SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF AEROSPACE ENGINEERING

Power Transmission Devices

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INTRODUCTION TO MECHANICAL ENGINEERING

➢ **Mechanical Elements**

Function, Sketch, Description & Uses of –

- Shaft
- Axle
- Keys (Parallel Keys)
- Coupling (Rigid Flanged Coupling)
- Bearing (Ball Bearing)
- Clutch (Single Plate Clutch)
- Brake (Disc Brake)

➢ **Power Transmission Devices**

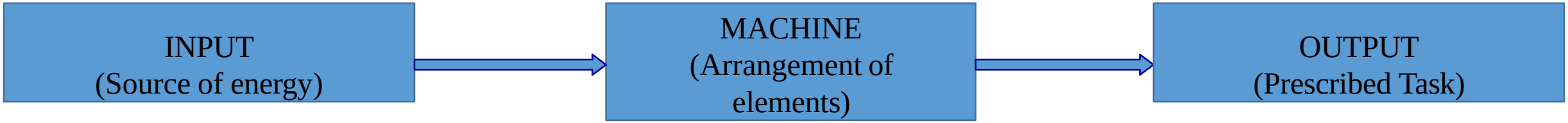
Construction, Working, Comparison & Applications of –

- Belt Drive (Flat & V Belt)
- Chain Drive
- Spur gear drive arranged with simple gear train

Introduction

What is Machine?

Machine is a device consisting of various elements arranged together, so as to perform the prescribe task to satisfy human needs.



Eg: A pump-set is a machine in which the input is electrical energy, the pump-set utilizes the electrical energy to perform the prescribed task of lifting water to the desired location (output).

Machine Elements

- Machine element is an individual component or a group of components of a machine which performs a specific function.
- Its function may be of holding the components together, to transmit power or to give supports.
- Depending upon these functions only, the machine elements are following types.
    1) Machine elements used for holding the components.
    2) Machine elements used for transmitting the power.
    3) Machine elements used for support of other components.

Machine elements

Machine elements

- Holding elements
- Supporting elements
- Power transmitting elements

Machine Elements

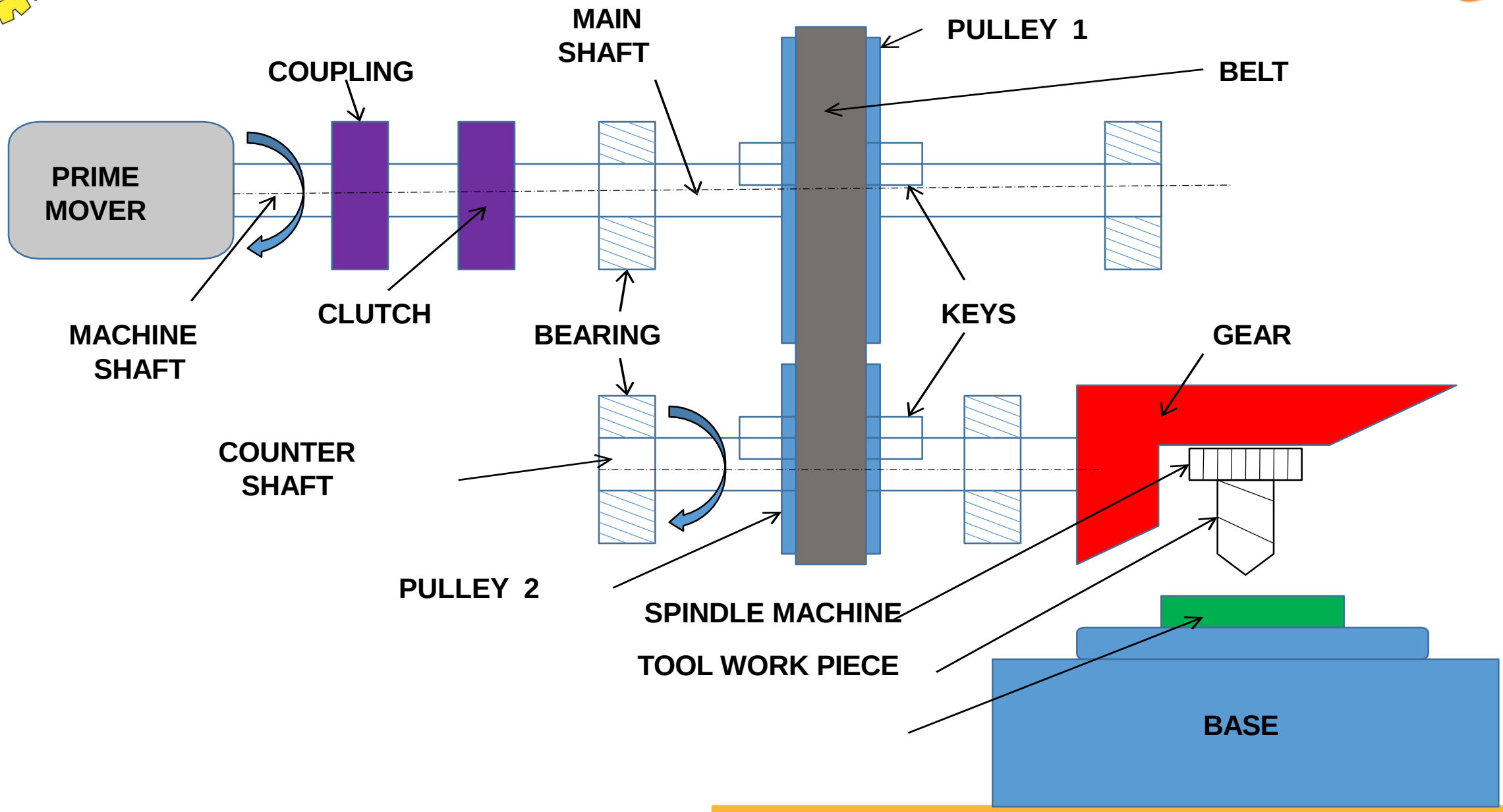
- Machine elements used for holding the components :- These type of machine elements include nuts and bolts, screw, cotters, keys, couplings, pins, revettes.

- Machine elements used for transmitting the power :- Machine elements like gears, shafts, clutches and brakes, pulleys, belts, chain, sprocket, are used to transmit power from one place to another.

- Machine elements used for support of other components:-

  Machine elements like bearings, axles, brackets, hangers etc. are used to give support to rotating or stationary members.

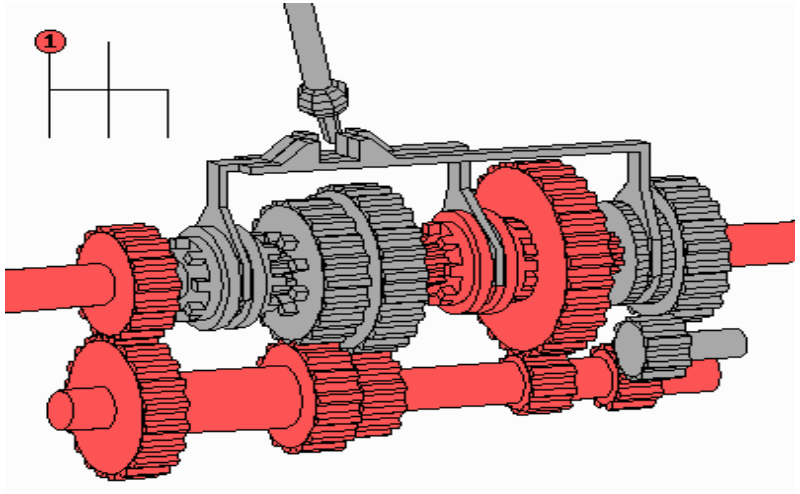
MECHANICAL SYSTEM



Shaft

Introduction

A shaft is a rotating member/machine element, which is used to transmit power from one place to another. In order to transfer the power from one shaft to another the various members such as pulleys, gears, crank etc. are mounted on it. These members are mounted on the shaft by means of keys or splines.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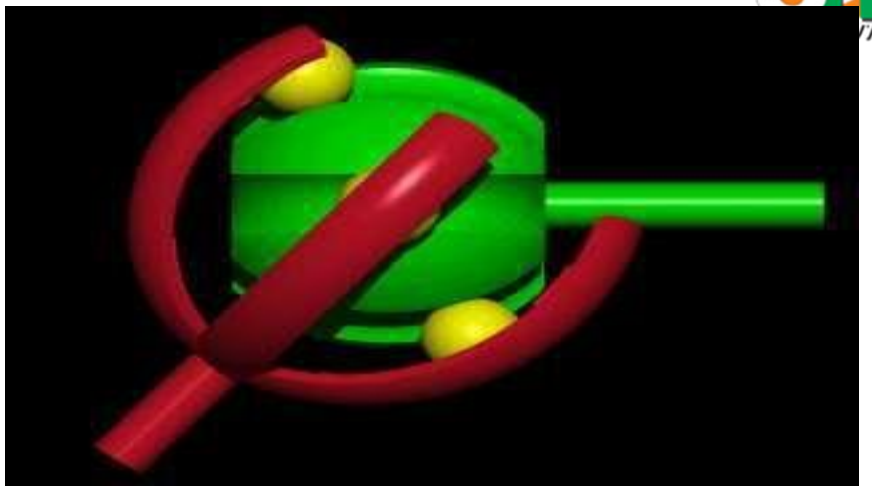
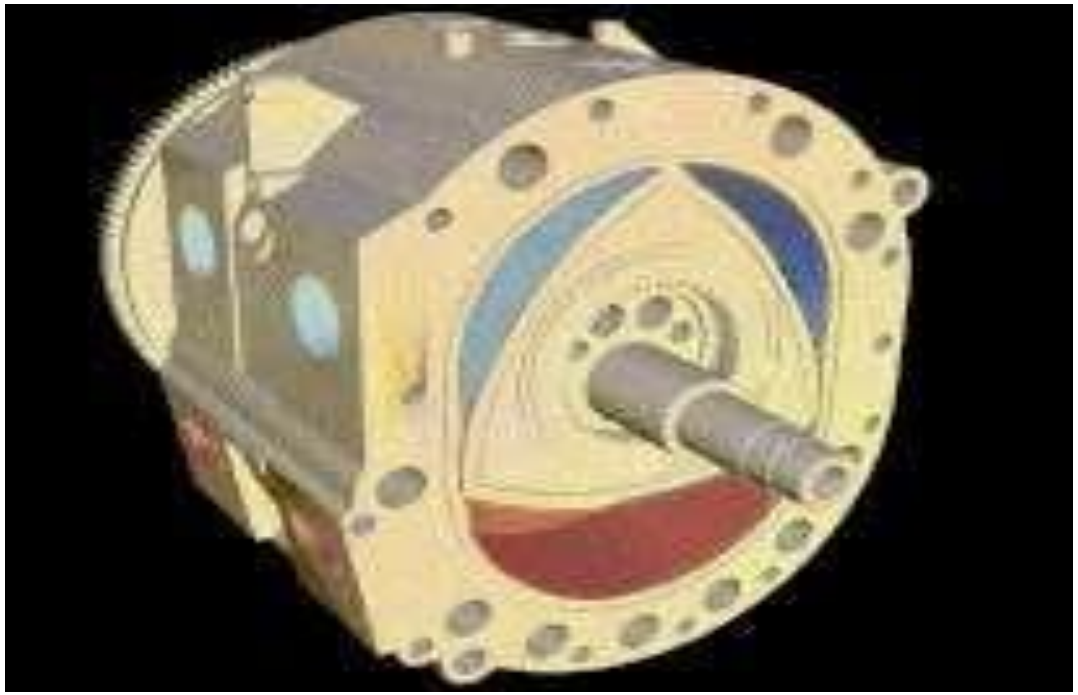


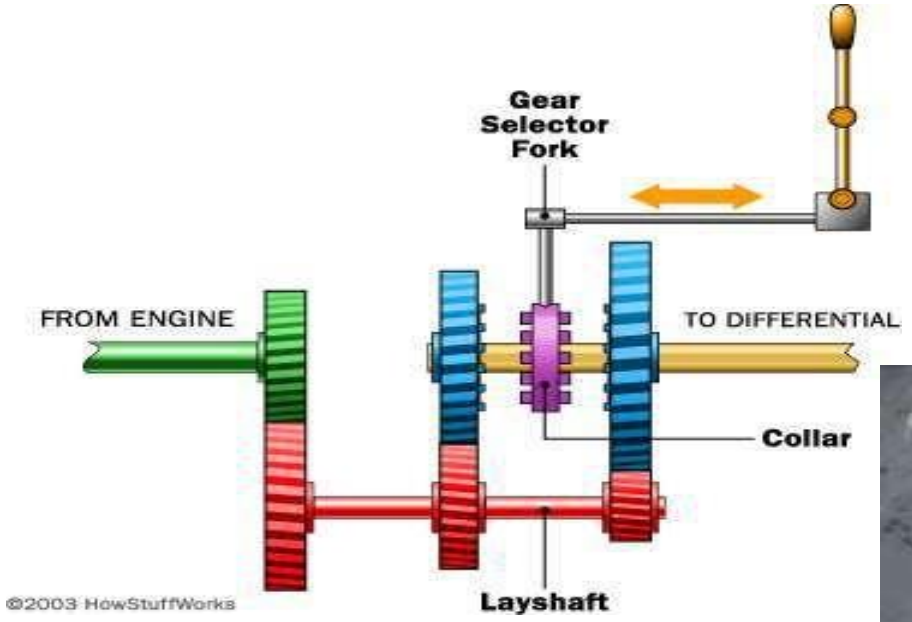


Types of shafts

1. Transmission
2. Machine shafts

Used to transmit the power between the source and the machine

1. **Line shaft**
2. **Counter shaft**

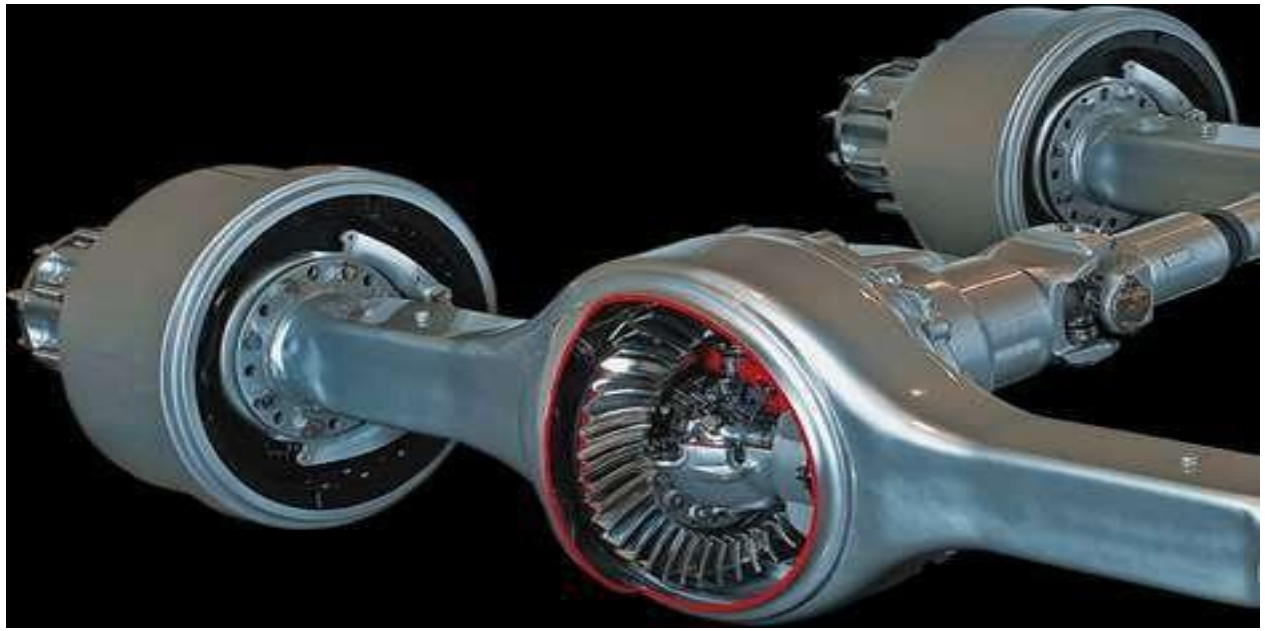


It is short rotating shaft which forms an integral part of the machine.

1. **Spindle**
2. **crankshaft**

Axles

- It is non-rotating machine element which is used to support rotating machine elements like : wheels, pulleys etc.



Sr. No.	Shaft	Axle
1	Rotating member	Non-Rotating member
2	Used to transmit the torque and support the transmission elements, like: gears, pulleys	Only used to support the transmission elements, like: wheels, pulleys etc
3	It is subject to torque, bending moment and axial force	It is subjected to bending moment and axial force
4	Example- line shaft, counter shaft, spindle, crankshaft	Example:- front axle of car, wheel axle of motorcycle etc.

Types of Shafts

A) Machine shaft:

These shafts form an integral part of the machine itself.
e.g. crank shaft of an I.C. engine.

Types :-

1) Axle

An axle is stationary shaft i.e. non rotating memb which supports a rotating element like wheel hoisting drum and fitted to the housing by means bearings. Axle is subjected to bending load only a does not transmit any useful torque.

e.g.

- rear axle of railway wagon
- axle of motor car
- supporting wheels.

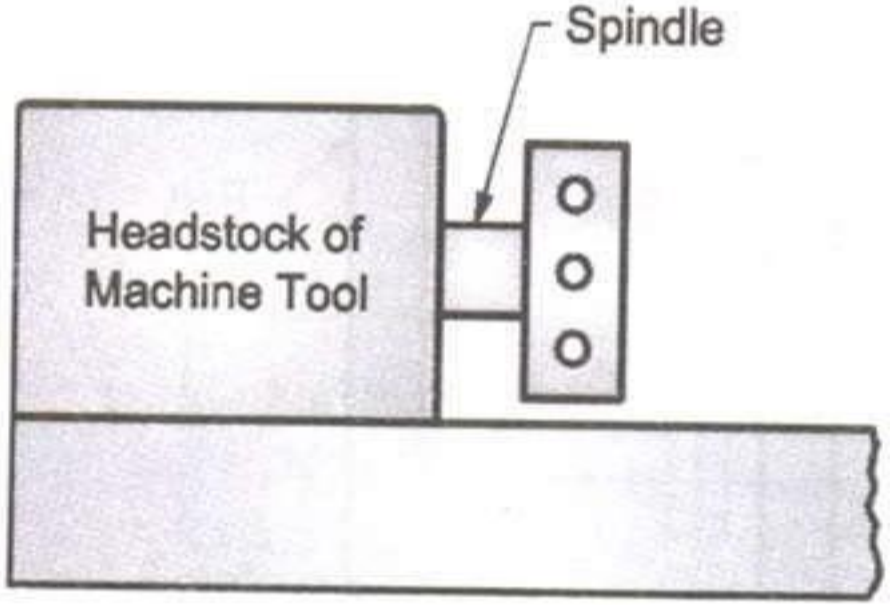
Types :-

2) Spindle:

A spindle is a short rotating shaft. Spindles are used in all machine tools to give motion to a cutting tool or to a work piece.

e.g.

- spindle of drilling machine.
- drive shaft of lathe.



Types of Shafts

B) Transmission shaft:

These shafts transmit power from the source of power to the machine which absorbs that power.

e.g. the power is transmitted from motor to compressor by means of a transmission shaft.

The transmission shaft is usually circular in cross section. The shaft is always stepped (having different cross sections of shafts) for positioning transmission elements like gears, pulleys and bearings. Transmission shafts may be solid or hollow.

