VIGYAN 2047 Volume 2 No. 11 November 2025 Pages 18–21

# Tribology of Transmission: Gear box

## Kamal Mukherjee

The relationship between torque and speed is inversely proportional to each other—if one goes up, the other goes down. So, as the size & weight of an object/machine increases it needs more torque to move it. The torque developed by the prime mover is transmitted to the output components—a) to 'the road wheels' in case of tyre mounted machine (Car, Jeep, SUV, Truck, Trailer, high-capacity Dumper, Payloader, Tractor, JCB, Crane etc.), b) to 'the track chain' in case of crawler (track chain) mounted machine (Excavator, Dozer, Drill etc.) where it needs a larger "propulsive force", or "tractive effort.", c) the torque is also transmitted to operate the hydraulic systems for actuating the hydraulic cylinders, hydraulic pump, hydraulic motor etc., d) to the stationary units e.g. small to a high capacity winches or haulage for pulling an object through a wire rope, e) for simply to increase the torque which are popularly known as speed reducers used in heavy machines. This necessitates the introduction of a considerable "**leverage**" between the prime mover (engine/motor) and the output components as mentioned above & is achieved by a set of gears which multiplies the turning force. Such a converting device with a gear set arrangement is known as "**gear box**" or "**transmission**" (Fig-1) and used in automobiles, turbines, and reduction units in heavy machinery of industrial application. ***Thus, "gear box/transmission does not develop power & it is only a torque multiplying device at the cost of speed."***

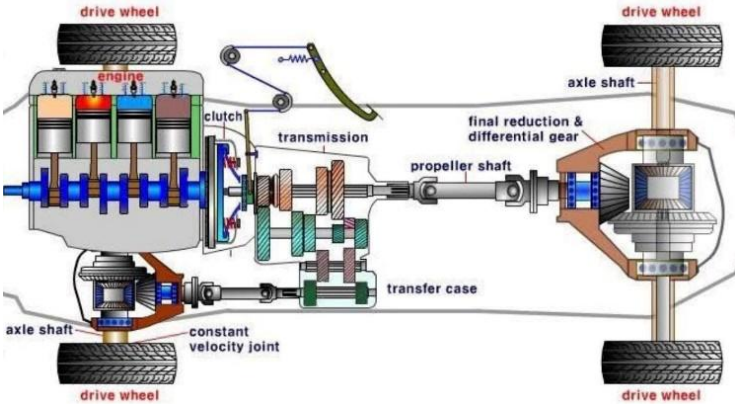


Fig-1: Schematic layout of engine, clutch, transmission, differential & final drive in a typical vehicle

## Types of Transmission Systems

The transmission systems can either be a mechanical or electrical or hydraulic (fluid devices in between).

**(A) Manual gearbox:** Most of the mainstream cars, jeeps, SUV's, tractor & trucks, come with a manual transmission of some kind. Here one has to select the gears manually to speed up & slow down as well as to operate clutch pedal. Manual transmissions (Fig-2) are affordable and easy to maintain compared to automatic transmissions.

**(B) Automated Manual Transmission (AMT) / Intelligent Manual Transmission (IMT):** AMTs

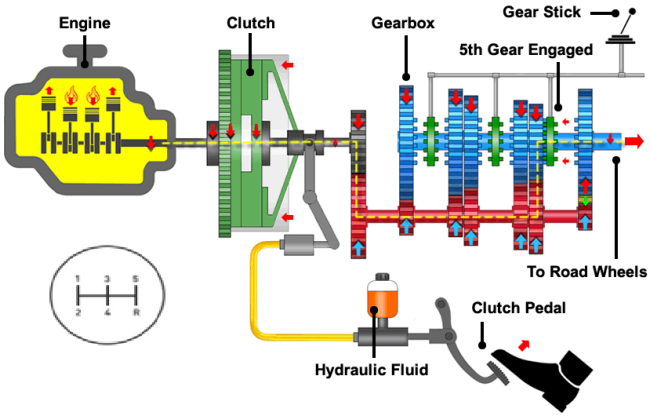


Fig-2: Manual Transmission with 'H' shape gear shifting slots.

use electronic sensors to control gear changes, eliminating the need for a clutch pedal. They are more affordable and fuel-efficient than traditional automatics, but their gear shifts can be slower and less smooth, which may result in a jerky driving experience.

**(C) Automatic Transmission:** There are many types of automatic transmission as shown below:

**(C.1) Continuously Variable Transmission (CVT):** This system includes cones at each pulley linked through a belt and moves to increase or decrease the chain belt diameter to change gear ratios. The CVT is reliable and offers higher fuel efficiency.

**(C.2) Dual Clutch Transmission (DCT):** It employs two clutches to shift gears, one for even gears and another for odd gears, reducing gear shift lag. DCTs have gained popularity in high-performance cars for their quick and smooth shifting making them ideal for sports cars. (Fig-3).

