts, you must determine whether the cause is external or internal to the trans. External causes of gear clash include:

- Worn clutch or bad clutch release
- Binding pilot bushing
- Misadjusted or worn shift components and linkage
- Air in hydraulic systems
- Worn clutch fork and pivot ball.

Internal causes of grinding shifts can include:

- Improper lubricant
- Worn or contaminated synchro rings
- Broken or missing keys or springs
- Excessive endplay on a gear or shaft
- Worn bearings
- Spline wear on the sliding sleeve and synchro hub
- Damaged pointing on the coupling teeth of the speed gear or slider
- Excessive wear on the key slots in the synchro rings
- Worn shift forks or internal shift linkage.

Gear hop-out occurs when a gear is selected and the clutch released, only to have the slider pop back into a neutral position, or after a shift is complete and when the throttle position is changed the slider cannot remain engaged with the speed gear and slips off. The causes of gear hop-out can be external, such as bad or worn powertrain mounts, improperly adjusted shift linkage, misalignment of the bellhousing to the block, excessive runout of the crankshaft, an out-of-balance clutch or flywheel, or a worn or out-of-balance driveshaft.

Internal causes of gear jump-out are too much endplay on the gears or shafts, worn back taper on the sides of the coupling teeth of the slider and speed gear, worn or bent shift forks, broken detents or springs that don't permit a complete shift, or worn sleeve-to-hub fit on the synchro assembly. A common fallacy is that the detents and springs on the shift rails hold a unit in gear. The detents and springs serve only to give the driver a positive feel for the position of the stick. Do not waste your time trying to install a heavier detent spring, because it increases shift effort and cannot hold the unit in gear against the torque load of the motor.

The only way to diagnose and repair a complex machine such as a transmission successfully is to understand how it operates. Although there are endless variations of transmission and synchronizer design, they all operate the same way. Forget about where the parts go; you can find that in any repair manual. Understand the theory and you will be a first-class problem solver. TD

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