CLUTCH

MODULE : TRUCK CLUTCH

Learning outcome

This Module Provides you with the skills

- To repair Truck clutch.
- To test and identify faults in the Truck clutch.

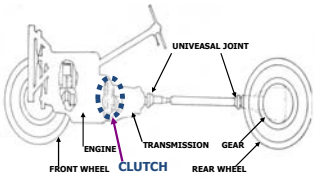
Outcome

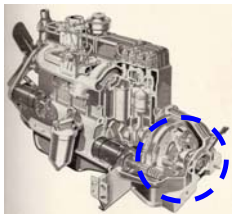
- On Completion of this module you should be able to:
  - Identify clutch assemblies and explain single plate dry clutch operation.
  - Identify faults in clutch.
  - Remove , replace and repair clutch.

CLUTCH LOCATION, FUNCTION AND TYPES

Location

- Located between the Engine and Gear Box.





Why is CLUTCH Required?

- IC engines develop low torque at starting speed and as the speed increases, develop enough torque to pick up the load.

- E.g. if the power from a running engine is transmitted to the drive wheels when the truck is at stand still
  - The truck will jump out if the power is too large.
  - The engine will stop or stall if the power is too small.

FUNCTION

- To connect and disconnect the Power from Engine to Gearbox.

Types of clutch

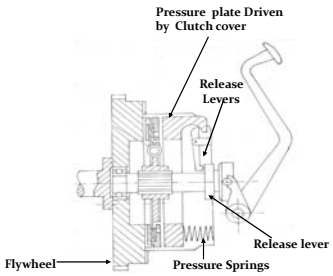
- Truck Clutches use SINGLE PLATE DRY CLUTCH which is Finger Type

CLUTCH CONSTRUCTION AND WORKING

Single plate dry clutch

- **MAIN PARTS of CLUTCH Assembly**
  - **Driving members**

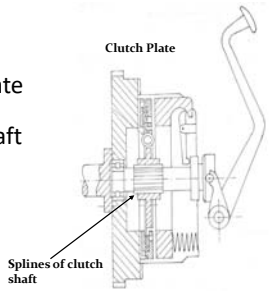
Consist of flywheel, Pressure plate, Pressure



Single plate dry clutch

– **Driven members**

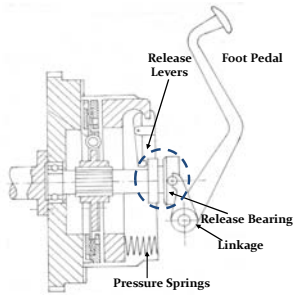
Consist of Clutch plate which slides on the splines of clutch shaft



Single plate dry clutch

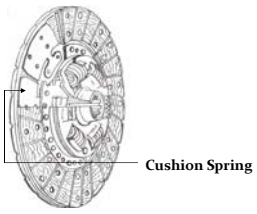
– **Operating member**

Consist of foot pedal linkage, release bearing, release levers and pressure springs



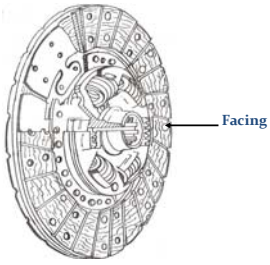
Construction of clutch plate

– **Cushion Springs** - Are mounted on the clutch hub, these are wavy springs. This provision is made to ensure engaging of clutch without any sound or jerk.



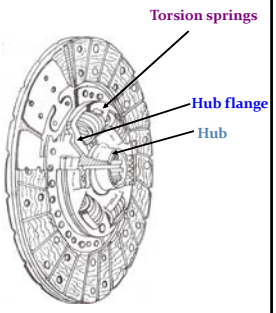
Construction of clutch plate

– **Facing** - Clutch facings made of fiber asbestos are riveted on both side of the cushion spring for correct operation and functioning of the modern clutch assembly.



Construction of clutch plate

- **Torsion Springs** - To absorb vibrations when the clutch is engaged or disengaged
- **Hub flange** - To accommodate torsion spring
- **Splined Hub** - Can slide on primary shaft splines



Clutch materials

- Materials for the structural parts of clutches: typically made of gray cast iron or steel.
- The friction surfaces are usually lined with material having a good coefficient of friction and sufficient compressive strength and temperature resistance: asbestos fiber, but no longer used in many applications because of its danger as a carcinogen.
- Linings may be molded, woven, sintered or of solid material
- Molded linings: use polymeric resins to bind a variety of powdered filled or fibrous materials.
- Brass or zinc chips are sometimes added to improve heat conduction and wear resistance
- Woven material: use long asbestos fibers
- Sintered metals provide high temperature resistance and compressive strength than molded or woven materials.
- Materials: cork, wood and cast iron are sometimes uses as lining as well

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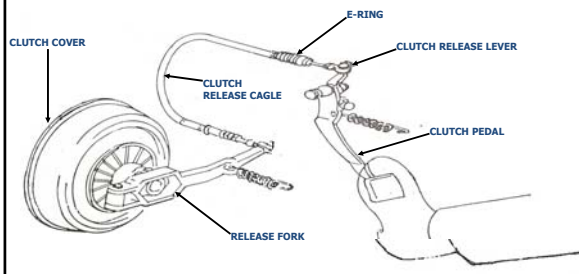
CLUTCH OPERATING MECHANISM

Clutch Actuation System Requirements

- Clutch release lever should have adequate clearance in clutch housing for actuation.
- It should not slip at high torque
- It should be able to damp torsional vibrations of crank shaft

Clutch Operation

- MECHANICAL TYPE



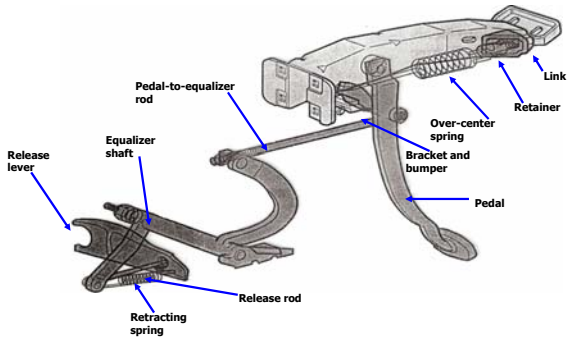
Clutch Operation

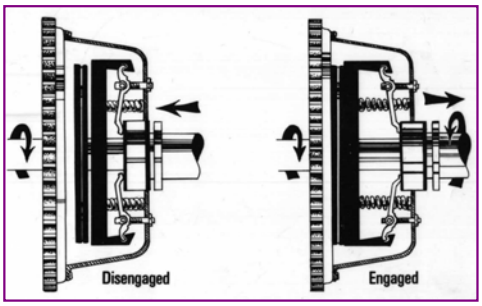
- HYDRAULIC TYPE

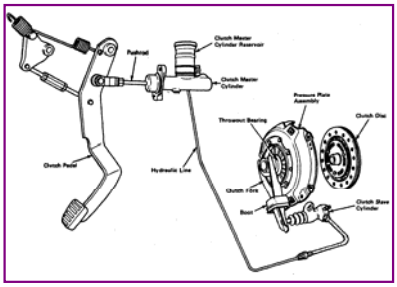
Clutch pedal free play Adjustment

- Adjustment should be perform when a pedal play is not correct
- Or when the clutch does not engage or disengage properly.
- Often pedal play can be increased or decreased by turning
- Treaded fastener located either under
- the dash at the clutch pedal or where
- the linkage attaches to the clutch fork

Clutch pedal free play adjustment



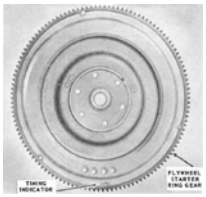




Hydraulic clutch

- No complicated linkage
- Can easily control mechanical advantage with piston sizes
- Self lubricating
- No motor mount problems

Flywheel



A flywheel is a rotating disk used as a storage device for kinetic energy. Flywheels resist changes in their rotational speed, which helps steady the rotation of the shaft when a fluctuating torque is exerted on it by its power source such as a piston-based (reciprocating)engine, or when the load placed on it is intermittent (such as a piston pump). Flywheels can be used to produce very high power pulses as needed for some experiments, where drawing the power from the public network would produce unacceptable spikes

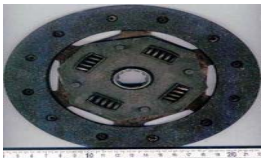
- **Advantages:**

  Flywheels store energy very efficiently (high turn-around efficiency) and have the potential for very high specific power compared with batteries. Flywheels have very high output potential and relatively long life. Flywheels are relatively unaffected by ambient temperature extremes.