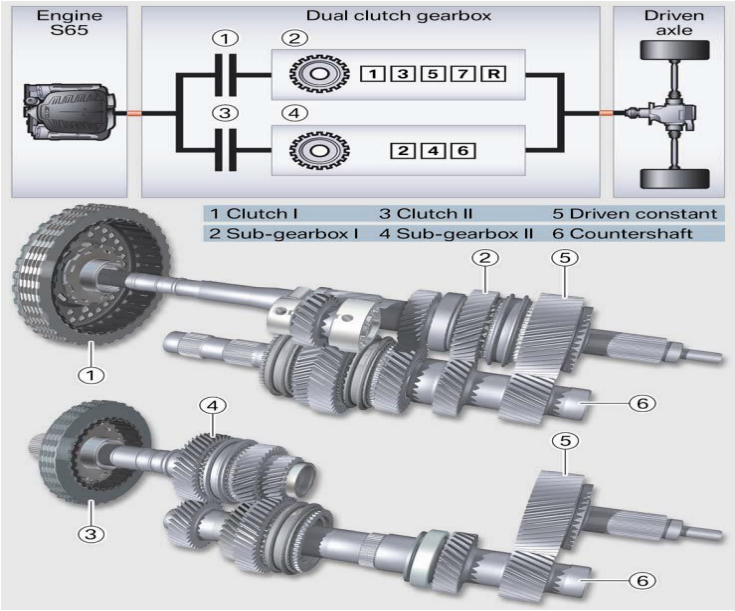


**Fig-3: BMW-7 speed double clutch transmission (DCT)**

**(C.3) Electronically Controlled Automatic Transmission or Hydrodynamic Transmission (HDT):** This type of transmission in the car is seen nowadays otherwise they are used in heavy vehicles. One has to select the gear lever position e.g. "P-R-N-D", it's as per the Society of Automotive Engineers (SAE) recommendation: (P) Park, (R) Reverse, (N) Neutral & (D) Drive. As the foot pedal is used to accelerate or decelerate, it automatically selects the speed range. It uses the high velocity of oil flow (kinetic energy) to the torque converter, lockup clutch and planetary gearing. Torque converter provides a continuous variation of speed ratio from lowest to the highest. With electronic control system (ECM), precise & smooth gear shifts with perfectly timed gear shifts are obtained. Additional advantage of electronic control system is that the microcomputer can store diagnostic trouble codes. This greatly assists the mechanics in the quick repair of faulty transmission units (Fig-4 & 5).

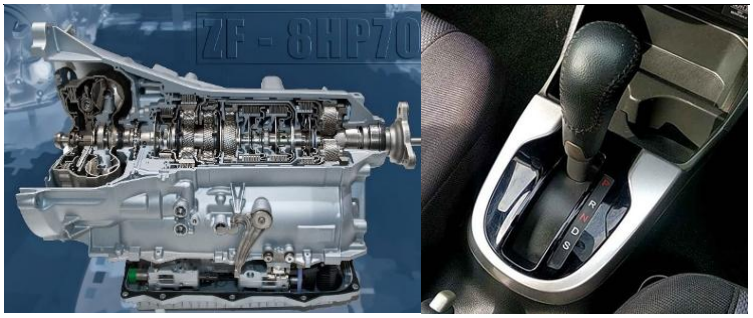


**Fig-4: Automatic transmission with PRNDL gear shifting lever**

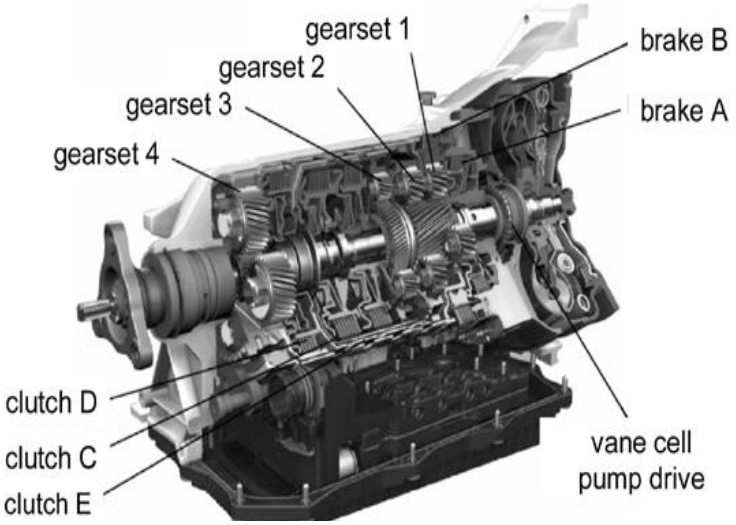


**Fig-5: The 8-speed transmission is based on a gear set system with 5 shifting elements and 4 planetary gear sets; the overall gear spread is 7.05.**

**(D) Electric Transmissions:** These have been used for higher capacity dumpers. Engine is coupled to invertor that is again connected to the wheel motors. It is a combo unit with planetary gear train for getting higher torque. Each wheel motor drives a sun pinion that turns a central sun gear and three planetary gears. The gear set is enclosed in a gearbox and lubricated with gear oil (Fig-6). In EV's the transmission fluid comes in contact with copper windings, insulations, laminates and rare earth materials in motors so its lubricant film is quite challenging.

