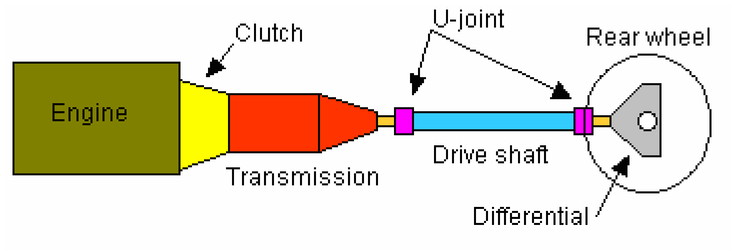
UNIT-III

TRANSMISSION SYSTEM

TRANSMISSION SYSTEM

Chief function of the device is to receive power at one torque and angular velocity and to deliver it at another torque and the corresponding angular velocity.



LAYOUT OF AUTOMOBILE POWER TRANSMISSION SYSTEM

REQUIREMENTS OF TRANSMISSION SYSTEM

1. To provide for disconnecting the engine from the driving wheels.

2. When the engine is running, to enable the connection to the driving wheels to be made smoothly and without shock.

3. To enable the leverage between the engine and driving wheels to be varied.

4. It must reduce the drive-line speed from that of the engine to that of the driving wheels in a ratio of somewhere between about 3:1 and 10:1 or more, according to the relative size of engine and weight of vehicle.

5. Turn the drive, if necessary, through 90° or perhaps otherwise re-align it.

6. Enable the driving wheels to rotate at different speeds.

7. Provide for relative movement between the engine and driving wheels.

CLUTCH

The clutch is housed between the engine and transmission where it provides a mechanical coupling between the engine's flywheel and the transmission input shaft. The clutch is operated by a linkage that extends from the passenger compartment to the clutch housing. The purpose of the clutch is to disconnect the engine from the driven wheels when a vehicle is changing gears or being started from rest.

Disengaging the clutch separates the flywheel, the clutch plate and the pressure plate from each other. The flywheel is bolted to the end of the crankshaft and rotates with it. The clutch plate is splined to the gearbox in order for both to rotate together and the pressure plate clamps the clutch plate to the flywheel. When the pressure is released by depressing the clutch pedal, the crankshaft and gearbox input shaft rotate independently. When the foot is taken off they rotate as one.

REQUIREMENTS OF A CLUTCH

The clutch must

1. Pick up its load smoothly without grab or clatter.

2. Have a driven disc of low moment of inertia to permit easy shifting.

3. Damp out any vibration of the crankshaft to prevent gear clatter.

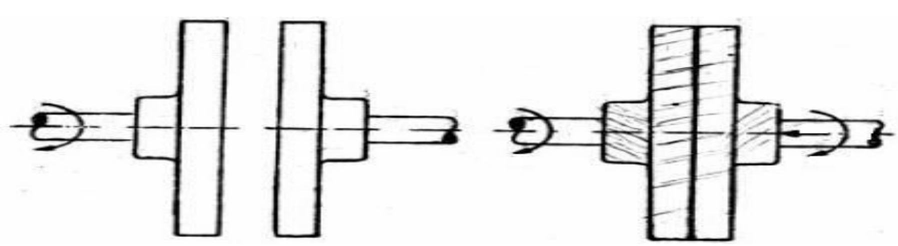
4. Require little pedal pressure to operate it.

5. Be easy to adjust and service.

6. Be cheap to manufacture.

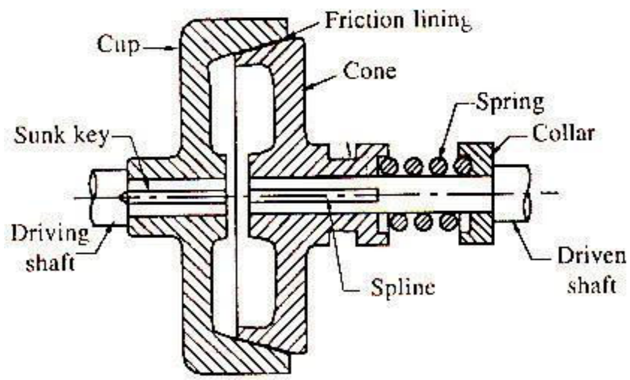
BASIC PRINCIPLE OF THE FRICTION TYPE CLUTCH

To understand the working principle of clutch, let‘s take two sanding discs, first one driven by a power drill corresponds to the flywheel of a car, driven by the engine. If a second sanding disc is brought into contact with the first, friction makes it revolve too but more slowly. But when the second disc pressed against the first disc which is connect to the power drill, as the pressure increases the two discs revolve as one. This is how a friction clutch works.



CONE CLUTCH

A simple form of a cone clutch is shown in fig. it consists of ;i driver or cup and the follower or cone. The cup is keyed to the driving shaft by a sunk key and has an inside conical surface or face which exactly fits the outside conical surface of the cone. The slope of the cone face is made small enough to give a high normal force. The cone is fitted to the driven shaft by a feather key. The follower may be shifted along the shaft by a forked shifting lever in order to engage the clutch by bringing the two conical surfaces in contact.



Advantages and disadvantages of cone clutch:

Advantages:

1. This clutch is simple in design.
2. Less axial force is required to engage the clutch.

Disadvantages *:*

1. There is a tendency to grab.
2. There is some reluctance in disengagement.

Strict requirements made to the co-axiality of the shafts being connected

TORQUE TRANSMITTED BY THE CONE CLUTCH:-

Let D_i = Inner diameter of cone, R_i = inner radius of cone,

D_o = Outer diameter of cone, R_o = Outer radius of cone,

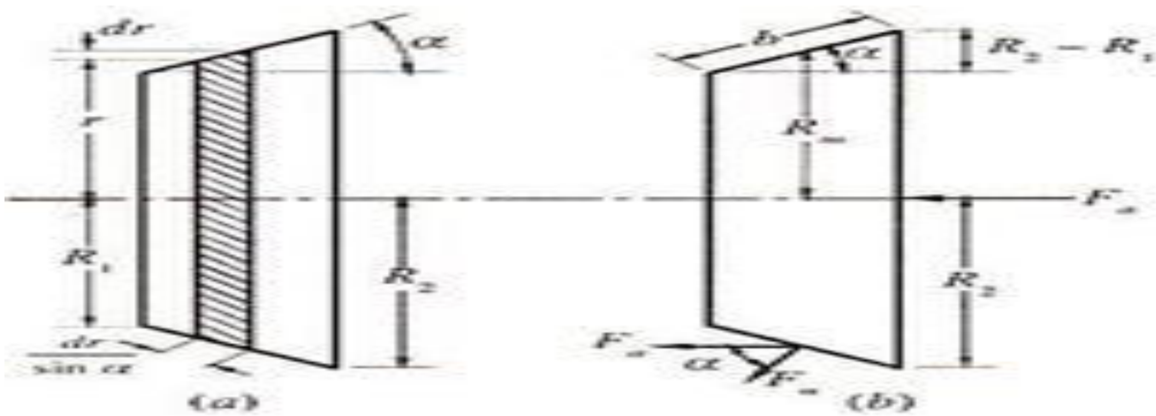
R_m = mean radius of cone, D_m = mean diameter of cone,

$\propto$= Semi cone angle or pitch cone angle or face angle,

P = Intensity of normal pressure at contact surface,

μ= Coefficient of friction, F_a = Axial force

F_n=Normal force $= \frac{Fa}{\sin \alpha}$



Consider an elemental ring of radius ‘r’ and thickness ‘dr’ as shown in the figure

The sloping length $= \dfrac{dr}{\sin\alpha}$

Area of elementary ring $= 2\pi r \dfrac{dr}{\sin\alpha}$

Normal force on the ring $= P\ 2\pi r \dfrac{dr}{\sin\alpha}$

Axial component of the above force $\dfrac{p 2\pi\ r.\ dr}{Sin\alpha} \cdot Sin\alpha$

$$= 2\pi pr\ dr$$

Total axial force $Fa = \int_{R_1}^{R_2} 2\pi\ pr\ dr$ ------------ (1)

Frictional force outer ring $= \propto p\, 2\pi r \dfrac{dr}{Sin\ \alpha}$

Moment of friction force about the axial

$$= \propto P 2\pi_r \frac{dr}{Sin\ \alpha} \cdot r$$

$$= 2\pi\ p \propto r^2 \frac{dr}{Sin\ \alpha}$$

Total torque $T = \int_{R_1}^{R_2} 2\pi \propto Pr^2 \dfrac{dr}{Sin\ \alpha}$ ---------- (2)

Uniform pressure theory: p constant

Equation (1) becomes

$$Fa = \int_{R_1}^{R_2} 2\pi\ pr\ dr \quad = 2\ \pi\ p \int_{R_1}^{R_2} dr$$

$$Fa = \pi\ P\ (R_2^2 - R_1^2)$$

$$p = \frac{Fa}{\pi\ (R_2^2 - R_1^2)} \quad ---------- \quad (3)$$

Equation 2 becomes

$$T = \int_{Ri}^{Ro} 2\pi\, p \propto r^2 \left(R_o^2 - r_i^2\right) \frac{dr}{Sin\alpha} = \frac{2\pi\, P \propto}{Sin\alpha} \int_{Ri}^{Ro} r^2\, dr$$

$$T = \frac{2\pi \propto p}{Sin\alpha} \cdot \frac{R_o^3 - R_i^3}{3}$$

Substitutes the value of P from equation ---------- (3)

$$T = \frac{2\pi \propto P}{Sin\alpha} \cdot \frac{Fa}{\pi\left(R_o^2 - R_i^2\right)} \cdot \frac{R_o^3 - R_i^3}{3}$$

$$T = \frac{2\pi\, Fa}{3\, Sin\alpha} \cdot \frac{Fa}{\pi\left(R_o^2 - R_i^2\right)} \cdot \frac{R_o^3 - R_i^3}{\left(R_o^2 - R_i^2\right)}$$

$$T = \frac{2\pi\, Fa2}{2\, Sin\alpha} \cdot \frac{}{3} \cdot \frac{\ ^3 - \ ^3}{D_o - D_i} \cdot \frac{\propto Fa}{2\, Sin\,\alpha} \cdot Dm \quad \text{--------- (4)}$$

Where $Dm = \frac{2}{3} \cdot \frac{R_o^3 - R_i^3}{D_o - D_i}$

Axial force $Fa = \pi\, P \left(D_o^2 - D_i^2\right)$ ---------- (5)

Uniform wear: For uniform wear condition $Pr = C$ Constant

Equation (1) become $Fa = \int_{Ri}^{Ro} 2\pi\, P\, r\, d\, r = 2\pi P \int_{Ri}^{Ro} dr$

$$Fa = 2\pi\, c\left(R_o - R_i\right) \text{ or}$$

$$c = \frac{Fa}{2\pi\left(R_o - R_i\right)}$$

Equation (2) become

$$T = \int_{R}^{Ro} 2\pi\, P \propto r^2 \frac{dr}{Sin\alpha} = \frac{2\pi \propto C}{Sin\alpha} \int_{Ri}^{Ro} r\, d\, r$$

$$T = \frac{2\pi \propto c}{Sin\alpha} \cdot \frac{\left(R_o^2 - R_i^2\right)}{2}$$

Substitute for C

$$T = \frac{2\pi \propto \left(R_o^2 - R_i^2\right)}{Sin\alpha} \cdot \frac{Fa}{2\pi\left(R_o - R_i\right)}$$

$$= \frac{\propto Fa}{2\, Sin\alpha} \cdot \frac{\left(D_o + D_i\right)}{2} \cdot \frac{\propto Fa\, D\, m}{2\, Sin\,\alpha}$$

Where Dm = Mean diameter $Dm = \frac{D_o + D_i}{2}$

If the clutch is engaged when one member is stationary and other rotating, then the cone faces will tend to slide on each other in the direction of an element of the cone. This will resist the engagement and then force

Axial load $\quad Fa^{i} = Fa\,(Sin\alpha + \cos\alpha)$

Force width $\quad b = \dfrac{D_o - D_i}{2\,Sin\,\alpha}$

Outer diameter $\quad D_o = Dm + b\,Sin\alpha$

Inner diameter $\quad D_i = Dm - b\,Sin\alpha$

SINGLE PLATE CLUTCH

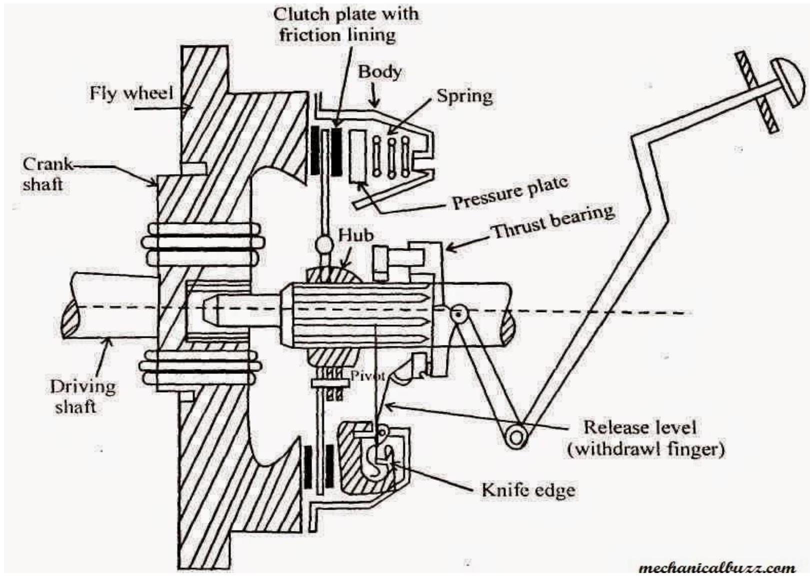
CONSTRUCTION

A typical clutch actuated by a number of coil springs on a pitch circle nears the periphery is shown. The driven shaft which normally is a forward extension of gearbox primary shaft is supported at its front end in ball bearing in a hole in the centre of flywheel web, which is spigot and bolted on to a flange at the rear end of the crankshaft.

In this clutch, the coil springs force the pressure plate forwards to clamp the driven plate between it and the rear face of the flywheel. Three lugs extend rearwards from periphery of pressure plate both to rotate the pressure plate and to cause it to rotate with the rest of the assembly. The driven plate of course is splined onto the shaft. There are three release levers pressing the coil springs at the outer end. The inner ends of the levers can be forced forward by means of thrust bearing made of graphite and slide along the clutch shaft when clutch pedal is depressed. The driven plate mounted between flywheel and pressure plate makes the clutch shaft to rotate to transmit power. It has the clutch facing made of friction materials around the periphery of disc.