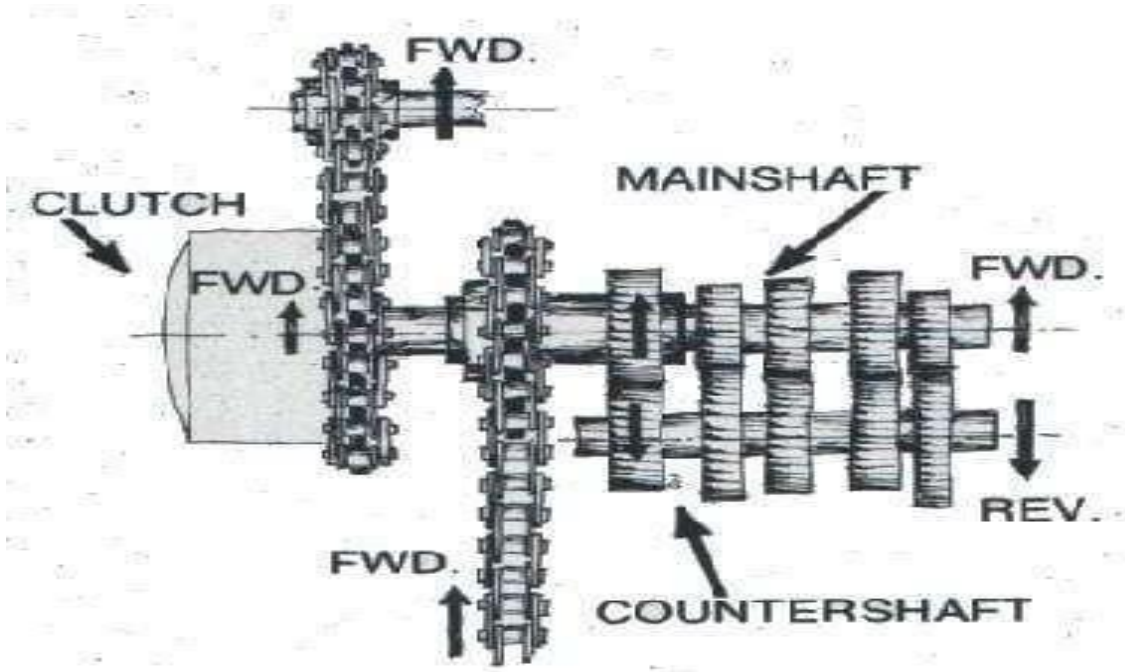
Types :-

1) Main shaft

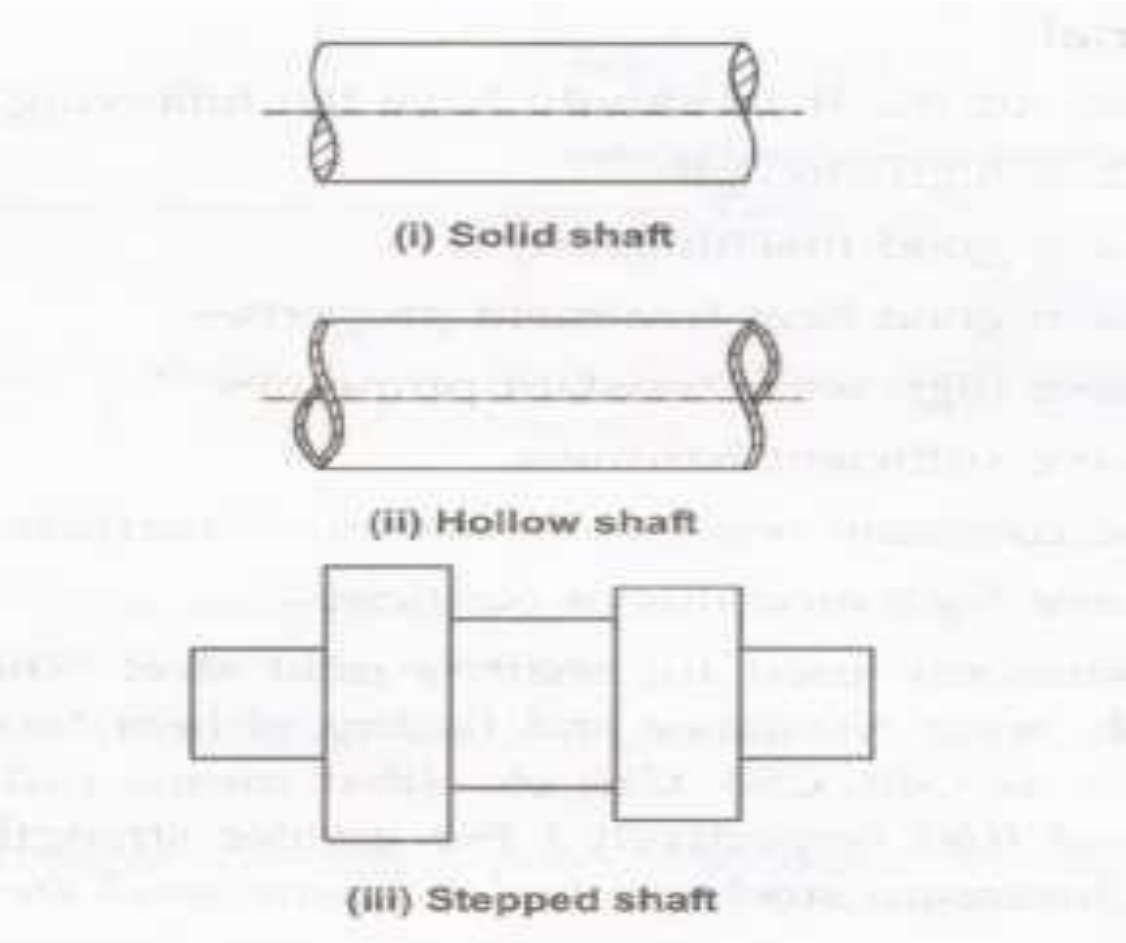
It is a primary shaft, which is driven by the machine shaft and from which the power is supplied to the counter shaft.

2) Countershaft

It is a secondary shaft, which is driven by the main shaft and from which the power is supplied to the machine components.



Types based on structure of Shafts



- Hollow shafts are lighter than solid shafts. They have more strength per kg weight of material compared to solid shaft.
- The various types of shafts are as shown in Fig.
- The examples of the hollow shafts are propeller shafts.
- Main shaft between air compressor and gas turbine in air craft engine.

Shaft Material

- The material used for the shaft should have the following properties

    1) It should have high strength.
    2) It should have good machinability.
    3) It should have good heat treatment properties.
    4) It should have high wear resistant properties.
    5) It should have sufficient hardness.
    6) It should be corrosion resistant in marine or corrosive environments.
    7) It should have high modulus of elasticity.

- The material commonly used for shaft is mild steel. The carbon steel is also used where strength, wear resistance and facility of heat treatment is needed.

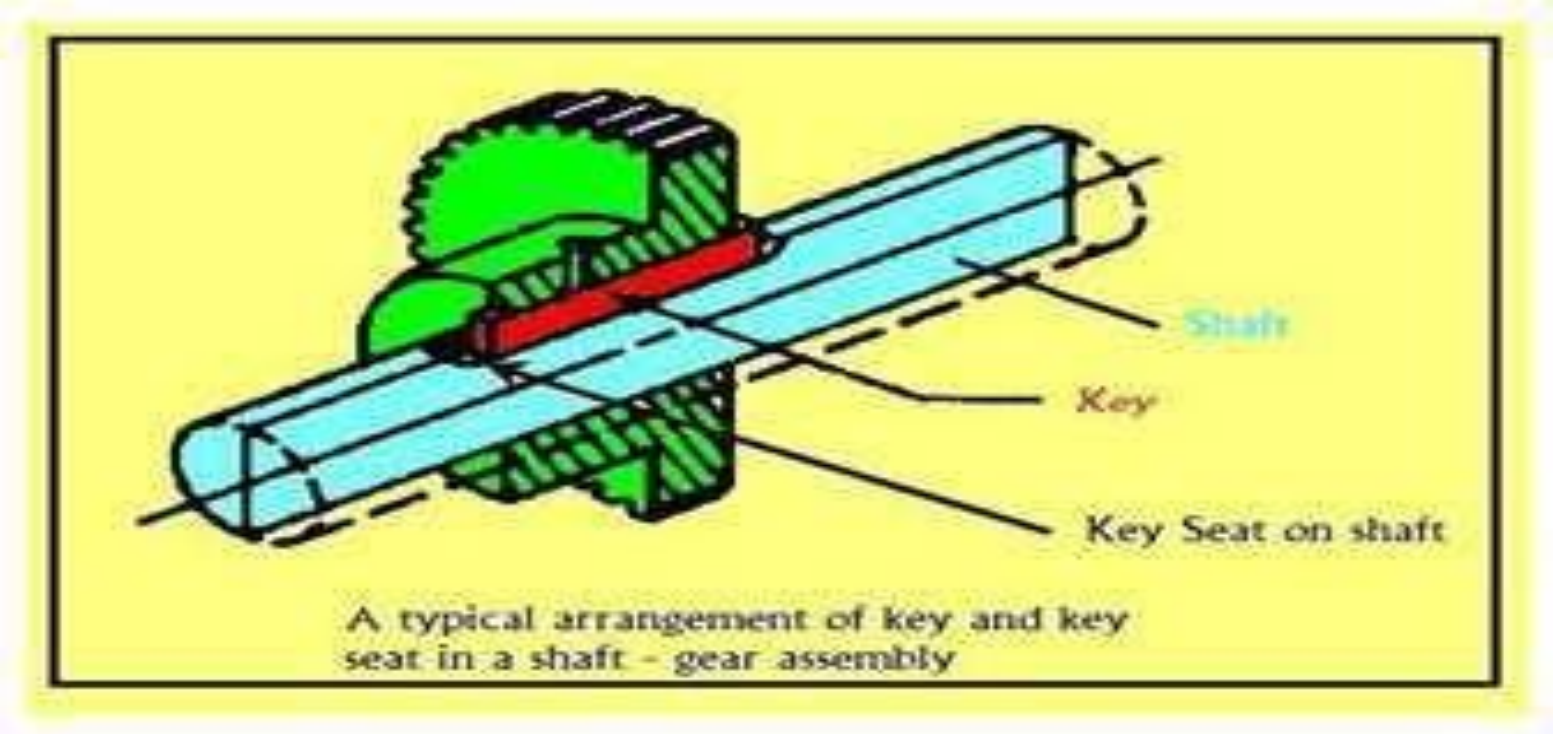
Keys

A key is a machine element used on shafts to secure the rotating elements like gears, pulleys or sprockets and prevent the relative motion between the two. It is always inserted parallel to the axis of the shaft. Keys are used as temporary fastenings and are subjected to considerable crushing and shearing stresses.

A keyway is a slot or recess in a shaft and hub of the pulley to accommodate a key.

Materials used:

- Plain carbon steels
- Alloy steels



A typical arrangement of key and key seat in a shaft - gear assembly

- A key performs following two basic functions.

1) The primary function of key is to transmit the torque from the shaft to the hub of machine element and vice-versa.

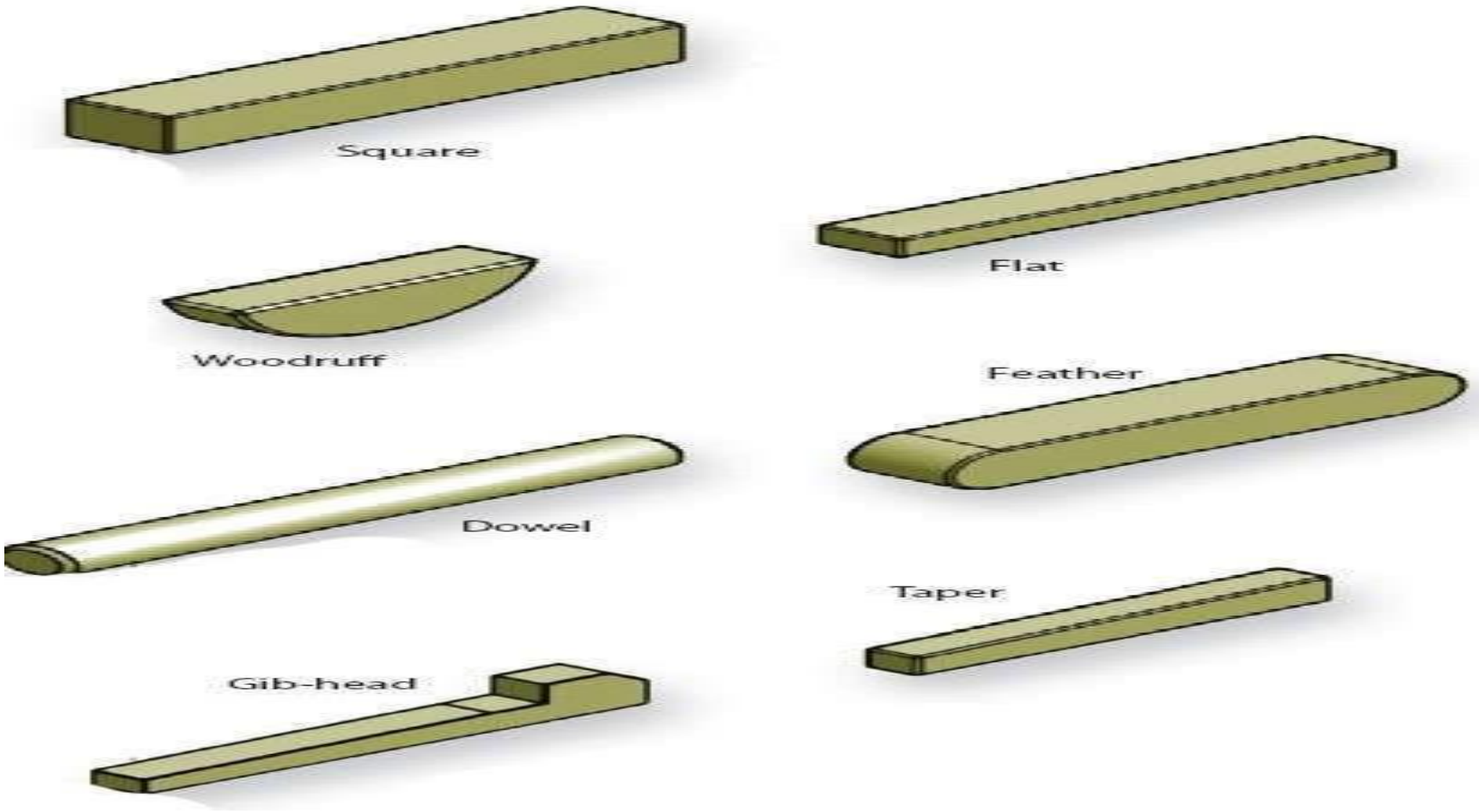
2) The second function of the key is to prevent relative rotational motion between the shaft and mounted machine element like gear or pulley.

- In most of the cases, key also prevents axial motion between the elements.
- A keyed joint consisting of shaft, hub and key is illustrated in Fig.
- A recess or slot machined on the shaft and or in the hub to accommodate the key is called as key way.
- One key way is usually cut by milling machine.
- Keys are designed in order to withstand shear and compressive stresses resulting from transmission of torque.
- Generally, material of the key is selected, which has less strength than the shaft material.

Types of Keys

- Keys are broadly classified as
    a) Saddle keys
    b) Sunk keys
    c) Round key
    d) Splines

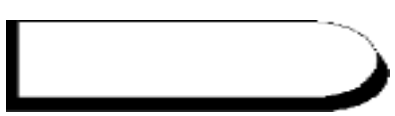
Keys

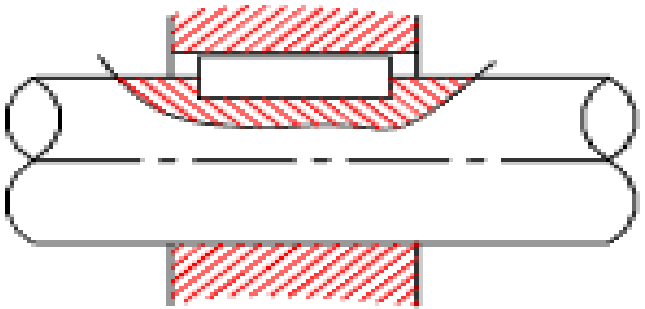


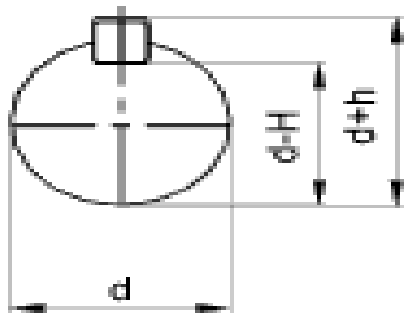
Parallel key

Parallel keys are the most widely used. They have a square or rectangular cross-section. Square keys are used for smaller shafts and rectangular faced keys are used for shaft diameters over 6.5 in

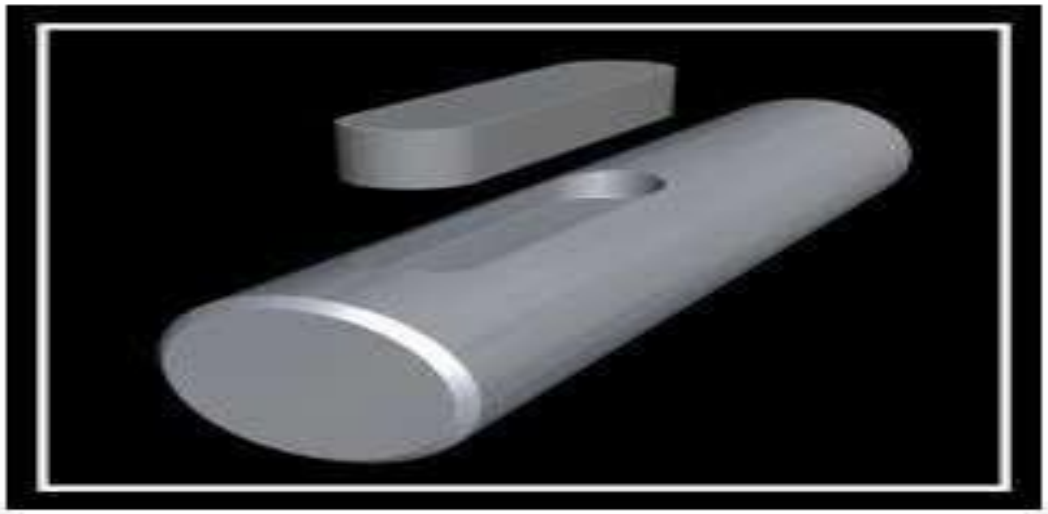
SS- 410 & SS- 316 material







used in automobile industries, Textile Industries, machine tool industries, Motor & pump Industries, Cement Industries etc