- **Disadvantages:**

  Current flywheels have low specific energy. There are safety concerns associated with flywheels due to their high speed rotor and the possibility of it breaking loose and releasing all of it's energy in an uncontrolled manner. Flywheels are a less mature technology than chemical batteries, and the current cost is too high to make them competitive in the market.

Single plate dry clutch



This type of clutch is used almost exclusively in vehicles. It consists of only one clutch plate, mounted on splines of the clutch shaft. The flywheel is mounted on the engine crankshaft and rotates with it while the pressure plate is bolted to flywheel through clutch springs, and is free to slide on the clutch. When the clutch is engaged ,clutch pedal is pressed between flywheel and pressure plates and due to friction between flywheel, clutch plate and pressure plate, the clutch plate revolves with the flywheel.

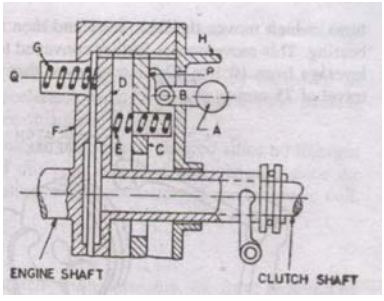
Advantages

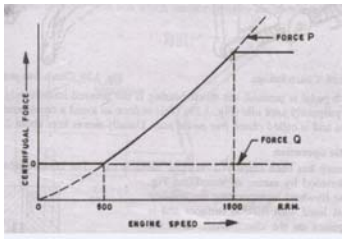
•It is easy to operate and provide sufficient frictional grip needed for transmission.
•Operation is quite and smooth.
•It does not suffer from bending problem .
•It is most reliable clutch design and hence widely used.
•With single plate clutch, gear changing is easier than with the cone clutch, because the pedal movement is less in this case.
•It does not suffer from disadvantages of clone clutch i.e, binding of cones etc. And hence it is more reliable.

Disadvantages

- Use of this clutch is limited to low and medium speed transmission.
- The design is not suitable where space criteria and compactness is prime consideration.
- As there is wear of friction facing. It requires more maintenance.
- The springs have to be more stiff and this means greater force required to be applied by the driver while disengaging.

Centrifugal clutch





Working

- When the engine reaches a certain RPM, the clutch activates, working almost like a continuously variable transmission. As the load increases the rpm drops, disengaging the clutch, letting the rpm rise again and reengaging the clutch. If tuned properly, the clutch will tend to keep the engine at or near the torque peak of the engine. These results in a fair bit of waste heat, but over a broad range of speeds it is much more useful then a direct drive in many applications.
- Centrifugal clutches are often used in mopeds, underbones, lawnmowers, battlebots, go-karts, chainsaws and mini bikes to:
- keep the internal combustion engine from stalling when the blade or weapon is stopped abruptly
- provide low load during starting allow engine to idle

CLUTCH

Clutch Introduction

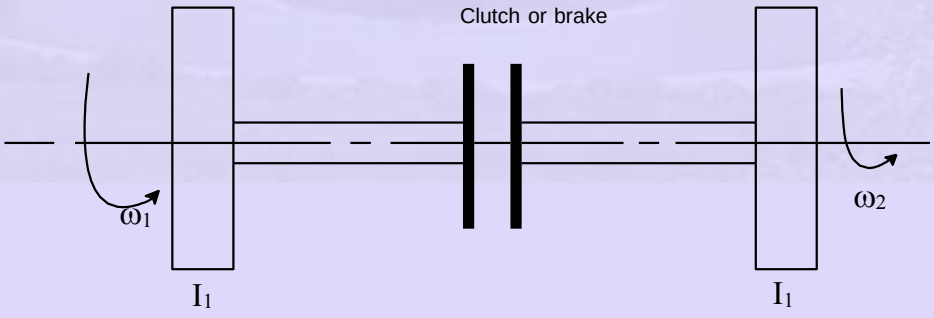
A *Clutch is* a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft. A clutch thus provides an interruptible connection between two rotating shafts

Clutches allow a high inertia load to be stated with a small power.

A popularly known application of clutch is in automotive vehicles where it is used to connect the engine and the gear box. Here the clutch enables to crank and start the engine disengaging the transmission Disengage the transmission and change the gear to alter the torque on the wheels. Clutches are also used extensively in production machinery of all types

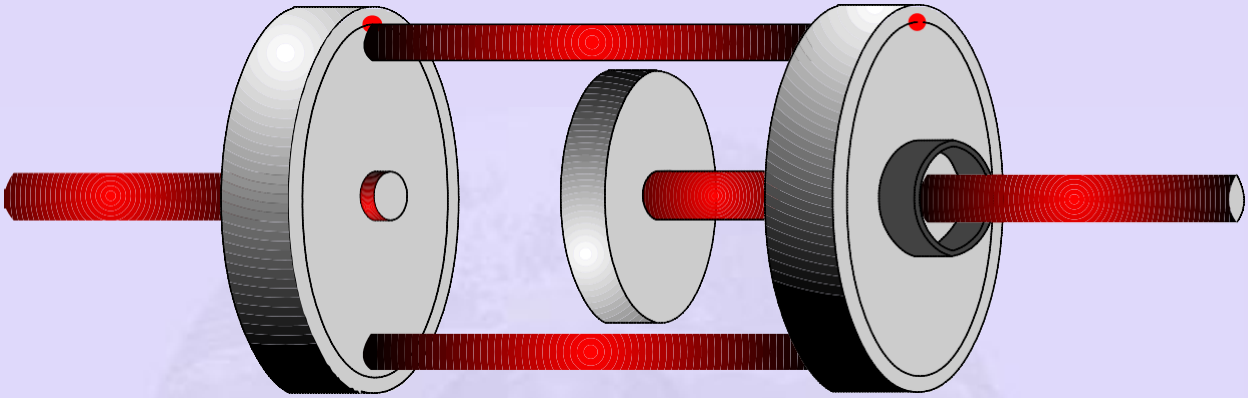
Mechanical Model

Two inertia's I_1 and I_2 and traveling at the respective angular velocities ω_1 and ω_2, and one of which may be zero, are to be brought to the same speed by engaging. Slippage occurs because the two elements are running at different speeds and energy is dissipated during actuation, resulting in temperature rise.



Dynamic Representation of Clutch or Brake

Figure 3.2.1



Animated

Figure 3.2.2

To design analyze the performance of these devices, a knowledge on the following are required.

1. *The torque transmitted*
2. *The actuating force.*
3. *The energy loss*
4. *The temperature rise*

FRICTION CLUTCHES

As in brakes a wide range of clutches are in use wherein they vary in their are in use their working principle as well the method of actuation and application of normal forces. The discussion here will be limited to mechanical type friction

clutches or more specifically to the plate or disc clutches also known as axial clutches

Frictional Contact axial or Disc Clutches

An axial clutch is one in which the mating frictional members are moved in a direction parallel to the shaft. A typical clutch is illustrated in the figure below. It consist of a driving disc connected to the drive shaft and a driven disc co9nnected to the driven shaft. A friction plate is attached to one of the members. Actuating spring keeps both the members in contact and power/motion is transmitted from one member to the other. When the power of motion is to be interrupted the driven disc is moved axially creating a gap between the members as shown in the figure.

