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TECHNOLOGY, RESEARCH, SOCIAL INNOVATION & PARTNERSHIPS

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Unit-2

Machine Elements, Mechanisms and Power transmitting Devices

Content:

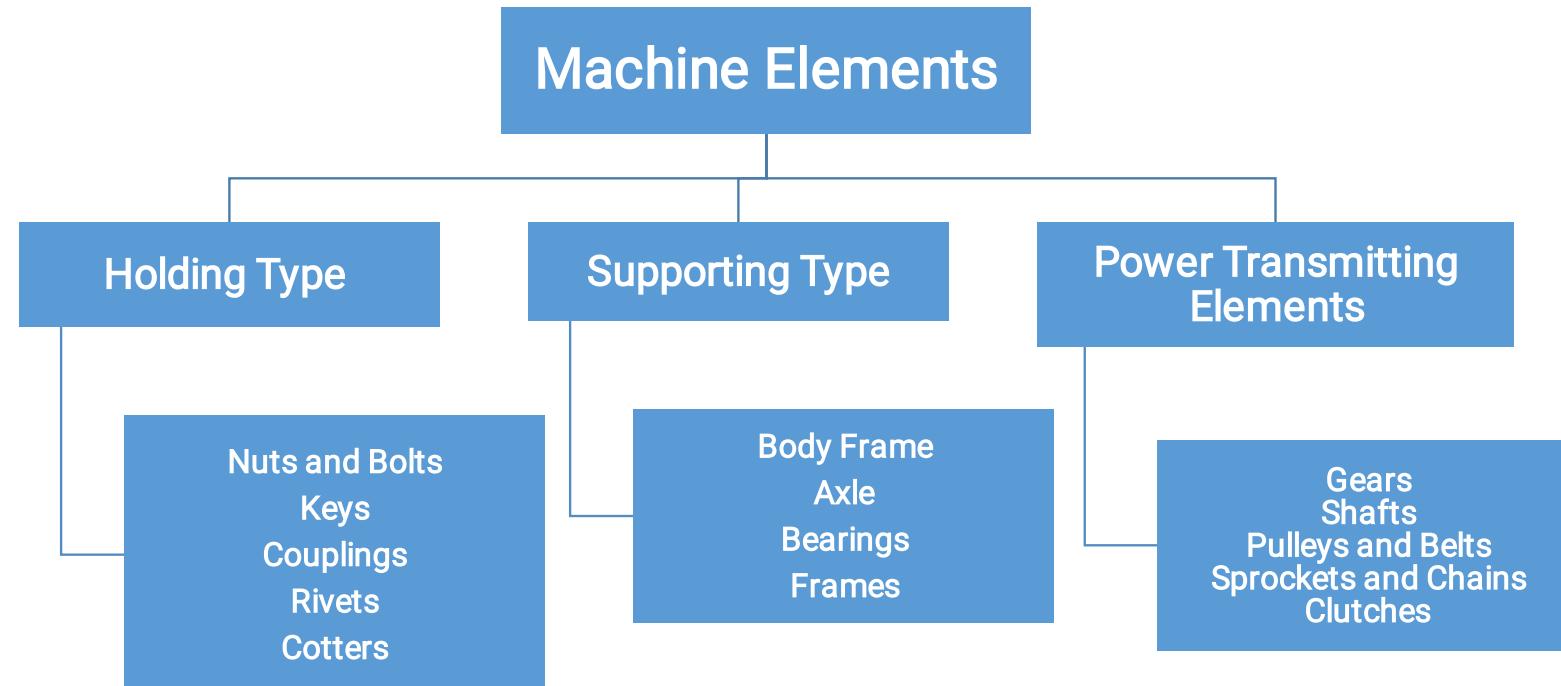
Machine Elements: Function, Types, Sketch, Description, and Uses of: Shafts and axles, Keys and couplings, Bearings, and Clutch and brakes

Mechanisms: Kinematic link, pair, chain and mechanism. Four bar mechanism and inversions, slider crank mechanism.

Power Transmission Devices: Construction, working principle, and applications of Belt drive, chain drive, and Gear drive

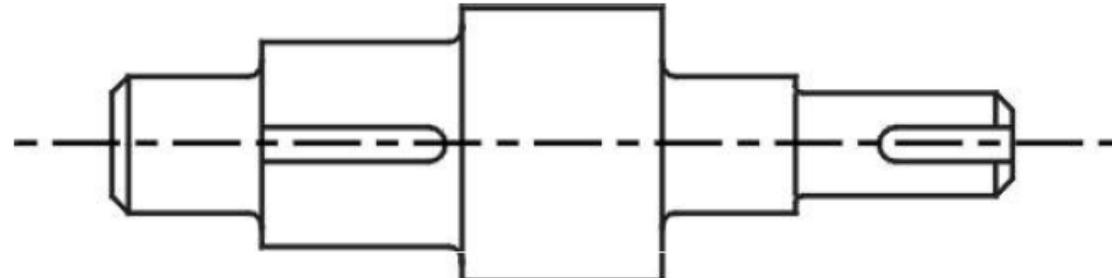
Mechanical Machine Elements

- Machine is a device consisting of various elements arranged together so as to perform the prescribed task to satisfy human needs



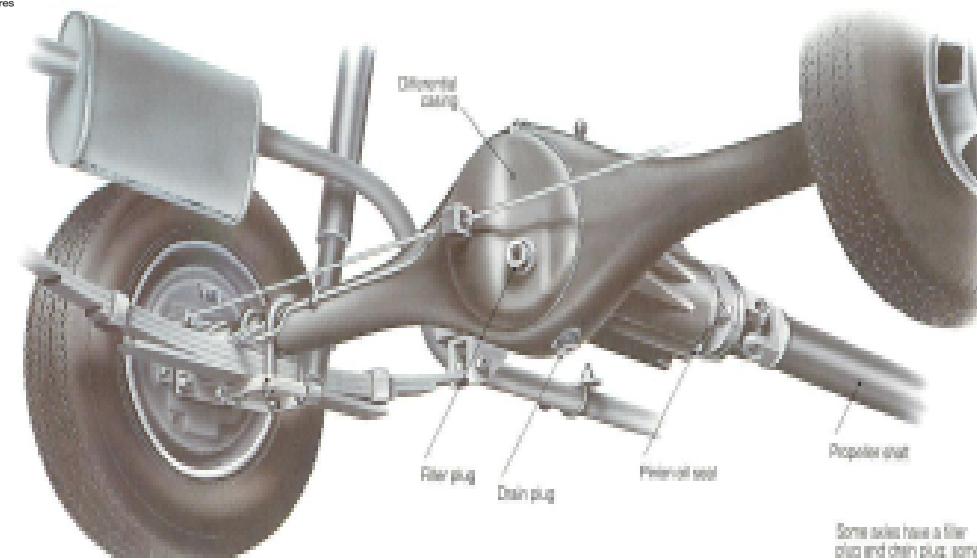
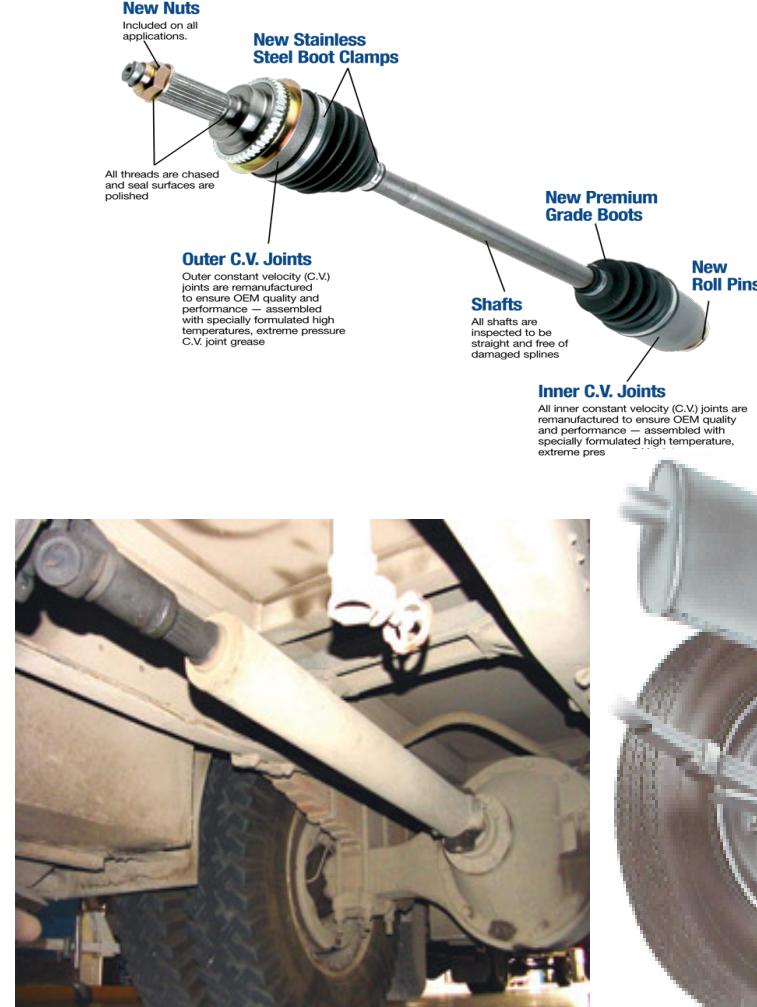
Shafts