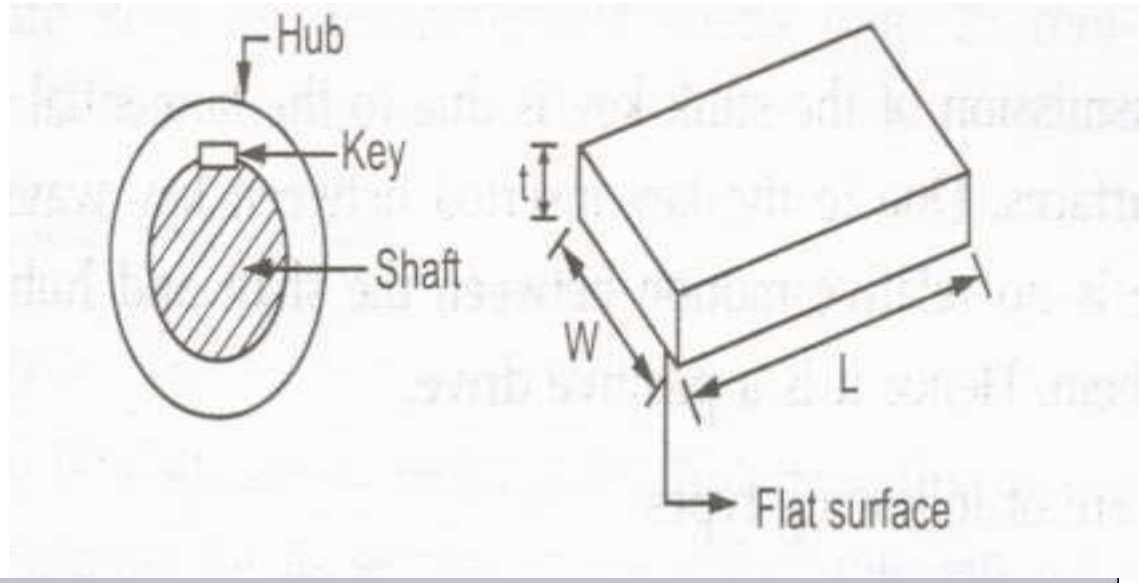


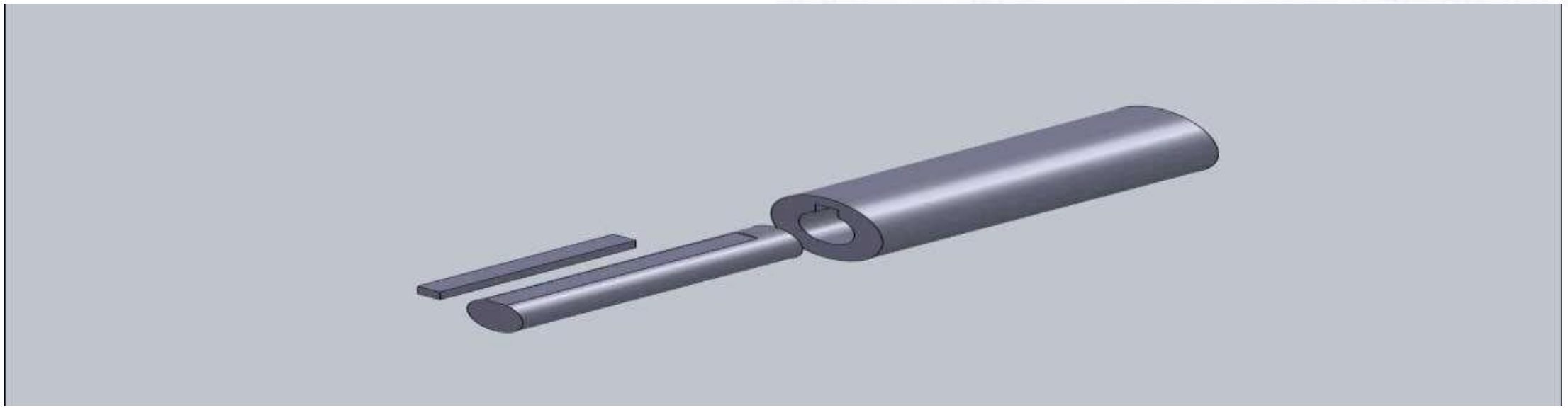
Saddle Keys

- Saddle keys are fitted only in the key way of one member of the mating surface i.e. either shaft or hub.
- Saddle keys are only of uniform width, and tapered in thickness along the length.
- Power transmission of the saddle key is due to the frictional forces set up between the keys and the shaft.
- Saddle keys are of two types -
  - i) Flat saddle key
  - ii) Hollow saddle key

Flat Saddle Key

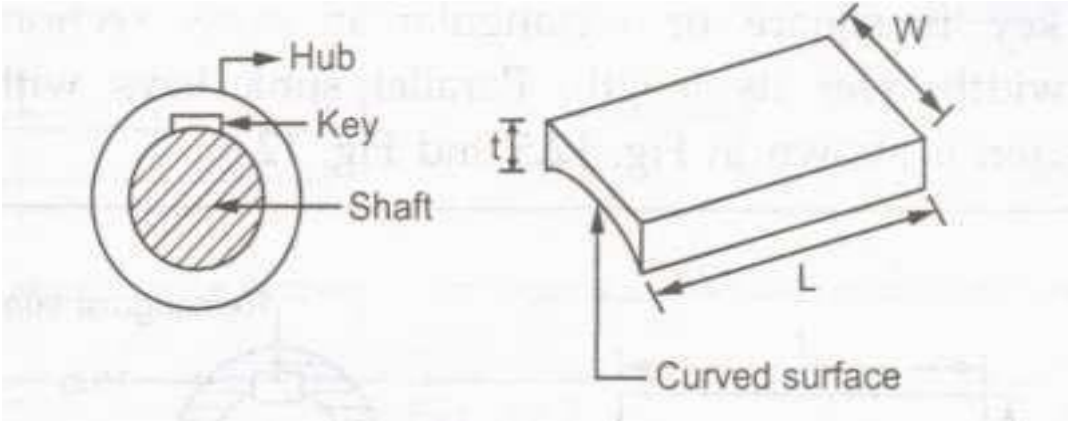
- The flat saddle key is a taper key which fits in a key way in the hub and is flat on the shaft as shown in Fig.

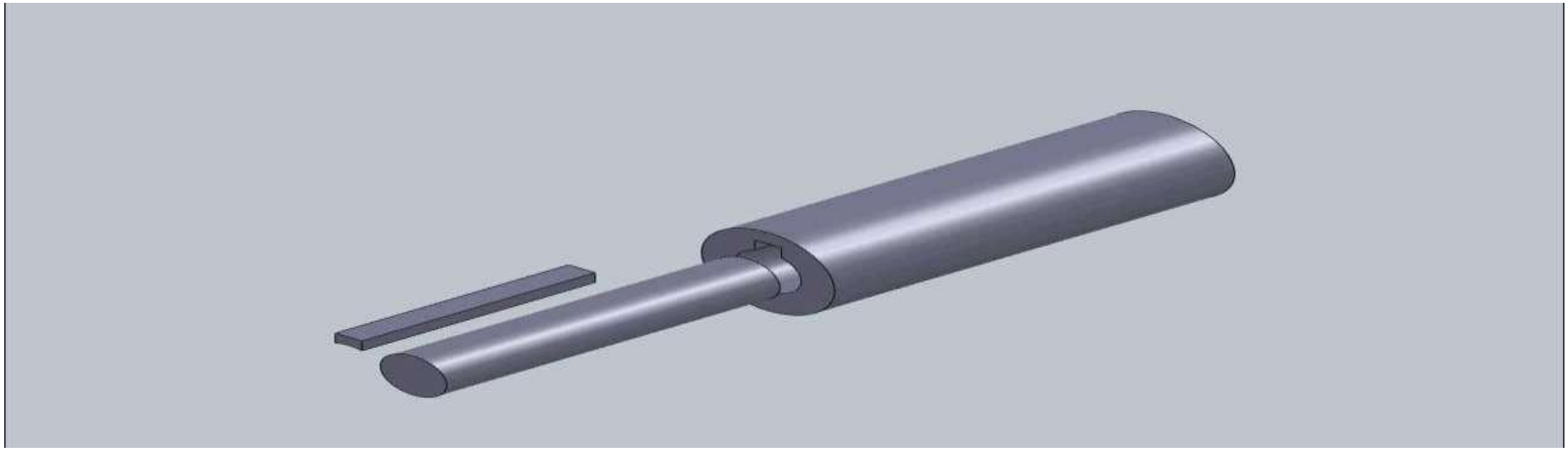




Hollow Saddle Key

- A hollow saddle key is a taper key which fits in a key way in the hub and its lower surface of the key is hollow or curved to fit on the curved surface of the shaft as shown in Fig.





- Advantages of Saddle Keys

1) Construction is simple.

2) Mounting cost is less as compared to other keys as there is key way on the hub only.

3) No weakning of shaft as there is no key way.

- Disadvantages of Saddle Keys

4) Used for transmission of lighter loads only.

5) No positive transmission of power as means of power transmission in friction.

- Applications

Used for light loads only like temporary fastening in fixing and setting of eccentric cams etc.

Sunk Keys

- Sunk keys are inserted half in the key way of hub and half in the key way of the shaft. Sunk keys are of uniform width and tapered in thickness along the length.
- Power transmission of the sunk key is due to the tangential force between key and mating surfaces. Due to the key inserted between key ways in both hub and the shaft there is no relative motion between the shaft and hub. Thus there is no slip between them. Hence it is a positive drive.
- Sunk keys are of following types.

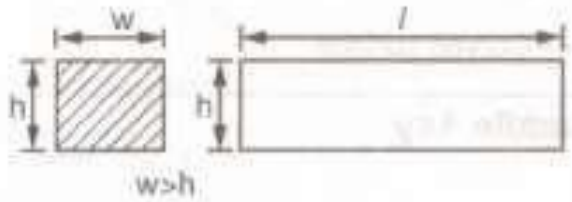
  i) Parallel sunk key

  ii) Taper sunk key

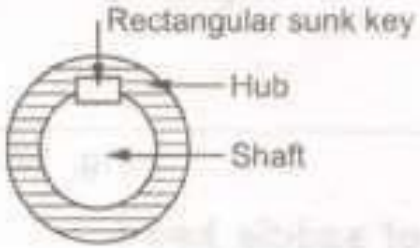
  iii) Feather key

  iv) Woodruff key

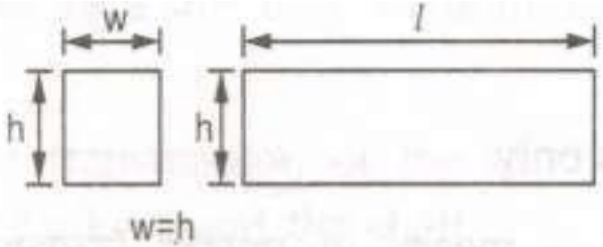
Parallel SunkKey



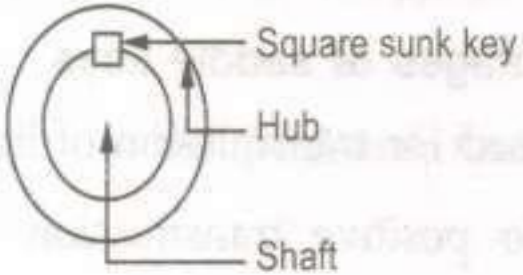
(a) Rectangular sunk key



(b) Rectangular sunk key with Shaft and Hub



(a) Rectangular sunk key



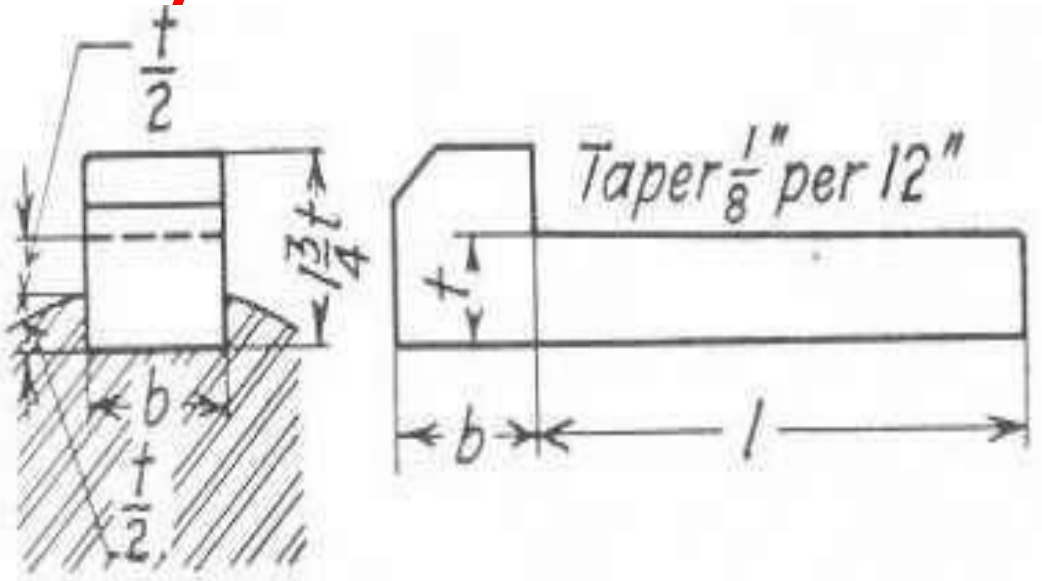
(b) Square sunk key with Shaft and Hub

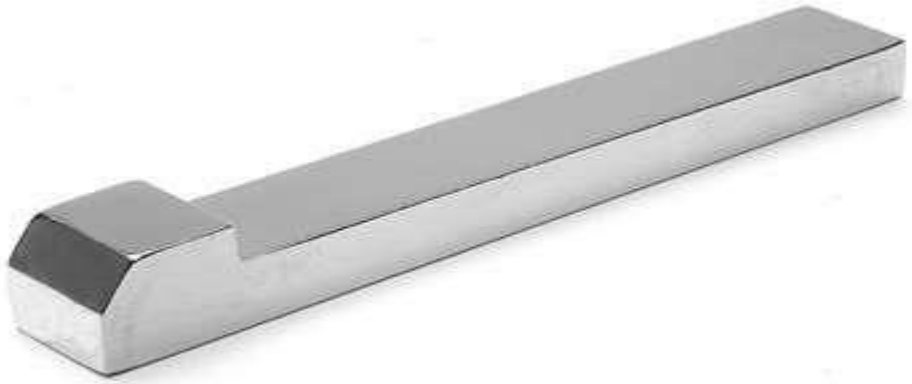
A parallel key is square or rectangular in cross section and of uniform thickness and width over its length.

Parallel sunk keys with rectangular and square cross section is shown in Figs.

Gib Headed Key

- The gib head keys are ordinary sunk keys tapered on top with a raised head on one side so that its removal is easy. This is shown in figure.



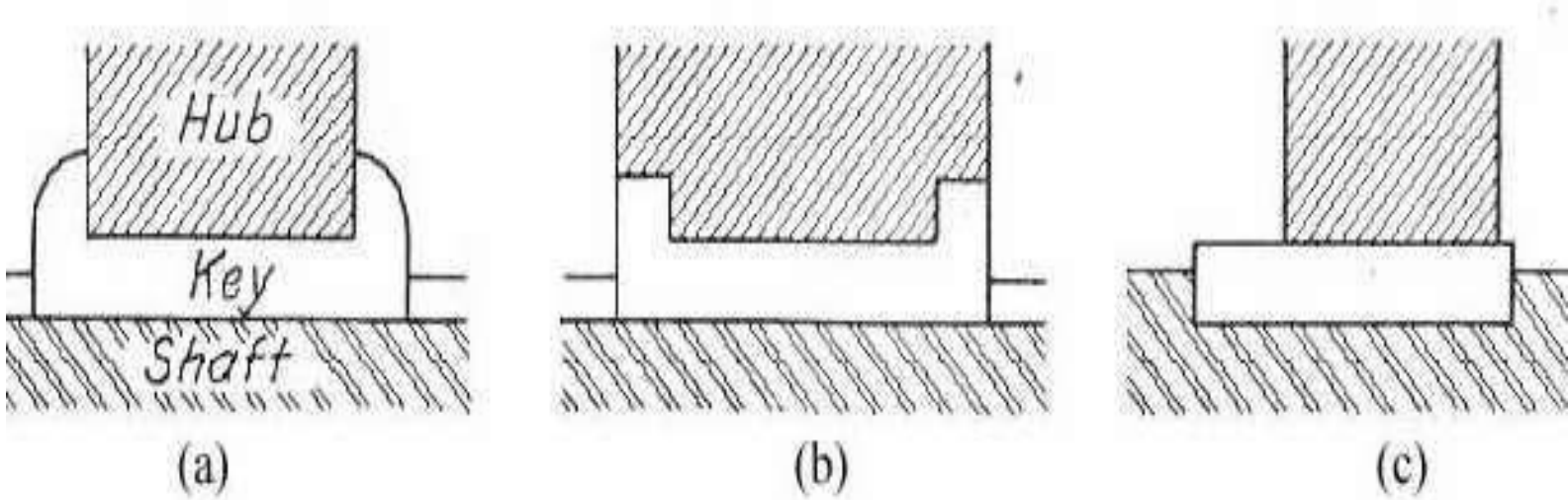


Feather Key

Some feather key arrangements are shown in figure.

A feather key is used when one component slides over another.

The key may be fastened either to the hub or the shaft and the keyway usually has a sliding fit.

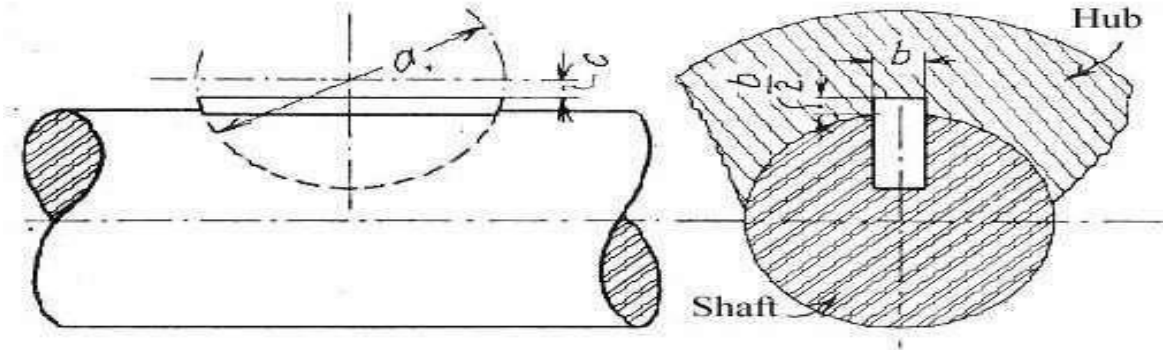


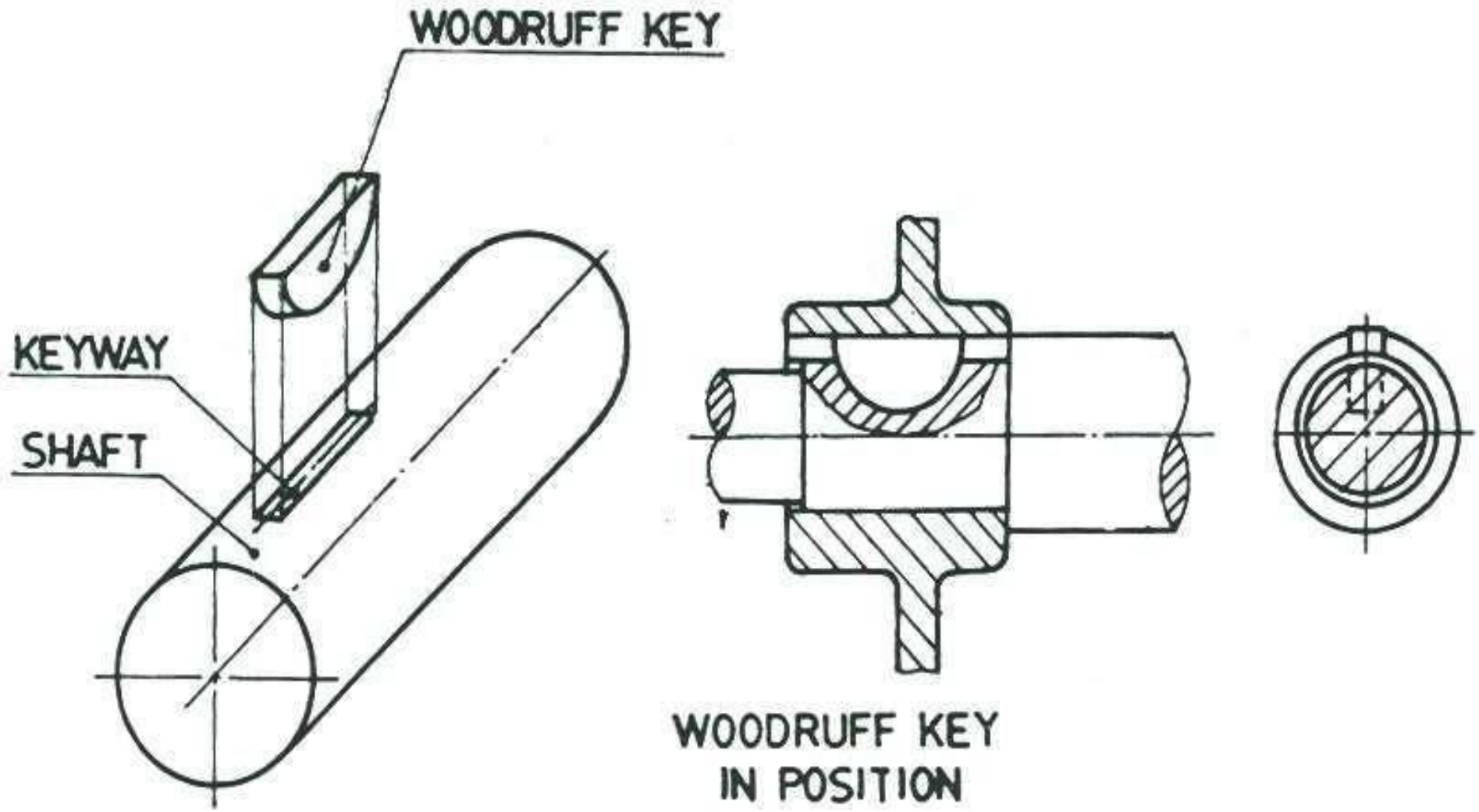
Woodruff Key

A woodruff key is a form of sunk key where the key shape is that of a truncated disc, as shown in figure.