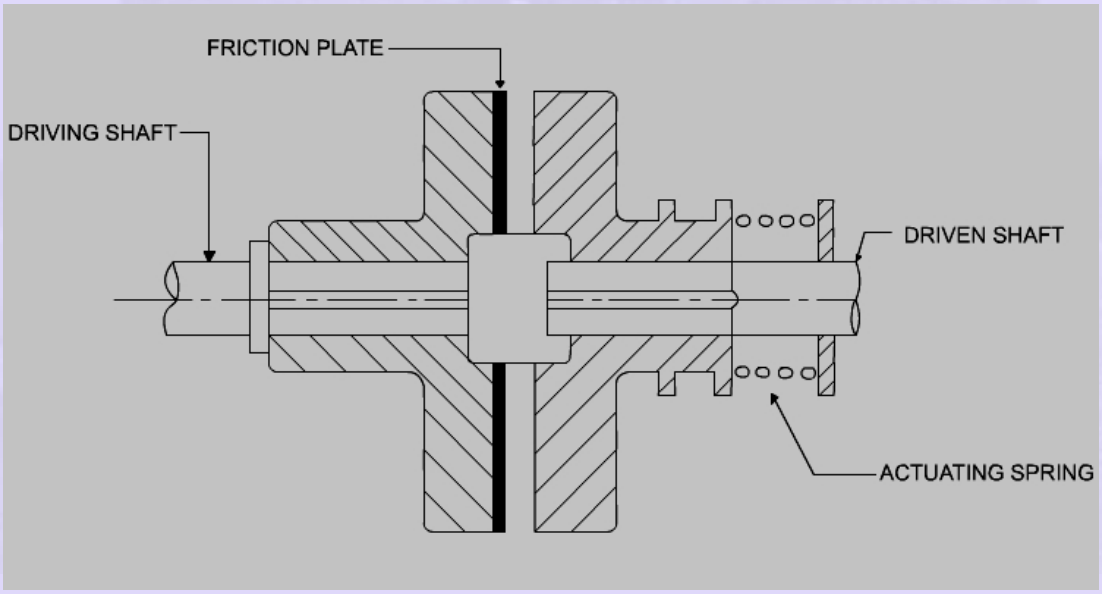
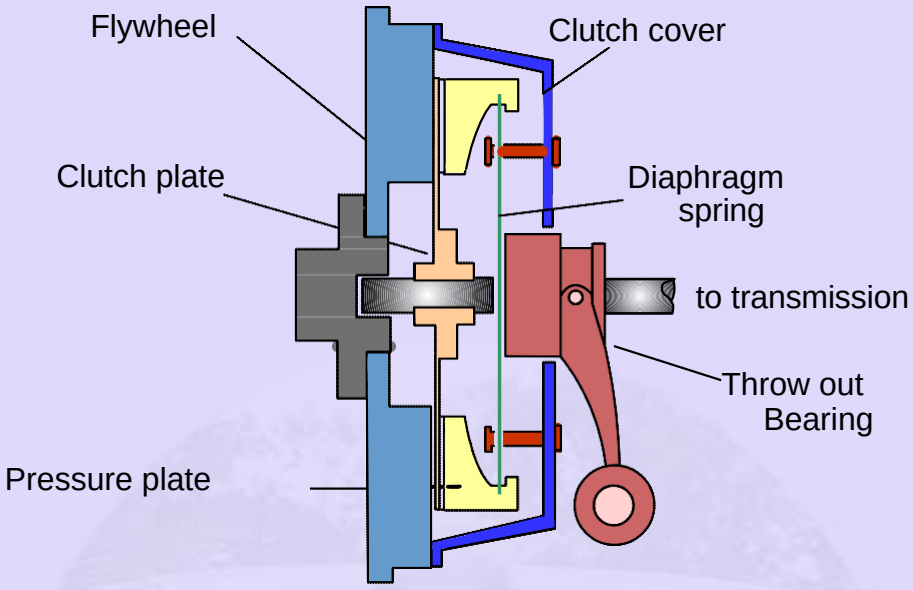


Figure 3.2.3



Animated

Figure 3.2.4

METHOD OF ANALYSIS

The torque that can be transmitted by a clutch is a function of its geometry and the magnitude of the actuating force applied as well the condition of contact prevailing between the members. The applied force can keep the members together with a uniform pressure all over its contact area and the consequent analysis is based on uniform pressure condition

Uniform Pressure and wear

However as the time progresses some wear takes place between the contacting members and this may alter or vary the contact pressure appropriately and uniform pressure condition may no longer prevail. Hence the analysis here is based on uniform wear condition

Elementary Analysis

Assuming uniform pressure and considering an elemental area dA

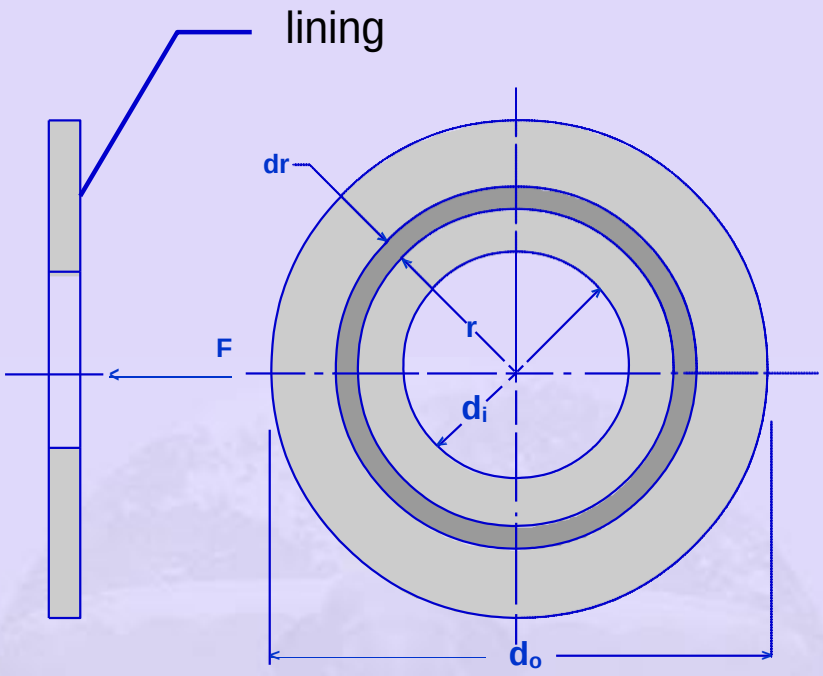
$$dA = 2\Pi.r\ dr$$

The normal force on this elemental area is

$$dN = 2\pi.r.dr.p$$

The frictional force dF on this area is therefore

$$dF = f.2\pi.r.dr.p$$



A single-Surface Axial Disk Clutch

Figure 3.2.5

Now the torque that can be transmitted by this elemental are is equal to the frictional force times the moment arm about the axis that is the radius 'r'

i.e. T = dF. r = f.dN. r = f.p.A.r

= f.p.2.π.r. dr .r

The total torque that could be transmitted is obtained by integrating this equation between the limits of inner radius ri to the outer radius ro

$$T = \int_{r_i}^{r_o} 2\pi p f r^2 dr = \frac{2}{3}\pi p f (r_o^3 - r_i^3)$$

Integrating the normal force between the same limits we get the actuating force that need to be applied to transmit this torque.

$$F_a = \int_{r_i}^{r_o} 2\pi p r dr$$

$$F_a = \pi\left(r_o^2 - r_i^2\right).p$$

Equation 1 and 2 can be combined together to give equation for the torque

$$T = fF_a \cdot \frac{2\,(r_o^3 - r_i^3)}{3\,(r_o^2 - r_i^2)}$$

Uniform Wear Condition

According to some established theories the wear in a mechanical system is proportional to the 'PV' factor where P refers the contact pressure and V the sliding velocity. Based on this for the case of a plate clutch we can state

The constant-wear rate R_w is assumed to be proportional to the product of pressure p and velocity V.

R_w= pV= constant

And the velocity at any point on the face of the clutch is $V = r.\omega$

Combining these equation, assuming a constant angular velocity ω

pr = constant = K

The largest pressure p_{max} must then occur at the smallest radius r_i ,

$$K = p_{max}\, r_i$$

Hence pressure at any point in the contact region

$$p = p_{max}\,\frac{r_i}{r}$$

In the previous equations substituting this value for the pressure term p and integrating between the limits as done earlier we get the equation for the torque transmitted and the actuating force to be applied.

I.e The axial force F_a is found by substituting $p = p_{max}\frac{r_i}{r}$ for p.

and integrating equation $dN = 2\pi prdr$

$$F = \int_{r_i}^{r_o} 2\pi prdr = \int_{r_i}^{r_o} 2\pi \left[\frac{r_i}{r}\right] rdr = 2\pi p_{max} r_i (r_o$$

Similarly the Torque

$$T = \int_{r_i}^{r_o} f\,2\pi p_{max} r_i rdr = f\pi p_{max} r_i (r_o^2 - r_i^2)$$

Substituting the values of actuating force Fa

The equation can be given as

$$T = fF_a.\frac{(r_o + r_i)}{2}$$

Single plate dry Clutch – Automotive application

The clutch used in automotive applications is generally a single plate dry clutch. In this type the clutch plate is interposed between the flywheel surface of the engine and pressure plate.