- A *shaft* is a rotating member, usually of circular cross section, used to transmit power or motion.
- It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion.



Shafts

- In machinery, the general term “shaft” refers to a member, usually of circular cross-section, which supports gears, sprockets, wheels, rotors, etc.
- An “axle” is a non-rotating member that supports wheels, pulleys,... and carries no torque.
- A “spindle” is a short shaft and it is a integral part of machine. Terms such as *line shaft*, *head shaft*, *stub shaft*, *transmission shaft*, *countershaft*, and *flexible shaft* are names associated with special usage.



Identify, Which is shaft and Which is Axle?

Some axles have a filter plug and drain plug; some have only a filter.



Uses of Shaft

- Usually, Shaft is used for power transmission from one point to another such as,
- Automobile Drive Shafts
- Marine Drive Shafts
- Locomotive Drive Shafts
- Machine Shafts
- Aeroplanes etc.

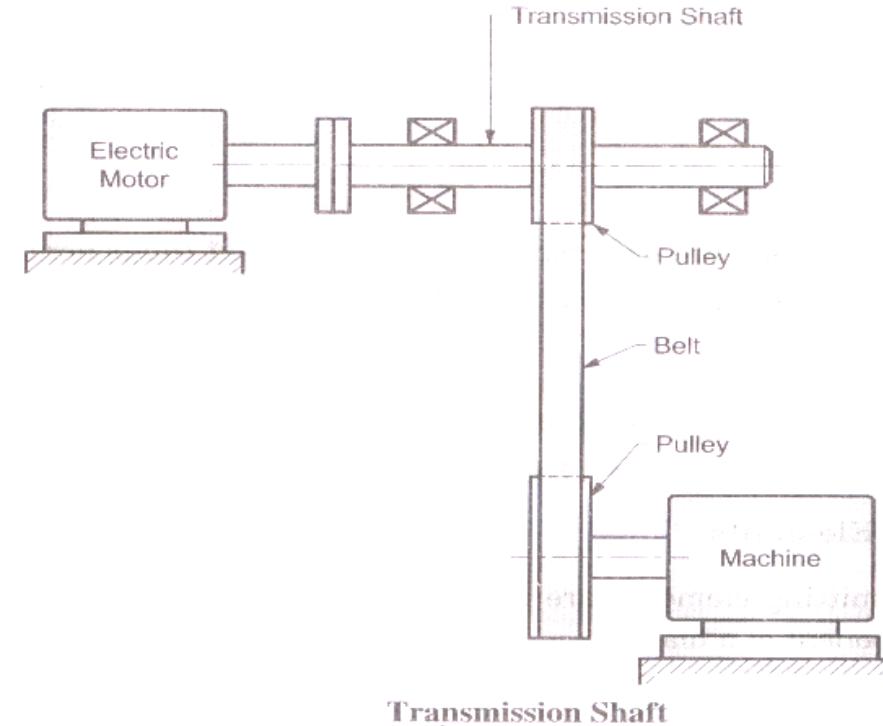
Types of Shafts

- Power Transmission Shafts: as the name implies, they transmit the power from one member to another member. These shafts carry machine parts such as pulleys, gears etc.
- Machine Shafts: these are the part of machine only. For example crank shaft, or shaft of Drill machine.



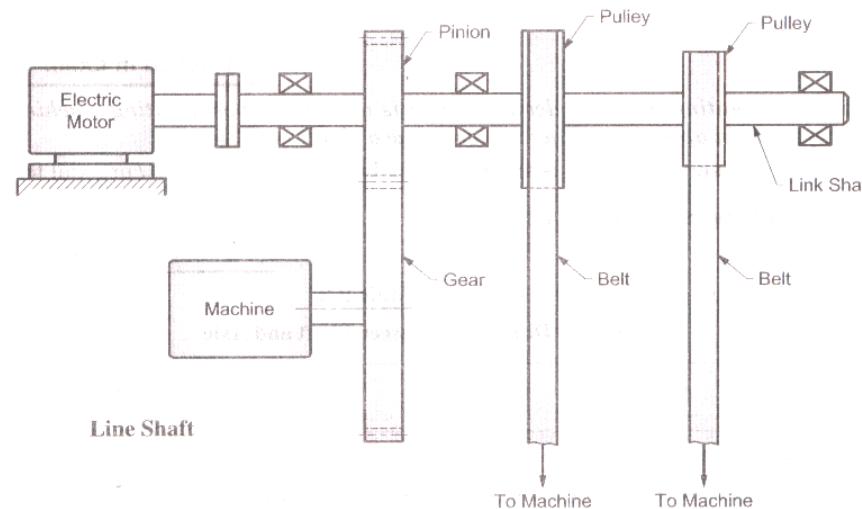
Transmission Shaft

- The shaft which is directly connected to power producing device is called transmission shaft.



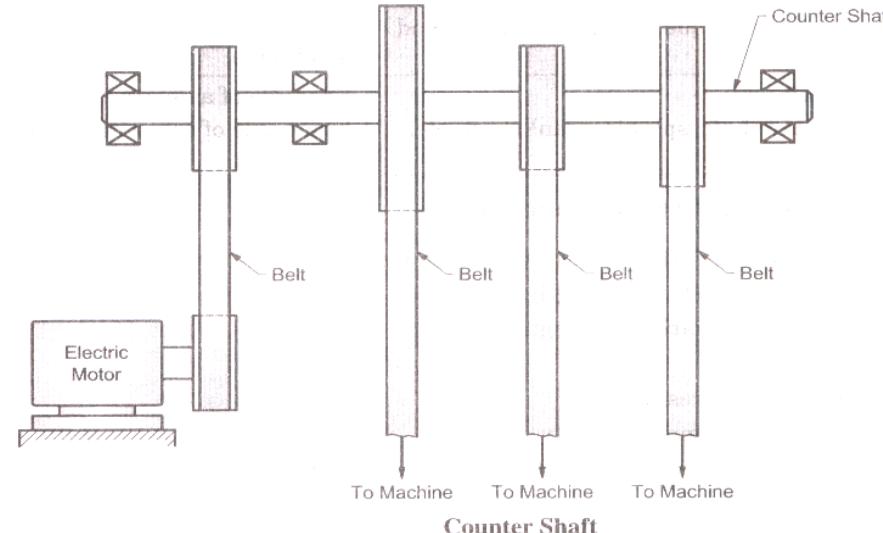
Line Shaft

- Line shaft is a very long transmission shaft which is directly driven by the prime mover (or power source) and which is used distribute power from main power source to different power consuming devices.