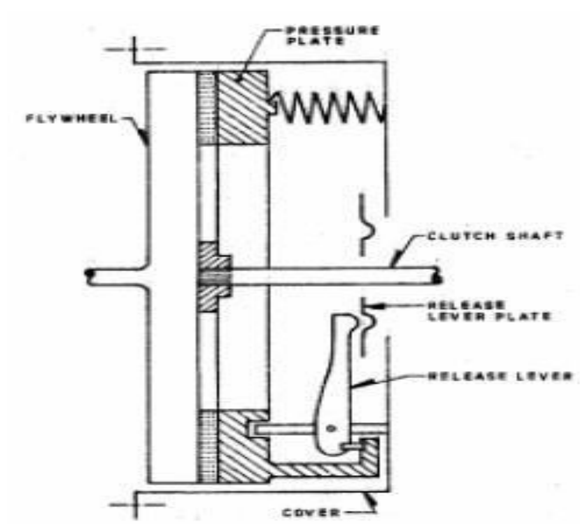
WORKING

When the clutch is engaged, the clutch plate is gripped between the flywheel and pressure plate. The friction linings are on both sides of clutch plate. Due to friction between flywheel, clutch plate and pressure plate, the clutch plate revolves with the flywheel. As clutch plate revolves the clutch shaft also revolves. Thus, engine power is transmitted to the clutch shaft. When the clutch pedal is pressed the pressure plate moves back against the spring force and clutch plate becomes free between flywheel and pressure plate. Thus flywheel remains rotating as long as the clutch pedal is pressed, the clutch is said to be disengaged and clutch shaft speed reduces slowly and finally it stops rotating.



DIAPHRAGM SINGLE PLATE CLUTCH

Diaphragm spring pressure plate assemblies are widely used in most modern cars. The diaphragm spring is a single thin sheet of metal which yields when pressure is applied to it. When pressure is removed the metal springs back to its original shape. The centre portion of the diaphragm spring is slit into numerous fingers that act as release levers. During disengagement of the clutch the fingers are moved forward by the release bearing. The spring pivots over the fulcrum ring and its outer rim moves away from the flywheel. The retracting spring pulls the pressure plate away from the clutch plate thus disengaging the clutch. When engaged the release bearing and the fingers of the diaphragm spring move towards the transmission. As the diaphragm pivots over the pivot ring its outer rim forces the pressure plate against the clutch disc so that the clutch plate is engaged to the flywheel.



ADVANTAGES OF DIAPHRAGM SPRING CLUTCH

1. It is more compact than other designs.

2. It is easier to balance rotationally and is less subjected to unwanted effects due to centrifugal force at high rotational speeds.

3. It gives uniformly distributed pressure on pressure plate.

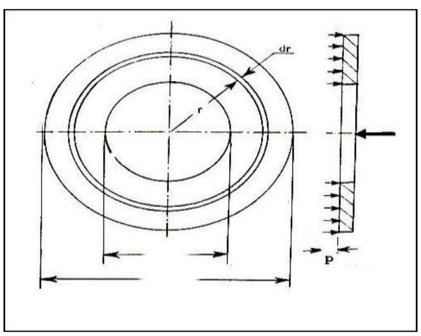
4. It needs no release levers.

5. Minimum effort is sufficient to disengage the clutch.

6. It provides minimum number of moving components and hence minimum internal friction is experienced.

7. This is very commonly used in cars, light Lorries and mini trucks but is not much used in heavy vehicles

Torque transmitted by plate or disc clutch



A friction disk of a single plate clutch is shown in above fig

The following notations are used in the derivation

D_o = Outer diameter of friction disc (mm)

D_i = Inna diameter of friction disc (mm)

P = pressure of intensity N/mm^2

F = Total operating force (N) (Axial force)

T = torque transmitted by friction (N-mm)

Consider an elemental ring of radius r and radial thickness dr

Area of elemental length = 2πr. dr

Axial force length = 2πr r. P

(∝ or f) friction force = 2πr. drp ∝ Friction torque = 2πr dr P∝ * r

Total axial force Fa = $F_a = \int_{D_i/2}^{D_0/2} 2\pi r\,dr\,p$ ------------ (1)

Torque Transmitted by friction $T = \int_{D_1/2}^{D_0/2} 2\pi r^2\,dr \propto p$ ------------ (2)

There are two criteria to obtain the torque capacity – uniform pressure and uniform wear

1. Uniform pressure Theory:

In case of new clutches, un playing assumed to be uniformly distributed over the entire surface area of the friction disc. With this assumption, P is regarded as constant.

Equation – 1 becomes

$$F_a = \int_{D_i/2}^{D_0/2} 2\pi r\,dr\,p$$

$$F_a = 2\pi p \int_{D_i/2}^{D_0/2} r\,dr = 2\pi p \left[\frac{r^2}{2}\right]_{D_1/2}^{D_0/2}$$

$$F_a = \frac{2\pi}{2} p \left[\frac{D_0^2}{2} - \frac{D_1^2}{2}\right]$$

$$F_a = \frac{1}{4}\pi p \left(D_0^2 - D_1^2\right)$$

or $$P = \frac{4F_a}{\pi\left[D_0^2 - D_1^2\right]}$$

From Equation -2

$$T = \int_{D_1/2}^{D_0/2} 2\pi \propto p r^2\,dr$$

$$T = 2\pi \propto p \int_{D_1/2}^{D_0/2} r^2\,dr$$

$$T = 2\pi \propto p \left[\frac{r^3}{3}\right]_{D_1/2}^{D_0/2}$$

$$T = \frac{2}{3} \pi \propto p \left[\frac{Do^3}{2} - \frac{Di^3}{2}\right]$$

$$T = \frac{1}{3}\pi \propto p\left(Do^3 - D_1^3\right)$$

Substituting the value of p from equation 3

$$T = \frac{\propto \left(D^3 - D_1^3\right)}{12} \qquad \frac{4Fa}{\pi\left(D_o^3 - D_1^3\right)}$$

$$T = \frac{1}{3} \propto Fa \frac{\left(D_0^3 - D_i^3\right)}{\left(D_0^2 - D_i^2\right)}$$

$$T = \frac{\propto Fa\, Dm}{2}$$

Where $\frac{2}{3} \frac{D_0^3 - D_i^3}{D_0^2 - D_i^2} = Dm$ mean diameter

Torque transmitted by n- friction surfaces

$$T = \frac{n^1 \propto Fa Dm}{2}$$

Axial force = $\pi P\left(R_2^2 - R_1^2\right) = \frac{\pi}{4} P\left(D_0^2 - D_i^2\right)$

Uniform Wear Theory:

According to this theory, it is assumed that the wear is uniformly distributed over the entire surface --- of the friction disc. This assumption is used for workout clutches. The axial wear of the friction disc is import ional to the frictional work. The work done by the frictional force (? P) and subbing velocity (2πrN) where 'N' is speed in rpm. Assuming speed N and coefficient of friction '?' is constant for given configuration

Wear ∝Pr

Pr = constant C

When clutch plate is new and rigid. The wear at the outer radius will be more, which will release the pressure at the outer edge due to the rigid pressure plate this will change the pressure distribution. During running condition, the pressure distribution is adjusted in such a manner that the product pressure is constant, C.

From equation - (1)

$$\text{Axial force Fa} = 2\pi \int_{D_1/2}^{D_0/2} \Pr\, dr$$

$$Fa = 2\pi c \int_{D_1/2}^{D_0/2} dr$$

$$Fa = 2\pi c \left[r \right]_{D_1/2}^{D_0/2}$$

$$Fa = 2\pi c \left[\frac{D_0}{2} - \frac{D_1}{2}\right]$$

$$\therefore C = \frac{Fa}{2\pi\,[D_0 - D_1]} \qquad - \qquad (7)$$

2

From equation - (2)

$$T = 2\pi \propto \int_{D_1/2}^{D_0/2} Pr^2\, dr = 2\pi \propto c \int_{D_1/2}^{D_0/2} r\, dr$$

$$= 2\pi \propto c \left[\frac{r^2}{2}\right]_{D_1/2}^{D_0/2}$$

$$= 2\pi \propto c \left[\frac{D_0^2}{8} - \frac{D_1^2}{8}\right]$$

$$T = \frac{\pi \propto c}{8}\left[D_0^2 - D_1^2\right]$$

Substitute the value of C from equation – (7)

$$T = \frac{\pi \propto}{4}\left[D_0^2 - D_1^2\right]\frac{Fa}{\pi\left[D_0 - D_1\right]}$$

$$T = \frac{\propto Fa}{2}\left[\frac{D_0}{2} - \frac{D_1}{}\right]$$

$$T = \frac{\propto Fa\ Dm}{2} \quad - \quad (8)$$

6

$$\text{Where } Dm = \frac{D_0 + D_1}{2} \quad - \quad (9)$$

Torque transmitted by “n” friction plates

$$T = \frac{n^1 \propto Fa\ Dm}{2}$$

Axial force Fa =

Average pressure occurs at mean radius ($r_m = D_m / 2$)

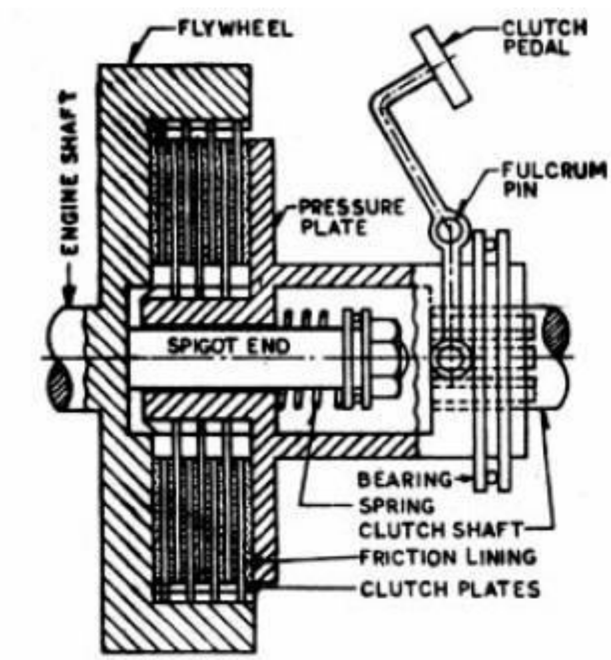
$$\therefore\ Fa = \frac{\pi b\ Dm\,(D_0 - D_1)}{2} \quad - \quad (10)$$

Maximum pressure occurs at inner radius

$$\therefore\ Fa = \frac{\pi\ p\ D_i}{2}(D_0 - D_i) \quad - \quad (11)$$

Note: The major portion of the life of friction lining comes under the uniform wear friction lining comes under the uniform wear criterion in design of clutches uniform wear theory is justified.

MULTIPLATE CLUTCH



The multi-plate clutch is an extension of single plate type where the number of frictional and the metal plates are increased. The increase in the number of friction surfaces obviously increase capacity of the clutch to transmit torque, the size remaining fixed. Alternatively, the overall diameter of the clutch is reduced for the same torque transmission as a single plate clutch. This type of clutch is, used in some heavy transport vehicles, in epicyclic gearboxes and racing cars where high torque is to be transmitted. Besides, this finds applications in case of scooters and motorcycles, where space available is limited.

Extension of flywheel is a drum; which on its inner circumference is splined to carry a number of thin metal plates. These must consequently revolve with drum but are able to slide axially. Interleaved with these outer plates are a number of inner plates that are splined to an inner drum which is coupled rotationally to the gearbox shaft.

This drum is supported on a spigot extension of crankshaft. Between the web of inner drum and sleeve in inner drum is a strong coil spring. The inner drum is thus pressed to left being provided with a flange it squeezes the inner and outer plates together so that friction between them transmits driving torque from outer to inner drum.

The clutch is disengaged by pulling inner drum right against spring force. The plates of multi-plate clutch were at one time made alternately of steel and phosphor bronze but now are all of steel or one set may be lined with a friction material. With metal contact lubrication is essential and so clutch is made oil-tight and partly filled with oil. The oil tends to make the plates drag when clutch is disengaged and so some mean should be provided to avoid this drag.

DRY MULTIPLATE CLUTCH

Multi plate clutches are also made to work dry, without any oil. The driving plates are then lined on each side with a friction fabric. In such clutches, the driving plates are sometimes carried on a number of studs screwed into the web of flywheel in the same way as the outer plate of a Single Plate Clutch is carried. This construction is inconvenient when oil is used. Several small springs can be used instead of a single spring.

AUTOMATIC CLUTCH

Many attempts have been made to produce motor vehicles that can be controlled by the accelerator pedal and brakes only. This can be done in several ways. A centrifugal clutch which automatically disengages itself when the speed falls below and which re-engages when the speed rises above some predetermined values may be used. Alternatively, a fluid coupling, fluid torque converter may be employed.

Torque transmitted by Multi Plate Clutch

Equations derived for torque transmitting velocity of single plate are modified to account for the number of pairs of contacting surfaces in the following way.

For uniform pressure $T = \frac{1}{2}\, i\, \alpha_1\, Fa\, Dm =$

$$\frac{\pi}{4}\, p\, (D_o^2 - D_i^2)$$

Uniform wear $T = (D_o^2 - D_i^2)$

Where I = number of pairs of contacting surfaces.

For uniform pressure theory

$$T = \frac{1}{2}\, i\, \alpha_1\, Fa\, Dm$$

$$D_m = \frac{2}{3}\, \frac{(D_o^3 - D_i^3)}{(D_o^2 - D_i^2)}$$

$$Fa = \frac{\pi}{4}\, p\, (D_o^2 - D_i^2)$$

Where I = number of friction surfaces

Uniform wear theory

$$T = \frac{1}{2}\, i\, \alpha_1\, Fa\, Dm$$

$$Dm = \frac{(D_o + D_i)}{2}$$

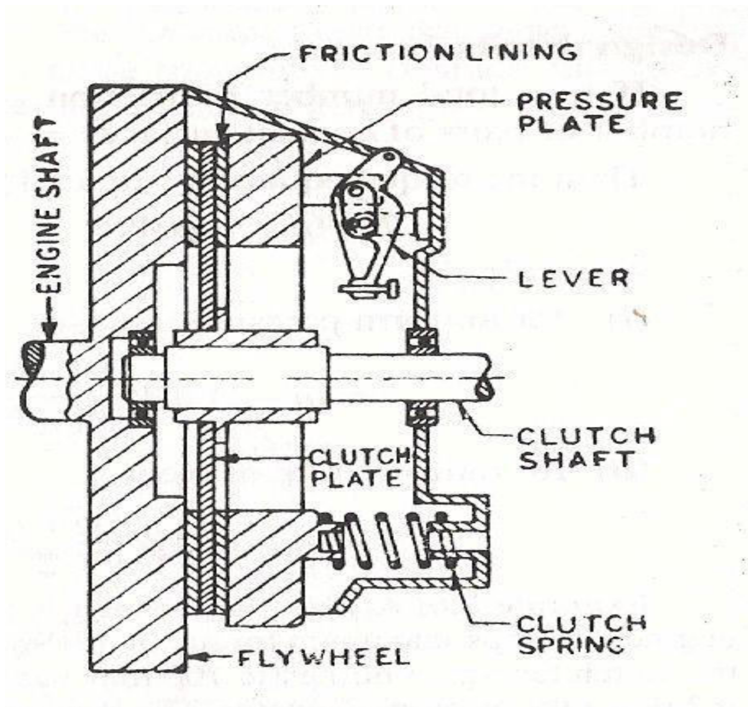
$$Fa = \frac{1}{2}\pi b\, D_m\, (D_o - D_i)$$

Maximum pressure occurs at inner radius

$$Fa = \frac{1}{2}\pi_i\, p\, D\, (D_{io} - D)$$

SEMI CENTRIFUGAL CLUTCH

It uses both centrifugal and spring force for keeping it in an engaged position. The springs are designed to transmit torque at normal speed, while centrifugal force assists in torque transmission at high speed. This clutch consists of three hinged and weighted levers and three clutch springs alternately arranged at equal spaces on the pressure plate. At low speeds the springs keep t he clutch engaged and the weighted levers do not have any pressure on pressure plate. At high speeds when power transmission is high, weights fly off and the levers also exert pressure on plate, keeping the clutch firmly engaged.