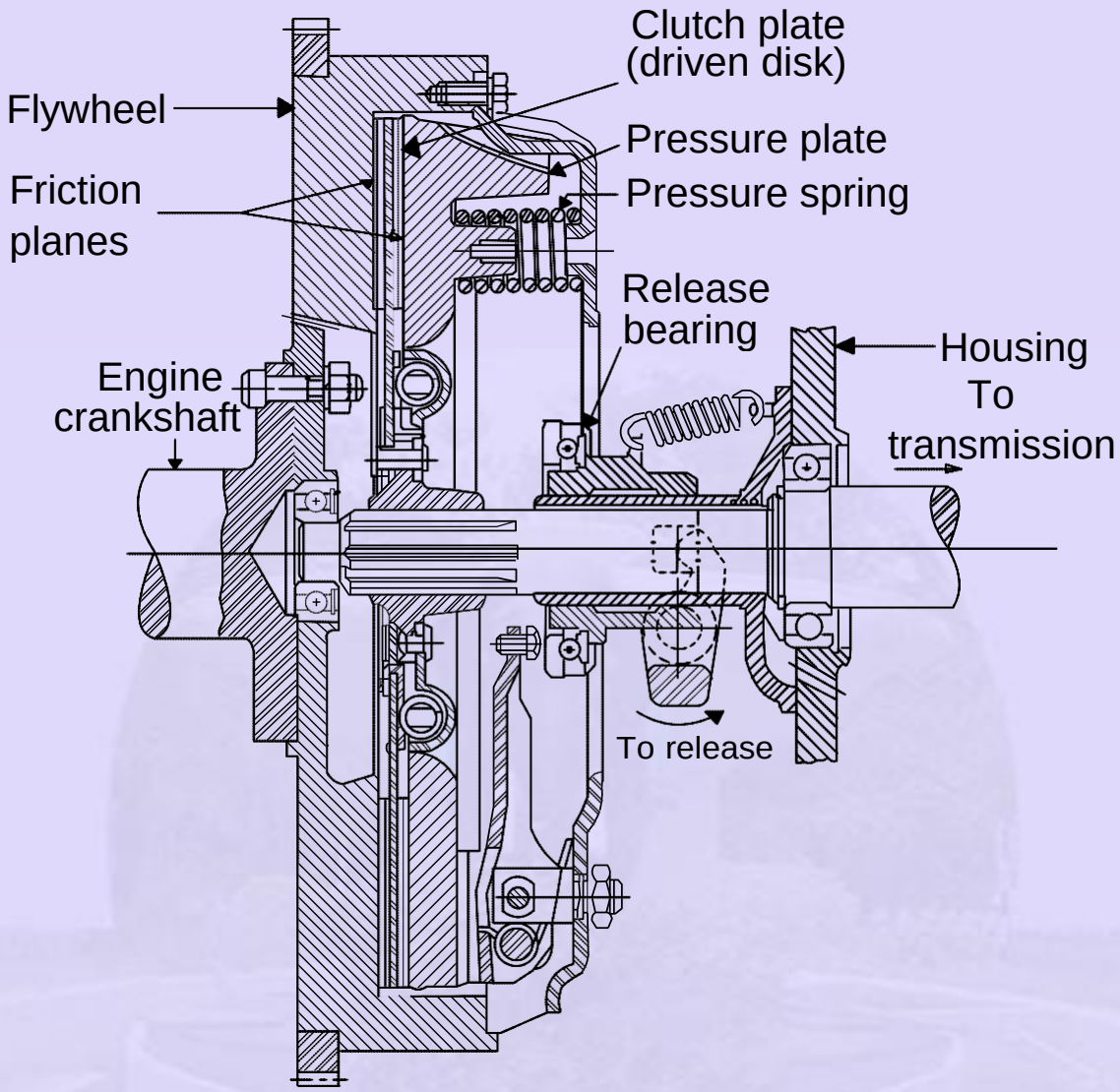


Figure 3.2.6

Single Clutch and Multiple Disk Clutch

Basically, the clutch needs three parts. These are the engine flywheel, a friction disc called the clutch plate and a pressure plate. When the engine is running and the flywheel is rotating, the pressure plate also rotates as the pressure plate is attached to the flywheel. The friction disc is located between the two. When

the driver has pushed down the clutch pedal the clutch is released. This action forces the pressure plate to move away from the friction disc. There are now air gaps between the flywheel and the friction disc, and between the friction disc and the pressure plate. No power can be transmitted through the clutch.

Operation Of Clutch

When the driver releases the clutch pedal, power can flow through the clutch. Springs in the clutch force the pressure plate against the friction disc. This action clamps the friction disk tightly between the flywheel and the pressure plate. Now, the pressure plate and friction disc rotate with the flywheel.

As both side surfaces of the clutch plate is used for transmitting the torque, a term 'N' is added to include the number of surfaces used for transmitting the torque

By rearranging the terms the equations can be modified and a more general form of the equation can be written as

$$T = N.f.F_a.R_m$$

T is the torque (Nm).

N is the number of frictional discs in contact.

f is the coefficient of friction

F_a is the actuating force (N).

R_m is the mean or equivalent radius (m).

Note that N = n1 + n2 -1

Where n1= number of driving discs

n2 = number of driven discs

Values of the actuating force F and the mean radius r_m for the two conditions of analysis are summarized and shown in the table

Clutch Construction

Two basic types of clutch are the coil-spring clutch and the diaphragm-spring clutch. The difference between them is in the type of spring used. The coil spring clutch shown in left Fig 3.2.6 uses coil springs as pressure springs (only two pressure spring is shown). The clutch shown in right figure 3.2.6 uses a diaphragm spring.

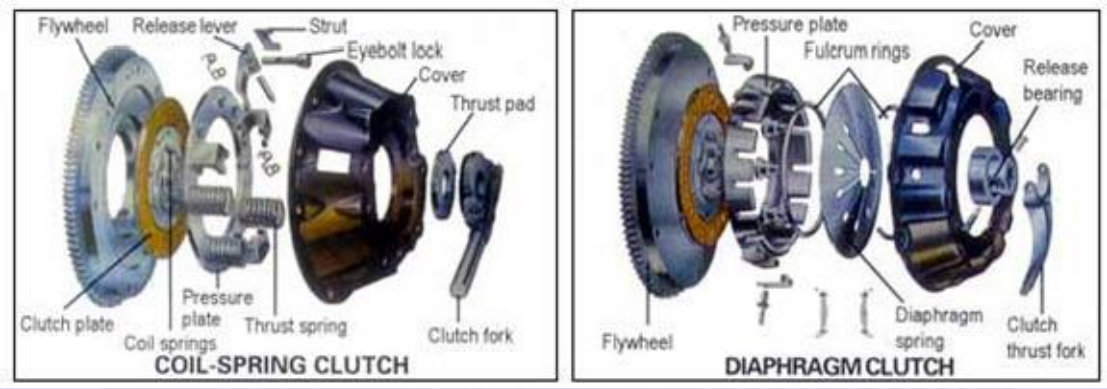


Figure 3.2.6

The coil-spring clutch has a series of coil springs set in a circle.

At high rotational speeds, problems can arise with multi coil spring clutches owing to the effects of centrifugal forces both on the spring themselves and the lever of the release mechanism.

These problems are obviated when diaphragm type springs are used, and a number of other advantages are also experienced

Clutch or Driven Plate

More complex arrangements are used on the driven or clutch plate to facilitate smooth function of the clutch

The friction disc, more generally known as the clutch plate, is shown partly cut away in Fig. It consists of a hub and a plate, with facings attached to the plate.