Counter Shaft

- Counter shaft is a secondary shaft which is driven by the main shaft through belt, chain or gear drive and from which the power is supplied to the different machines.



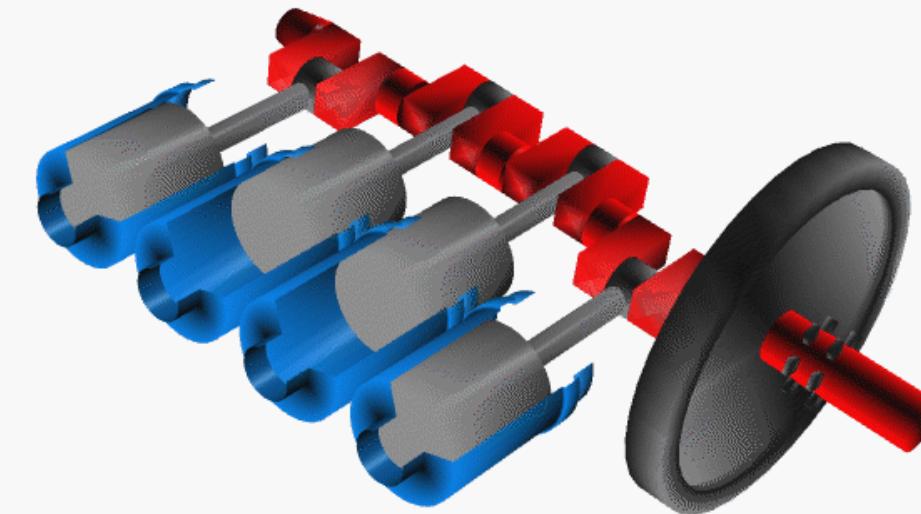


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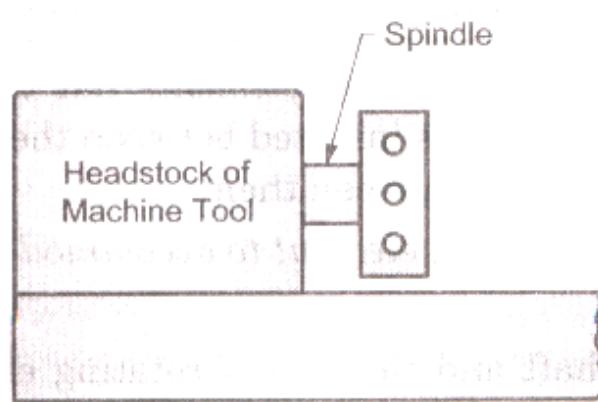
Crankshaft

- The shaft which used in multi cylinder IC engine to which cranks are embedded is called crankshaft.



Spindle

- Spindle is peculiar terminology associated with shafts of machine tools which provide rotary motion either to a cutting tool or to a work piece.

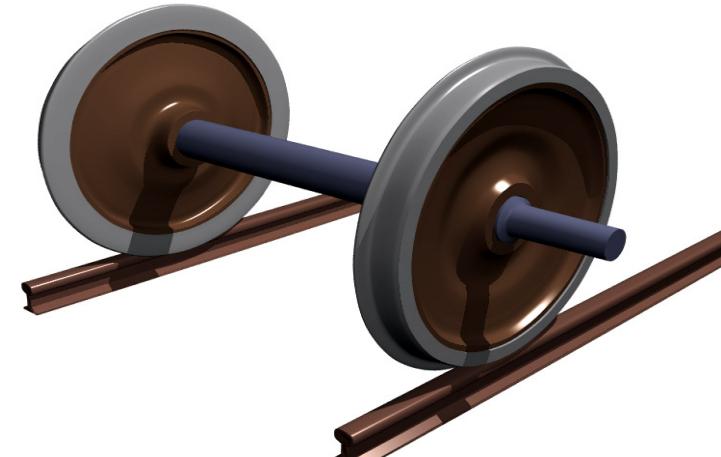
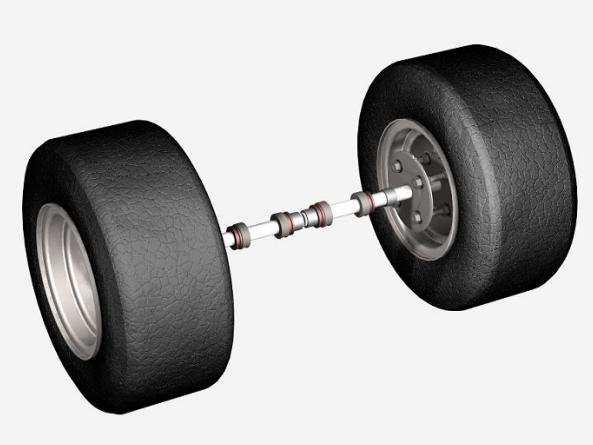


(a) Spindle



AXLE

- The axle is a non rotating bar which doesn't transmit any torque but only used to supports rotating machine elements like wheels, pulleys etc.

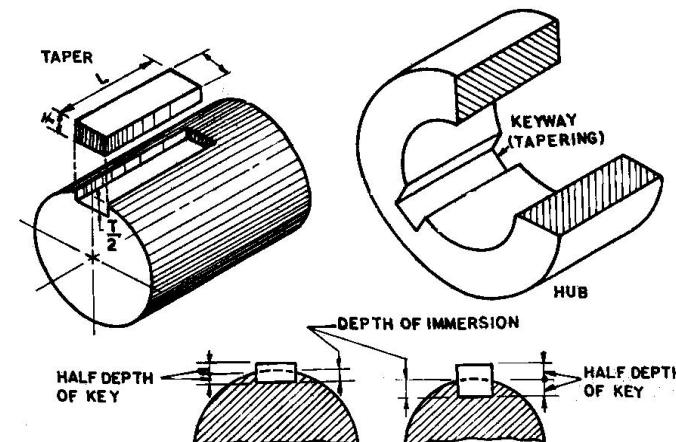


Difference between Axle and Shaft

Axle	Shaft
Axle is a non rotating member	Shaft is rotating member
Primary function is to provide support to elements like wheel, pulley etc.	Primary function is to transmit torque.
Axle is subjected to bending moment	Shaft is subjected to bending moment, as well as torsional moment (torque)
Depending upon loading condition, cross sectional area of axle can be different e. g. Rectangular, Circular, I-section, T-section etc.	Cross sectional area of shaft is generally circular because it causes minimum vibrations and peaking of torsional stress. (For a given cross section area circular shape provides minimum peak stress under same torsional loading.)
Examples: Axles of automobiles, railway buggies.	Examples: Shaft of electric motor, shaft of IC engine

Keys

- A key is a piece of mild steel inserted between the shaft and hub or boss of the pulley or a gear to connect these together in order to prevent relative motion between them.
- It is always inserted parallel to the axis of the shaft. Keys are used as temporary fastenings.
- A keyway is a slot or recess in a shaft and hub of the pulley to accommodate a key.