When the speed decreases the weights do not exert any pressure on the pressure plate. Only spring pressure is exerted on pressure plate which keeps the clutch engaged. An adjusting screw is provided at the end of the lever by means of which the centrifugal force on pressure plate can be adjusted. At low speeds pressure on the spring is sufficient to transmit the torque required. However at high speeds, the centrifugal force due to weight moves about the fulcrum thereby pressing the pressure plate. The centrifugal force is proportional to the square of speed so that adequate pressure level is attained.

CEN TRIFUGAL CLUTCH

In this type of clutches the springs are eliminated altogether and only the centrifugal force is used to apply the required pressure for keeping the clutch in engagement position.

The advantage of the centrifugal clutch is that no separate clutch pedal is required. The clutch is operated automatically depending upon the engine speed. This means that car can be stopped in gear without stalling the engine. Similarly while starting, the driver can first select the gear, put the car into the gear and simply press the accelerator pedal. This makes the driving operation very easy.

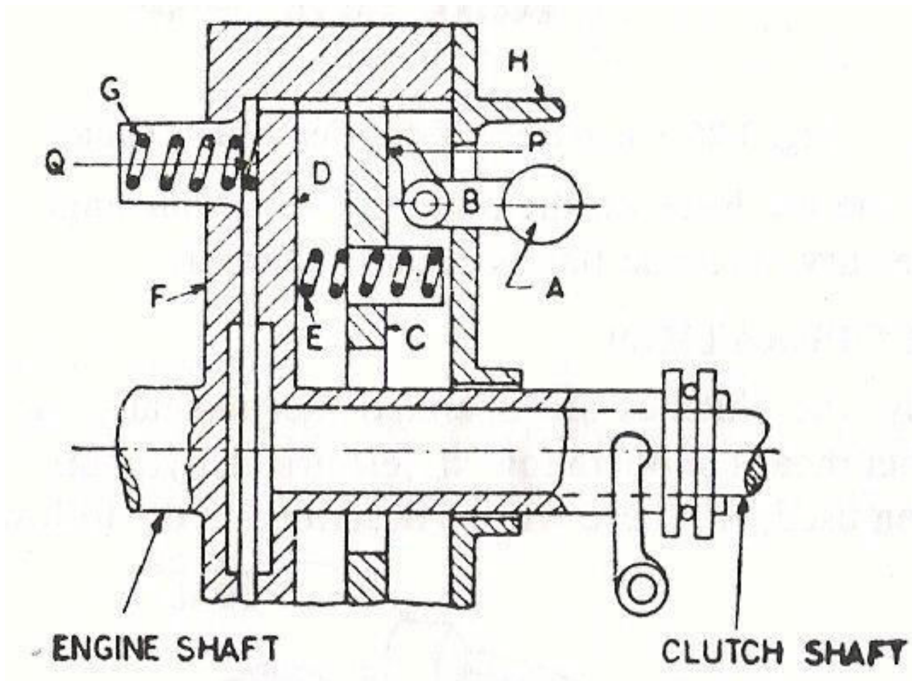


Figure shows a schematic diagram of a centrifugal clutch. As the speed increases, the weight A fly off, thereby operating the bell crank lever B that presses the plate C. This force is transmitted to the plate D by means of springs E. The plate D containing friction lining is thus pressed against the flywheel F thereby engages the clutch. Spring G serves to keep the clutch disengaged at low s peed say 500 rpm. The stop H limits the amount of centrifugal force.

The operating characteristics of this type of clutch will be then as shown in figure. Force P is proportional to the centrifugal force at a particular speed, while force Q exerted by spring G is constant at all speeds. The firm line in the figure shows that net force on the plate D for various engine speeds. At the upper end the curve is made f lat by means of stop H.

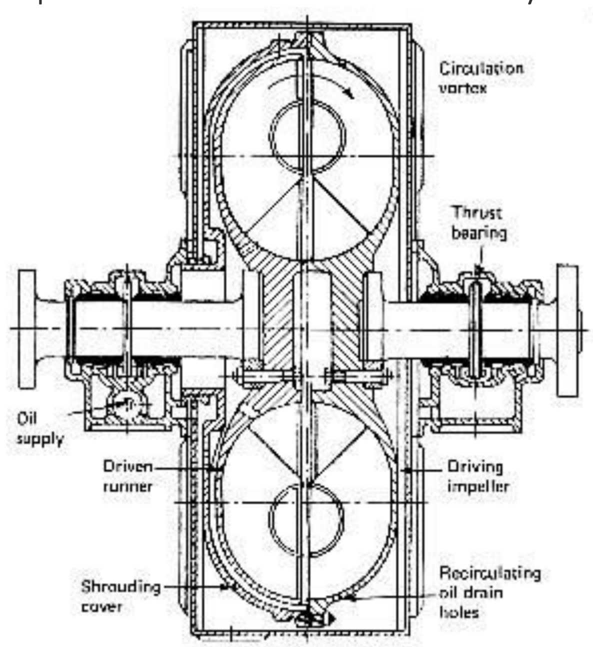
FLUID FLY WHEEL

A liquid coupling is used to transmit engine turning effort (torque) to a clutch and transmission. The coupling is always a major part of the engine flywheel assembly. As such it is sometime called a fluid flywheel.

Construction of flywheel

The fluid flywheel details can be seen in the picture. It consists of two half dough nut shaped shells equipped with interior fins. The fins radiate from the hub, and thereby form radial passages. The areas of these passages, perpendicular to their centre line, are kept constant by a suitable design. Since the circumferential width of the opening close to the hub is less than that at the periphery, the radial size of the opening, close to the hub is made greater than that at the periphery.

One of the shells is fixed to the crankshaft of the engine and the other to the clutch/gearbox shaft. The two shells are mounted very close, with their open ends facing each other, so that they can be turned independently without touching. Housing surrounds both units to make a closed assembly. About 80 percent of the interior of the assembly is filled with oil.



Working of fluid flywheel

The driving unit, called impeller, is linked to the engine crankshaft. When the engine throttle is opened, the oil in the impeller starts moving. Due to the force of the rotating, trapped oil impinges on the fins of the driven unit called runner and causes it to move. In this way, the moving liquid transmits the engine power to the clutch driving plat or to any other unit to which the runner is attached. This happens without any metal contact.

In the actual units, the runner speed becomes almost equal to that of the impeller only under the best operating conditions, when the efficiency of liquid coupling is highest. But usually the runner speed is less than that of the impeller. The (speed) lag of the runner behind the impeller is known as slip. This (speed) slip varies with many factors such as engine speed, vehicle speed and engine and vehicle load.

The slip is greatest with the vehicle at rest (ie runner stationary), and the engine throttle being opened to cause the impeller to start circulating the oil. Under these conditions, the oil moves in two general directions at the same time. It rotates at right angles to the shafts, i.e., undergoes rotary flow. The oil also circulates between the impeller and runner, i.e., undergoes vortex flow. When the rotary flow attains sufficient force and volume, it causes the movement of the runner.

The vortex flow is at right angles to the rotary flow. The vortex flow is produced by the oil trapped in the fins of the impeller. The oil flies out against the curved interior, because of centrifugal force. The centrifugal force directs the oil across to the runner, thereby returning it to the impeller in the region of the hub.

The vortex flow is maximum when the slip is 100 percent (runner stationary), and decreases as the runner speed approaches that of the impeller. This results from the centrifugal force produced by the oil in the runner, which moves out and opposes the vortex flow. At cruising speeds, there is little or no vortex flow because the centrifugal forces produced in the impeller and runner is almost equal. As such, the efficiency of coupling increases rapidly from zero at rest to nearly 99 percent at higher speeds.

The torque or turning effort delivered to the runner through the liquid is equal to the torque applied to the impeller by the engine. But the power (ie the rate at which the energy is furnished) received by the runner is always less than that furnished by the engine. The power losses in the coupling appear as heat, which is dissipated as the assembly revolves.

Advantages of fluid flywheel

An ordinary friction clutch would be damaged by prolonged slipping, with increased fuel consumption. But by prolonged slipping, the fluid flywheel will not suffer any mechanical damage although it may become so hot as to burn one’s hand if one touched it.

When a liquid coupling is used with a conventional clutch and transmission, it enables the driver to use the clutch and gears with less skill and fatigue than with an all mechanical linkage. Unskillful clutch engagement or selection of the improper gear will not produce any chattering and bucking. Any sudden load is cushioned and absorbed by the coupling so that dynamic stresses on the gear teeth of the transmission and rear (drive) axle are greatly reduced.

Liquid coupling at low speeds are not as efficient as mechanical clutch. As such it reduces engine braking when slowing down the vehicle speed, particularly during coming down a hilly track, Further, it requires higher speeds to start a vehicle by pushing or towing it.

GEARS

Why do we need gears?

Let's think about cars. A car has a whole box full of gears—**the gearbox**—sitting between the crankshaft and the driveshaft. But what do they actually do?

A car engine makes power in a fairly violent way by harnessing the energy locked in gasoline. It works efficiently only when the pistons in the cylinders are pumping up and down at high speeds—about 10-20 times a second. Even when the car is simply idling by the roadside, the pistons still need to push up and down roughly 1000 times a minute or the engine will cut out. In other words, the engine has a minimum speed at which it works best of about 1000 rpm. But that creates an immediate problem because if the engine were connected directly to the wheels, they'd have a minimum speed of 1000rpm as well—which corresponds to roughly 120km/h or 75mph. Put it another way, if you switched on the ignition in a car like this, your wheels would instantly turn at 75mph! Suppose you put your foot down until the rev counter reached 7000 rpm. Now the

wheels should be turning round about seven times faster and you'd be going at 840 km/h or about 525 mph!

It sounds wildly exciting, but there's a snag. It takes a massive amount of force to get a car moving from a standstill and an engine that tries to go at top speed, right from the word go, won't generate enough force to do it. That's why cars need gearboxes. To begin with, a car needs a huge amount of force and very little speed to get it moving, so the driver uses a low gear. In effect, the gearbox is reducing the speed of the engine greatly but increasing its force in the same proportion to get the car moving. Once the car's going, the driver switches to a higher gear. More of the engine's power switches to making speed—and the car goes faster.

Transmission Manual Gear Box

- **Gear box**
- **Introduction:-**
  - The mechanism that transmits engine four to the rear wheel (in case of rear wheel drive vehicle) or to the front wheel. (In front wheel drive vehicle) or to all the four wheel (in four wheel drive vehicles) is known as a transmission system.
  - It comprises of the following man units.

- **Function of gear box:-**
  - The gear box and its associated units perform the following function on.
  - A gear box assists in variation of torque (or tractates effort) produced by the engine in accordance with the driving conditions.
  - A large torque is required at the start of the vehicle and a low torque at higher speeds.
  - It helps in smooth running of the vehicle at different speed since variation a torque induces.

- **Types of transmission:**
- Several kinds of transmission are employed on auto vehicles. These can be4 classified as follows.

1) Manual transmission.

1) Sliding mesh gearbox.

2) Constant mesh gearbox.

3) Synchromesh gearbox.

4) Synchromesh gear box with over drive.

2) Semi- Automatic transmission.

1)Electric controlled with a avid drive.

2) Electric controlled with over drive.

3) Fluid – torque drive.

3) Automatic drive.

1) Hydromantic drive.

2) Torque converter drive.

SLIDING MESH GEAR BOX

It is the simplest and oldest type of gear box.

1. The clutch gear is rigidly fixed to the clutch shaft.

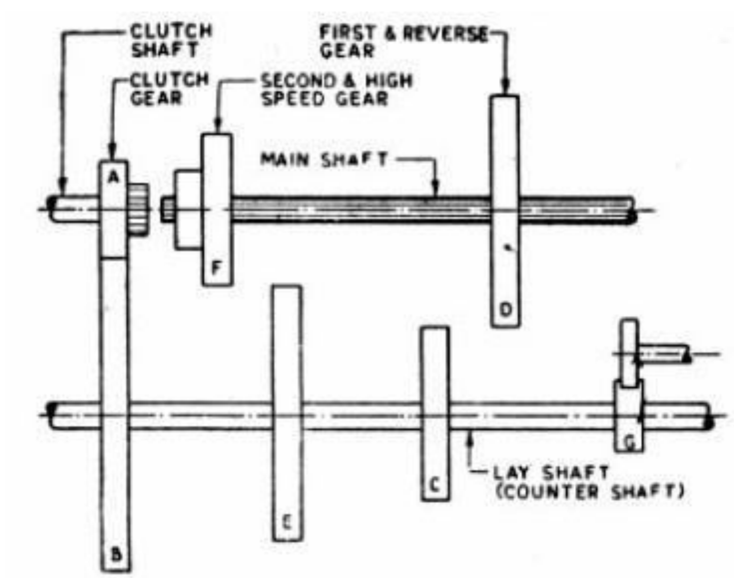
2. The clutch gear always remains connected to the drive gear of countershaft.

3. The other lay shaft gears are also rigidly fixed with it.

4. Two gears are mounted on the main shaft and can be sliding by shifter yoke when shifter is operated.

5. One gear is second speed gear and the other is the first and reverse speed gears. All gears used are spur gears.

6. A reverse idler gear is mounted on another shaft and always remains connected to reverse gear of counter shaft.



FIRST GEAR

By operating gearshift lever, the larger gear on main shaft is made to slide and mesh with first gear of countershaft. The main shaft turns in the same direction as clutch shaft in the ratio of 3:1.

SECOND GEAR

By operating gear shaft lever, the smaller gear on the main shaft is made to slide and mesh with second gear of counter shaft. A gear reduction of approximately 2:1 is obtained.

TOP GEAR

By operating gearshift lever, the combined second speed gear and top speed gear is forced axially against clutch shaft gear. External teeth on clutch gear mesh with internal teeth on top gear and the gear ratio is 1:1.

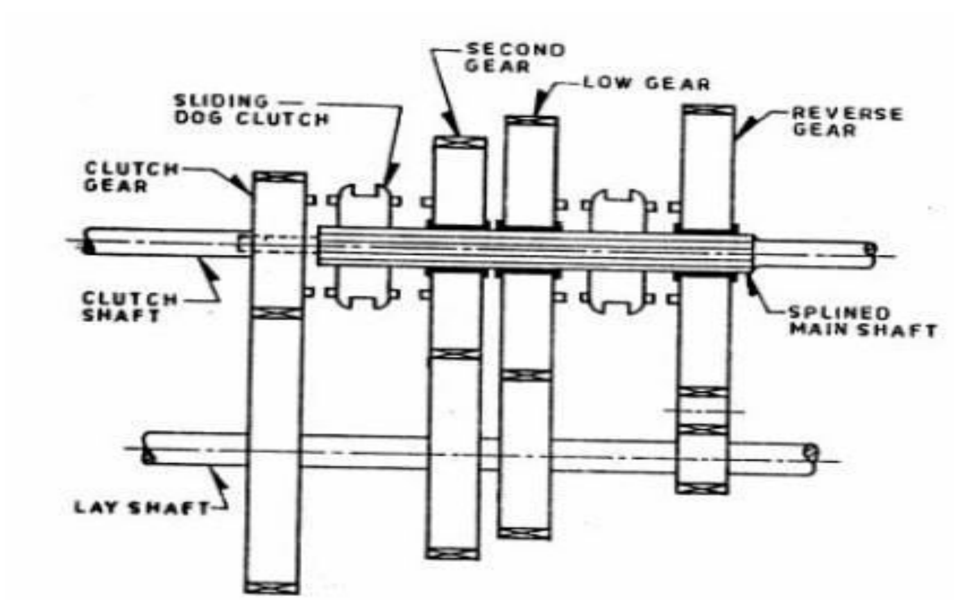
REVERSE GEAR

By operating gearshift lever, the larger gear of main shaft is meshed with reverse idler gear. The reverse idler gear is always on the mesh with counter shaft reverse gear. Interposing the idler gear, between reverse and main shaft gear, the main shaft turns in a direction opposite to clutch shaft.