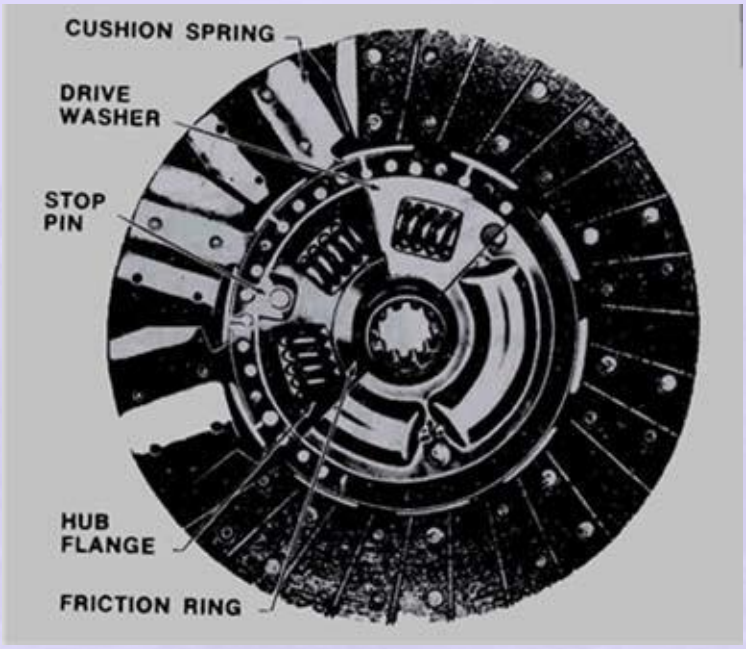


Figure 3.2.7

First to ensure that the drive is taken up progressively, the centre plate, on which the friction facings are mounted, consists of a series of cushion springs which is crimped radially so that as the clamping force is applied to the facings the crimping is progressively squeezed flat, enabling gradual transfer of the force

On the release of the clamping force, the plate springs back to its original position crimped (wavy) state

This plate is also slotted so that the heat generated does not cause distortion that would be liable to occur if it were a plain plate. This plate is of course thin to keep rotational inertia to a minimum.

Plate to hub Connection

Secondly the plate and its hub are entirely separate components, the drive being transmitted from one to the other through coil springs interposed between them. These springs are carried within rectangular holes or slots in the hub and plate and arranged with their axes aligned appropriately for transmitting the drive. These dampening springs are heavy coil springs set in a circle around the hub. The hub is driven through these springs. They help to smooth out the torsional vibration (the power pulses from the engine) so that the power flow to the transmission is smooth.

In a simple design all the springs may be identical, but in more sophisticated designs the are arranged in pairs located diametrically opposite, each pair having a different rate and different end clearances so that their role is progressive providing increasing spring rate to cater to wider torsional damping

The clutch plate is assembled on a splined shaft that carries the rotary motion to the transmission. This shaft is called the clutch shaft, or transmission input shaft.

This shaft is connected to the gear box or forms a part of the gear box.

Friction Facings or Pads

It is the friction pads or facings which actually transmit the power from the fly wheel to hub in the clutch plate and from there to the out put shaft. There are

grooves in both sides of the friction-disc facings. These grooves prevent the facings from sticking to the flywheel face and pressure plate when the clutch is disengaged. The grooves break any vacuum that might form and cause the facings to stick to the flywheel or pressure plate. The facings on many friction discs are made of cotton and asbestos fibers woven or molded together and impregnated with resins or other binding agents. In many friction discs, copper wires are woven or pressed into the facings to give them added strength. However, asbestos is being replaced with other materials in many clutches. Some friction discs have ceramic-metallic facings.

Such discs are widely used in multiple plate clutches

The minimize the wear problems, all the plates will be enclosed in a covered chamber and immersed in an oil medium

Such clutches are called wet clutches

Multiple Plate Clutches

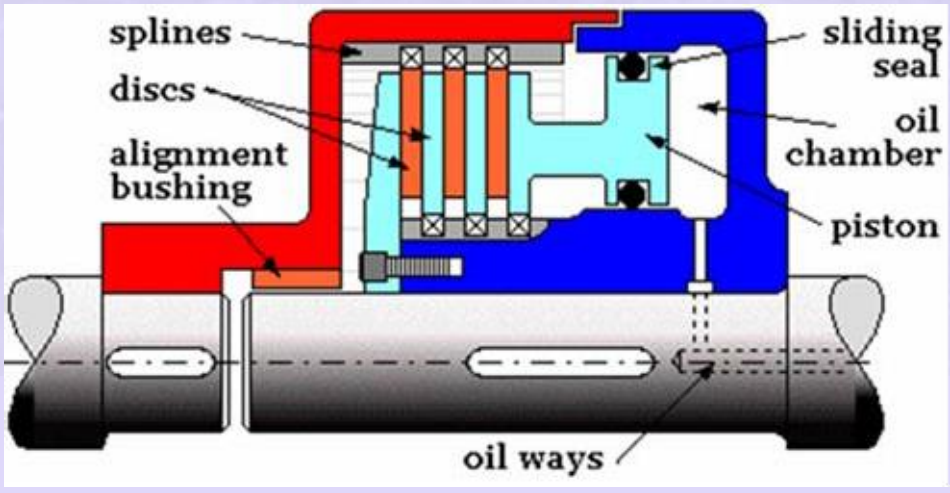


Figure 3.2.8

The properties of the frictional lining are important factors in the design of the clutches

Typical characteristics of some widely used friction linings are given in the table

Table Properties of common clutch/ Brake lining materials

Friction Material Against Steel or Cl	Dynamic Coefficient of Friction		Maximum Pressure KPa	Maximum Temprerature ^{o}C
	dry	in oil		
Molded	0.25-0.45	0.06-0.09	1030-2070	204-260
Woven	0.25-0.45	0.08-0.10	345-690	204-260
Sintered metal	0.15-0.45	0.05-0.08	1030-2070	232-677
Cast iron of hard steel	0.15-0.25	0.03-0.06	690-720	260

Table 3.2.1

Ch-4 Propeller Shaft & Universal Joint

Introduction of Propeller Shaft

- Propeller shaft is connecting the drive from gear box to final drive. Hence it is also called Drive Shaft.

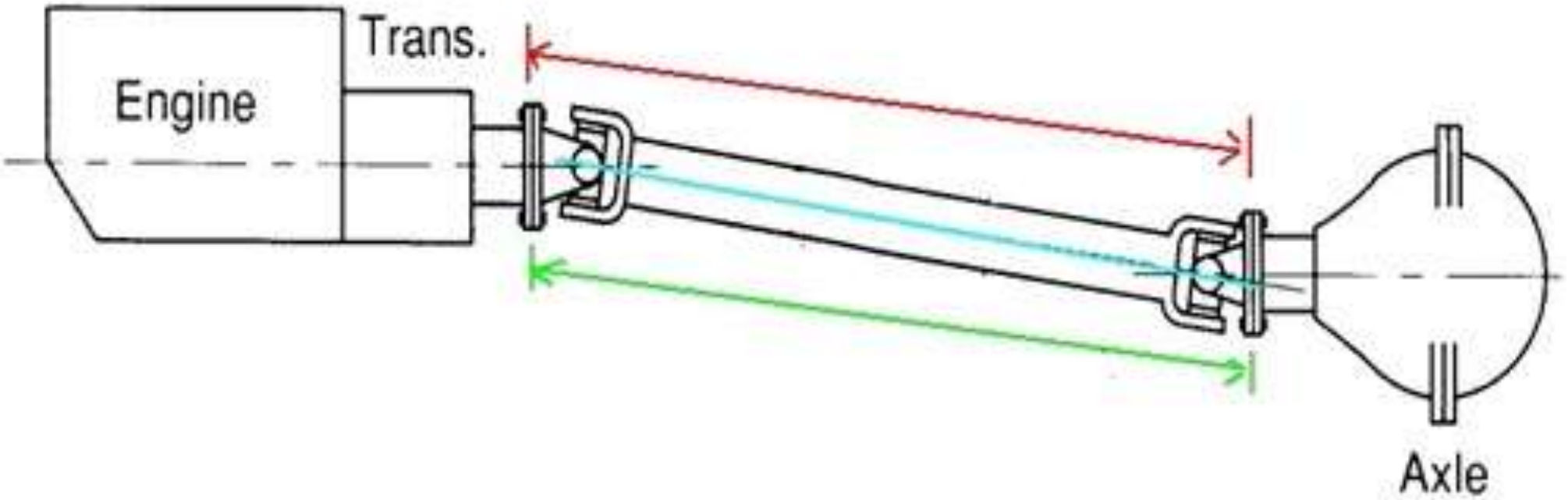
OR

- It is the group of parts connecting the transmission with the drive wheels. It consists of propeller shaft (also called Drive Shaft), Universal Joints/Constant Velocity Joints and Slip Joints.