It is usually used for shafts less than about 60 mm diameter and the keyway is cut in the shaft using a milling cutter.

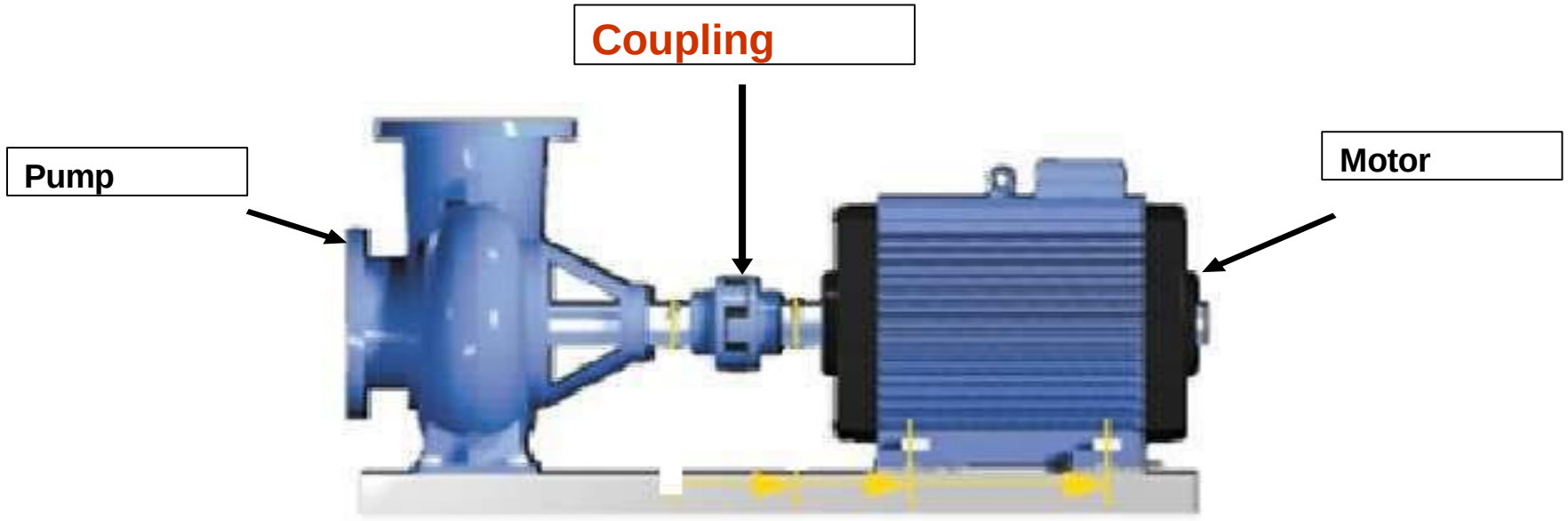
It is widely used in machine tools and automobiles due to the extra advantage derived from the extra depth.




WOODRUFF KEY
KEYWAY
SHAFT
WOODRUFF KEY
IN POSITION

Couplings

Coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power



Uses of coupling

- To provide connection of shafts of units made separately
- To allow misalignment of the shafts or to introduce mechanical flexibility.
- To reduce the transmission of shock loads
- To introduce protection against overloads.
- To alter the vibration characteristics

Types of coupling

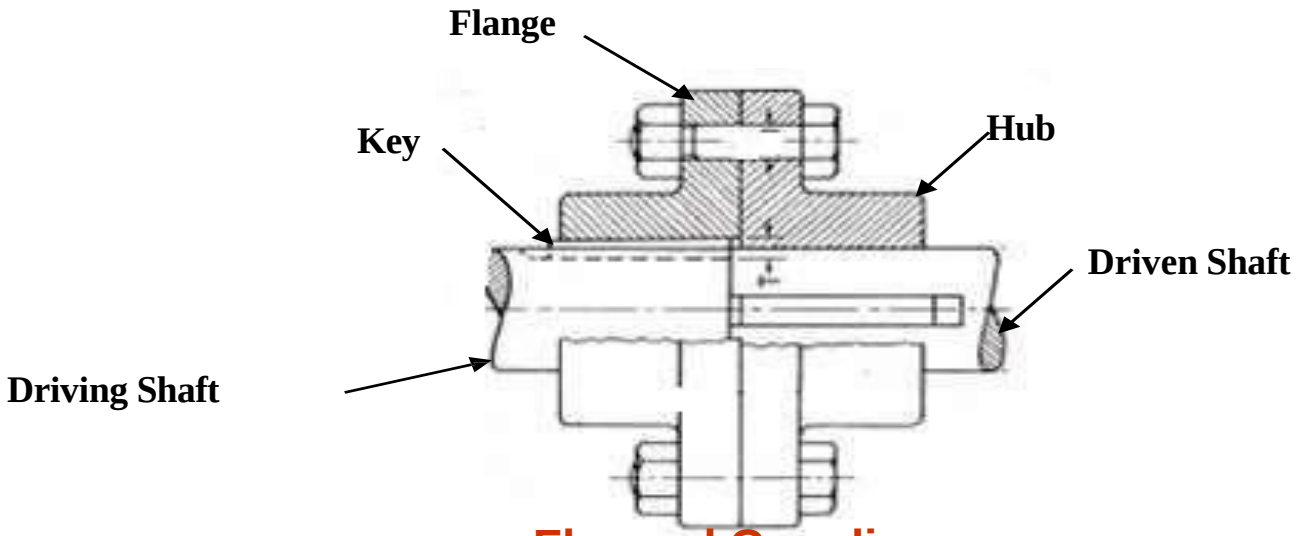
- Rigid
- Flexible
- Universal

Rigid coupling

Flexible coupling

Universal coupling

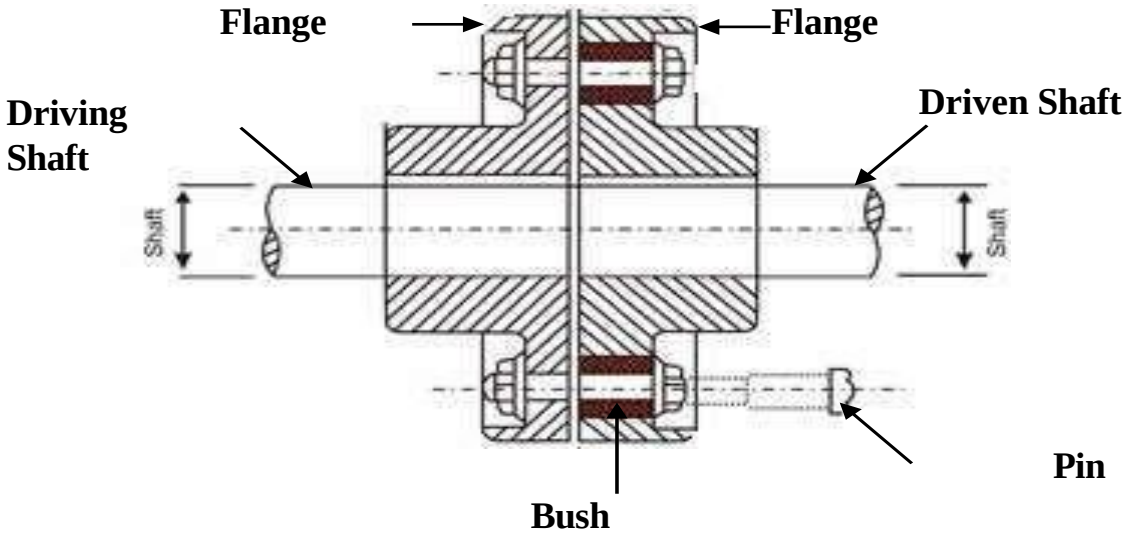
Rigid coupling



Flanged Coupling

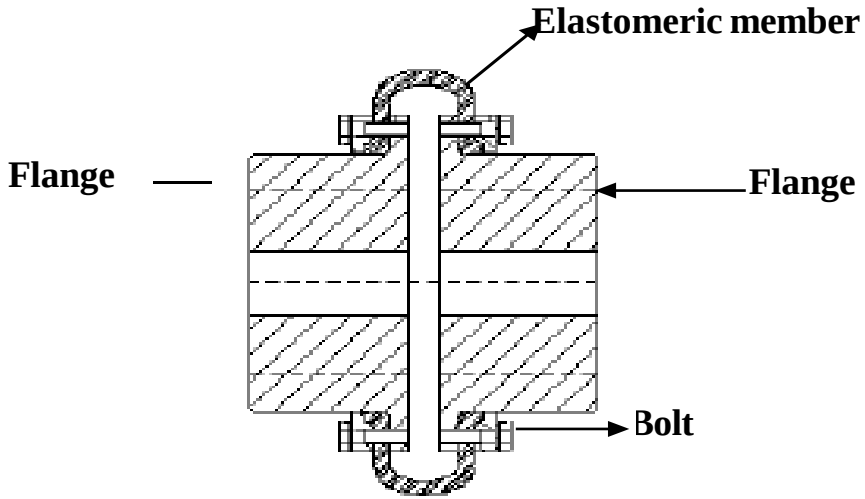
- Rigid couplings are used when precise shaft alignment is required
- Simple in design and are more rugged
- Generally able to transmit more power than flexible couplings
- Shaft misalignments cannot be compensated

Flexible Coupling



- A flexible coupling permits with in certain limits, relative rotation and variation in the alignment of shafts
- Pins (Bolts) covered by rubber washer or bush is used connect flanges with nuts
- The rubber washers or bushes act as a shock absorbers and insulators.

Elastomeric coupling (Tyre Coupling)



- **An assembly of components designed to connect axially oriented shafts in order to provide power transmission**

- **Able to accommodate shaft misalignment through elastomeric materials**

Advantages and Limitations

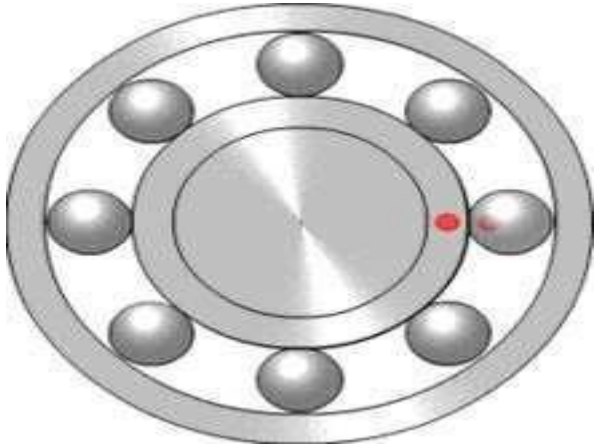
Advantages

- Torsionally stiff
- No lubrication or maintenance
- Good vibration damping and shock absorbing qualities
- Less expensive than metallic couplings
- More misalignment allowable than most metallic couplings

Limitations

- Sensitive to chemicals and high temperatures
- Usually not torsionally stiff enough for positive displacement
- Larger in outside diameter than metallic coupling
- Difficult to balance as an assembly

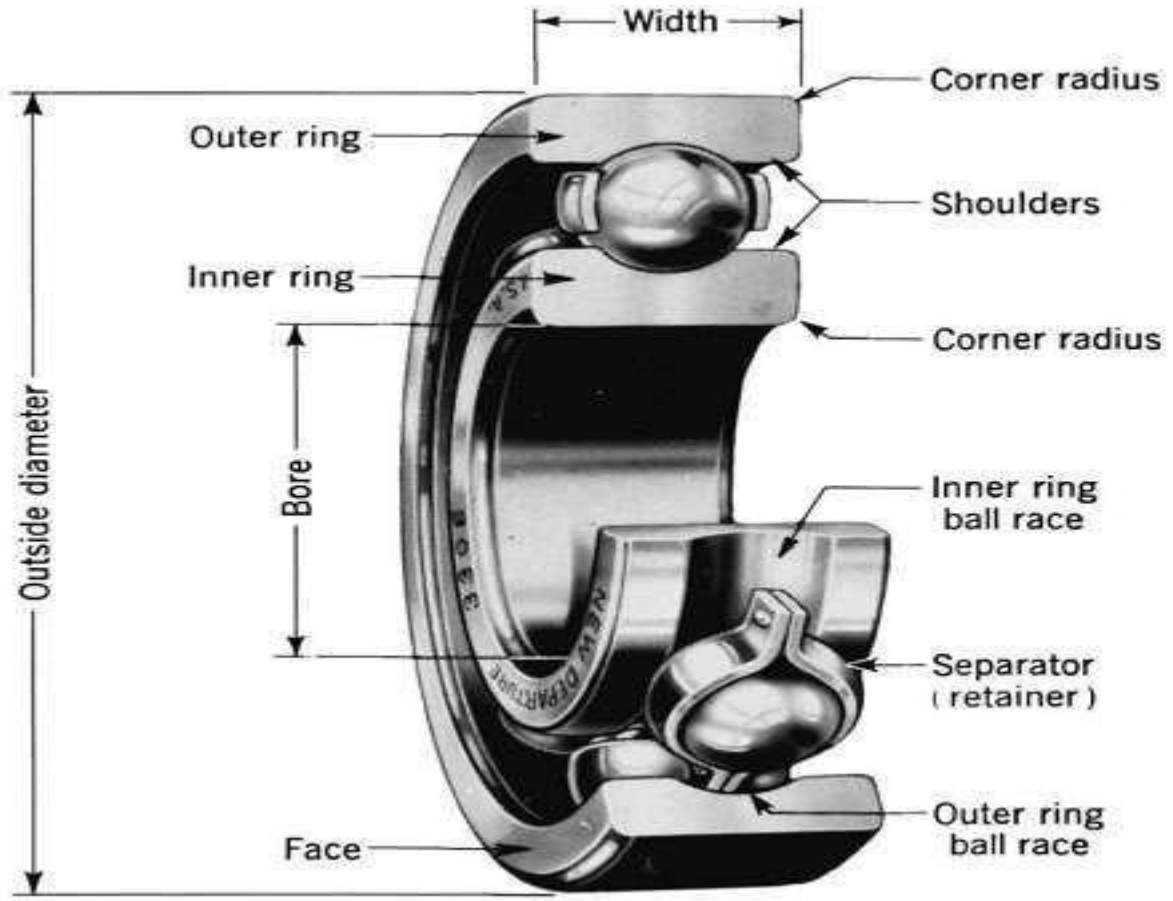
Bearings



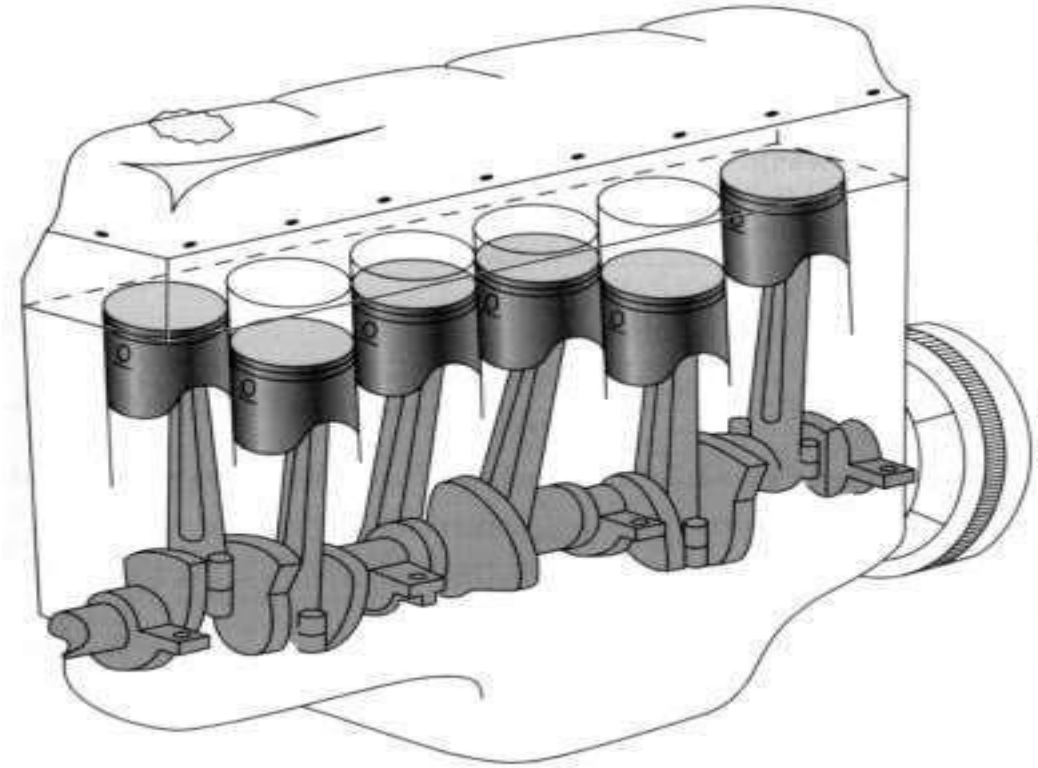
Bearings are used for carrying loads while allowing relative motion(rotation) with minimum friction

- Types of bearings:
  - Rolling contact or anti-friction bearing
  - Journal or sleeve bearings(sliding contact bearing)

Rolling Contact Bearings – load is transferred through rolling elements such as balls, straight and tapered cylinders and spherical rollers.



Journal (sleeve) Bearings – load is transferred through a thin film of lubricant (oil).



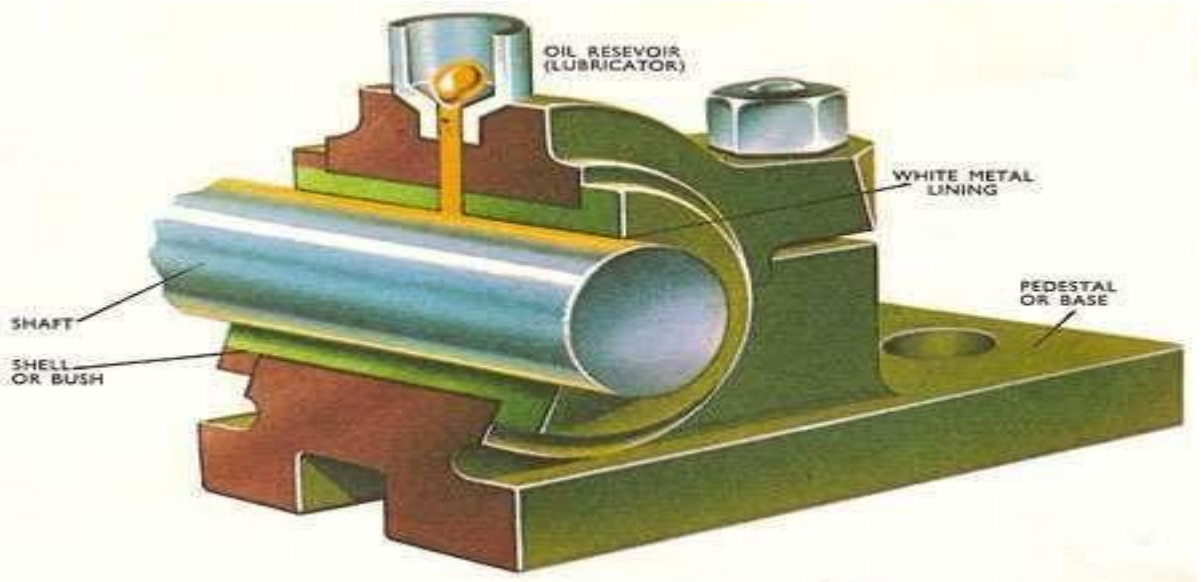
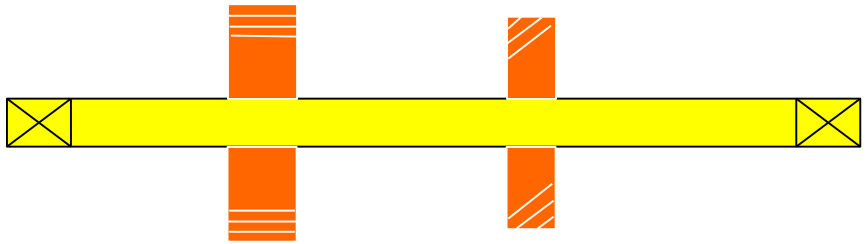


Figure 12.41 Cross section of internal combustion engine, showing main bearing.