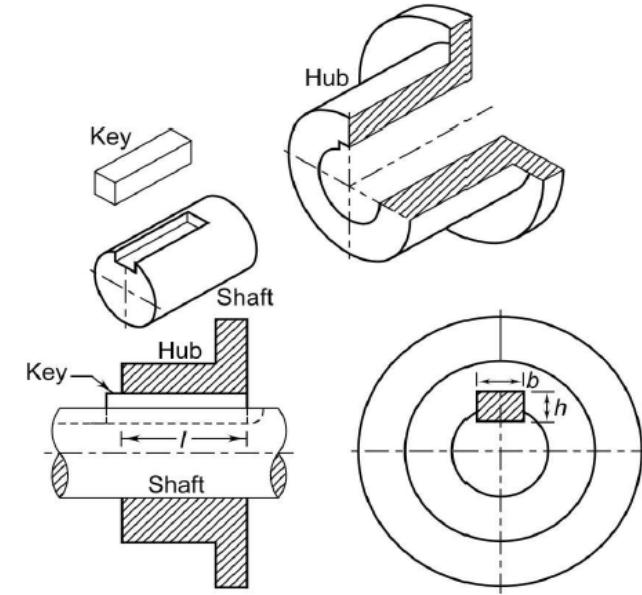
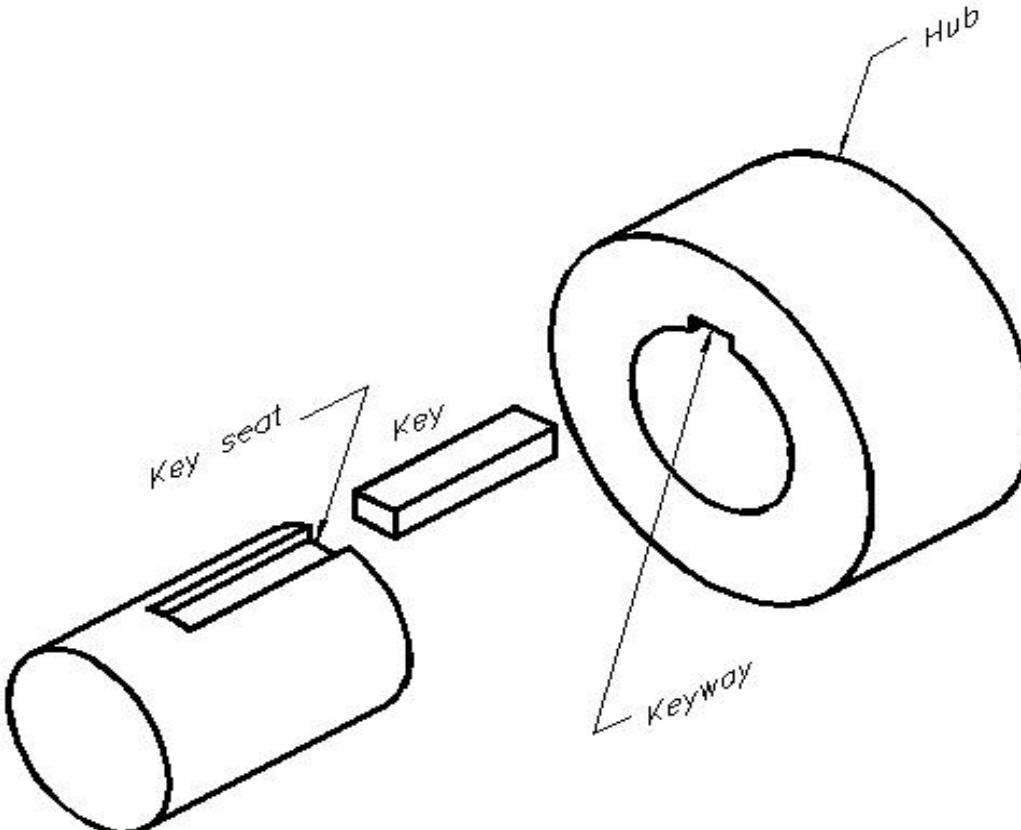


Fig. 9.16 Key-joint



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Keys

- Keys are temporary fastening and are always made of mild steel because they are subjected to shearing and compressive stresses caused by the torque they transmit.
- A keyway is the groove cut in the shaft or hub to accommodate a key. Key ways can be milled horizontally or vertically .

Definition: The key can be defined as a machine element which is used to connect the transmission shaft to rotating elements like pulleys, gears, sprockets or flywheels.

FUNCTIONS of KEYS

1. Used to prevent the relative motion between the shaft and the hub of rotating element like : gear, pulley, or sprocket.
2. To transmit the torque from the shaft to the rotating element or vice-versa.



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Classification of Keys

- The keys are broadly classified into six types:-

1. Sunk Key

- i. Square sunk key
- ii. Rectangle sunk key
- iii. Parallel sunk key
- iv. Gib-head sunk key
- v. Feather sunk key
- vi. Woodruff key.

2. Saddle key

- i. Flat saddle key
- ii. Hollow saddle key

3. Round key and taper pins

- 4. Kennedy key
- 5. Tangent key
- 6. Splines



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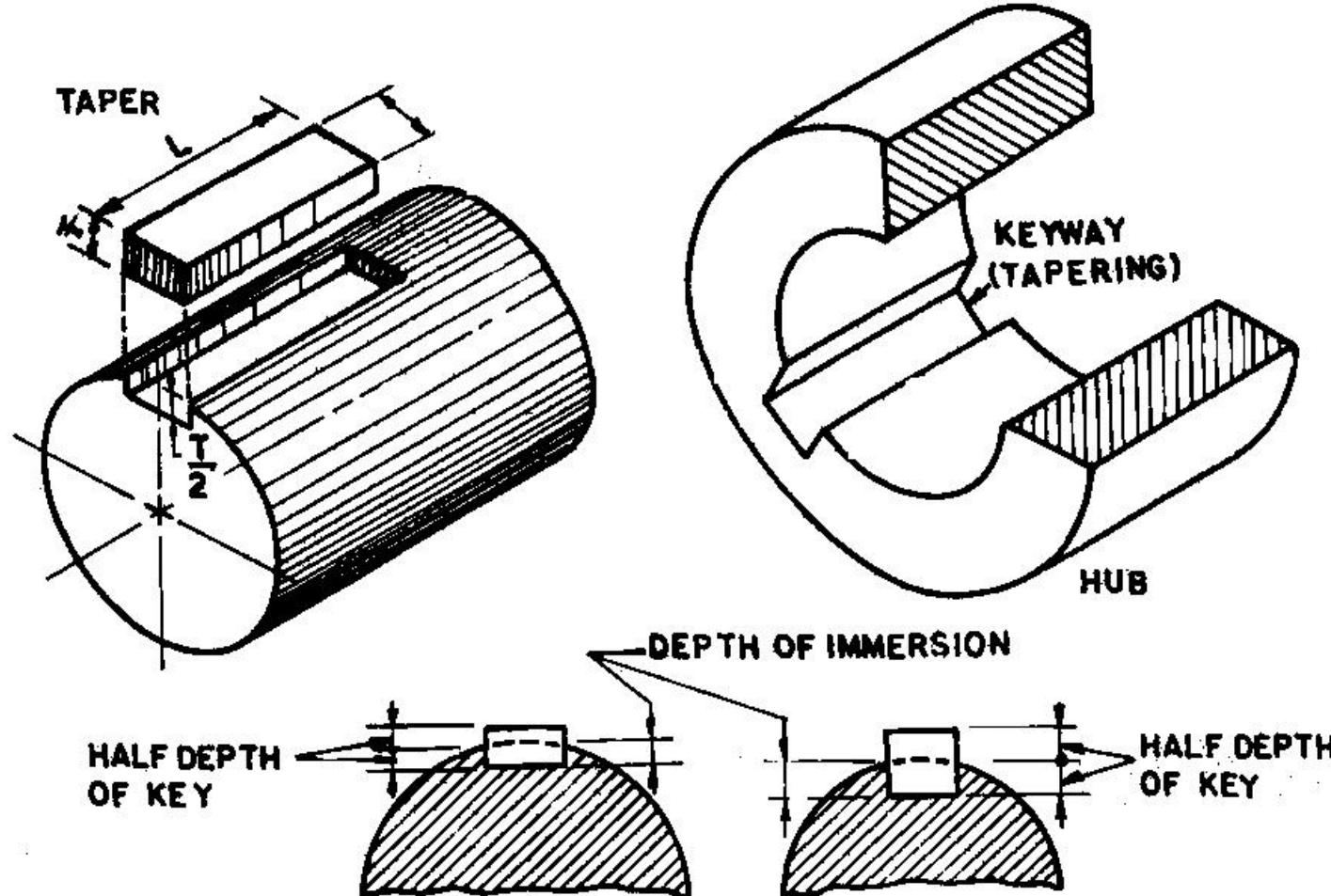
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Sunk keys

1. Sunk keys:

- The sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or boss of the rotating element.
- These keys are suitable for heavy duty since they rely on positive drive.
- This is the standard form of the key and may be either of rectangular or square cross-section. The key is sunk in the shaft to a depth of half its nominal thickness when measured at the side.
- This key gives a very sound fastening without any fear of slipping between the two parts, unless , of course, the key shears. Such a key can be safely used for heavy duty work.