Introduction of Propeller Shaft

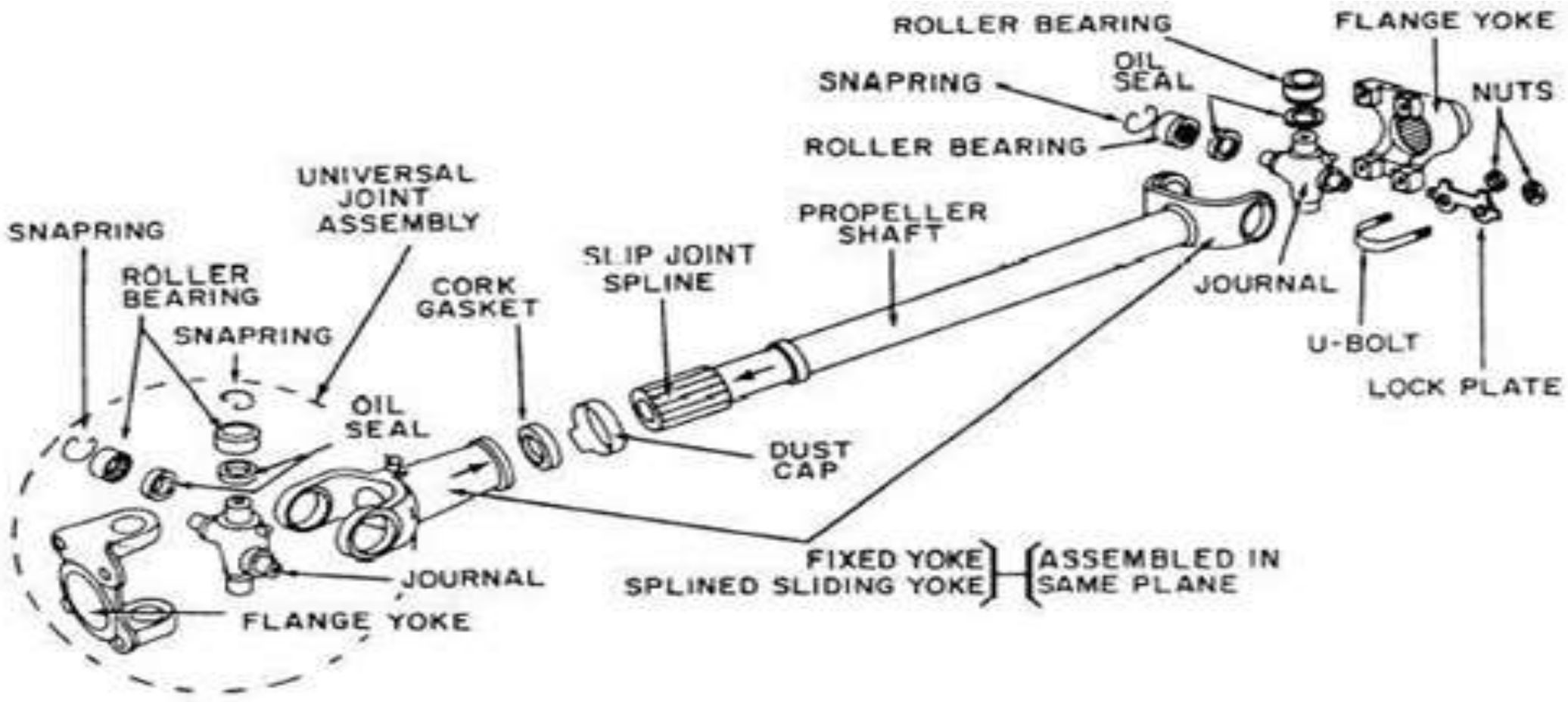
- **Shaft:** As this has to withstand torsional loads, it is usually made of tubular cross-section. It also has to be well balanced to avoid whirling at high speeds. Shafts are made of steel, aluminum or composite materials.
- **Universal Joint:** One or two universal joints, depending upon the type of rear axle drive used. The universal joints account for the up and down movements of the rear axle when the vehicle is running.
- **Slip Joint:** Depending upon the type of drive, one slip joint may be there in shaft. This serves to adjust the length of the propeller shaft when demanded by rear axle movements.

Introduction of Propeller Shaft



PROPELLER SYSTEM

Introduction of Propeller Shaft



COMPONENTS OF PROPELLER SHAFT

More about Propeller Shaft

- The propeller shaft is used as a driving shaft to joint the output shaft of the gear box with the differential unit in the rear axle.
- The rotational motion of the gear box main shaft is transferred to the differential unit for rotating the drive wheels mainly torsional load acts on the propeller shaft, hence it is made of tubular cross-section.
- To prevent the turbulence generation at high speed, it is perfectly balance.
- Universal joint is provide to transmit the power at changing angles of the propeller shaft, while vehicle is running.
- Slip joint is provided with the propeller shaft, to take care of increase in length of propeller shaft, while vehicle is running.

Function of Propeller Shaft

- Propeller shaft take power from the gear box output shaft without making any change in power, it transmits the same to the input pinion of the differential unit, from where power is transmitted to the drive wheels through rear axle.
- To accommodate the change in line and level between gear-box output shaft and differential input pinion shaft.

Constructional details of Propeller Shaft

- The propeller shaft used to transmit the power from gear box output shaft to differential with tubular cross-section & one or two piece construction.
- The two piece propeller shaft is supported at the center by rubber mounted bearing.
- Propeller shaft should be rigid enough to absorb the twisting action due to driving torque and the torsional shock.
- It should also be capable of resisting the vibration.

Constructional details of Propeller Shaft

- Tubular propeller shaft is generally used because...
  - It weight less
  - It can resist misalignment
  - It has good torsional strength
  - It provide less resistance to change of angular speed caused when hook type coupling is used.
- Propeller shaft is running faster when overdrive is used, hence it should be produce as per required design specification and good limit of balances.

Vibration of Propeller Shaft

- The vehicle having bigger wheel base need long propeller shaft. Long propeller shaft generated whirling by bending at its center.
- In such condition resonant vibrations are produced in the body. Hence along with the whirls, vehicle body also vibrates.
- For resonant frequency of propeller shaft there are two groups of main factors producing vibration.
  - Factors related to Propeller Shaft
  - Factors related to Vehicle Body