Design Considerations

Bearings are selected from catalogs, before referring to catalogs you should know the followings:

- Bearing load – radial, thrust (axial) or both



Thrust load

Radial load

Radial load

Rolling Contact Bearings

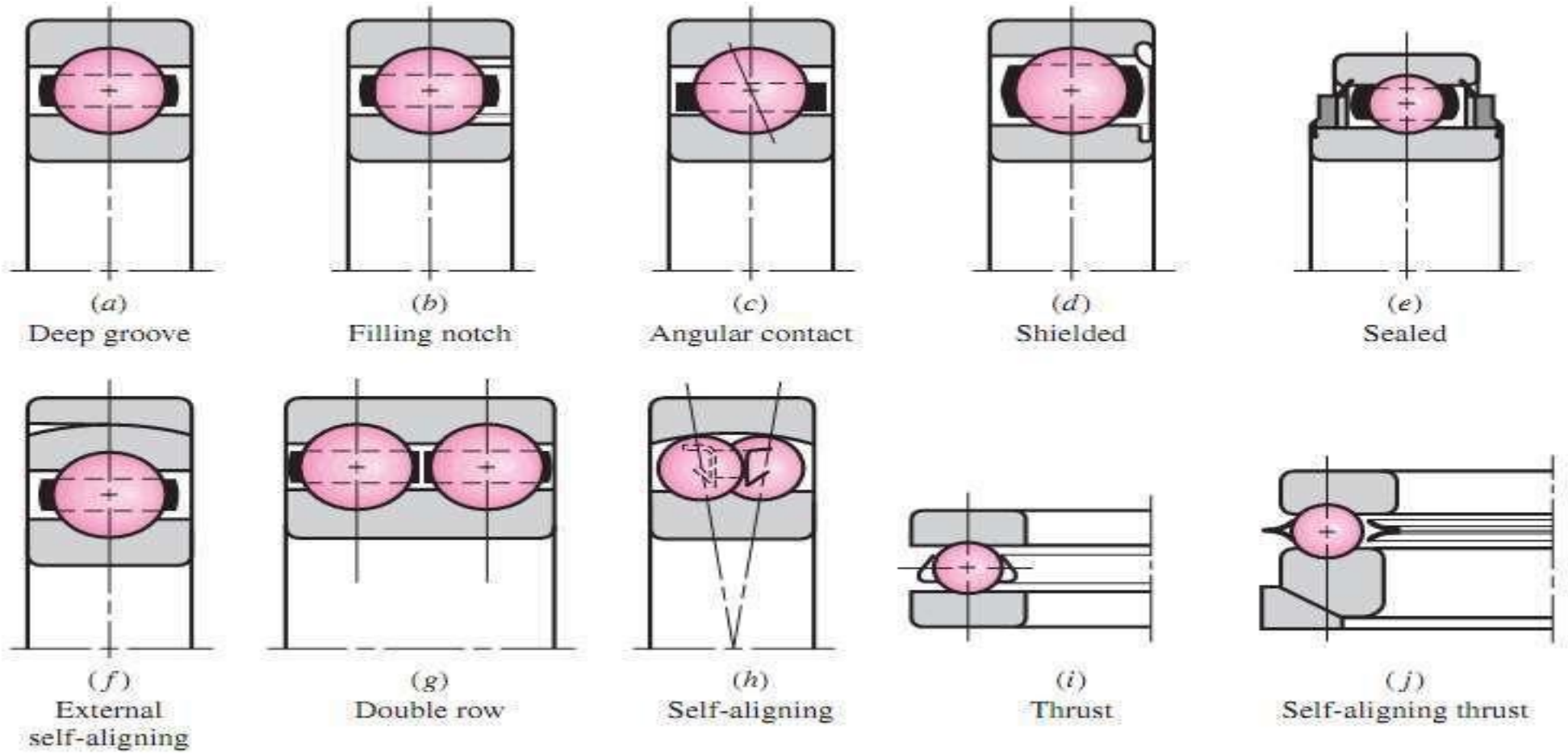
1. ***Ball bearings***
   - Deep groove ball bearing
   - Angular contact bearings (AC)
   - Self alignment ball bearing

2. ***Roller bearings***
   - Cylindrical bearings(straight roller bearing)
   - Needle bearings
   - Tapered bearings
   - Spherical bearings

3. ***Thrust bearings***

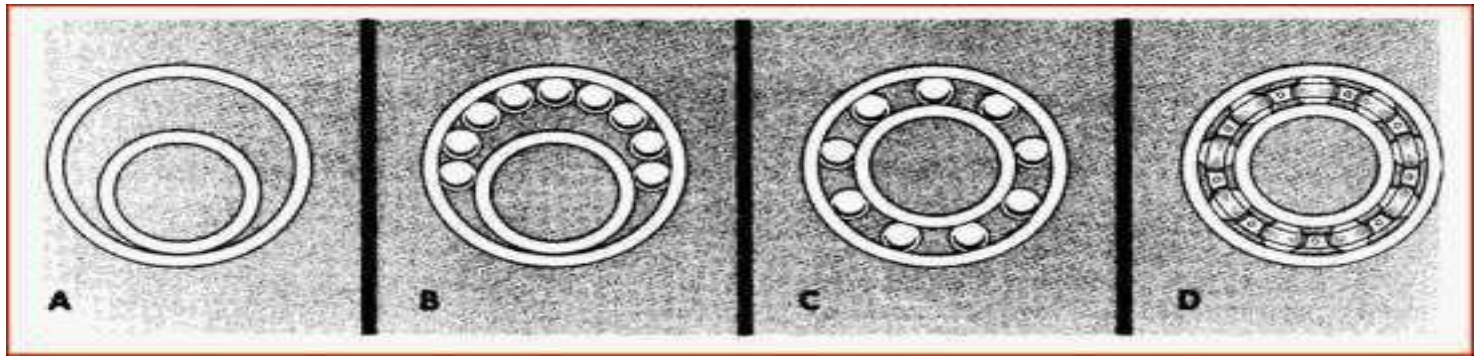
In general, ball bearings are capable of higher speeds and roller bearings can carry greater loads

Types of Ball bearings



Ball Bearings

Deep groove (Conrad) bearing



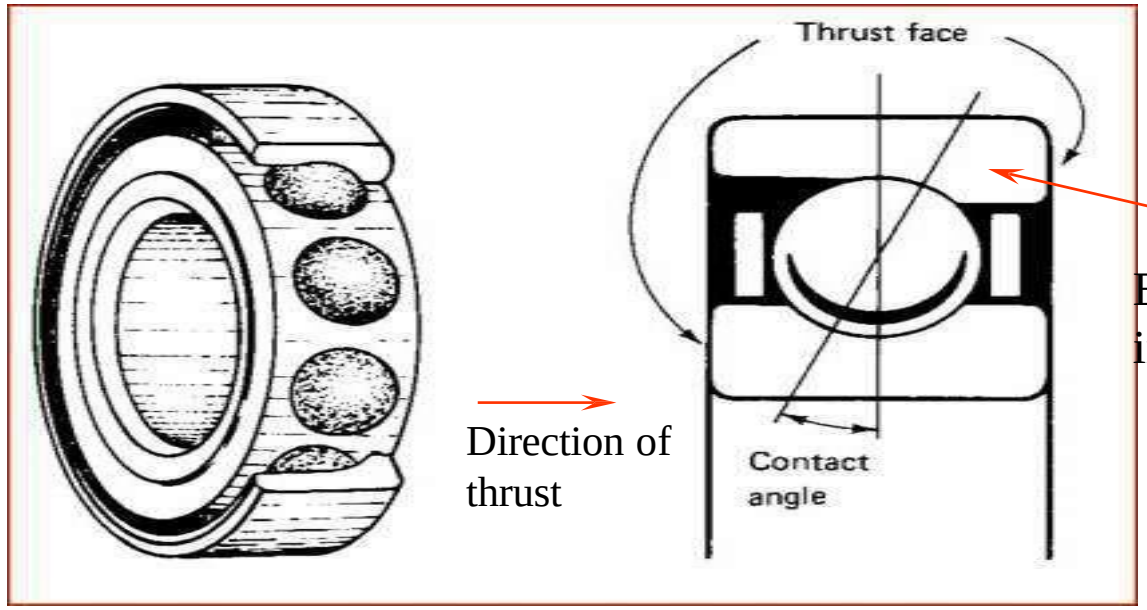
Load capacity is limited by the number of balls

Primarily designed to support radial loads, the thrust capacity is about 70% of radial load capacity

Ball Bearings

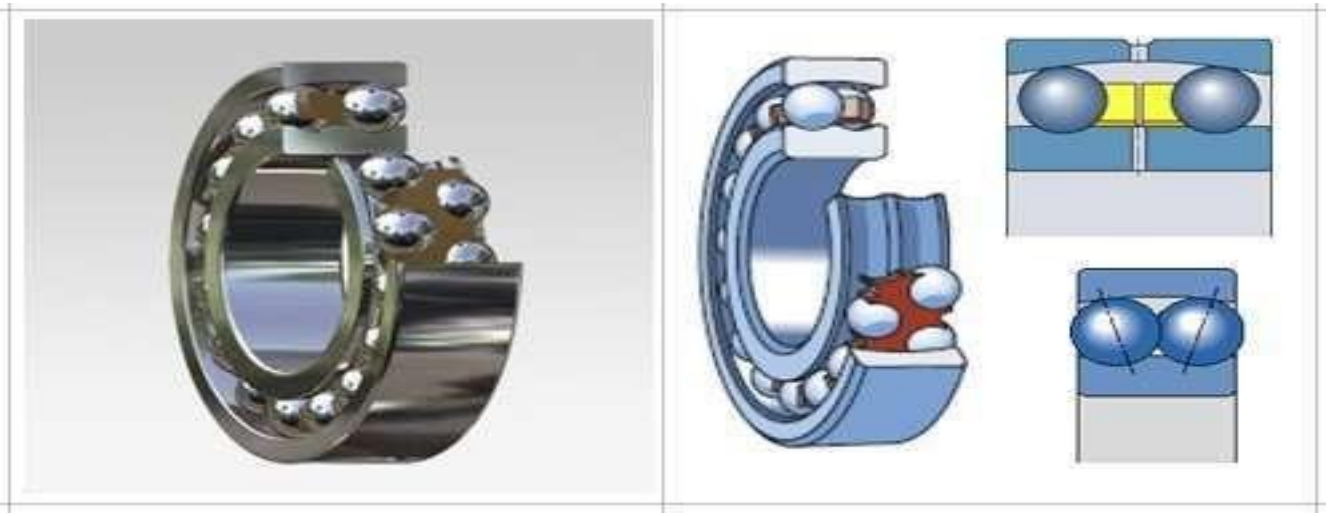
Angular contact bearings (AC)

The centerline of contact between the balls and the raceway is at an angle to the plane perpendicular to the axis of rotation.



Used for high radial and thrust load applications

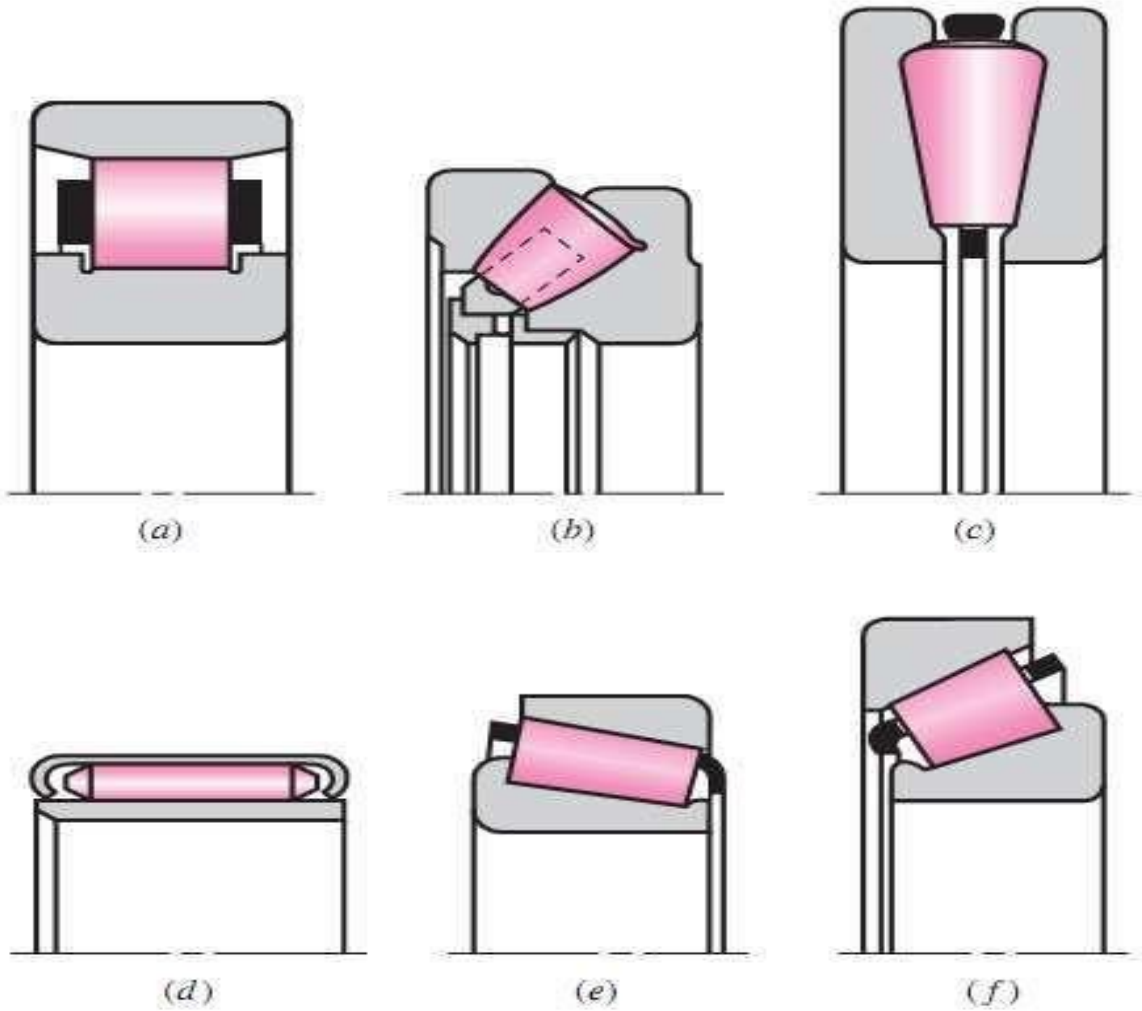
Self alignment bearing



Roller bearings have higher load capacity than ball bearings, load is transmitted through line contact instead of point contact.

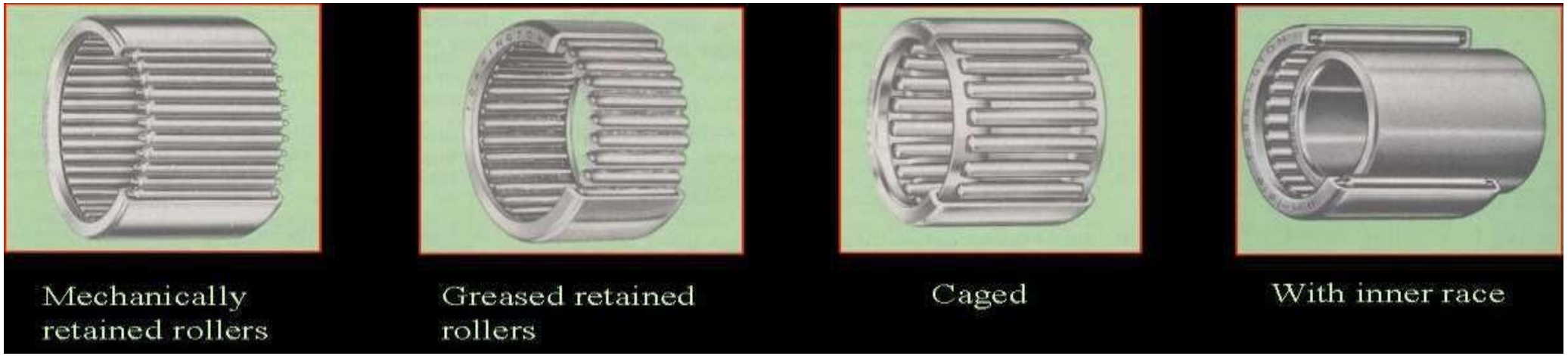
Figure 11–3

Types of roller bearings: (*a*) straight roller; (*b*) spherical roller, thrust; (*c*) tapered roller, thrust; (*d*) needle; (*e*) tapered roller; (*f*) steep-angle tapered roller. *(Courtesy of The Timken Company.)*

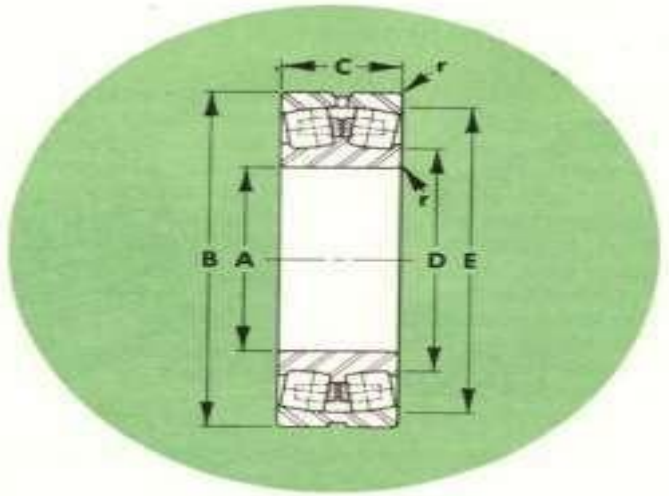


Cylindrical bearing

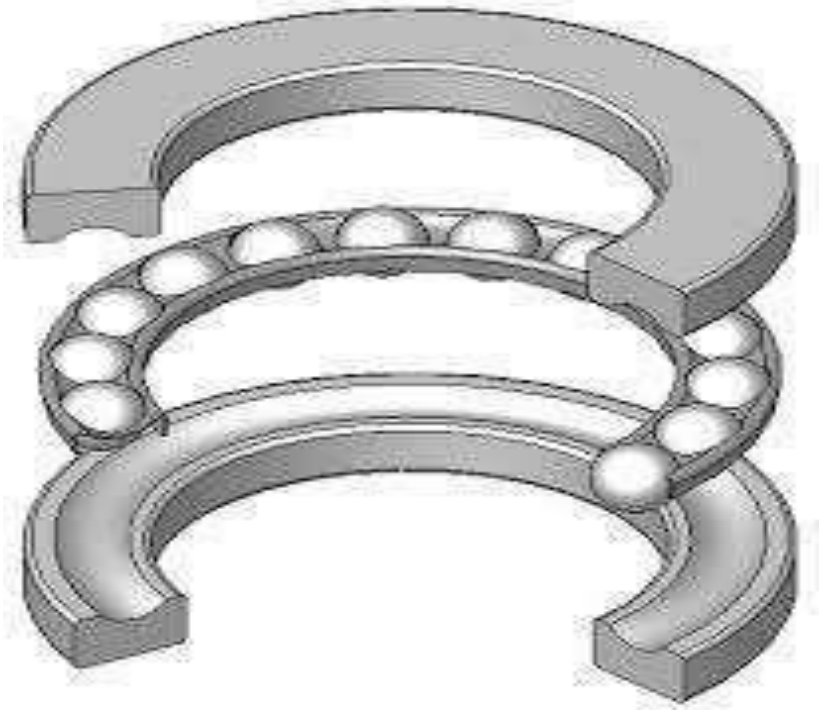
Needle bearing



Roller Bearings



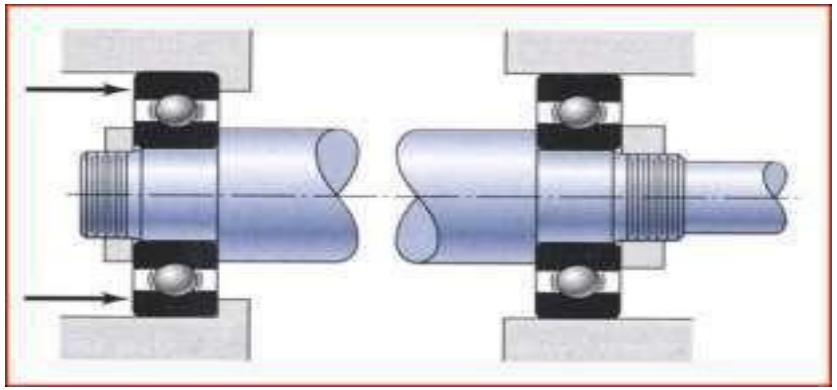
Ball thrust bearing

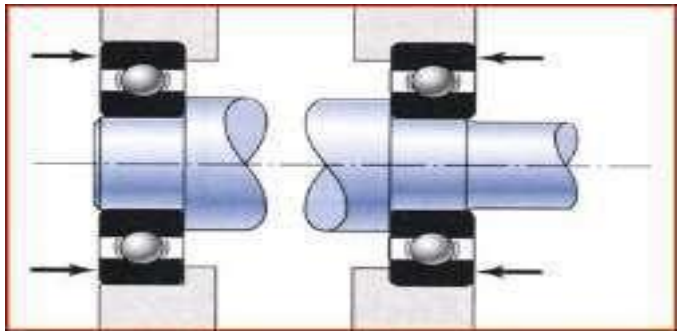


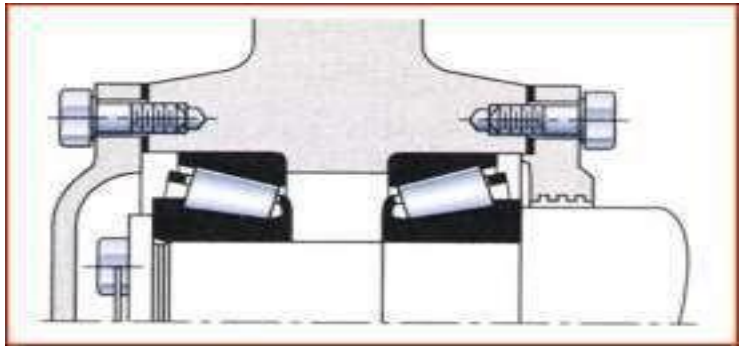
Mounting Bearings

Pillow Block

Flange







CLUTCHES
Objectives

- Describe the basic clutch parts
- Explain the operation of the clutch
- Compare differences in clutch design
- Describe the different methods of releasing the clutch