Sunk key

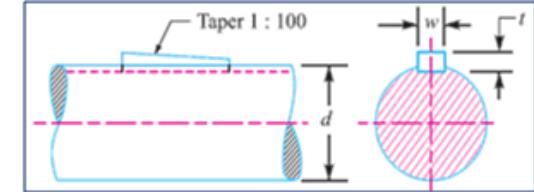


Sunk key

a) Square sunk Key:-

$$w = t = d/4$$

Taper of 1:100 is provided on hub side.

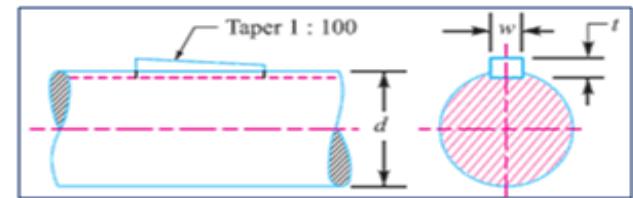


Square sunk key

b) Rectangular sunk key:-

$$w = d/4, \quad t = d/6$$

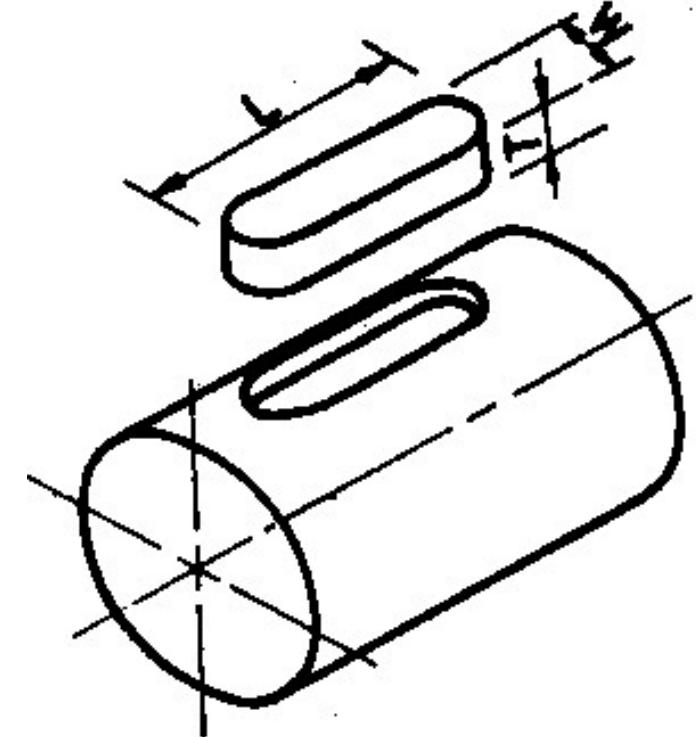
Taper of 1:100 is provided on hub side.



Rectangular sunk key

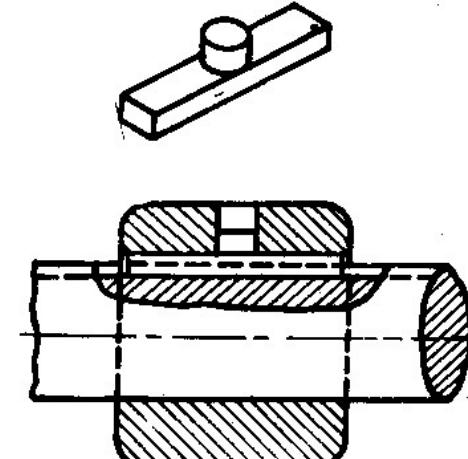
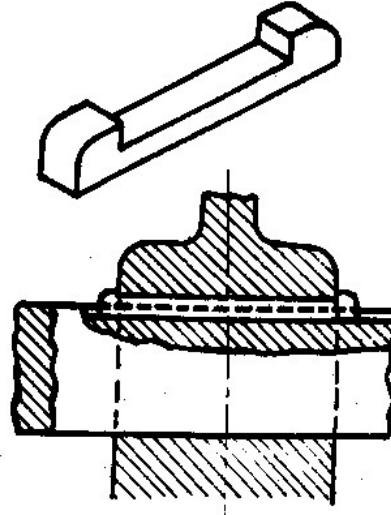
c) Parallel sunk key:-

- No taper is provided.
- It is uniform in width and thickness throughout. It is thus taper less and is used where the pulley or other mating piece is required to slide along the shaft. It may be rectangular or square cross-section and their ends may be squared or rounded.



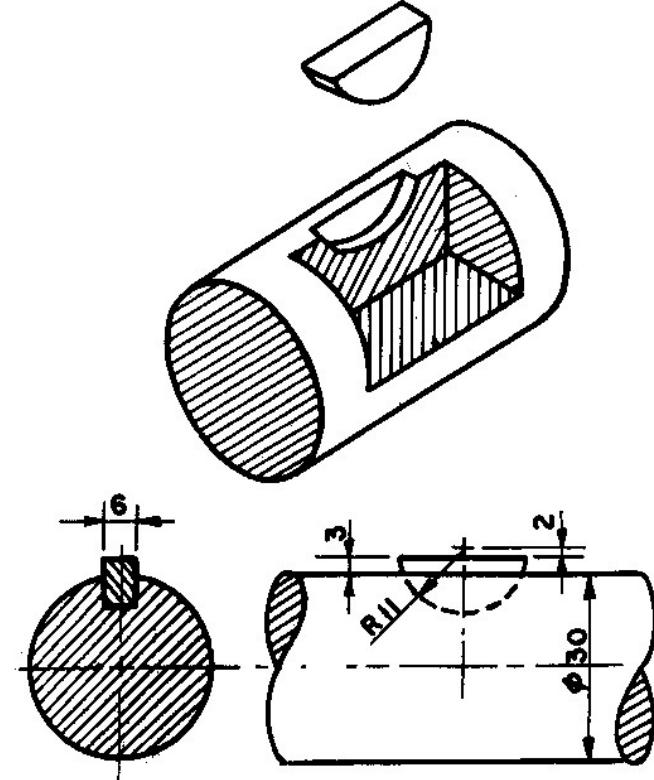
d) Feathered sunk key:-

- It is a key attached to either to shaft or hub of a pair and permitting relative axial movement thus it is particular kind of parallel key which permits axial moment .
- A feather key is secured either to the shaft or to the hub, the key being a sliding fit in the keyway of the moving piece.



f) Woodruff key:-

- It is an adjustable sunk key. It is in the form of a semi-circular disc of uniform thickness.
- The key fits into a semi-circular keyway in the shaft and the top of the key fits into a plain rectangular key way in the hub of the wheel.
- Since the key and the key seat bear the same radius , it has the advantage of adjusting itself to any taper of the slot of the hub or boss of wheel.
- Used to transmit small torques.
- Easy to remove from the shaft.