NEUTRAL GEAR

When engine is running and the clutch is engaged, clutch shaft gear drives the drive gear of the lay shaft and thus lay shaft also rotates. But the main shaft remains stationary as no gears in main shaft are engaged with lay shaft gears.

CONSTANT MESH GEARBOX



In this type of gearbox, all the gears of the main shaft are in constant mesh with corresponding gears of the countershaft. The gears on the main shaft which are bushed are free to rotate. The dog clutches are provided on main shaft. The gears on the lay shaft are, however, fixed.

When the left Dog clutch is slid to the left by means of the selector mechanism, its teeth are engaged with those on the clutch gear and we get the direct gear. The same dog clutch, however, when slid to right makes contact with the second gear and second gear is obtained. Similarly movement of the right dog clutch to the left results in low gear and towards right in reverse gear. Usually the helical gears are used in constant mesh gearbox for smooth and noiseless operation.

SYNCHROMESH GEARBOX

This type of gearbox is similar to the constant mesh type gearbox. Instead of using dog clutches here synchronizers are used. The modern cars use helical gears and synchromesh devices in gearboxes, that synchronize the rotation of gears that are about to be meshed.

SYNCHRONIZERS

This type of gearbox is similar to the constant mesh type in that all the gears on the main shaft are in constant mesh with the corresponding gears on the lay shaft. The gears on the lay shaft are fixed to it while those on the main shaft are free to rotate on the same. Its working is also similar to the constant mesh type, but in the former there is one definite improvement over the latter. This is the provision of synchromesh device which avoids the necessity of double-declutching. The parts that ultimately are to be engaged are first brought into frictional contact, which equalizes their speed, after which these may be engaged smoothly.

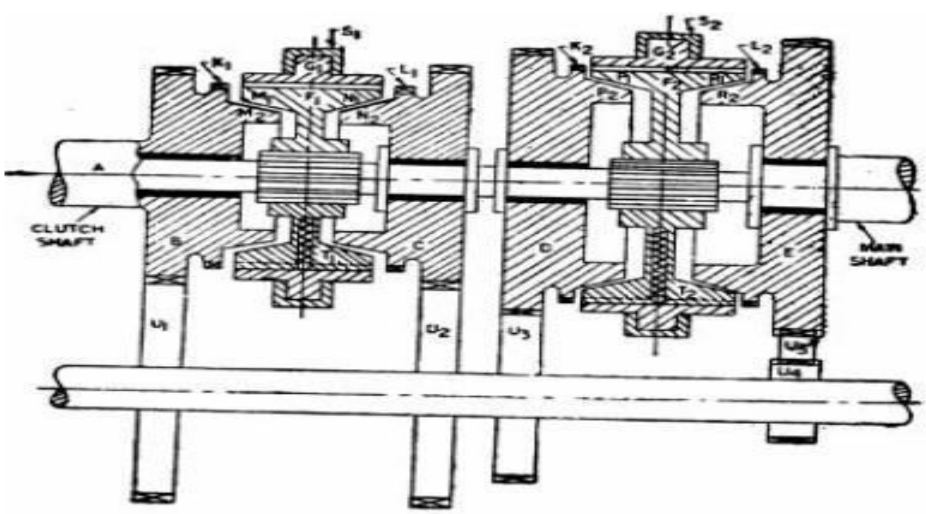
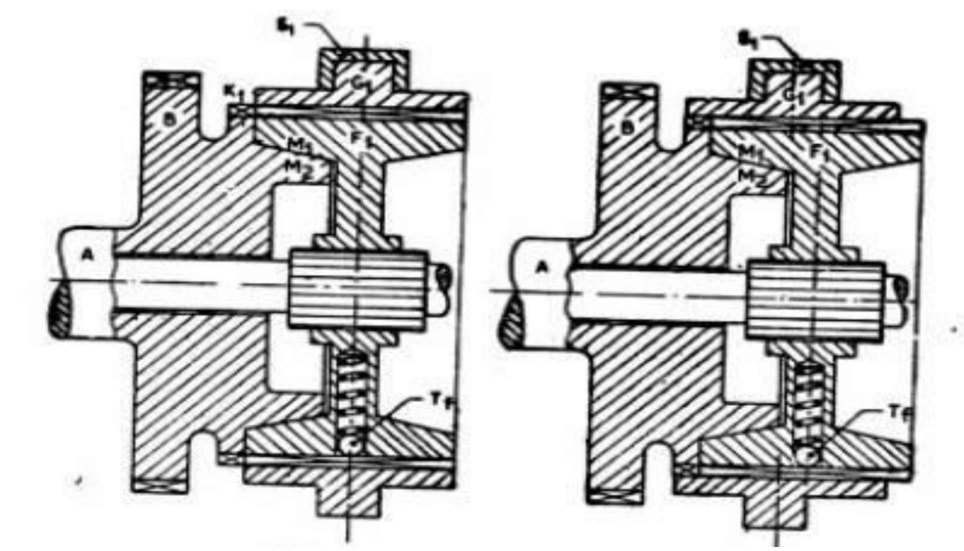


Figure shows the construction and working of a synchromesh gearbox. In most of the cars, however, the synchromesh devices are not fitted to all the gears as is shown in this figure. They are fitted only on the high gears and on the low and reverse gears ordinary dog clutches are only provided. This is done to reduce the cost. In figure A is the engine is the engine shaft, Gears B, C, D, E are free on the main shaft and are always in mesh with corresponding gears on the lay shaft. Thus all the gears on main shaft as well as on lay shaft continue to rotate so long as shaft A is rotating. Members F1 and F2 are free to slide on splines on the main shaft. G1 and G2 are ring shaped members having internal teeth fit onto the external teeth members F1 and F2 respectively. K1 and K2 are dogteeth on B and D respectively and these also fit onto the teeth of G1 and G2. S1 and S2 are the forks. T1 and T2 are the balls supported by spring. These tend to prevent the sliding of members G1 (G2) on F1 (F2). However when the force applied on G1 (G2) slides over F1 (F2). These are usually six of these balls symmetrically placed circumferentially in one synchromesh device. M1, M2, N1, N2, P1, P2, R1, R2 are the frictional surfaces.



To understand the working of this gearbox, consider figure which shows in steps how the gears are engaged. For direct gear, member G1 and hence member F1 (through spring- loaded balls) is slid towards left till cones M1 and M2 rub and friction makes their speed equal. Further pushing the member G1 to left causes it to overdrive the balls and get engaged with dogs K1. Now the drive to the main shaft is direct from B via F1 and the splines. However, if member G1 is pushed too quickly so that there is not sufficient time for synchronization of speeds, a clash may result. Likewise defect will arise in case springs supporting the balls T1 have become weak. Similarly for second gear the members F1 and G1 are slid to the right so that finally the internal teeth on G1 are engaged with L1. Then the drive to main shaft will be from B via U1, U2, C, F1 and splines. For first gear, G2 and F2 are moved towards left. The drive will be from B via U1, U2, D, F2 and splines to the main shaft. For reverse gear, G2 and F2 are slid towards right. In this case the drive will be from B via U1, U2, U5, E, F2 and splines to the main shaft.

A synchro's purpose is to allow the collar and the gear to make frictional contact before the dog teeth make contact. This lets the collar and the gear synchronizes their speeds before the teeth need to engage, like this: The cone on the blue gear fits into the cone-shaped area in the collar, and friction between the cone and the collar synchronize the collar and the gear. The outer portion of the collar then slides so that the dog teeth can engage the gear.

AUTOMATIC TRANSMISSION SYSTEM

There are broadly of two types, *viz* The semi automatic and Fully automatic ones. In the first type only the clutch is operated automatically, the driver still has to select the gears. In the later type which is employed in modern are, even the gears are changed automatically by a control mechanism which is actuated by the accelerator pedal only. In the cars with fully automatic transmission, there are only two pedals, *viz.,* for braking and for accelerating. In addition there is a selector lever.

The present days automatic transmission consists of multi plate clutches, torque converters, and epicyclic gear box

Automatic transmissions operate basically by controlling vehicle speed and engine load. Increasing vehicle speed needs changing gears upwards, whereas increasing engine load necessitate change from higher to lower gears

EPICYCLIC GEAR BOX

An **epicyclic gear train** consists of two gears mounted so that the center of one gear revolves around the center of the other. A carrier connects the centers of the two gears and rotates to carry one gear, called the *planet gear*, around the other, called the *sun gear*. The planet and sun gears mesh so that their pitch circles roll without slip. A point on the pitch circle of the planet gear traces an epicycloid curve. In this simplified case, the sun gear is fixed and the planetary gear(s) roll around the sun gear.

An epicyclic gear train can be assembled so the planet gear rolls on the inside of the pitch circle of a fixed, outer gear ring, or ring gear, sometimes called an annular gear. In this case, the curve traced by a point on the pitch circle of the planet is an hypocycloid.

The combination of epicycle gear trains with a planet engaging both a sun gear and a ring gear is called a planetary gear train. In this case, the ring gear is usually fixed and the sun gear is driven.

We have already discussed that in an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train is shown in Fig. 13.6, where a gear A and the arm C have a common axis at O1 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at O2, about which the gear B can rotate. If the arm is fixed, the gear train is simple and gear A can drive gear B or vice- versa, but if gear A is fixed and the arm is rotated about the axis of gear A (i.e. O1), then the gear B is forced to rotate upon and around gear A. Such a motion is called epicyclic and the gear trains arranged in such a manner that one or more of their members move upon and around another member is known as epicyclic gear trains (epi. means upon and cyclic means around). The epicyclic gear trains may be simple or compound. The epicyclic gear trains are useful for transmitting high velocity ratios with gears of moderate size in a comparatively lesser space. The epicyclic gear trains are used in the back gear of lathe, differential gears of the automobiles, hoists, pulley blocks, wrist watches etc.

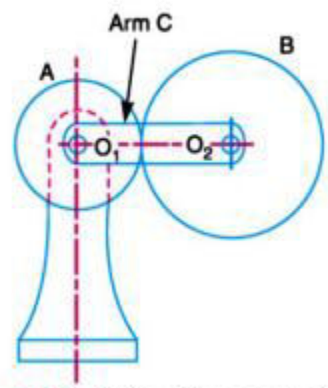


Fig. 13.6. Epicyclic gear train.

VELOCITY RATIOS OF EPICYCLIC GEAR TRAIN:

The following two methods may be used for finding out the velocity ratio of an epicyclic gear train. 1. Tabular method, and 2. Algebraic method.

These methods are discussed, in detail, as follows:

1. Tabular method. Consider an epicyclic gear train as shown in Fig. 13.6. Let TA = Number of teeth on gear A, and TB = Number of teeth on gear B.

First of all, let us suppose that the arm is fixed. Therefore the axes of both the gears are also fixed relative to each other. When the gear A makes one revolution anticlockwise, the gear B will make TA / TB revolutions, clockwise. Assuming the anticlockwise rotation as positive and clockwise as negative, we may say that when gear A makes + 1 revolution, then the gear B will make (– TA / TB) revolutions. This statement of relative motion is entered in the first row of the table (see Table 13.1).Secondly, if the gear A makes + x revolutions, then the gear B will make (– x × TA / TB) revolutions. This statement is entered in the second row of the table. In other words, multiply the each motion (entered in the first row) by x. Thirdly, each element of an epicyclic train is given + y revolutions and entered in the third row. Finally, the motion of each element of the gear train is added up and entered in the fourth row

Table 13.1. Table of motions.

		Revolutions of elements		
Step No.	*Conditions of motion*	*Arm C*	*Gear A*	*Gear B*
1.	*Arm fixed-gear A rotates through + 1 revolution i.e. 1 rev. anticlockwise*	*0*	*+1*	$-\frac{T_A}{T_B}$
2.	*Arm fixed-gear A rotates through + x revolutions*	*0*	*+x*	$-x\frac{T_A}{T_B}$
3.	*Add + y revolutions to all elements*	$+y$	$+y$	$+y$
4.	*Total motion*	$+y$	$+x+y$	$y-x\frac{T_A}{T_B}$

Compound Epicyclic Gear Train—Sun and Planet Gear:

A compound epicyclic gear train is shown in Fig. 13.9. It consists of two co-axial shafts S1 and S2, an annulus gear A which is fixed, the compound gear (or planet gear) B-C, the sun gear D and the arm H. The annulus gear has internal teeth and the compound gear is carried by the arm and revolves freely on a pin of the arm H. The sun gear is co-axial with the annulus gear and the arm but independent of them. The annulus gear A meshes with the gear B and the sun gear D meshes with the gear C. It may be noted that when the annulus gear is fixed, the sun gear provides the drive and when the sun gear is fixed, the annulus gear provides the drive. In both cases, the arm acts as a follower.

Note: The gear at the centre is called the sun gear and the gears whose axes move are called planet gears.

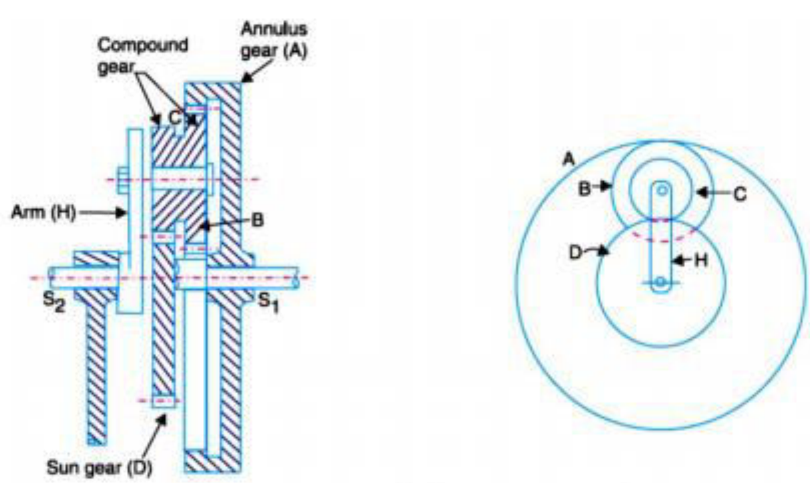


Fig. 13.9. Compound epicyclic gear train.