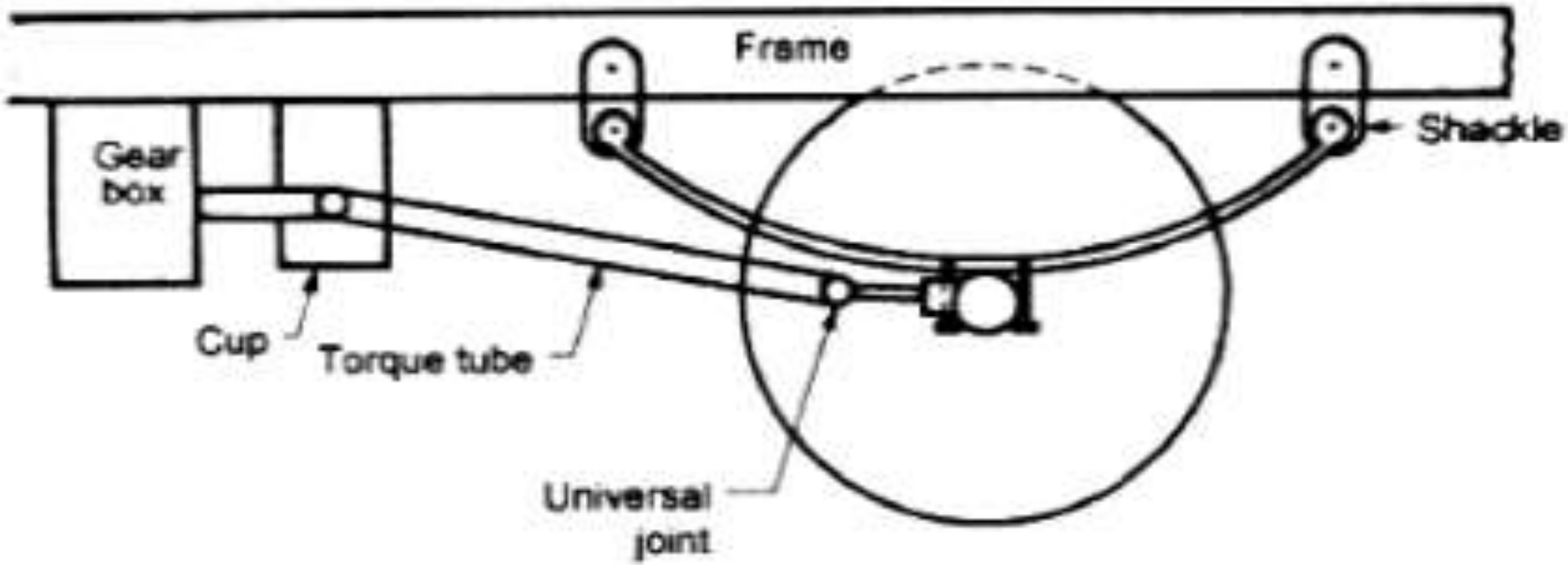
Vibration of Propeller Shaft

- Factors related to Propeller Shaft
  - Shaft Diameter and Length
  - Balancing of assembled shaft and Joints
  - Bending resistance of the Shaft
- Factors related to Vehicle Body
  - Shape and type of body structure
  - Location of body structure parts
  - Engine transmission mountings, springs, bushing and penal insulation by clamping quality for drive shaft vibration

Vibration of Propeller Shaft

- Shifting of center of gravity is also responsible for vibration.
  - Bending of shaft at center
  - Irregular thickness of wall of shaft tube
  - By rolling from flat sheet the shaft is produced finally by welding. The welded portion may not have weight same as that of opposite metal
  - The joints of yoke and trunnions are at one side of axis
  - The clearance of splines shaft is allowing shaft to shift towards one side

Torque Tube Drive



Torque tube drive

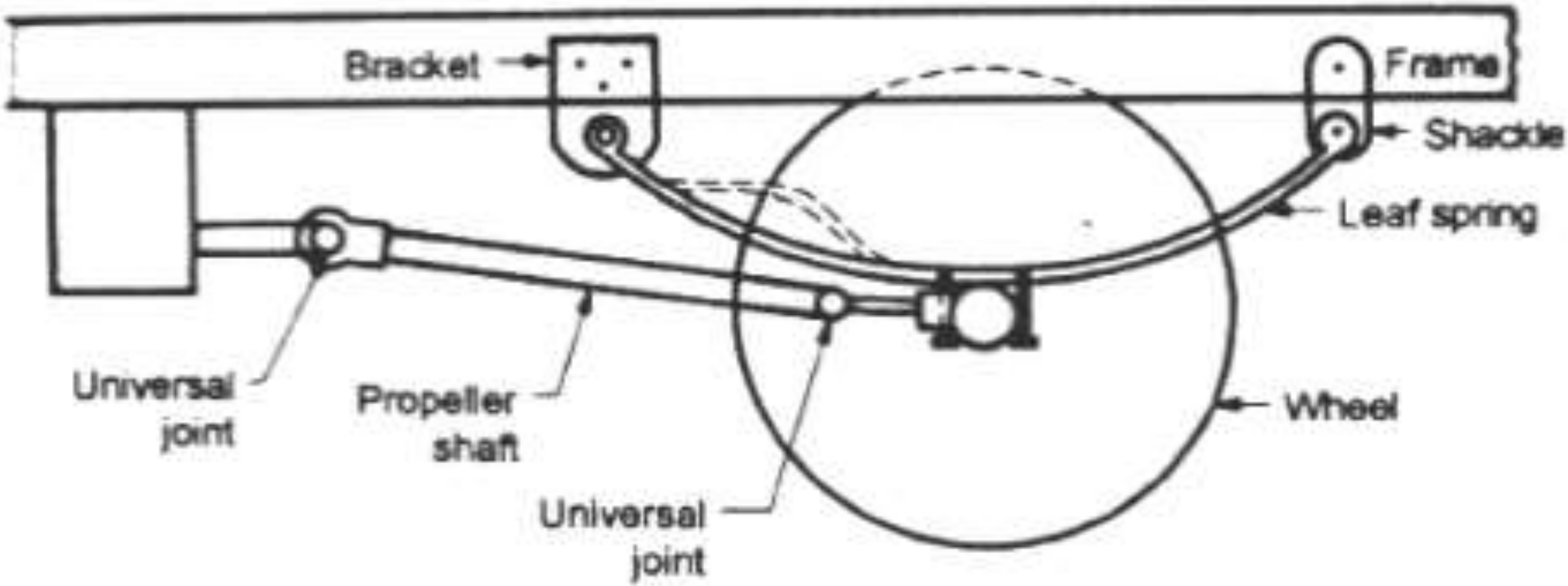
Torque Tube Drive

- In torque drive, the propeller shaft is enclosed in a hollow tube.
- The tube is rigidly bolted to the differential housing at one end and is fastened at the other end to the transmission through a somewhat flexible joint (universal joint) situated in spherical cup fixed to the frame.
- The torque reaction and driving thrust are taken up by torque tube.
- When the vehicle comes across a bump or shocks, the centre line of the bevel pinion shaft will not be shift and always passes through the centre of spherical cup.

Torque Tube Drive

- Hence, only one universal joint is required at front end and no universal joint at the rear end.
- The tube incorporates bearing, which support the propeller shaft.
- It is usually located between the (transmission) gear box and the propeller shaft.
- No sliding joint is required in the propeller shaft.
- In this drive, the leaf springs takes only the side thrust besides supporting weight of the body.

Hotchkiss Drive



Hotchkiss Drive

Hotchkiss Drive

- The Hotchkiss drive is simplest and most popular form of rear axle suspension.
- Hotchkiss drive combines the springing and positioning or locating of the rear axle. It uses a rigid axle with leaf spring mounted at its extremities as far apart as possible on the rear axle.
- The Hotchkiss drive consists of a leaf spring and a propeller shaft with two universal joints and one sliding joint.
- The front end of the leaf spring is pivoted in pin of bracket which is bolted to the vehicle frame.
- While rear end of the leaf spring is supported in swinging shackle with antifriction bush material.
- The leaf springs are bolted rigidly to the rear axle casing at middle.
- The spring takes weight of body, torque reaction and driving thrust.