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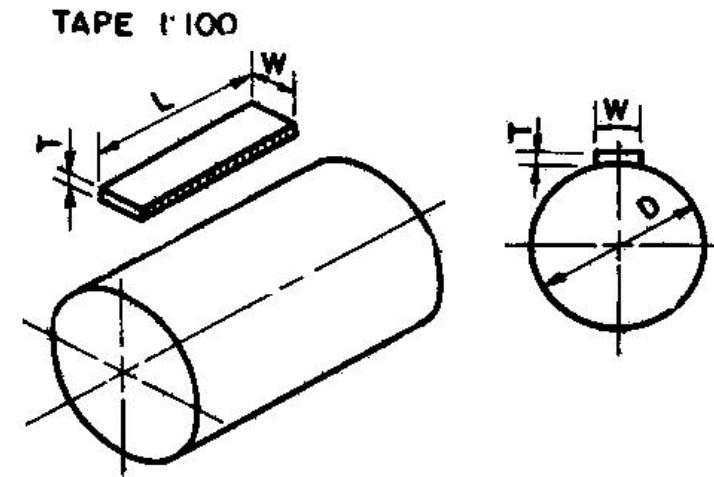
2. Saddle keys

- Saddle key are taper keys which are sunk into the hub only.(note: a taper key is uniform in width but tapered in thickness on one side, usually 1:100 and is used where no axial movement along the shaft is required).
- The torque is transmitting due to the friction between the key and the shaft. Hence the torque transmitting capacity of saddle is low.
- Saddle key is suitable for light duty, since they rely on a friction device alone and are liable to slip on the shaft under load.

Type of the saddle key

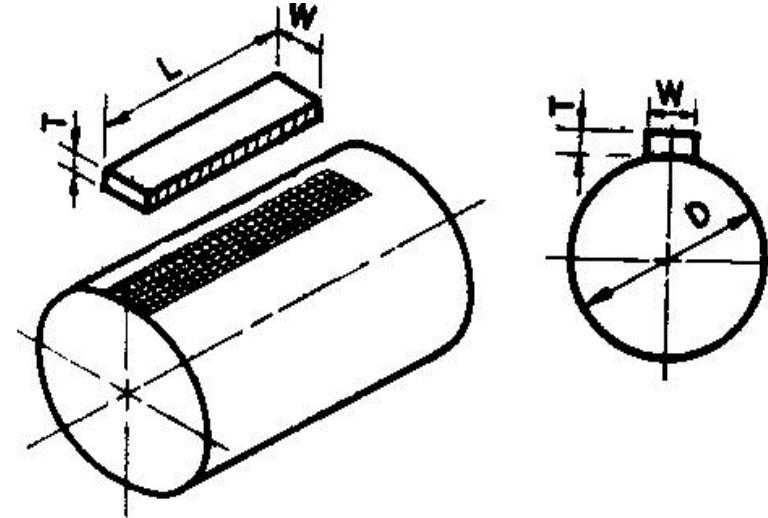
a) Hollow saddle key:

- This key has its underside hollow out so that it can be placed on the curved surface of the shaft.
- The keyway is cut in the mating piece (hub) only. Hollow saddle key is used for light duty.



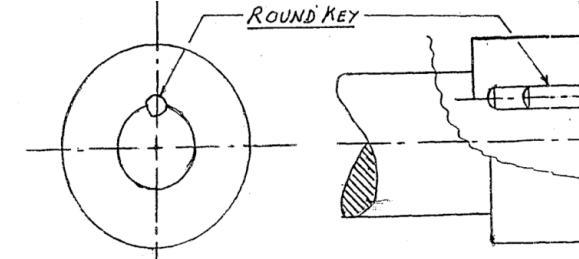
b) Flat saddle key:

- In this the flat surface is made on the shaft over which the key is placed in position .
- In this, holding force is comparative large than the hollow saddle key. It is used for light duty.



3. Round Keys:-

- Circular in cross section.
- Fitted into the partly drilled holes in shaft and hub.
- Used for low power transmission.



Round Key

4. Tapered pins:-

- Taper of 1:50 is provided.
- Used for low power transmission.



Tapered pin

5. Splined shaft:-

- Consist of multiple integral keys in 4,6,10 or 16 in number.
- Strength is more than single keyway shaft.
- Used for large power transmission.
- Used in automobile gear box.

FIGURES FOR SOFT BROACHED HOLES IN FITTINGS

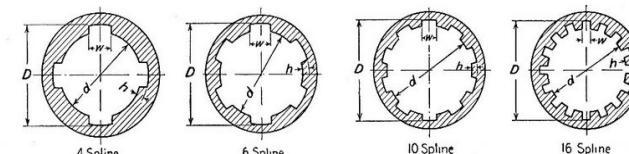
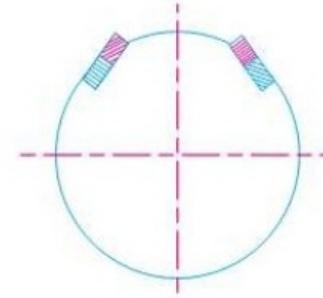


FIG. 1—DIMENSIONS FOR 4, 6, 10, AND 16 SPLINE FITTINGS (SEE TABLE I)

Splines

6. Tangent key:-

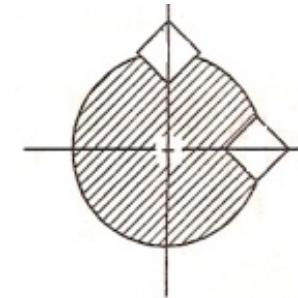
- Consist of two tapered rectangular keys placed at 90^0 apart.
- Each key withstands torque in one direction.
- Used in heavy duty industrial application.



Tangent Key

7. Kennedy Key:-

- Consist of two tapered square keys placed at 90^0 apart.
- Used in heavy duty industrial application.



Kennedy Key



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COUPLING

- Coupling is an important mechanical element used to connect two shafts or to couple driver shaft with driven shaft.
- Shafts are usually available up to 7 meters length due to inconvenience in transport.
- Inorder to have greater length, it is necessary to join two or more pieces of shaft by means of couplings.
- So a coupling is a device used to connect two shafts permanently so that necessary power and torque can be transmitted.
- Coupling is the mechanical element used **to connect two shafts of a transmission system** and transmit the torque from one shaft to another.



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COUPLING

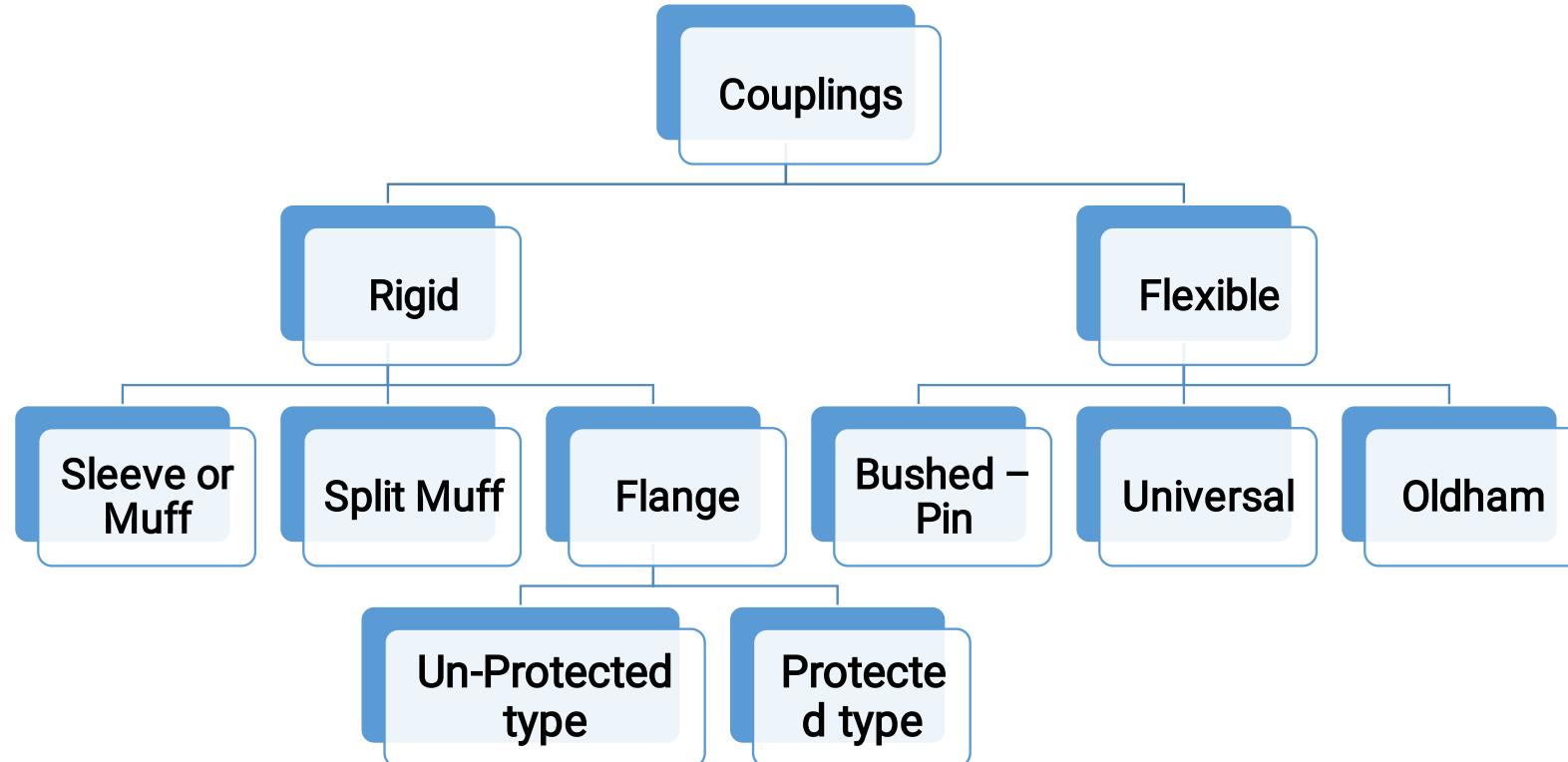
- The coupling can be used when,
 - When axes of shaft are collinear.
 - When two shafts are intersecting.
 - When two shafts are parallel and some distance apart.