Let T_A, T_B, T_C, and T_D be the teeth and N_A, N_B, N_C and N_D be the speeds for the gears *A*, *B*, *C* and *D* respectively. A little consideration will show that when the arm is fixed and the sun gear *D* is turned anticlockwise, then the compound gear *B-C* and the annulus gear A will rotate in the clockwise direction. The motions of rotations of the various elements are shown in the table below. ***Revolutions of elements***

Step No.	*Conditions of motion*	*Arm*	*Gear D*	*Compound gear B-C*	*Gear A*
1.	*Arm fixed-gear D rotates through + 1 revolution*	*0*	*+1*	$-\frac{T_D}{T_C}$	$-\frac{T_D}{T_C} \times \frac{T_B}{T_A}$
2.	*Arm fixed-gear D rotates through + x revolutions*	*0*	*+x*	$-x\frac{T_D}{T_C}$	$-x\frac{T_D}{T_C} \times \frac{T_B}{T_A}$
3.	*Add + y revolutions to all elements*	$+y$	$+y$	$+y$	$+y$
4.	*Total motion*	$+y$	*+x+y*	$y - x\frac{T_D}{T_C}$	$y - x\frac{T_D}{T_C} \times \frac{T_B}{T_A}$

Note: If the annulus gear A is rotated through one revolution anticlockwise with the arm fixed, then the compound gear rotates through (T_A / T_B) revolutions in the same sense and the sun gear D rotates through (T_A / T_B)× (T_C / T_D) revolutions in clockwise direction.

Epicyclic Gear Train with Bevel Gears:

The bevel gears are used to make a more compact epicyclic system and they permit a very high speed reduction with few gears. The useful application of the epicyclic gear train with bevel gears is found in Humpage's speed reduction gear and differential gear of an automobile as discussed below :

1. ***Humpage's speed reduction gear*****.** The Humpage's speed reduction gear was originally designed as a substitute for back gearing of a lathe, but its use is now considerably extended to all kinds of workshop machines and also in electrical machinery. In Humpage's speed reduction gear, as shown in Fig. 13.20, the driving shaft *X* and the driven shaft *Y* are co-axial. The driving shaft carries a bevel gear *A* and driven shaft carries a bevel gear *E*. The bevel gear *B* meshes with gear *A* (also known as pinion) and a fixed gear *C*. The gear *E* meshes with gear *D* which is compound with gear *B*. This compound gear *B-D* is mounted on the arm or spindle *F* which is rigidly connected with a hollow sleeve *G*. The sleeve revolves freely loose on the axes of the driving and driven shafts.

2. ***Differential gear of an automobile*****.** The differential gear used in the rear drive of an automobile is shown in Fig. 13.21. Its function is

(*a*) to transmit motion from the engine shaft to the rear driving wheels, and

(*b*) to rotate the rear wheels at different speeds while the automobile is taking a turn.

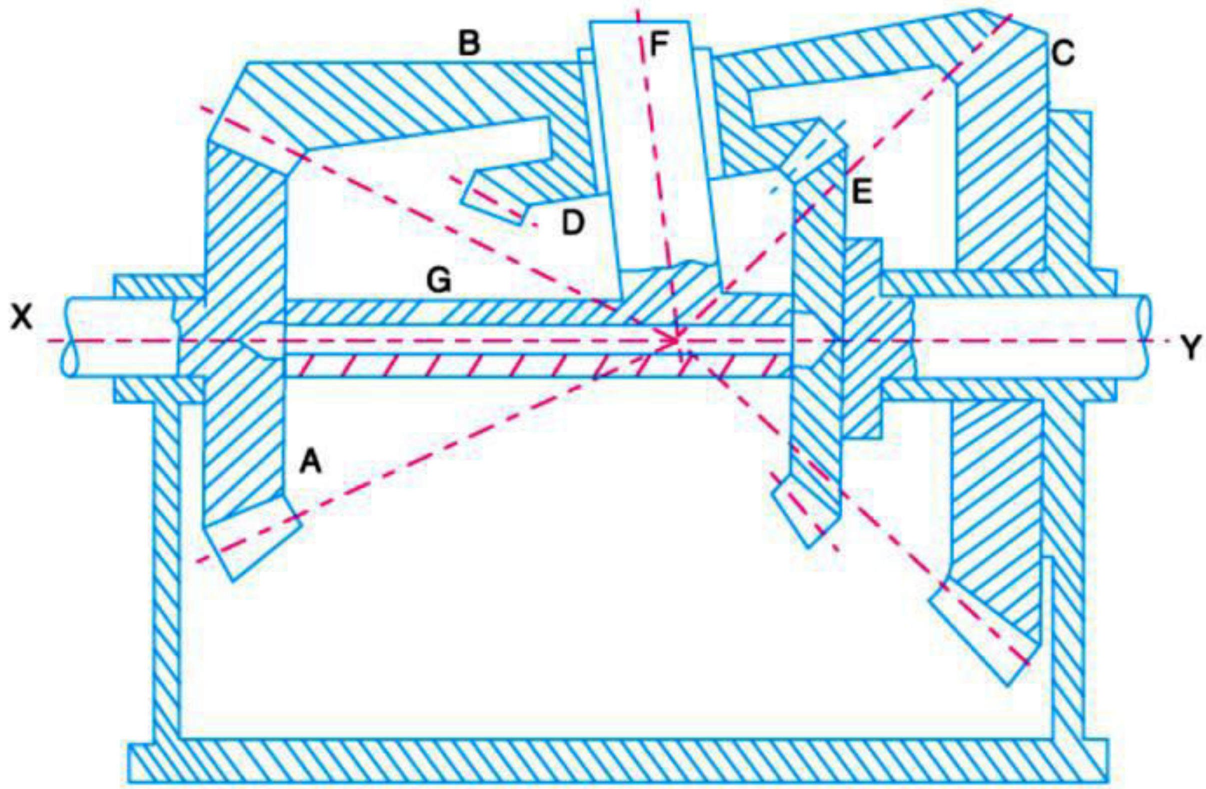
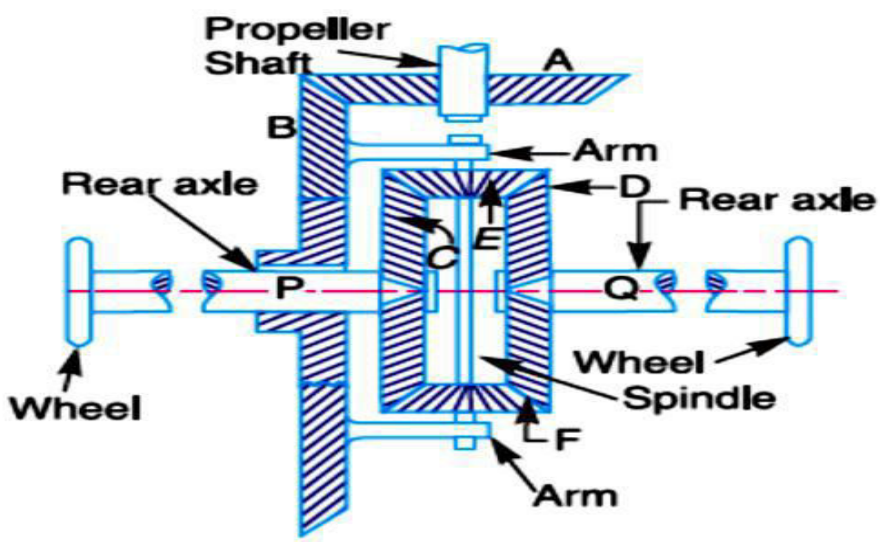


Fig. 13.20. Humpage's speed reduction gear.

As long as the automobile is running on a straight path, the rear wheels are driven directly by the engine and speed of both the wheels is same. But when the automobile is taking a turn, the outer wheel will run faster than the inner wheel because at that time the outer rear wheel has to cover more distance than the inner rear wheel. This is achieved by epicyclic gear train with bevel gears as shown in Fig. 13.21.



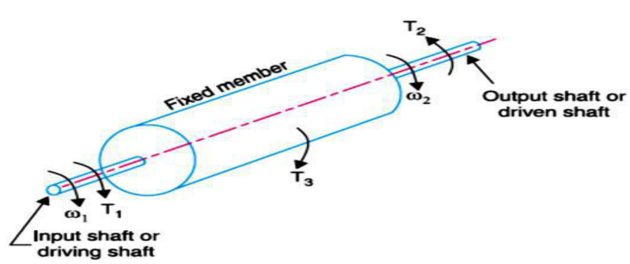
The bevel gear *A* (known as pinion) is keyed to the propeller shaft driven from the engine shaft through universal coupling. This gear *A* drives the gear *B* (known as crown gear) which rotates freely on the axle *P*. Two equal gears *C* and *D* are mounted on two separate parts *P* and *Q* of the rear axles respectively. These gears, in turn, mesh with equal pinions *E* and *F* which can rotate freely on the spindle provided on the arm attached to gear *B*.
When the automobile runs on a straight path, the gears *C* and *D* must rotate together. These gears are rotated through the spindle on the gear *B*. The gears *E* and *F* do not rotate on the spindle. But when the automobile is taking a turn, the inner rear wheel should have lesser speed than the outer rear wheel and due to relative speed of the inner and outer gears *D* and *C*, the gears *E* and *F* start rotating about the spindle axis and at the same time revolve about the axle axis.

Due to this epicyclic effect, the speed of the inner rear wheel decreases by a certain amount and the speed of the outer rear wheel increases, by the same amount. This may be well understood by drawing the table of motions as follows:

		Revolutions of elements			
Step No.	*Conditions of motion*	*Arm B*	*Gear C*	*Gear E*	*Gear D*
1.	*Gear B fixed-Gear C rotated through +1 revolution (i.e. 1 revolution anticlockwise)*	*0*	*+1*	$+\frac{T_C}{T_E}$	$-\frac{T_C}{T_E}\times\frac{T_E}{T_D}=-1$ $T_C=T_D$
2.	*Gear B fixed-Gear C rotated through +x revolutions*	*0*	*+x*	$+x\frac{T_C}{T_E}$	*-x*
3.	*Add +y revolutions to all elements*	*+y*	*+y*	*+y*	*+y*
4.	*Total motion*	*+y*	*+x+y*	$y+x\frac{T_C}{T_E}$	*-x+y*

From the table, we see that when the gear *B*, which derives motion from the engine shaft, rotates at *y* revolutions, then the speed of inner gear *D* (or the rear axle *Q*) is less than *y* by *x* revolutions and the speed of the outer gear *C* (or the rear axle *P*) is greater than *y* by *x* revolutions. In other words, the two parts of the rear axle and thus the two wheels rotate at two different speeds. We also see from the table that the speed of gear *B* is the mean of speeds of the gears *C* and *D*.

Torques in Epicyclic Gear Trains:



When the rotating parts of an epicyclic gear train, as shown in Fig. 13.25, have no angular acceleration, the gear train is kept in equilibrium by the three externally applied torques, *viz*.

1. Input torque on the driving member (T_1),

2. Output torque or resisting or load torque on the driven member (T_2),

3. Holding or braking or fixing torque on the fixed member (T_3).

The net torque applied to the gear train must be zero. In other words,

$T_1 + T_2 + T_3 = 0$ ...(***i***)

$F_1.r_1 + F_2.r_2 + F_3.r_3 = 0$ ...(***ii***)

where F_1, F_2 and F_3 are the corresponding externally applied forces at radii r_1, r_2 and r_3.

Further, if ω_1, ω_2 and ω_3 are the angular speeds of the driving, driven and fixed members respectively, and the friction be neglected, then the net kinetic energy dissipated by the gear train must be zero, *i.e*.

$T_1.\ \omega_1 + T_2.\ \omega_2 + T_3.\ \omega_3 = 0$ ...(***iii***)

But, for a fixed member, $\omega_3 = 0$

$$\therefore\ T_1.\ \omega_1 + T_2.\ \omega_2 = 0 \qquad \text{...}(iv)$$

***Notes: 1.** From equations (i) and (iv), the holding or braking torque T3 may be obtained as follows:*

$$T_2 = T_1 \times \frac{\omega_1}{\omega_2} \qquad \text{...[From equation (iv)]}$$

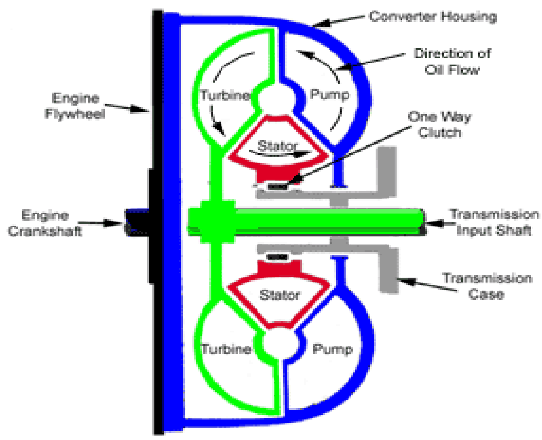
and $\quad T_3 = -(T_1 + T_2) \qquad$ *...[From equation (i)]*

$$T_3 = T_1\left(\frac{\omega_1}{\omega_2} - 1\right) = T_1\left(\frac{N_1}{N_2} - 1\right)$$

TORQUE CONVERTER

In modern usage, a **torque converter** is generally a type of fluid coupling that is used to transfer rotating power from a prime mover, such as an internal combustion engine or electric motor, to a rotating driven load. The torque converter normally takes the place of a mechanical clutch in a vehicle with an automatic transmission, allowing the load to be separated from the power source. It is usually located between the engine's flex plate and the transmission.

The key characteristic of a torque converter is its ability to multiply torque when there is a substantial difference between input and output rotational speed, thus providing the equivalent of a reduction gear. Some of these devices are also equipped with a temporary locking mechanism which rigidly binds the engine to the transmission when their speeds are nearly equal, to avoid slippage and a resulting loss of efficiency



The torque converter connects and transfers power from the engine's crankshaft to the transmission input shaft. It can act as a clutch to stop this power flow when the vehicle stops. The converter can also multiply torque to improve vehicle performance

Torque converter elements

A fluid coupling is a two element drive that is incapable of multiplying torque, while a torque converter has at least one extra element—the stator—which alters the drive's characteristics during periods of high slippage, producing an increase in output torque.

In a torque converter there are at least three rotating elements: the impeller, which is mechanically driven by the prime mover; the turbine, which drives the load; and the stator, which is interposed between the impeller and turbine so that it can alter oil flow returning from the turbine to the impeller. The classic torque converter design dictates that the stator be prevented from rotating under any condition, hence the term *stator*. In practice, however, the stator is mounted on an overrunning clutch, which prevents the stator from counter-rotating with respect to the prime mover but allows forward rotation.

Modifications to the basic three element design have been periodically incorporated, especially in applications where higher than normal torque multiplication is required. Most commonly, these have taken the form of multiple turbines and stators, each set being designed to produce differing amounts of torque multiplication. For example, the Buick Dynaflow automatic transmission was a non-shifting design and, under normal conditions, relied solely upon the converter to multiply torque. The Dynaflow used a five element converter to produce the wide range of torque multiplication needed to propel a heavy vehicle.

Although not strictly a part of classic torque converter design, many automotive converters include a lock-up clutch to improve cruising power transmission efficiency and reduce heat. The application of the clutch locks the turbine to the impeller, causing all power transmission to be mechanical, thus eliminating losses associated with fluid drive.