Introduction

- Clutch
  - Found on vehicles with manually shifted transmissions
  - Disengages engine from transmission
  - Releases engine from transmission during gear shifts
  - Driver controls clutch application from inside the vehicle with a clutch pedal
    - Engine does not make sufficient torque at lower rpm to be able to move the car
    - Clutch must gradually couple rear wheels to engine

Clutch Parts and Operation

- Clutch parts
  - Flywheel
  - Pressure plate
  - Friction disc
  - Release mechanism
- Clutch disc pushed against flywheel with enough force
  - Disc will rotate with flywheel

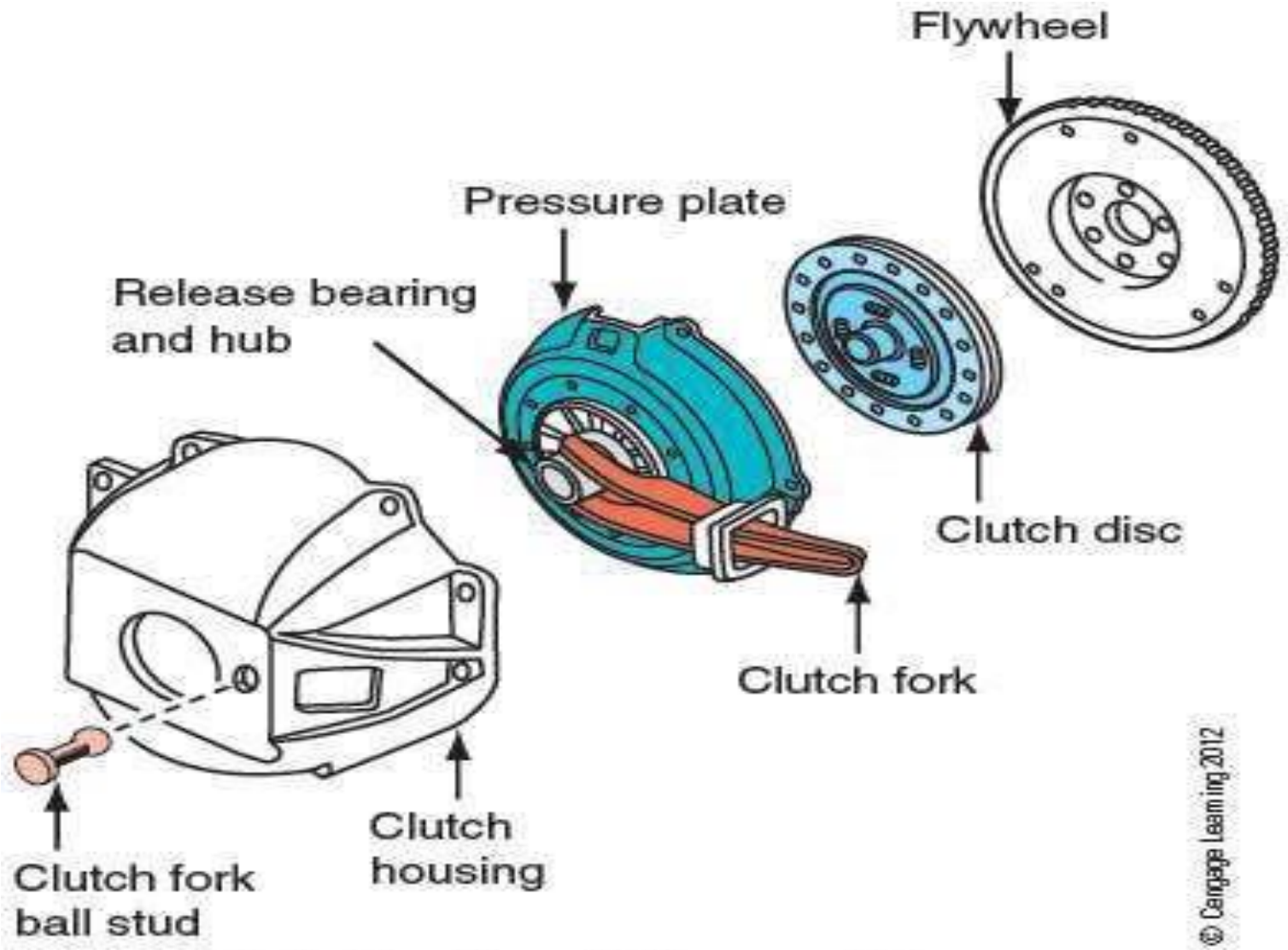


Figure 69.2 Parts of the clutch assembly.

Clutch Disc

- Characteristics
  - Clutch hub: inner part of disc and has splines
  - Torsional dampers: absorb shock
  - Clutch disc has facings made of friction material
    - Contain molded or woven asbestos
  - Facings riveted to both sides of cushion plate
    - Cushion plate is riveted to disc plate
  - Clutch is engaged: air is trapped in grooves
    - Clutch is released: trapped air pushes disc away from pressure plate and flywheel

Pressure Plate

- Pressure plate is cast iron plate
  - Part of cover assembly
- Cover assembly is bolted to the flywheel
  - Clutch disc is wedged between pressure plate and flywheel
  - Space between pressure plate and flywheel is less than thickness of clutch disc
  - Engine and transmission are physically connected when clutch pedal released

Types of Clutch Covers

- Clutch covers types
  - Coil spring
  - Diaphragm
  - Other designs are less common

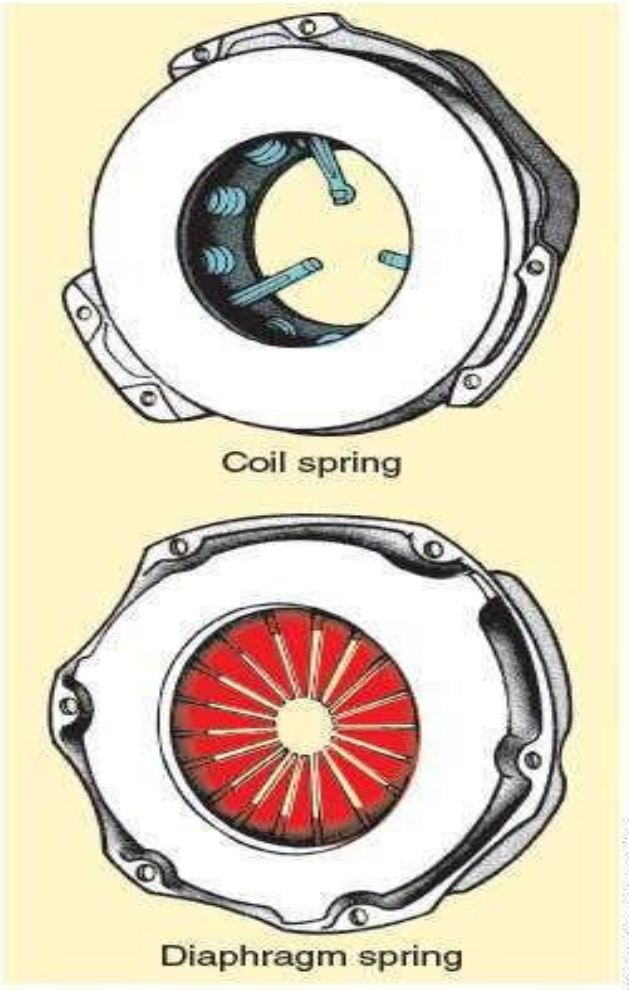


Figure 69.8 Coil and diaphragm spring clutch covers.

Coil Spring Clutch

- Pressure plate springs are preloaded when clutch cover assembled at factory
  - Springs are compressed further when cover assembly is bolted to flywheel
  - Clutch is engaged: pressure plate exerts 1000-3000 pounds force on the disc
  - Disc worn out: ten percent more torque carrying capacity left in the clutch than engine can deliver

Release Levers

- Attached to cover assembly at pivot points
  - Pushing clutch pedal moves pivot lever
    - Pulls pressure plate away from flywheel
- Advantages of coil springs
  - More coil springs can be installed
  - Centrifugal force applies clutch more tightly
- Disadvantages of coil springs
  - More pedal pressure required
  - Clutch applied less heavily as disc wears
  - Must be precisely balanced after assembly

Diaphragm Clutch

- Diaphragm spring replaces release levers and coil springs
  - Diaphragm pivots off pivot rings when clutch pedal is depressed
- Advantages
  - Requires less effort and takes up less space
  - Spring pressure becomes greater as disc wears
  - Well balanced
- Dual mass flywheel: reduces noise and vibration
  - Allows smoother gear shifting

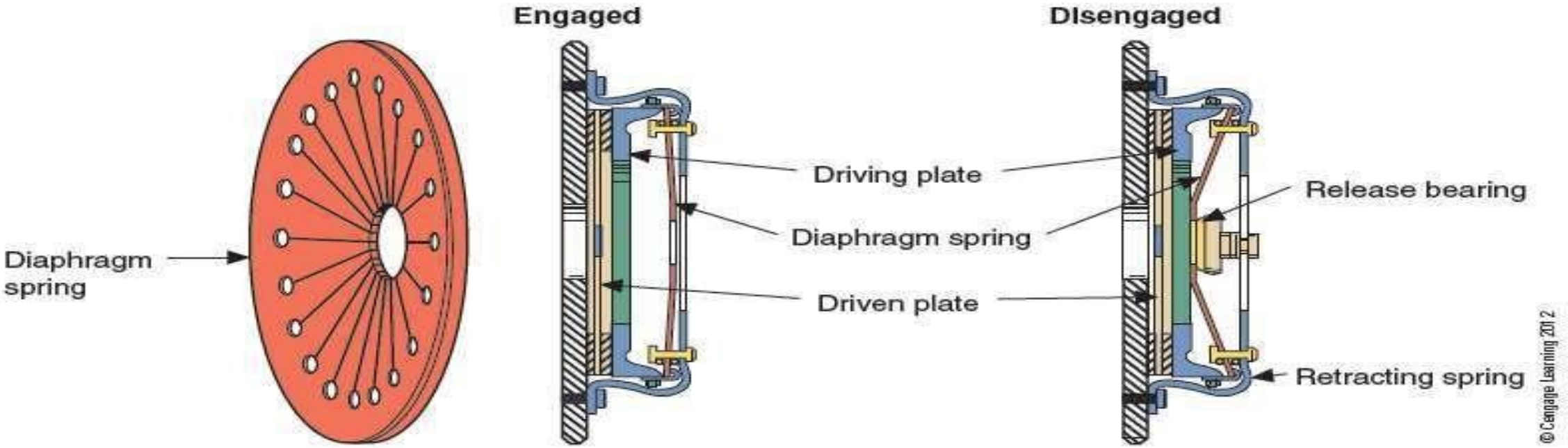


Figure 69.11 A clutch pressure plate assembly with a diaphragm spring.

Pilot Bearing or Bushing

- Engine side of transmission input shaft
  - Supported by sealed pilot bearing or sintered bronze bushing
    - Some FWD transaxles do not use pilot bearing

Figure 69.16 This front-wheel-drive transaxle does not use a pilot bearing.

Release Bearing

- Allows pressure plate release mechanism to operate as crankshaft rotates
  - Slides on the front transmission bearing retainer
  - Lubricated and sealed at the factory
- Self-centering release bearings
  - Used on FWD cars
  - Do not use pilot bearing in the crankshaft
- Specially designed release bearings
  - Found on vehicles that have pressure plates that pull to release

Clutch Fork

- Release bearing hub has provision to attach it to the clutch fork
  - Clutch fork fits between release bearing and clutch cable or linkage
    - Has pivot shaft, pivot ball, or raised area in the bell housing off which it pivots

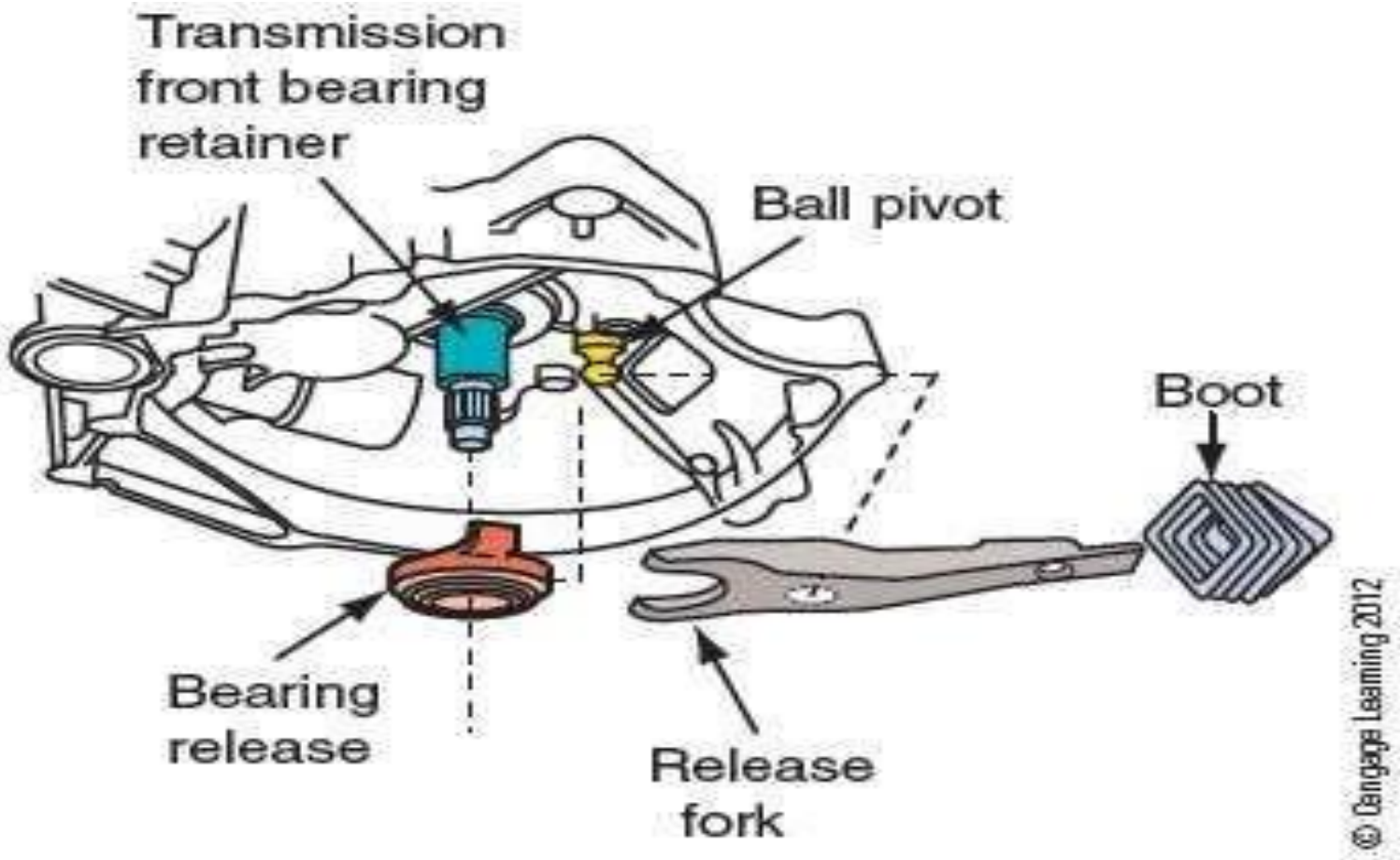


Figure 69.18 The clutch fork fits between the release bearing and the clutch linkage.

Clutch Release Methods

- Clutch pedal operates clutch fork using:
  - Linkage
  - Cable
  - Hydraulic cylinders
- Clutch start switch
  - Included on the clutch pedal
  - Prevents engine from starting unless the clutch pedal is depressed

Clutch Cable

- Some cars use a cable to operate the clutch
  - Adjustment remains the same as the engine moves
  - Develop friction and wear with repeated use
- Linkage can push on clutch arm
  - Cable can only pull on it
- Pivot point of fork
  - Must be on the outside of input shaft
    - Away from cable end

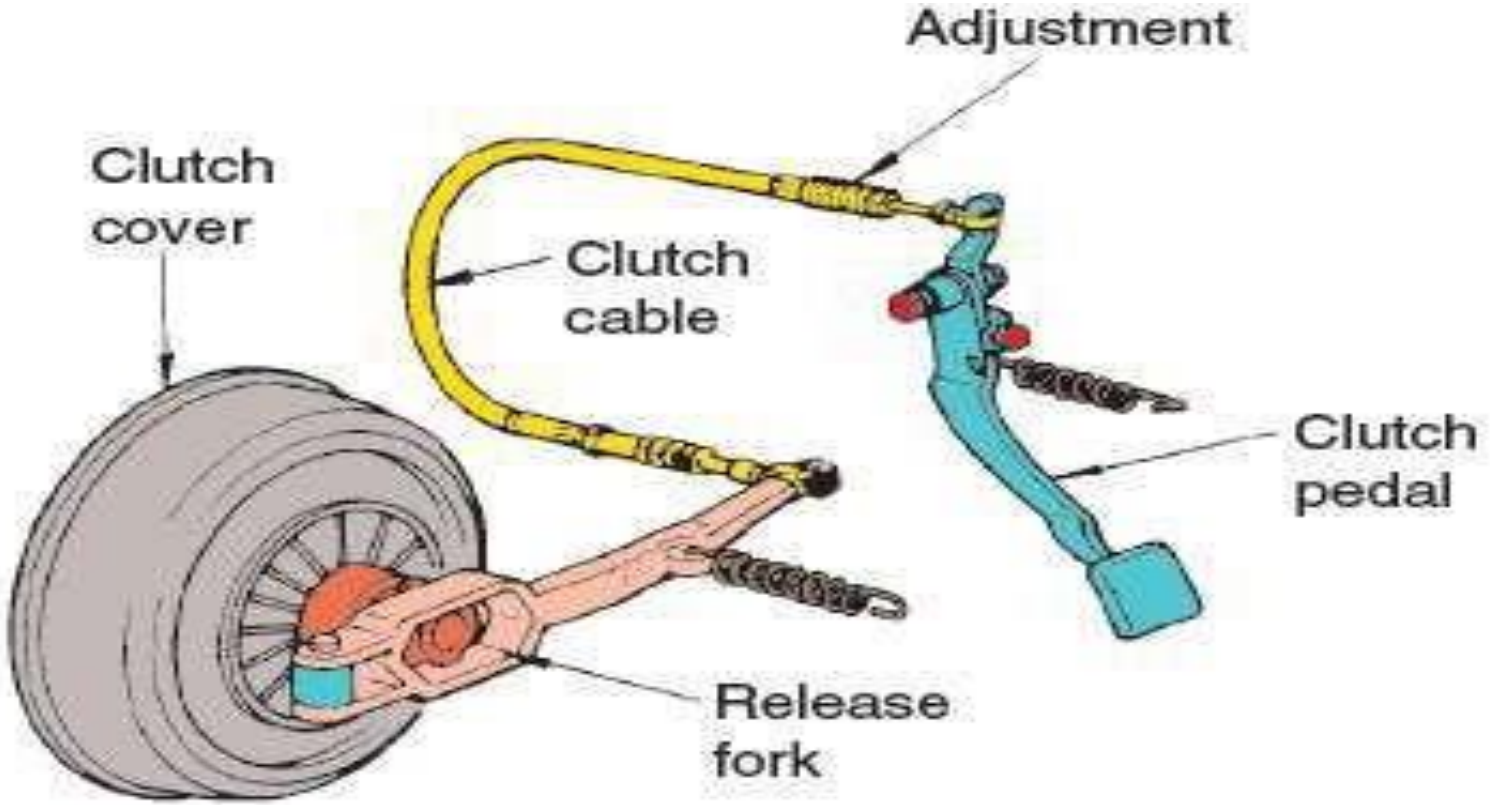


Figure 69.19 A cable-operated clutch release.