Functions of Coupling :

- Connects two shafts.
- Introduces mechanical flexibility and tolerates small misalignment.
- Reduces the transmission of vibrations and shocks.

- The requirements of good couplings are,
 - i. It must transmit full power of the driving shaft.
 - ii. It should keep the shaft in perfect alignment or it should absorb the slight mis-alignment between the shaft.
 - iii. It should be easy to connect and disconnect the coupling.
 - iv. It should be able to operate in any type of operating condition.
 - v. It should not transmit shock loads.
 - vi. It should be easily available at low cost.
 - vii. It should not have any projected part.

Classification of Couplings





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Rigid Couplings

- Rigid couplings are used to connect two shafts which are perfectly aligned.
 - These couplings are not capable of tolerating any misalignment between two shafts.
 - These couplings are not capable of absorbing shocks and vibrations.
 - These are simple and inexpensive.
- Following are types of rigid couplings:-
- a) Flange coupling
 - b) Sleeve or Muff coupling
 - c) Clamp or compression coupling

Flexible Couplings

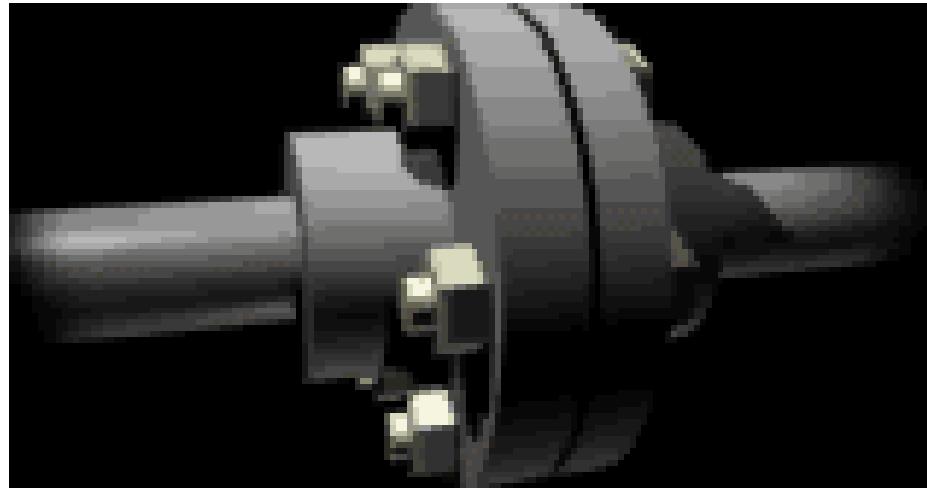
B. Flexible coupling:-

- Flexible coupling used to connect two shafts consisting of small amount of mis-alignment which may be lateral or angular.
- The shock and vibration absorption capacity of these couplings is more.
- Following are types of flexible couplings:-
 - a) Bushed pin type flexible coupling
 - b) Oldham's coupling
 - c) Universal coupling or Hook's joint

Rigid Couplings

1. Rigid flange coupling:-

- It consists of two separate cast iron flanges, which are mounted on shaft with the help of key.
- The two flanges are coupled together by means of nut and bolts.



Rigid flange Coupling



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Rigid Couplings

- **Advantages:**

- i. It is simple in construction.
- ii. It is easy to assemble and disassemble.
- iii. It has high torque transmitting capacity.

- **Disadvantage:**

- i. If there is small misalignment between shafts, then flange coupling can not be used.
- ii. This coupling is used when the motion is free from shocks and vibrations.

- **Applications:**

- i. Used to connect electric motor to pump or electric motor to compressor.
- ii. Flange coupling is generally used for heavy loads and in long shafts.