Fig-6: Electric drive of an off-highway, high-capacity dumper

**(E) Hydrostatic Transmission (HTS):** It works on the principle of Pascal's law i.e. pressure exerted at any point on a confined fluid is transmitted undiminished throughout the fluid in all directions. Some of the applications are in automobiles, excavator in mining, agriculture & construction machinery.

**(F) Final Drive:** uses a set of "**planetary gears**" (sun-and-pinion gear system) to convert force into torque, it allows the combination of sun pinion, planetary gears, ring gear & carrier to deliver power. The double reduction process further multiplies the torque in heavy duty application.

**(G) Industrial Reduction Units:** It's a combination of—i) "**spur gearing**"—whose axes are parallel, 'rack and pinion' (for converting rotary to reciprocating motion & vice versa), 'helical' gearing and 'herringbone' gearing (herringbone are to take up the end thrust/axial load & smooth-silent operation). ii) "**bevel gearing**", which is used for connecting the intersecting shafts e.g. straight bevel gears, 'miter', 'crown' & 'spiral' gears. iii) gearing for shafts whose axes are neither parallel nor intersecting axes consisting of "**worm and worm wheels**" (worm resembles a screw having number of threads which connects to wheel having teeth cut at its outer periphery) are used for a large speed reduction or a high increase of torque by means of worm gears.

## Tribology Aspects for Reducing the Energy Losses from Transmission

The working principle of gear implies the presence of a loaded sliding & rolling contact condition. The contact implies the presence of several failure modes, such as tribological damages (i.e. scuffing, scratching, wear & rust) and fatigue damages (e.g., macro/micro-pitting, tooth flank/ fatigue fracture). Maximum deterioration of gears takes place on the surface of gears as teeth are responsible for power transmission. For noise sensitive applications, nonlinear materials like polymer with lower stiffness and good damping characteristics are preferred. The part of the fuel energy is converted into mechanical power '**to overcome friction**'. As per the published studies, losses are ~13% in the transmission system. The friction loss in a gearbox occur in the rolling bearings, gears, gear synchronizers, shaft seals & partly in the oil churning inside the sump in an automobile.

**Efforts of reducing friction:**

**a)** For the strength & surface hardness, heat treatment is used such as hardening, carburizing or case hardening, nitriding, induction & flame hardening etc.

**b) Low-Friction Coatings on Mechanical Components**

**The surface coating technology** has shown the major improvement in reducing the friction losses over few decades e.g. **Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD),** and **Thermal Spraying (TS)** in industrial & automotive components to enhance their residual life. The role of a coating is then to work as a safety layer. The lifetime improvements achieved using surface coatings have been impressive e.g. a three-fold increase in gear lifetime have been reported by the experts.

Scientist have found that by using **Diamond-like carbon (DLC)** coating as against the standard steel-to-steel contact resulted in **~30% reduction in friction.** Further, by applying **tungsten carbide/carbon (WC/C)** coatings in FZG gear tests, about **70-fold increase in lifetime** was obtained. Similarly other **composite coatings** within $Si_3N_4$ or **SiC ceramic matrices,** & various **nanostructured coatings,** have given potential friction reduction.

**c)** Recent research shows that when gear surfaces are made smoother using **superfinishing,** friction can drop by **about 30%.** Likewise, using **fine-particle peening** to make tiny **dimples** on the surface can cut friction in **lubricated systems by as much as 50%.**

**d) Lubricants:** The lubricant has several functions—i) provides a fluid film between load-carrying and fast-moving components, assuring that shear takes place within the lubricant with low friction, and that solid contacts are avoided, ii) helps to form a chemical film on surfaces to avoid wear and breakdown, iii) prevents corrosion, iv) provides cooling by heat transport, and v) transports contamination away from the system. However, oil churning results in energy losses due to the viscosity of the lubricant. The use of lubricating oils of lower viscosity will reduce the energy losses from viscous work. A reduction of the engine oil viscosity by approximately 25% corresponds the fuel savings for a similar lowering of the viscosity of a gear oil is on the order of 0.2–2.5%. Another issue for gearboxes lubrication is to retain efficient lubricant boundary throughout their life. Additive e.g. friction modifiers, anti-wear, extreme pressure & nano particles help to maintain the proper film of lubricants in the gear surfaces.

Keeping perspective of long and reliable service, tribological needs must be identified and addressed at early transmission design stages always outperform many low-cost motion solutions in market. ◆

***Kamal Mukherjee**, a prolific science writer and nutritionist, is an active member of the Tribological Society of India and has held executive leadership roles in major national organizations. He can be contacted at kamalcbm28@gmail.com.*