Hotchkiss Drive

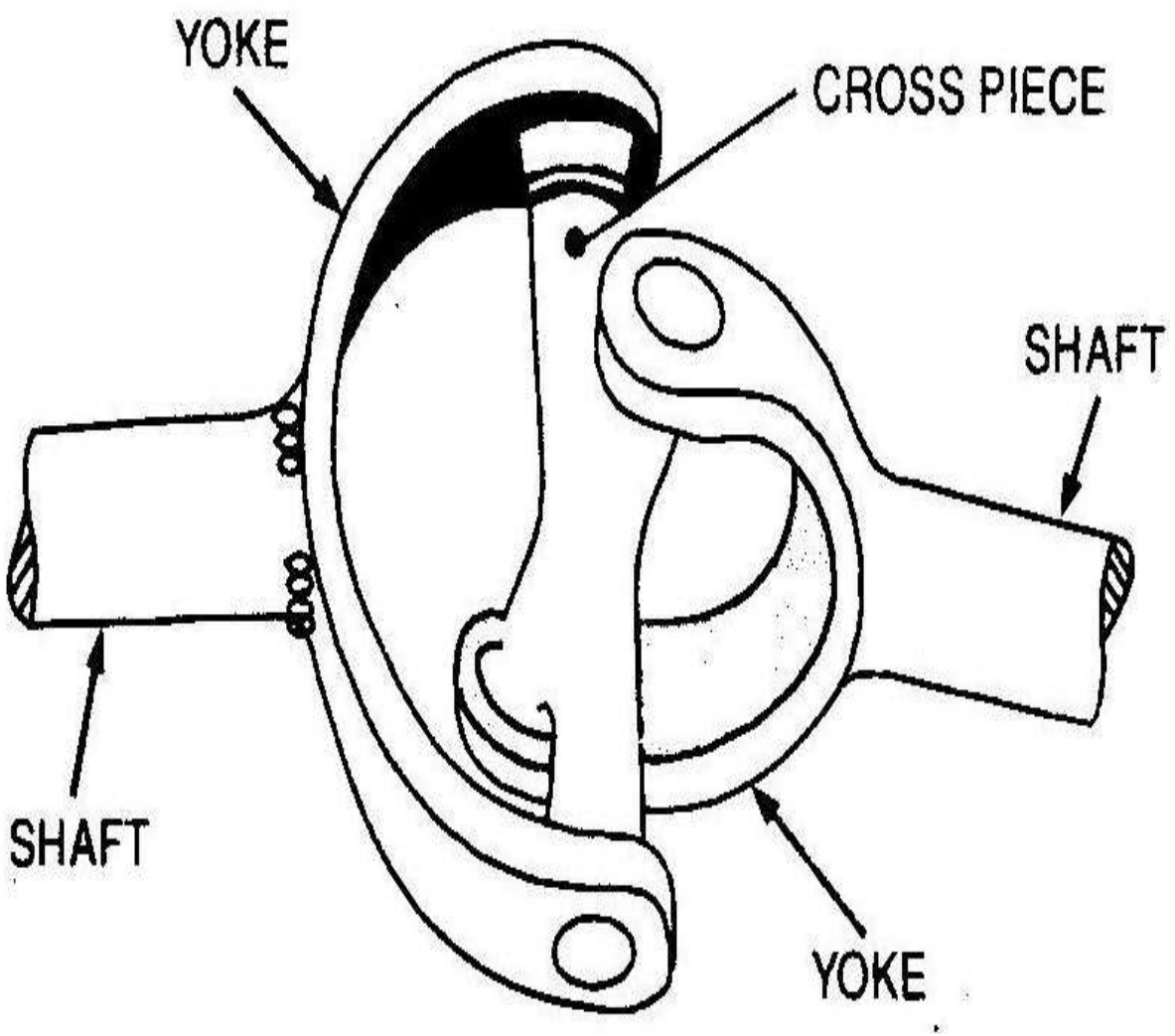
- The driving and braking torques are absorbed through the front half of the rear leaf spring shown by dotted line.
- During driving and braking, the bevel pinion changes the position so the length and angle of propeller shaft changes which will be adjusted by universal joint and sliding joint. Therefore if only one universal joint is at the front end, then the propeller shaft may bend or damage.
- To avoid this, another universal joint is provided at rear end.
- When the vehicle comes across a bump or shocks, the rear axle moves up and down and it has to move in a circle with front spring supported at the frame as centre.
- During this movement of rear axle, the length of the propeller shaft changes which will be adjusted by sliding joint.

Universal Joint

- A universal joint allows driving torque to be carried through two shafts that are at an angle with each other.
- A simple universal joint consist two Y- shaped yoke, one on the driving shaft and other on the driven shaft.
- The four arms of spider are assembled in needle bearings in the two yokes. The driving shaft and yoke force the spider to rotate.
- The other two trunnions of the spider then cause the driven yoke to rotate.
- When the two shafts are at an angle with each other, the needle bearings permit the yokes to swing around on the trunnions with each revolution.

Universal Joint

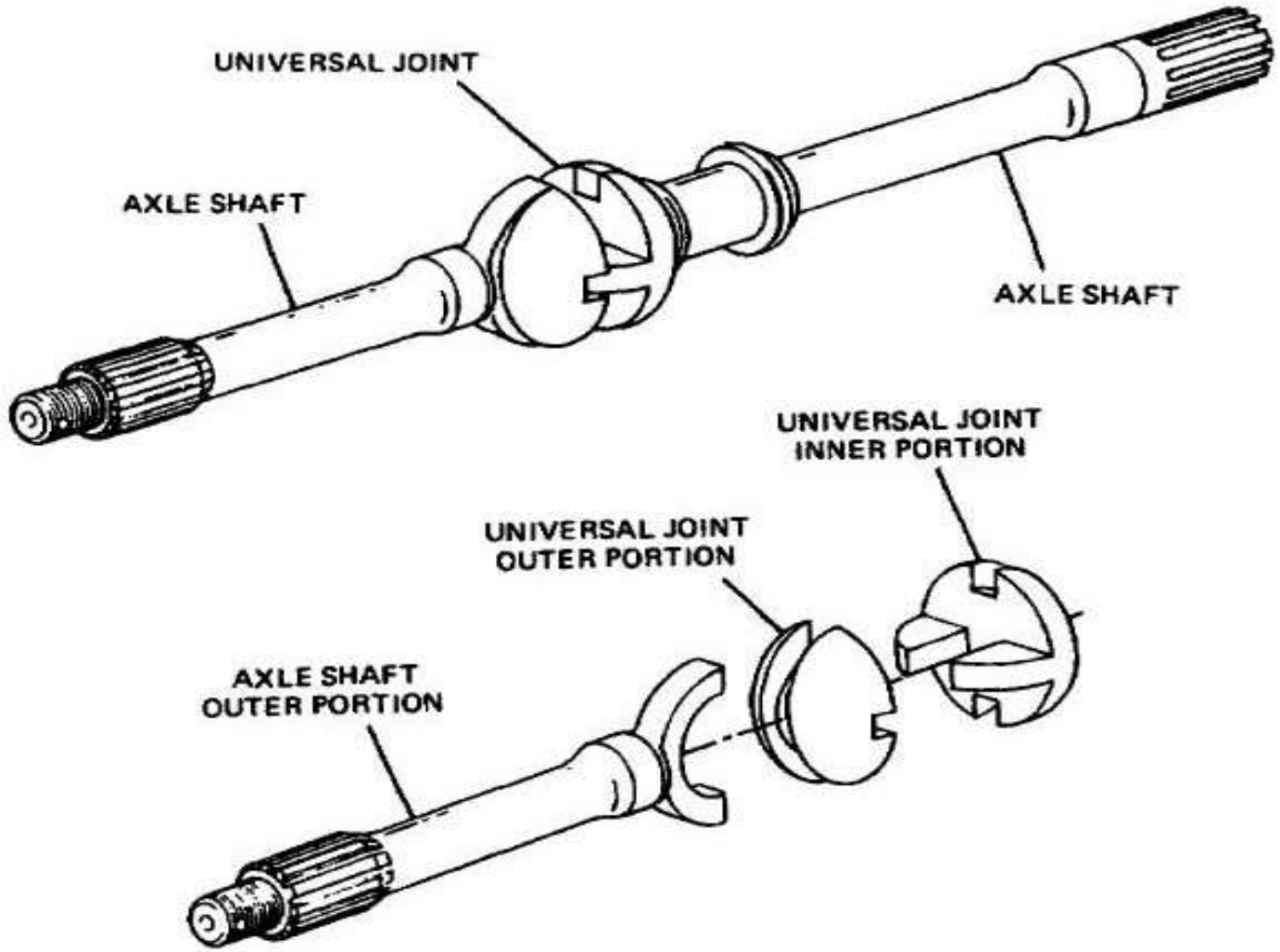
- A simple universal joint does not transmit the motion uniformly when the shafts are operating an angle. Because of this, two universal joints are used in a vehicle, one between the gear box and the propeller shaft and other between the propeller shaft and the differential pinion shaft.



Constant Velocity Joint

- Constant-velocity joints (aka homo kinetic or CV joints) allow a drive shaft to transmit power through a variable angle, at constant rotational speed, without an appreciable increase in friction or play.
- They are mainly used in front wheel drive and many modern Rear wheel drive cars with independent rear suspension typically use CV joints at the ends of the rear axle half shafts, and increasingly use them on the prop shafts.
- Constant-velocity joints are protected by a rubber boot, a CV gaiter. Cracks and splits in the boot will allow contaminants in, which would cause the joint to wear quickly.

Constant Velocity Joint



Slip Joint

- Slip joint is attached to the driven yoke in order the increase or decrease the length of propeller shaft.
- It has outside splines on the shaft and matching internal splines in a mating hollow shaft or yoke.
- When assembled the splines cause the shafts to rotate together while they can move back and forth. This changes the length of propeller shaft.

Slip Joint