Hydraulic Clutch Operation

- Characteristics
  - Hydraulic clutches are found on many manual transmission–equipped vehicles
  - Master cylinder input piston: connected to clutch pedal
  - Output piston: located in reaction or actuator cylinder (i.e., slave cylinder)
  - Difference between clutch master cylinder and brake cylinder
    - Clutch master cylinder does not have a fill port or residual check valve

Clutch Free Travel

- Free travel
  - Usually adjusted to about one inch at pedal
- Newer vehicles have self-adjusting clutches
  - Maintain contact between release levers and release bearing
- Standard release bearings
  - Don’t remain in constant contact with clutch cover
- Some vehicles have self-adjusting cables
  - Spring-loaded sector gear pinned to pedal arm
    - Clutch released: pawl lifted and raised

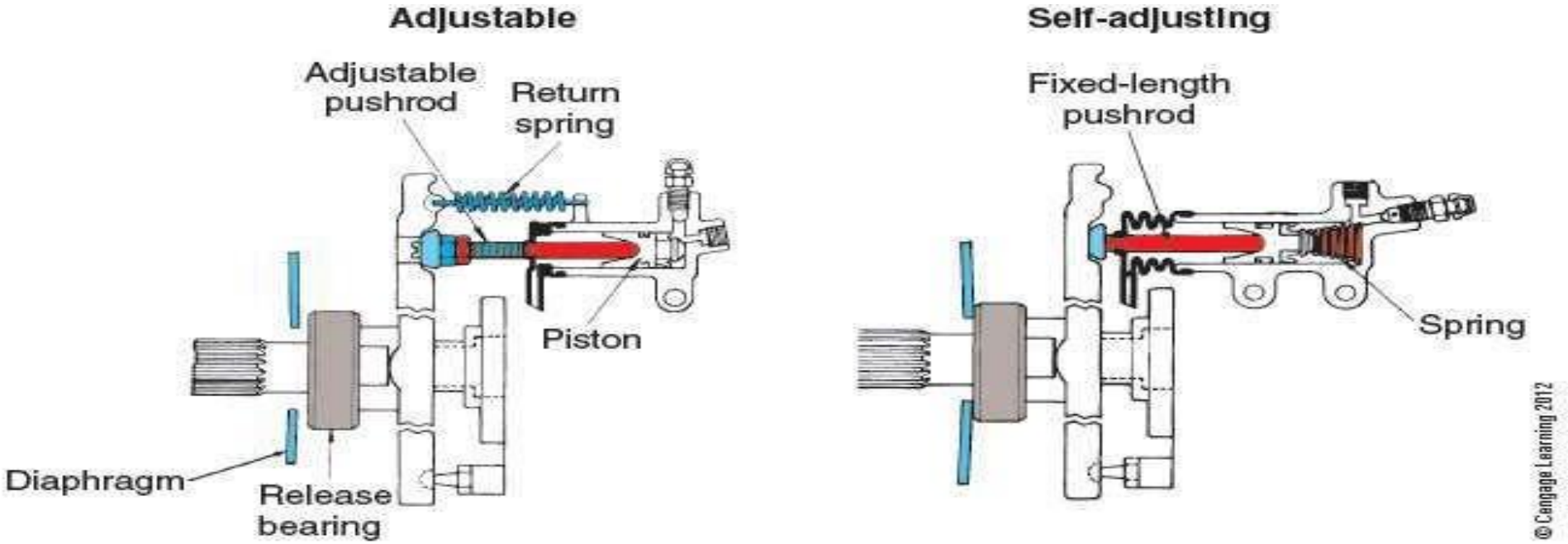


Figure 69.21 Comparison of adjustable and self-adjusting slave cylinders. Note the spring at the right side of the self-adjusting slave cylinder.

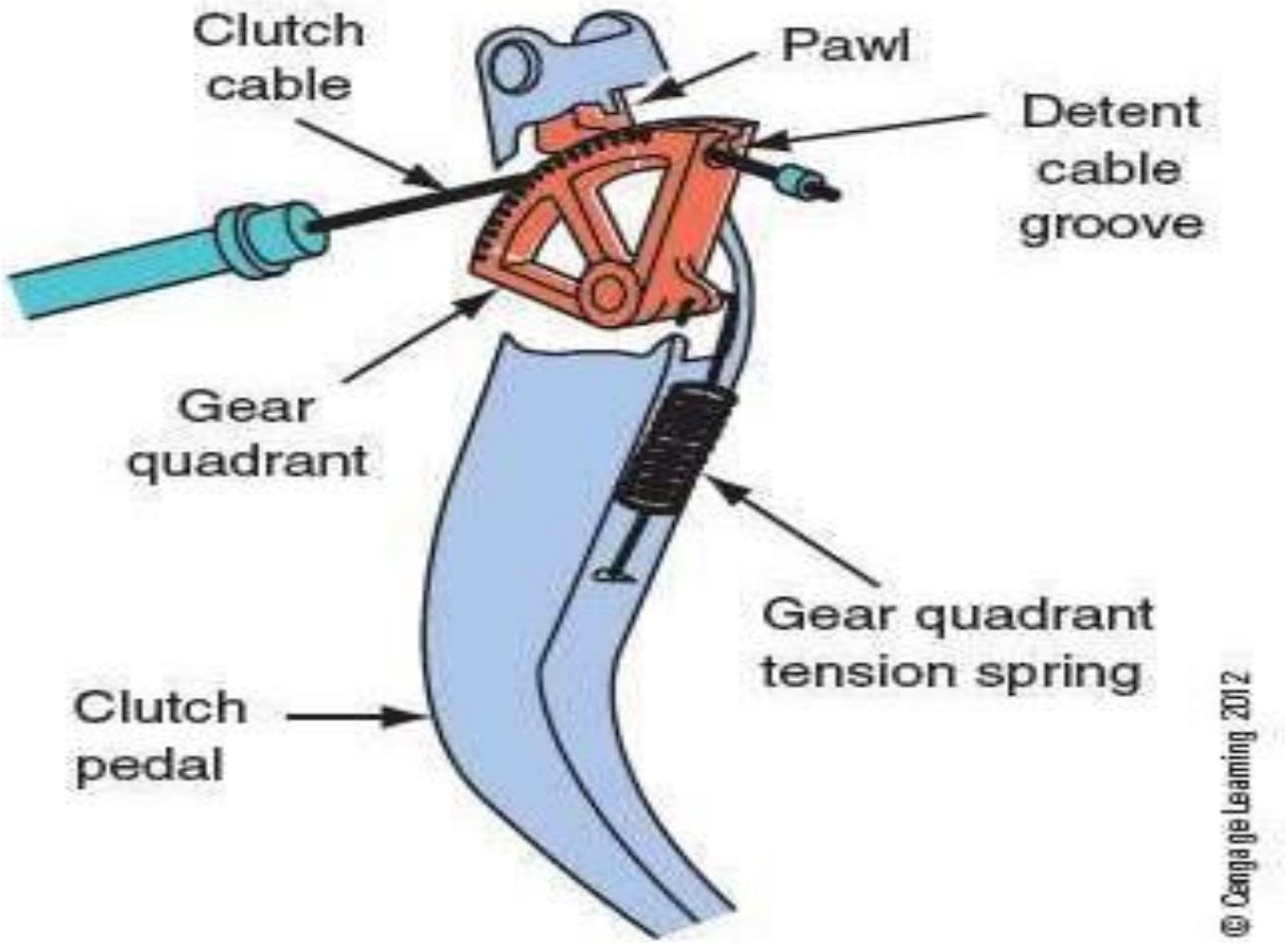


Figure 69.22 A clutch cable self-adjuster.

Dual Clutch Transmissions

- Being used by several manufacturers
  - Two clutches connect to two separate geartrains within one transmission housing

Dual Clutch Module with integral torsional damper—Photo courtesy of BorgWarner

Figure 69.23 A dual clutch transmission employs two clutches that alternately connect engine output to transmission input shafts for odd-numberd gears or even-numbered gears, respectively.

Purpose of the Clutch

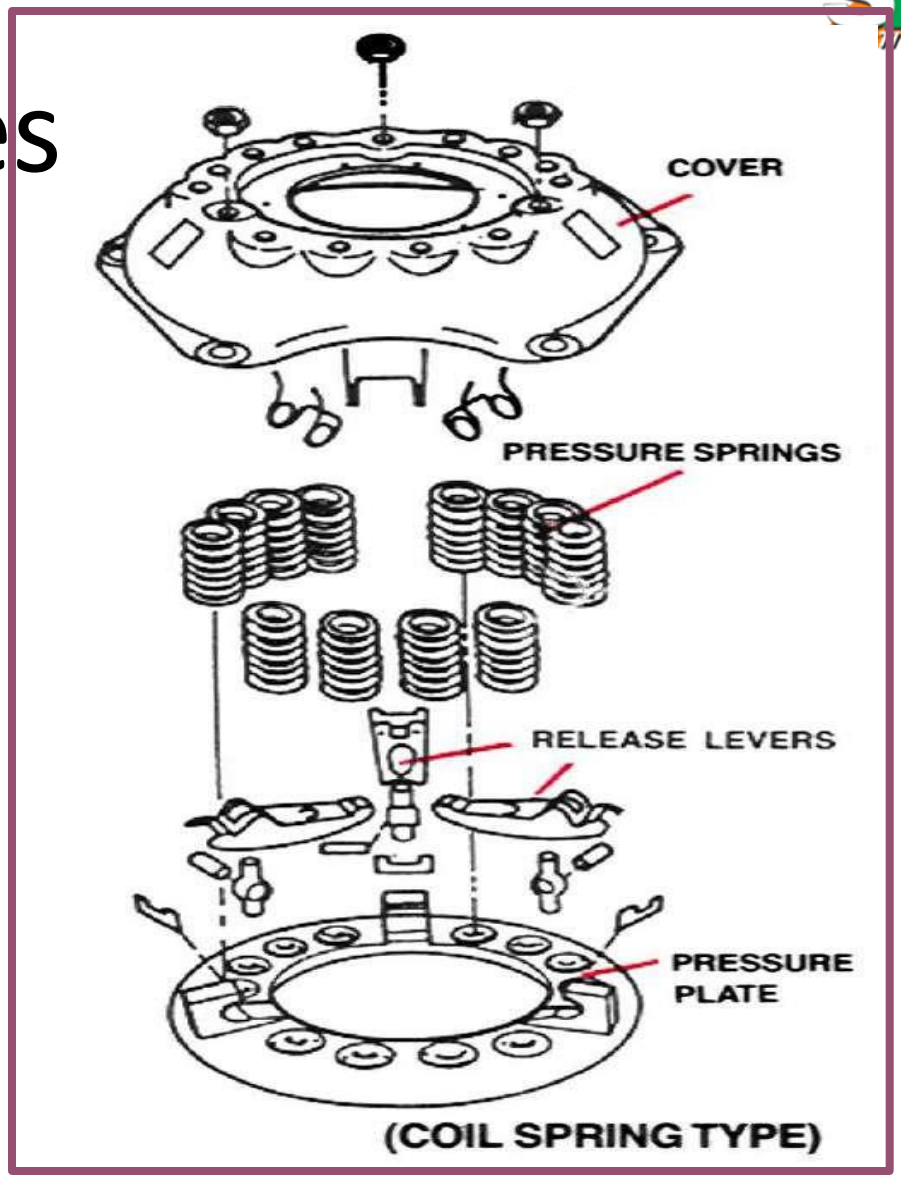
- Allows engine to be *disengaged* from transmission for shifting gears and coming to a stop
- Allows smooth *engagement* of engine to transmission

Clutches

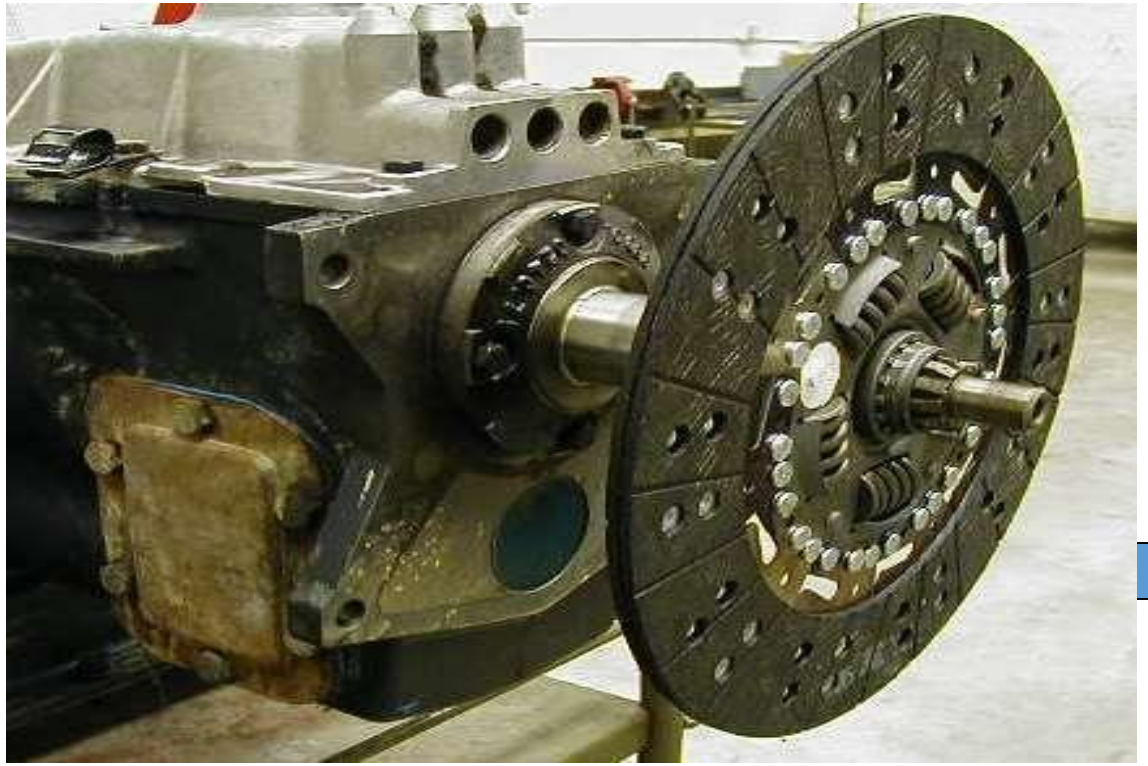
- Rear wheel drive
  - Front engine
  - Rear engine
  - Mid engine
- Front wheel drive

Clutches

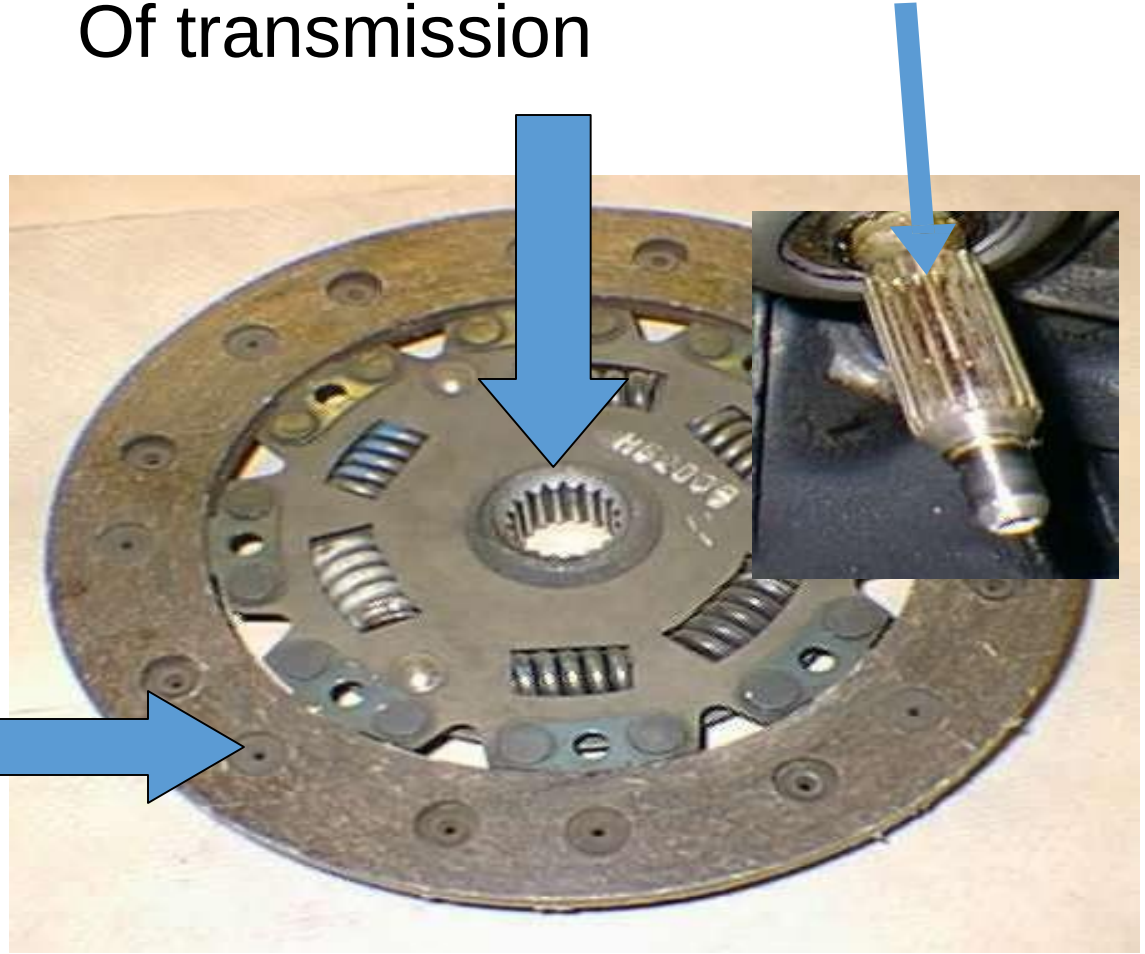
- Coil spring *pressure plate*
- *(cover and pressure plate)*



Clutches



Splines to *input shaft*
Of transmission



READ ON

Pilot Bushing or bearing

READ ON

Clutches

Pressure plate & cover bolt to flywheel

Flywheel bolts to crankshaft

When unbolting pressure plate from the flywheel, remove bolts evenly as not to bend the cover.