Operational phases

A torque converter has three stages of operation:

- **Stall**. The prime mover is applying power to the impeller but the turbine cannot rotate. For example, in an automobile, this stage of operation would occur when the driver has placed the transmission in gear but is preventing the vehicle from moving by continuing to apply the brakes. At stall, the torque converter can produce maximum torque multiplication if sufficient input power is applied (the resulting multiplication is called the *stall ratio*). The stall phase actually lasts for a brief period when the load (e.g., vehicle) initially starts to move, as there will be a very large difference between pump and turbine speed.
- **Acceleration**. The load is accelerating but there still is a relatively large difference between impeller and turbine speed. Under this condition, the converter will produce torque multiplication that is less than what could be achieved under stall conditions. The amount of multiplication will depend upon the actual difference between pump and turbine speed, as well as various other design factors.
- **Coupling**. The turbine has reached approximately 90 percent of the speed of the impeller. Torque multiplication has essentially ceased and the torque converter is behaving in a manner similar to a simple fluid coupling. In modern automotive applications, it is usually at this stage of operation where the lock-up clutch is applied, a procedure that tends to improve fuel efficiency.

The key to the torque converter's ability to multiply torque lies in the stator. In the classic fluid coupling design, periods of high slippage cause the fluid flow returning from the turbine to the impeller to oppose the direction of impeller rotation, leading to a significant loss of efficiency and the generation of considerable waste heat. Under the same condition in a torque converter, the returning fluid will be redirected by the stator so that it aids the rotation of the impeller, instead of impeding it. The result is that much of the energy in the returning fluid is recovered and added to the energy being applied to the impeller by the prime mover. This action causes a substantial increase in the mass of fluid being directed to the turbine, producing an increase in output torque. Since the returning fluid is initially traveling in a direction opposite to impeller rotation, the stator will likewise attempt to counter-rotate as it forces the fluid to change direction, an effect that is prevented by the one-way stator clutch.

Unlike the radially straight blades used in a plain fluid coupling, a torque converter's turbine and stator use angled and curved blades. The blade shape of the stator is what alters the path of the fluid, forcing it to coincide with the impeller rotation. The matching curve of the turbine blades helps to correctly direct the returning fluid to the stator so the latter can do its job. The shape of the blades is important as minor variations can result in significant changes to the converter's performance.

During the stall and acceleration phases, in which torque multiplication occurs, the stator remains stationary due to the action of its one-way clutch. However, as the torque converter approaches the coupling phase, the energy and volume of the fluid returning from the turbine will gradually decrease, causing pressure on the stator to likewise decrease. Once in the coupling phase, the returning fluid will reverse direction and now rotate in the direction of the impeller and turbine, an effect which will attempt to forward-rotate the stator. At this point, the stator clutch will release and the impeller, turbine and stator will all (more or less) turn as a unit.

Unavoidably, some of the fluid's kinetic energy will be lost due to friction and turbulence, causing the converter to generate waste heat (dissipated in many applications by water cooling). This effect, often referred to as pumping loss, will be most pronounced at or near stall conditions. In modern designs, the blade geometry minimizes oil velocity at low impeller speeds, which allows the turbine to be stalled for long periods with little danger of overheating.

Efficiency and torque multiplication

A torque converter cannot achieve 100 percent coupling efficiency. The classic three element torque converter has an efficiency curve that resembles ∩: zero efficiency at stall, generally increasing efficiency during the acceleration phase and low efficiency in the coupling phase. The loss of efficiency as the converter enters the coupling phase is a result of the turbulence and fluid flow interference generated by the stator, and as previously mentioned, is commonly overcome by mounting the stator on a one-way clutch.

Even with the benefit of the one-way stator clutch, a converter cannot achieve the same level of efficiency in the coupling phase as an equivalently sized fluid coupling. Some loss is due to the presence of the stator (even though rotating as part of the assembly), as it always generates some power-absorbing turbulence. Most of the loss, however, is caused by the curved and angled turbine blades, which do not absorb kinetic energy from the fluid mass as well as radially straight blades. Since the turbine blade geometry is a crucial factor in the converter's ability to multiply torque, trade-offs between torque multiplication and coupling efficiency are inevitable. In automotive applications, where steady improvements in fuel economy have been mandated by market forces and government edict, the nearly universal use of a lock-up clutch has helped to eliminate the converter from the efficiency equation during cruising operation.

The maximum amount of torque multiplication produced by a converter is highly dependent on the size and geometry of the turbine and stator blades, and is generated only when the converter is at or near the stall phase of operation. Typical stall torque multiplication ratios range from 1.8:1 to 2.5:1 for most automotive applications (although multi-element designs as used in the Buick Dynaflow and Chevrolet Turboglide could produce more). Specialized converters designed for industrial, rail, or heavy marine power transmission systems are capable of as much as 5.0:1 multiplication. Generally speaking, there is a trade-off between maximum torque multiplication and efficiency—high stall ratio converters tend to be relatively inefficient below the coupling speed, whereas low stall ratio converters tend to provide less possible torque multiplication.

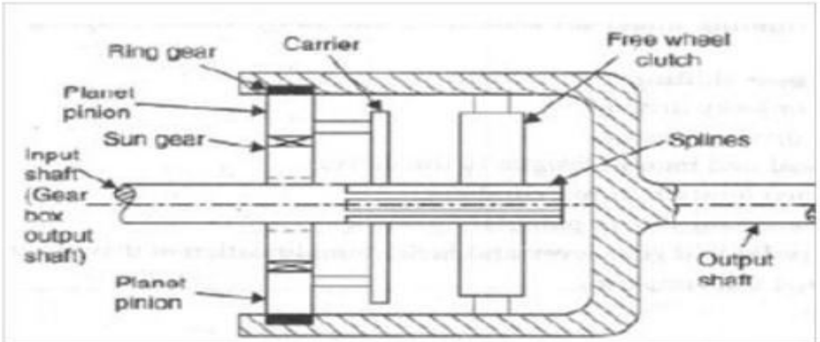
The characteristics of the torque converter must be carefully matched to the torque curve of the power source and the intended application. Changing the blade geometry of the stator and/or turbine will change the torque-stall characteristics, as well as the overall efficiency of the unit. For example, drag racing automatic transmissions often use converters modified to produce high stall speeds to improve off-the-line torque, and to get into the power band of the engine more quickly. Highway vehicles generally use lower stall torque converters to limit heat production, and provide a more firm feeling to the vehicle's characteristics.

A design feature once found in some General Motors automatic transmissions was the variable-pitch stator, in which the blades' angle of attack could be varied in response to changes in engine speed and load. The effect of this was to vary the amount of torque multiplication produced by the converter. At the normal angle of attack, the stator caused the converter to produce a moderate amount of multiplication but with a higher level of efficiency. If the driver abruptly opened the throttle, a valve would switch the stator pitch to a different angle of attack, increasing torque multiplication at the expense of efficiency.

Some torque converters use multiple stators and/or multiple turbines to provide a wider range of torque multiplication. Such multiple-element converters are more common in industrial environments than in automotive transmissions, but automotive applications such as Buick's Triple Turbine Dynaflow and Chevrolet's Turboglid also existed. The Buick Dyna flow utilized the torque-multiplying characteristics of its planetary gear set in conjunction with the torque converter for low gear and bypassed the first turbine, using only the second turbine as vehicle speed increased. The unavoidable trade-off with this arrangement was low efficiency and eventually these transmissions were discontinued in favor of the more efficient three speed units with a conventional three element torque converter.

OVER DRIVE

Overdrive is a term used to describe the operation of an automobile cruising at sustained speed with reduced engine revolutions per minute (RPM), leading to better fuel consumption, lower noise and lower wear. Use of the term is confused, as it is applied to several different, but related, meanings.



The most fundamental meaning is that of an overall gear ratio between engine and wheels, such that the car is *over-geared*, and cannot reach its potential top speed, i.e. the car could travel faster if it were in a lower gear, with the engine turning at higher RPM.

The purpose of such a gear may not be immediately obvious. The power produced by an engine increases with the engine's RPM to a maximum, then falls away. The point of maximum power is somewhat lower than the absolute maximum RPM to which the engine is limited, the "redline" RPM. A car's speed is limited by the power required to drive it against air resistance, which increases with speed. At the maximum possible speed, the engine is running at its point of maximum power, or *power peak*, and the car is traveling at the speed where air resistance equals that maximum power. There is therefore one specific gear ratio at which the car can achieve its maximum speed: the one that matches that engine speed with that travel speed.[1] At travel speeds below this maximum, there is a range of gear ratios that can match engine power to air resistance, and the most fuel efficient is the one that results in the lowest engine speed. Therefore, a car needs one gearing to reach maximum speed but another to reach maximum fuel efficiency at a lower speed.

With the early development of cars and the almost universal rear-wheel drive layout, the final drive (i.e. rear axle) ratio for fast cars was chosen to give the ratio for maximum speed. The gearbox was designed so that, for efficiency, the fastest ratio would be a "direct-drive" or "straight-through" 1:1 ratio, avoiding frictional losses in the gears. Achieving an overdriven ratio for cruising thus required a gearbox ratio even higher than this, i.e. the gearbox output shaft rotating *faster* than the engine. The propeller shaft linking gearbox and rear axle is thus overdriven, and a transmission capable of doing this became termed an "overdrive" transmission.

The device for achieving an overdrive transmission was usually a small separate gearbox, attached to the rear of the main gearbox and controlled by its own shift lever.[1] These were often optional on some models of the same car.

As popular cars became faster relative to legal limits and fuel costs became more important, particularly after the 1973 oil crisis, the use of 5-speed gearboxes became more common in mass-market cars. These had a direct (1:1) fourth gear with an overdrive 5th gear, replacing the need for the separate overdrive gearbox.

With the popularity of front wheel drive cars, the separate gearbox and final drive have merged into a single transaxle. There is no longer a propeller shaft and so one meaning of "overdrive" can no longer be applied. However the fundamental meaning, that of an overall ratio higher than the ratio for maximum speed, still applies. Although the deliberate labelling of an overdrive is now rare, the underlying feature is now found across all cars.

PROPELLER SHAFT

1. This is the shaft which transmits the drive from the gear box to the bevel pinion or worm of final drive in front engine rear drive vehicle.
2. Also called drive shaft
3. It consists of three parts.

1) Shaft: As this has to withstand mainly torsional loads, it is usually made of tubular cross section

2) One or two universal joints, depending upon the type of the rear axle drive used. The universal joints act for the up and down movements of rear axle when the vehicle is running.

3) Slip joint -Depending upon the type of drive one slip joint may be there in the shaft. This serves to adjust the length of the propeller shaft when demanded by the rear axle movement.

4. Fig shows a propeller shaft with two universal joints at end and a slip or sliding joint, Slip joint is formed by the internal splines on the sleeve attached to the left universal joint and external splines on the propeller as shown.

FIG. 1—PROPELLER SHAFT ASSEMBLY

5. In vehicles with large wheel base, the long propeller shaft would tend to sag and whirl.
6 Whirl is like the action of a rope that is in an arc while held at both ends.
7At certain speed the whirling becomes critical and the shaft vibrates violently. This also sets up sympathetic resonant vibrations in the vehicle body.

UNIVERSAL JOINT

1 A universal joint is a particular type of connection between two shafts, whose axes are inclined to each other.
2 The most simple type of universal joint is Hookes's joint

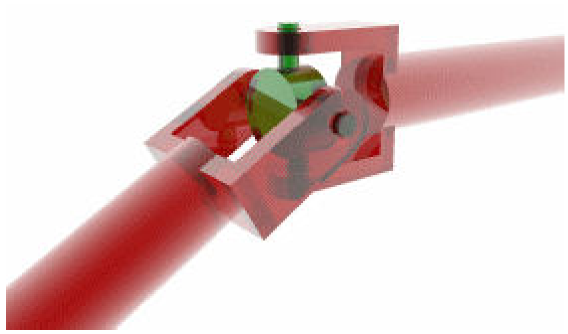
3 An universal joint is used where two shafts are connected at to transmit torque

Hooke's joint

1 **Hooke's joint** is a joint in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft.

2 Hooke's joint is most widely used because of the fact that it is simple and compact in construction.

3 Reasonably efficient at small angles of propeller shaft movement up and down (say up to 18 degree)



Construction and working

1. The axes of shafts (say A and B) Intersects with each other. Each of these shafts contain a yoke.

2. The cross C has four arms. The two opposite arms of the cross are supported in bushes in the yoke of shaft A , while the other two arms of the cross are supported in yoke of shaft B. thus shaft A will have angular rotation about axis XX and shaft B about axis YY.

3 Thus it is possible for shafts A and B to have positive drive while allowing angular movement between them.

Defect

1The universal joints have one defect in common.

2 In all these joints the speed of driven shaft does not remain uniform. Depending upon the angle of inclination of shafts , the driven shaft speed undergoes cyclic variation.

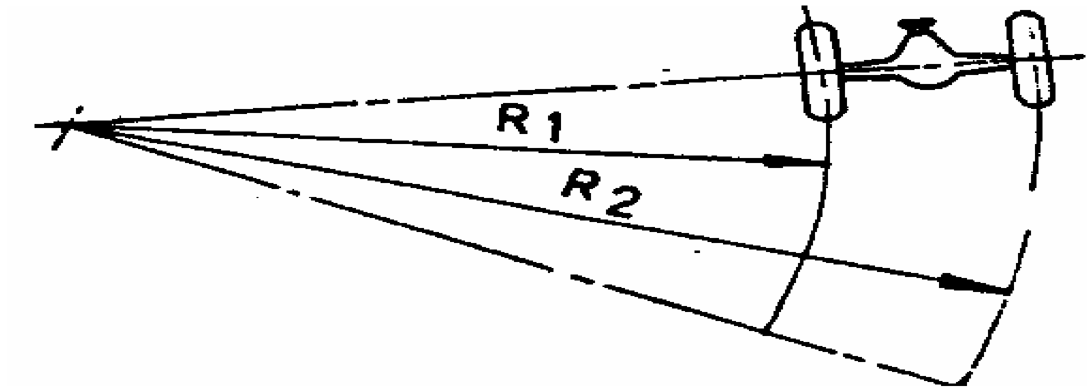
3This variation is zero from zero angle of inclination, but its magnitude becomes considerable when angle is large.

Differential

1.If a vehicle travels in a straight line, the two rear wheels turn on the road exactly at same speed. There is no relative movement between the two rear wheels. But when the vehicle takes a turn, the outer wheel travels on a longer radius than the inner wheel.

2 The outer wheel turns faster than the inner wheel, that is, there is a relative movement between the two rear wheels. If the two rear wheels are rigidly fixed to a rear axle the inner wheel will slip which will cause rapid tyre wear, steering difficulties and poor road holding.

3 Therefore there must be some devices to provide relative movement to the two rear wheels when the vehicle is taking a turn. The differential serve this purpose



When the car is taking a turn , the outer wheels will have to travel greater distance as compared to inner wheels at same time.

4 If therefore , the car has a solid rear axle only and no other device , there will be tendency for vehicles to skid.

5 Hence , if the wheel skidding is to be avoided , some mechanism must be incorporated in the rear axle , which should reduce the speed of the inner wheels and increase the speed of outer wheels when taking turns.

6 It should at the same time keep the speeds of all the wheels same when going straight ahead , Such a device which serves the above function is called **Differential** The function of the differential is to allow each rear wheel to rotate at different speeds during running but at the same time transmit equal torque to each wheel when both wheels have equal traction.

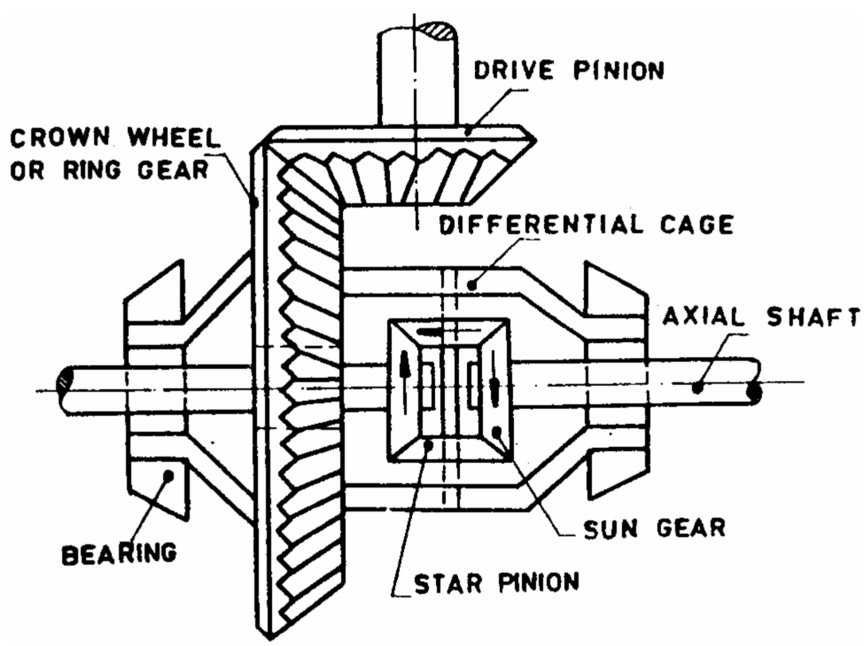
TYPES OF DIFFERENTIAL

(i)Conventional

(ii)Power lock or Non-slip

(iii) Double reduction type.

CONVENTIONAL TYPE (CONSTRUCTION)



1 It consists of a cage which contains differential gears. The differential gear consists of two sun gears and four star pinions all the bevel type.
2 The star pinions are fitted on a pin if there are two in number and a spider, if four are in number. The pinions are free to move around their axes. The pin or spider is held in between the two parts of the cage which encloses the differential gears. The sun gear and star pinions are always In mesh with each other.
3The differential assembly is supported on taper roller bearing provided on both sides of the cage**.**
4 The ring gears or crown wheel is attached to the differential cage which forms part of the final drive. Drive is given to the ring gear by means of drive pinion to which propeller shaft is attached.
5 Such gears are located parallel to ring gear inside the differential cage and face towards each other. Shaft of each wheel is splined into the sun gear of that side.

POWER LOCK OR NON-SLIP

A **locking differential**, **differential lock**, **diff lock** or **locker** is a variation on the standard automotive differential. A locking differential may provide increased traction compared to a standard, or "open" differential by restricting each of the two wheels on an axle to the same rotational speed without regard to available traction or differences in resistance seen at each wheel.

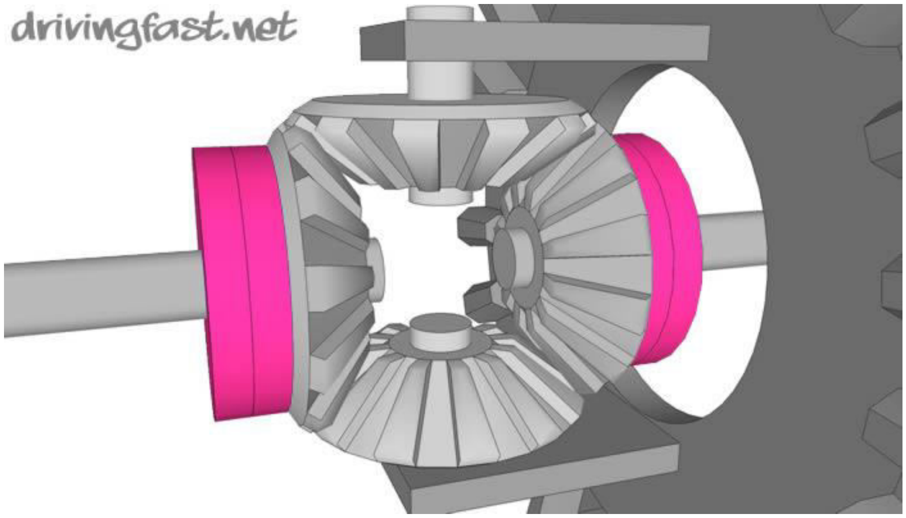
A locking differential is designed to overcome the chief limitation of a standard open differential by essentially "locking" both wheels on an axle together as if on a common shaft. This forces both wheels to turn in unison, regardless of the traction (or lack thereof) available to either wheel individually.

When the differential is unlocked (open differential), it allows each wheel to rotate at different speeds (such as when negotiating a turn), thus avoiding tire scuffing. An open (or unlocked) differential always provides the same torque (rotational force) to each of the two wheels, on that axle. So although the wheels can rotate at different speeds, they apply the same rotational force, even if one is entirely stationary, and the other spinning. (Equal torque, unequal rotational speed).

By contrast, a locked differential forces both left and right wheels on the same axle to rotate at the same speed under nearly all circumstances, without regard to tractional differences seen at either wheel. Therefore, each wheel can apply as much rotational force as the traction under it will allow, and the torques on each side-shaft will be unequal. (Unequal torque, equal rotational speeds). Exceptions apply to automatic lockers, discussed below.

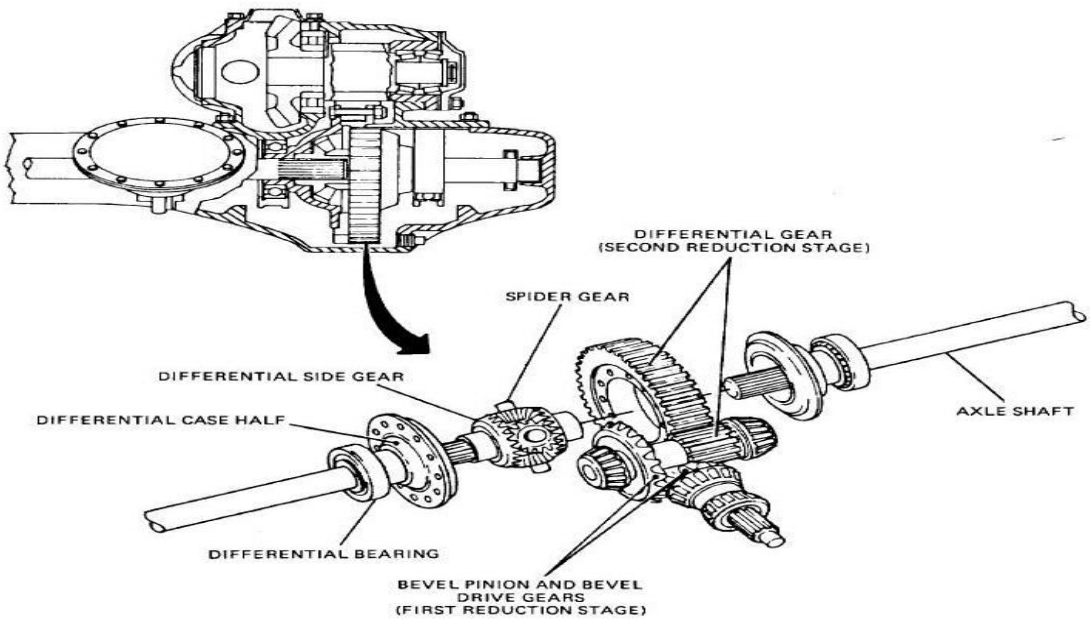
A locked differential can provide a significant traction advantage over an open differential, but only when the traction under each wheel differs significantly.

All the above comments apply to central differentials as well as to those in each axle: full-time four-wheel-drive (often called "All Wheel Drive") vehicles have three differentials, one in each axle, and a central one between the front and rear axles (transfer case).



DOUBLE REDUCTION TYPE.

1.Member, consisting of the sun gear and a dog clutch,with the dog clutch, it also is locked fast to the bearingslides on one of the axle shafts and usually is controlledadjusting ring and remains stationary.
2. The internal gear by hand lever accessible to the driver.
3. When this rotates the planetary gears around the stationary sun sliding part is in the high-ratio position, the sun gear gear and the differential case is driven by the ring on meshes with internal teeth on the ring carrying the which the planetary gears are pivoted.
4. This action planetary gears and disengages the dog clutch from the produces the gear reduction, or low speed, of the axle.
5.left bearing adjusting ring, which is rigidly held in the differential carrier.
6.In this position, the planetary gear train is locked together, there is no relative motion Double-reduction, dual-ratio rear axles also are between the gears in the planetary train, and the sometimes used in heavy-duty motor vehicles.
7.Rear differential case is driven directly by the differential drive axles of this type combine the features of the double- ring gear the same as in the conventional single-ratio reduction and dual-ratio axles in one unit.
8. A spiral-bevel rear axle. In the low-ratio position, the sun gear is slid pinion drives a out of mesh with the ring carrying the planetary gears, and the dog clutch makes a rigid connection with the left bearing adjusting ring. Because the sun gear is integra

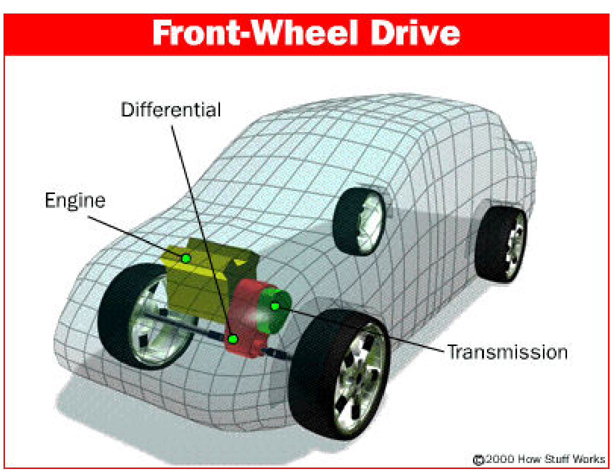


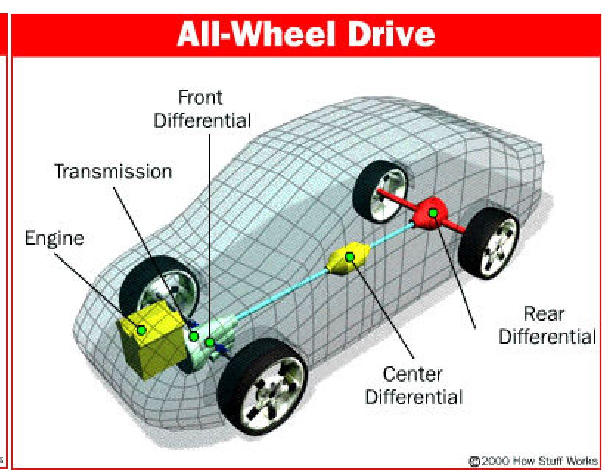
WORKING OF DIFFERENTIAL

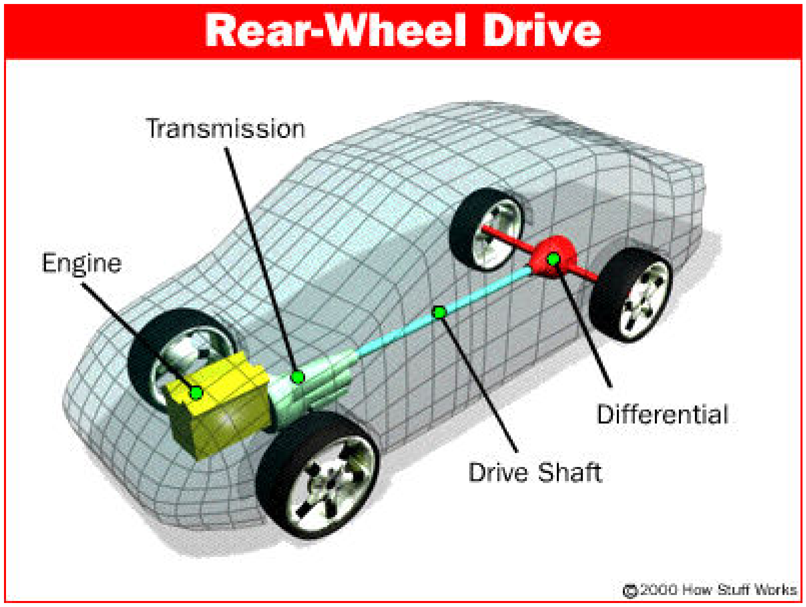
1 When the vehicle is moving on straight level road and the resistance effecting both the driving wheels is the same, there is no relative movement among the differential gears. The whole arrangement meshed together moves as one unit and both the half shafts in the driving wheel rotate at the same speed.

2 When the front wheels are turned to any directions to take a turn, a binding force acts on the inner wheel being nearer to the point around which wheels move in a circle. The sun gear of the side is held slow in relation to the movement of the complete cage or crown wheel While taking a turn when the bonding acts on the inner side sun gear and its speed is slowed down, the star pinion rotate the other side sun gear at a speed as a result of loss on the inner side and gain on the outer side plus the speed at which the complete differential assembly is rotating.

3 This results in a faster movement of the outer wheel than the inner one.







Rear Axles

The forces experienced by the rear axle are given as under

i)Weight of the body

ii) Torque reaction

iii) Driving thrust

v) Side thrust

Weight of the body:

The rear axle may be considered a beam supported at the ends and loaded at two points. The rear weight of the body is transmitted to the rear axle through springs.

Torque reaction:

If the road wheels are prevented from rotation with the propeller shaft rotating , it is seen that bevel pinion will tend to roll round the crown wheel. This tendency is also present when the vehicle is running , so that bevel pinion always tend to climb round the crown wheel. Thus there is a force on the axle casing to rotate .This is called torque reaction.

Driving Thrust:

Driving torque is produced in the engine causes the thrust to be produced in the road wheels , which has to be transmitted from the axle casing to the chassis frame and the body of the vehicle. This is most conveniently done by some form of members connecting the axle casing and the chassis frame in the longitudinal direction. Such members are called thrust members or radius rods.