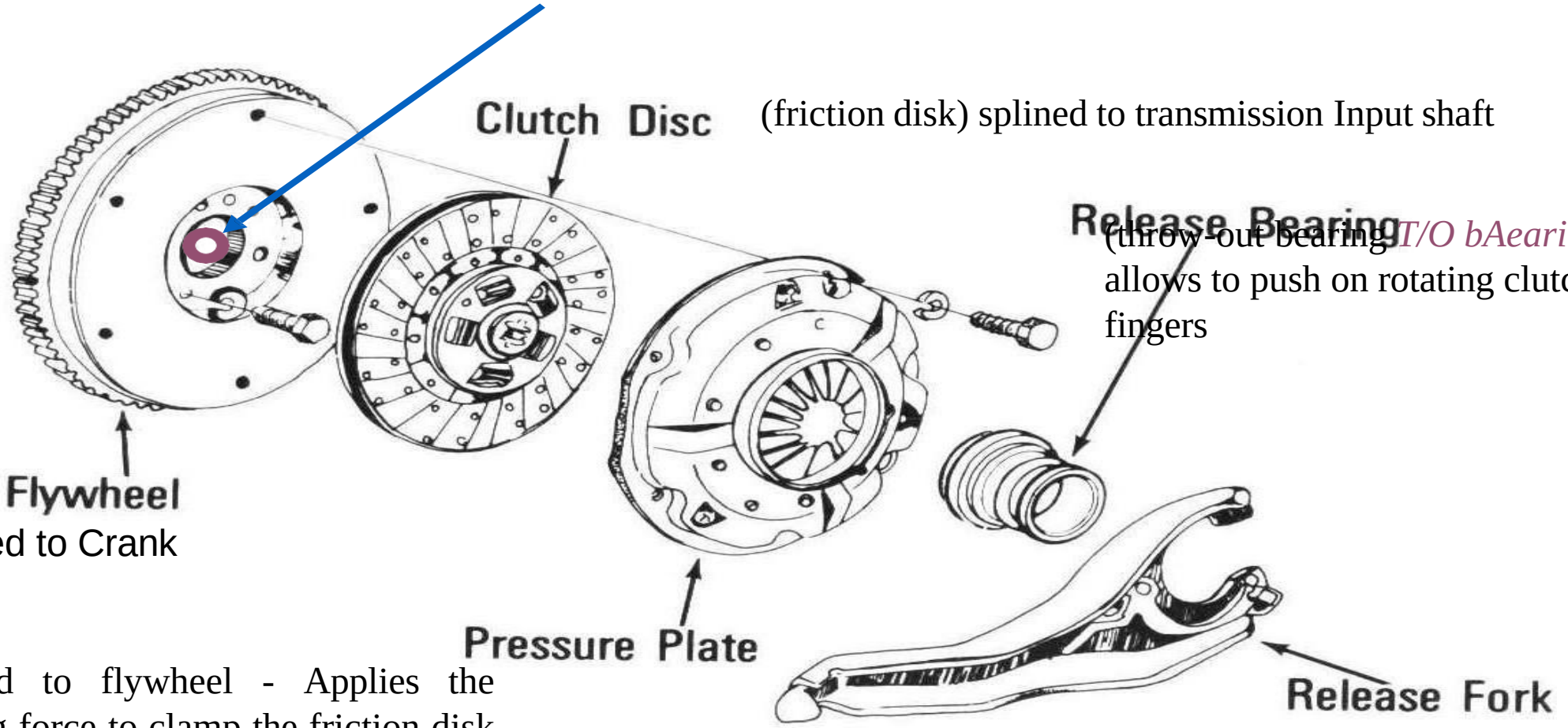
REMEMBER, this is under high spring pressure.

Flywheels

- Add weight to crank for non-power strokes
- Has ring-gear for cranking engine **(usually replaceable)**

Clutches

Pilot bushing or bearing in center of flywheel or crankshaft, supports the end of input shaft



(friction disk) splined to transmission Input shaft

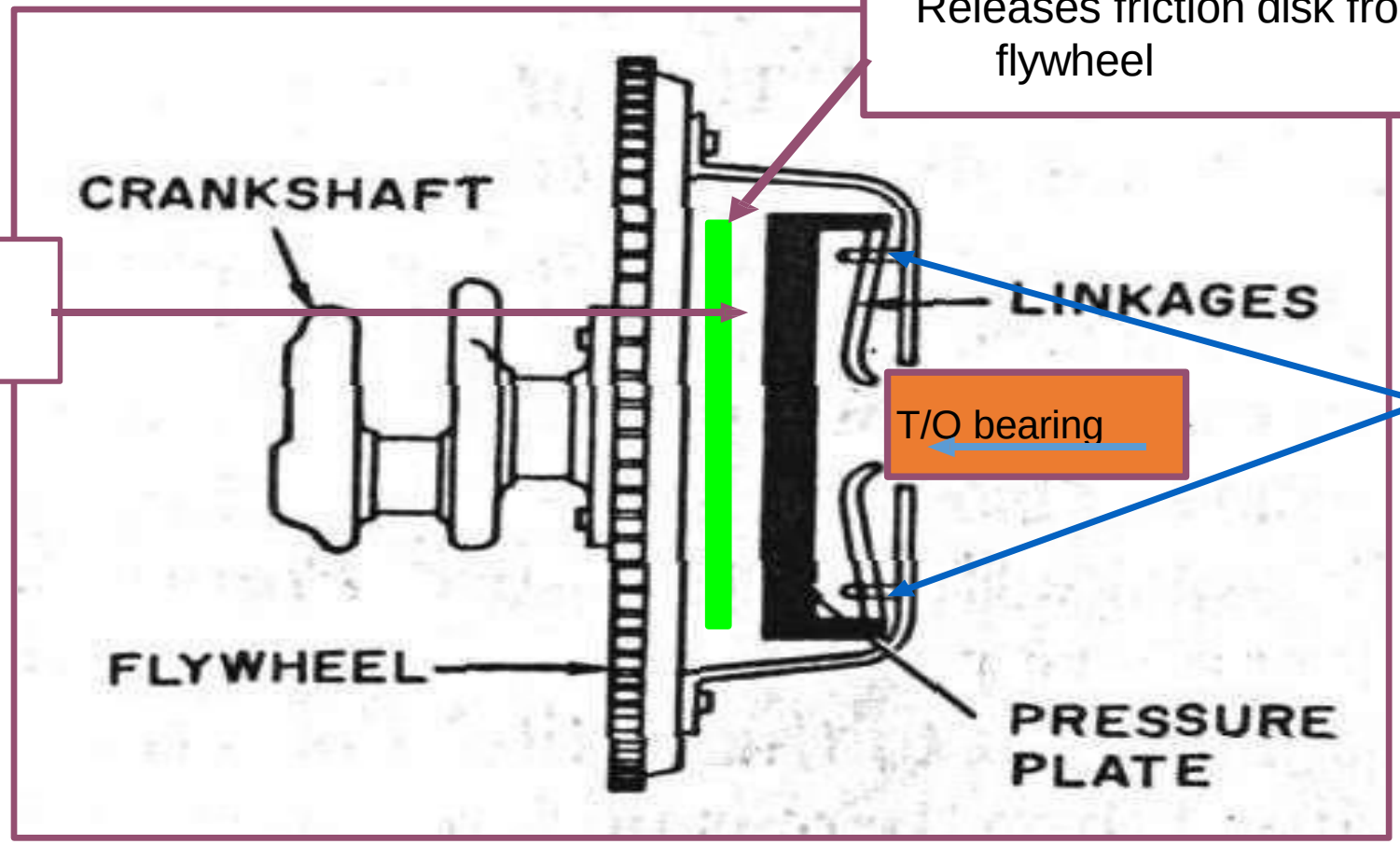
(throw-out bearing *T/O bAearing*) allows to push on rotating clutch fingers

Bolted to Crank

Bolted to flywheel - Applies the spring force to clamp the friction disk to the flywheel

(clutch fork) pushes T/O bearing to release rotating clutch

Pressure Plate



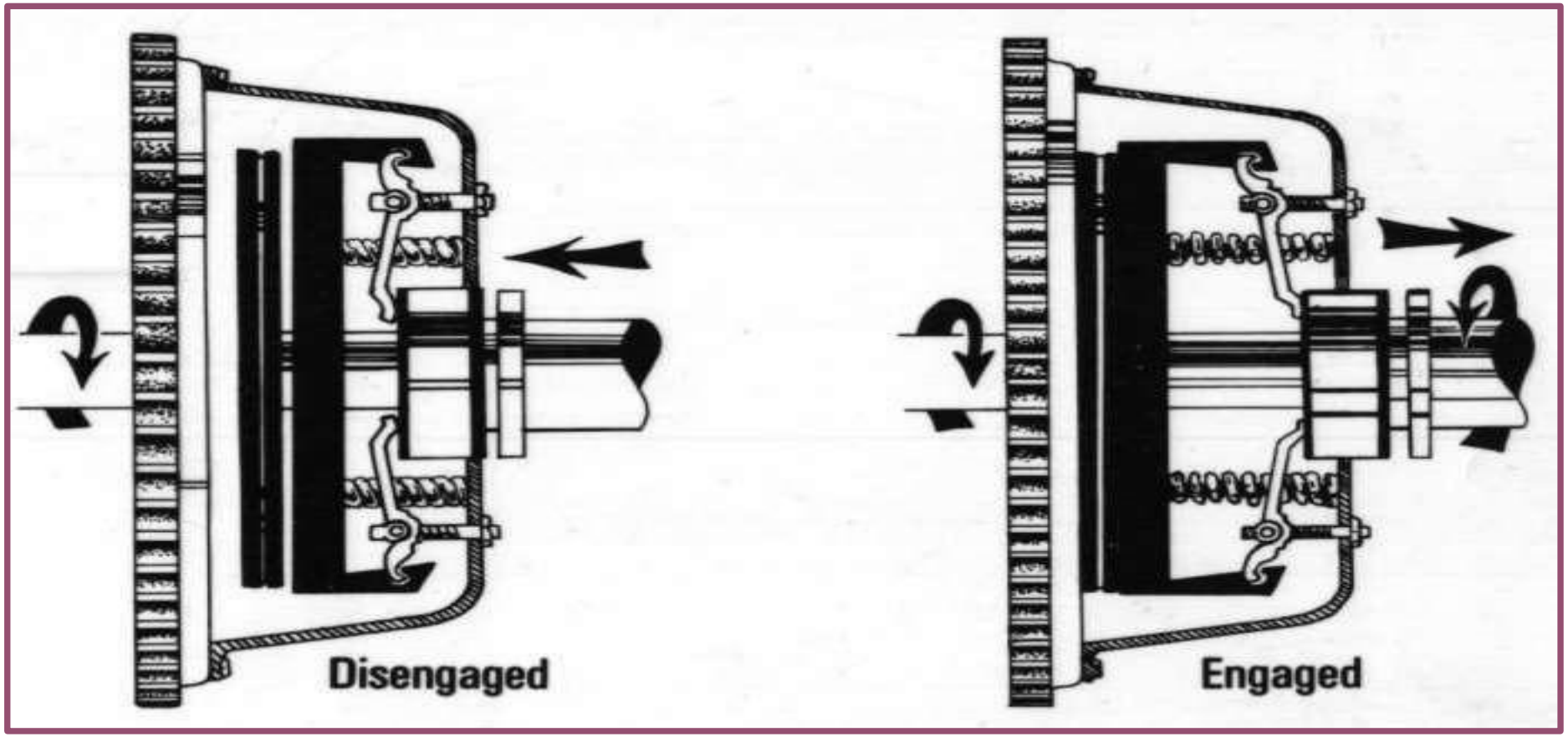
Clutch terms

- Clutch ***disengaged***
  - Clutch pedal is **in** or **down**
- Clutch ***engaged***
  - Clutch pedal is **out** or **up**

What would it mean if someone said the clutch pedal Is engaged?

Make sure you know if you are talking about the clutch or the clutch pedal !!!

Clutches

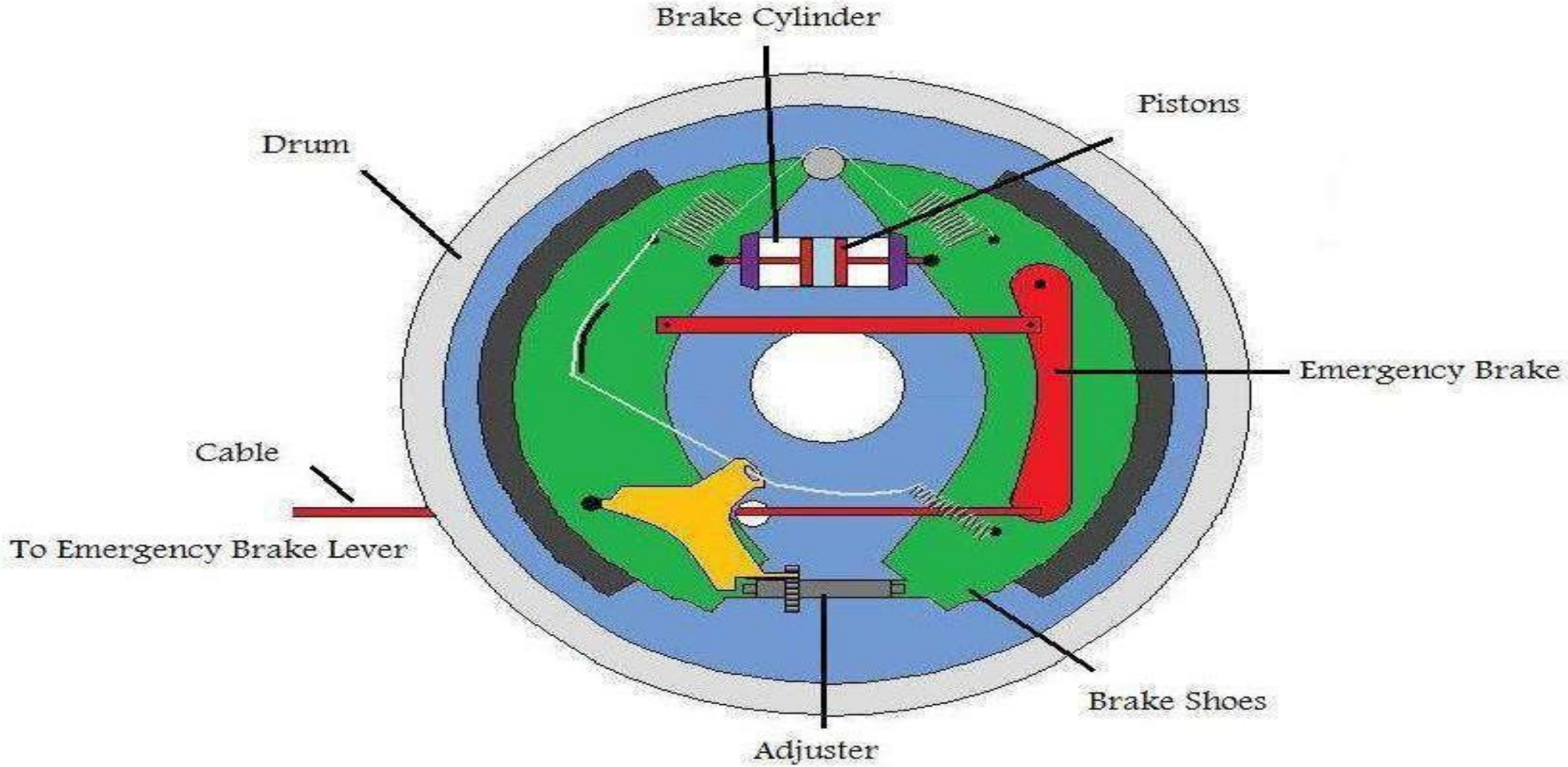


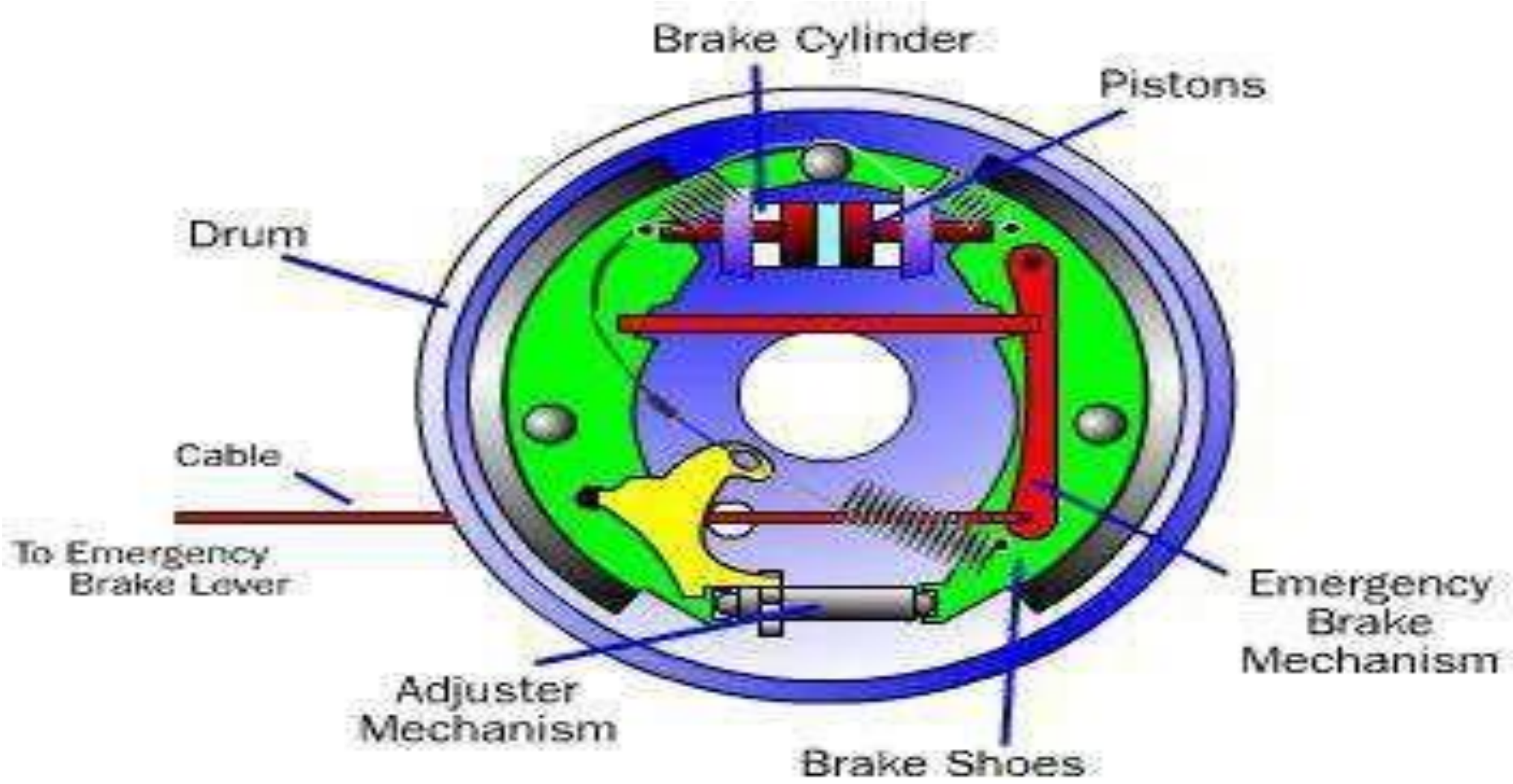
Throw out bearings

- Most need clearance between fingers of pressure plate so it isn't spinning all the time ***(free play)***
- Riding the clutch (foot resting on pedal)
  - Pushes T/O bearing into pressure plate fingers
  - Causes it spin constantly
    - Wearing it out too soon
  - Releases some of clutch spring pressure
    - Causing clutch to slip

Free play

- Clearance between T/O bearing and clutch fingers
- Measured at clutch pedal
  - Usually 1 ½ inches of free movement
- Goes away as clutch disk wears thinner
- Some manufactures use T/O bearings that always ride on the clutch fingers
  - Usually self adjusting


Brake Cylinder
Pistons
Drum
Emergency Brake
Cable
To Emergency Brake Lever
Brake Shoes
Adjuster


Brake Cylinder
Pistons
Drum
Cable
To Emergency
Brake Lever
Emergency
Brake
Mechanism
Adjuster
Mechanism
Brake Shoes


Thank You