Side Thrust:

The rear axle experiences side thrust or pull due to any side load on the wheel

REAR AXLE DRIVES

To transmit the torque from the gear box to the rear axle, the common drives are use are:

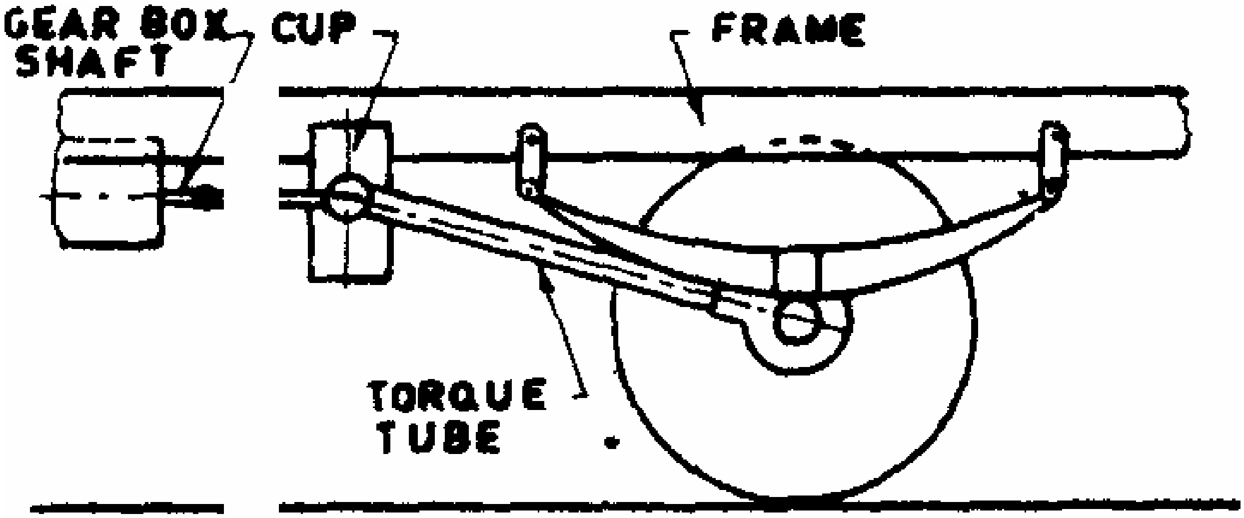
1 Hotchkiss Drive

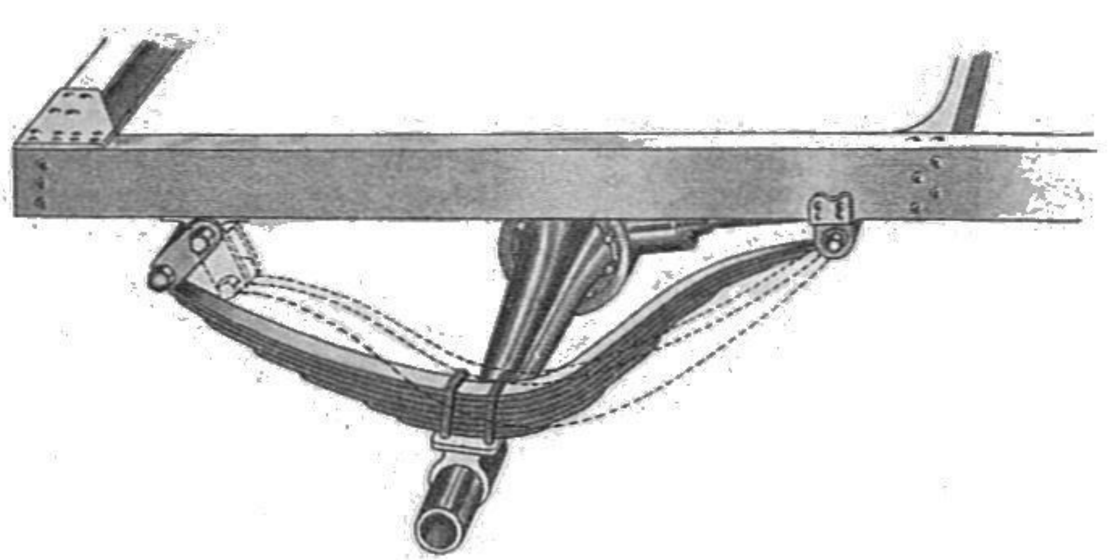
2 Torque Tube Drive

3 Radius Arm Drive

HOTCHKISS DRIVE

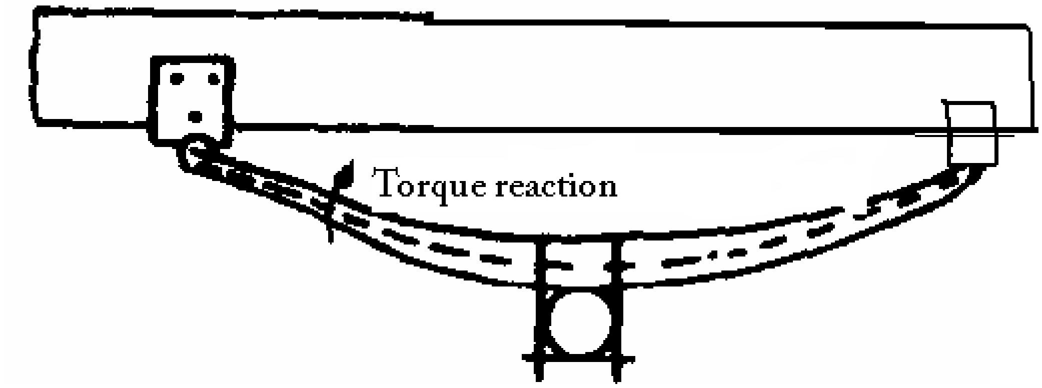
Simplest and most widely used rear axle drive. The arrangement of the parts is shown in fig:





In this case the springs beside taking weight of the body,also take the torque reaction, driving thrust and the Side thrust. The propeller shaft is provided with two universal joints and one sliding joint. The spring is fixed rigidly in the middle , to the rear axle. Front end of the spring is fixed rigidly on the frame while the rear end is supported in a shackle

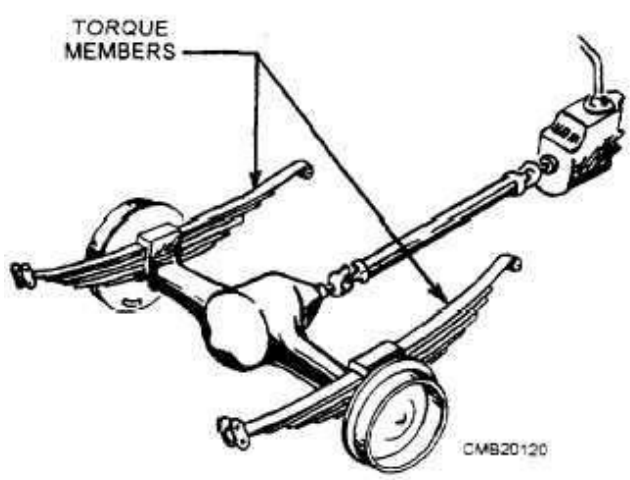
Due to torque reaction the front half spring deflects as shown in figure means that the driving thrust is transmitted to the frame by this portion of the spring.



When the spring deflects in the manner bevel pinion shaft will change its position. Therefore, If there is one universal joint near the gear box then under the torque reaction the propeller shaft will bend. Therefore, to avoid the bending of the propeller shaft another universal joint is used at is rear end. Again when axle moves up and down relatively to the frame it has to move in a circle whose centre lies at the front end of the spring. Then propeller shaft also has to move in circle keeping its centre at the front universal joint. As these two centers do not coincide, therefore, the length of propeller shaft always has to vary this condition which is accommodated by the sliding joint in the propeller shaft

TORQUE TUBE DRIVE

In this type of drive, the spring take only the side thrust besides supporting the body weight. The torque reaction , braking torque and the driving thrust are taken by another member which is called the torque tube. One end of the torque tube is attached to the axle casing, while the other end which is spherical in shape fits in the cup fixed to the frame. Since in this case the torque reaction and the driving thrust are taken by the torque tube., the bevel pinion shaft axis will always pass through the universal joint at the front end of the propeller shaft if this joint is situated exactly at the centre of the spherical end of the torque tube. Due to this reason no universal joint is at the rear end. Since both pinion shaft and propeller shaft will work about the same centre that of the spherical cup while moving up and down the axle then no sliding joint will be necessary. In this case **no universal joint is provided** at the rear end of the propeller shaft. Also **no sliding joint is provided** because both the pinion shaft and the propeller shaft in this case will move about the same centre i.e. about the centre of the spherical cup

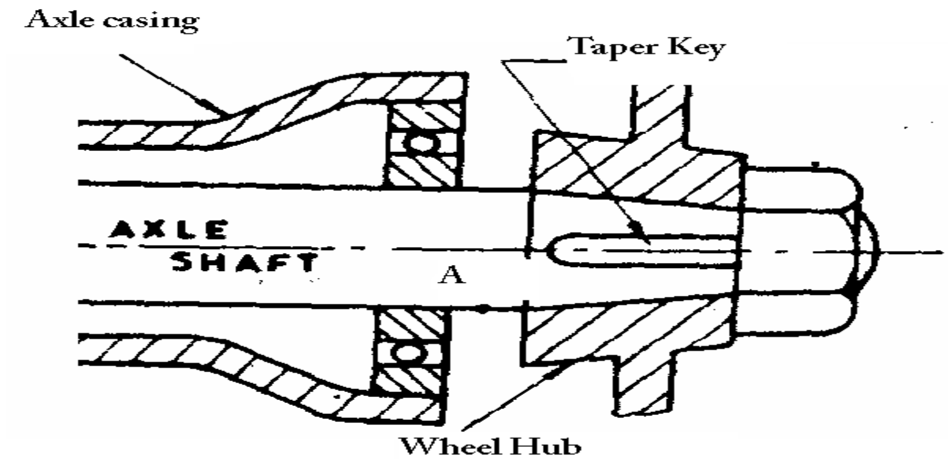


TYPES OF REAR AXLES

Depending upon the method of supporting the rear axles and mounting the rear wheels, the rear axles are of three types:

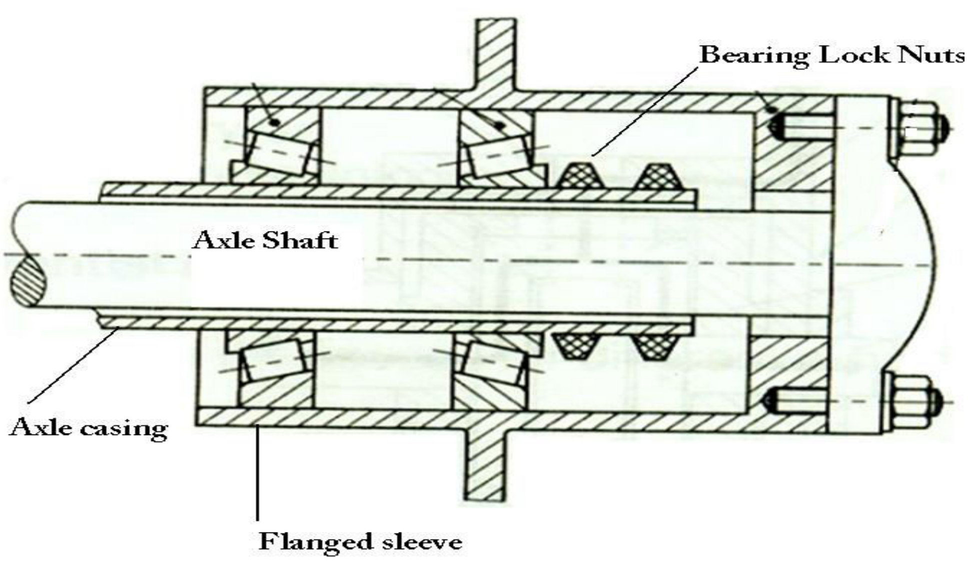
1) Semi floating axle
2) Full floating axle
3) Three quarter floating axle

SEMI FLOATING AXLE



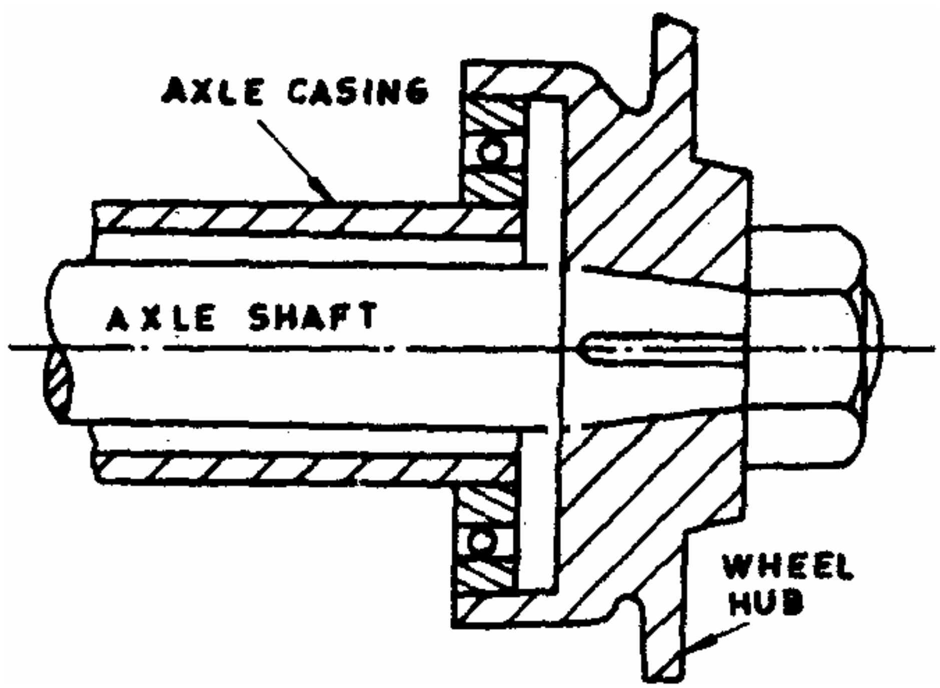
The wheel hub is directly connected to the axle shaft or is an extension of the same. The inner end of axle shaft is splined and is supported by final drive unit, whereas the outer end is supported by single bearing inside the axle casing. All the loads are taken by axle shaft. The vehicle load is transmitted to each of half shafts through the casing and the bearing. This causes a bending load and tendency to shear at point marked 'A'. Semi floating axle is simplest and cheapest of all types therefore it is widely use on cars. However , since the axle shafts have to support all loads , they have to be of large diameter for the same torque transmitted compared to the other type of axle supporting

FULL FLOATING AXLE



This type is very robust one and is used for heavy vehicles. In this the **axle shaft carry only the driving torque .** A full floating axle has two deep-groove ball or taper roller bearings, located between the axle casing wheel hub. The outer of the axle is made flanged to which the wheel hub is bolted. The axle is not supported by bearings at either end, and its position is maintained by the way that it is supported at both ends The weight of the vehicle and end thrust are not carried by them , the weight being completely supported by the wheels and the axle casing . As the axle shaft carry only driving torque , their failure or removal does not affect the wheels. The axle may be removed from the housing without disturbing the wheel by removing the nuts An additional advantage of the design is the ability to withstand the vehicle even if it has a broken axle. This type of axle is more expansive and heavier than the other axles.

THREE QUARTER FLOATING AXLE:



In the three quarter floating axle the single bearing located between the hub and the axle casing. Thus, the weight of the vehicle is transferred to the axle casing, and only the side thrust and driving' torque are taken by the axle. The inner end of this axle has the same construction as that of the semi-floating axle. The axle shaft does not take any shearing or bending loads due to the weight of the vehicle. However it has to take the end loads and driving torque. Although the three quarter floating axle is more reliable but it is not as simple as the semi floating axle