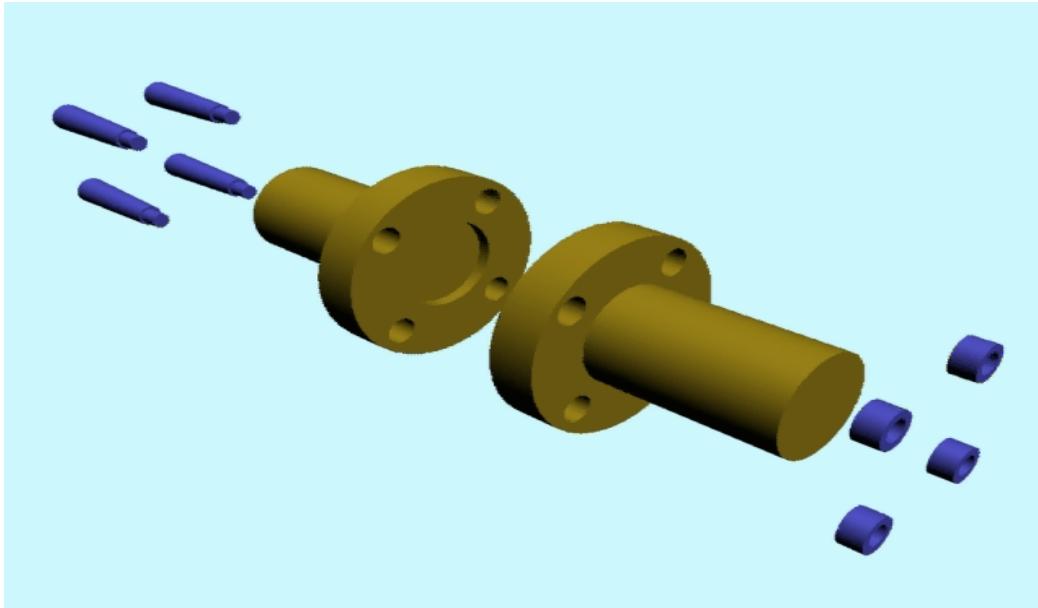


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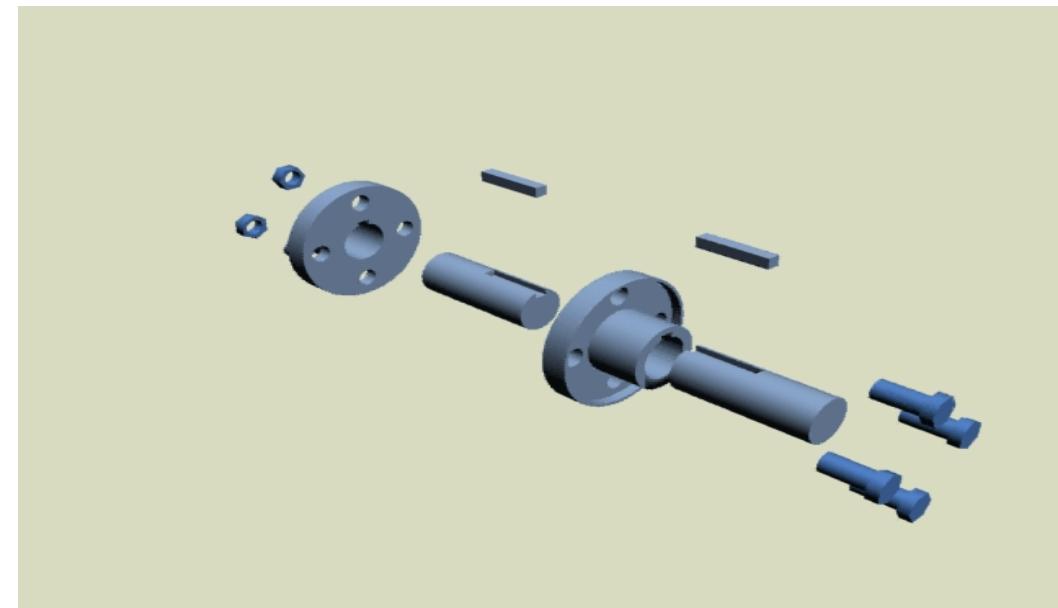
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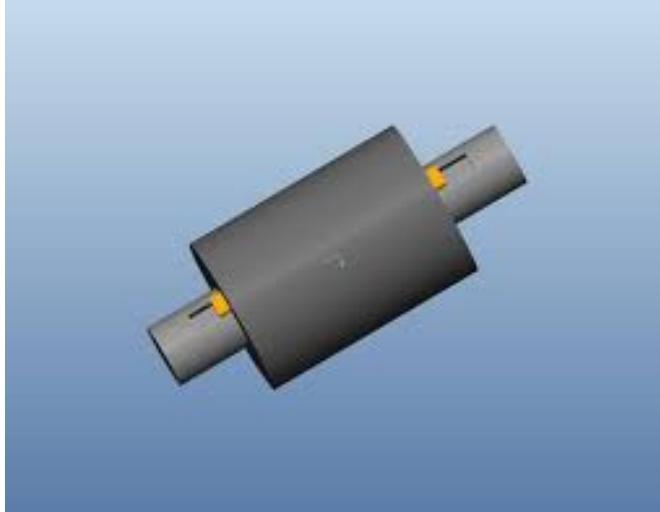
NON-PROTECTED TYPE FLANGE COUPLING



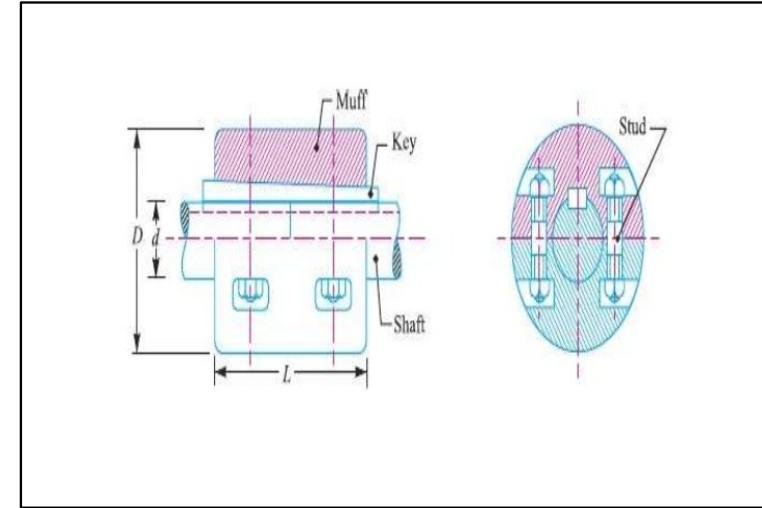
PROTECTED FLANGE COUPLING



2. Sleeve or muff coupling:- spring



3. Clamp or compression



Flexible coupling

1. Bush pin type coupling:-

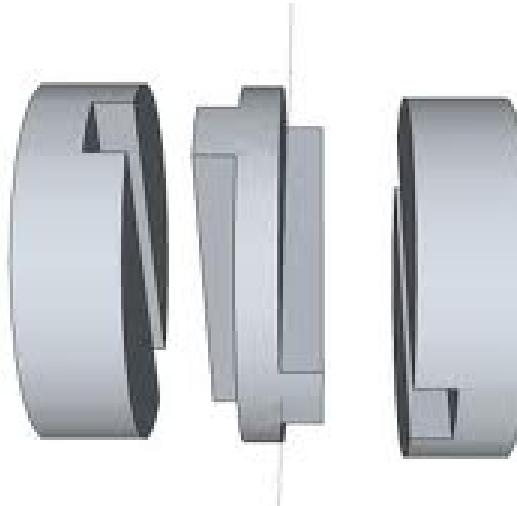
- In bush pin type flexible coupling, rubber bushes are used which are inserted into the flanges.
- It can tolerate very small amount of lateral or angular misalignment.



Flexible coupling

2. Oldham coupling:-

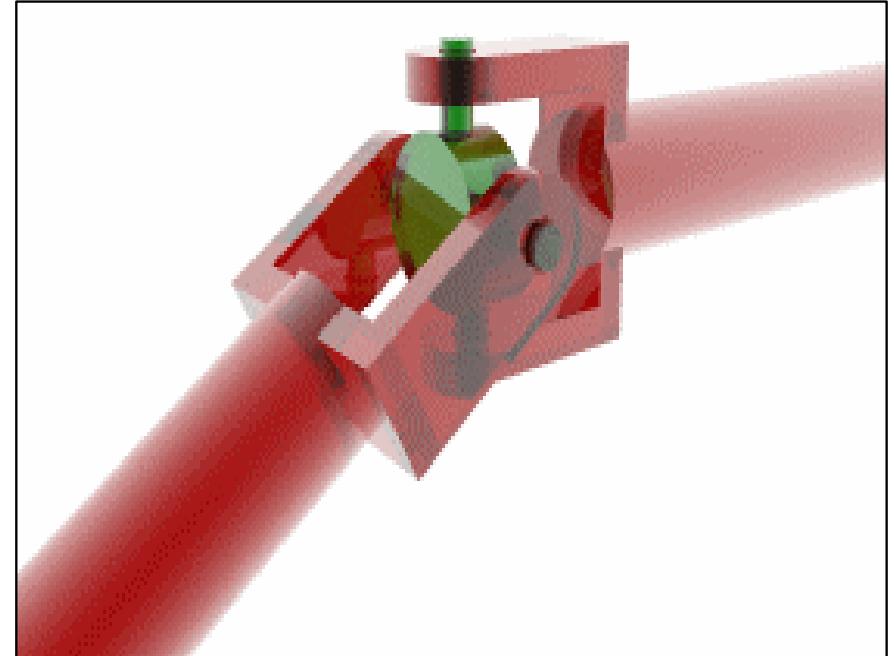
- Used for connecting two shafts whose axes are parallel and at a small distance(lateral) apart.
- There is a relative sliding motion between flanges and intermediate circular disk.



Flexible coupling

3. Universal coupling or Hook Joint:-

- Used for connecting two non parallel and intersecting shafts having small angle between them.
- It consists of two U shaped yokes or forks and a cross or connecting link.
- This is used to transmit power from the gear box of automobile engine to the rear axle.



Bearings

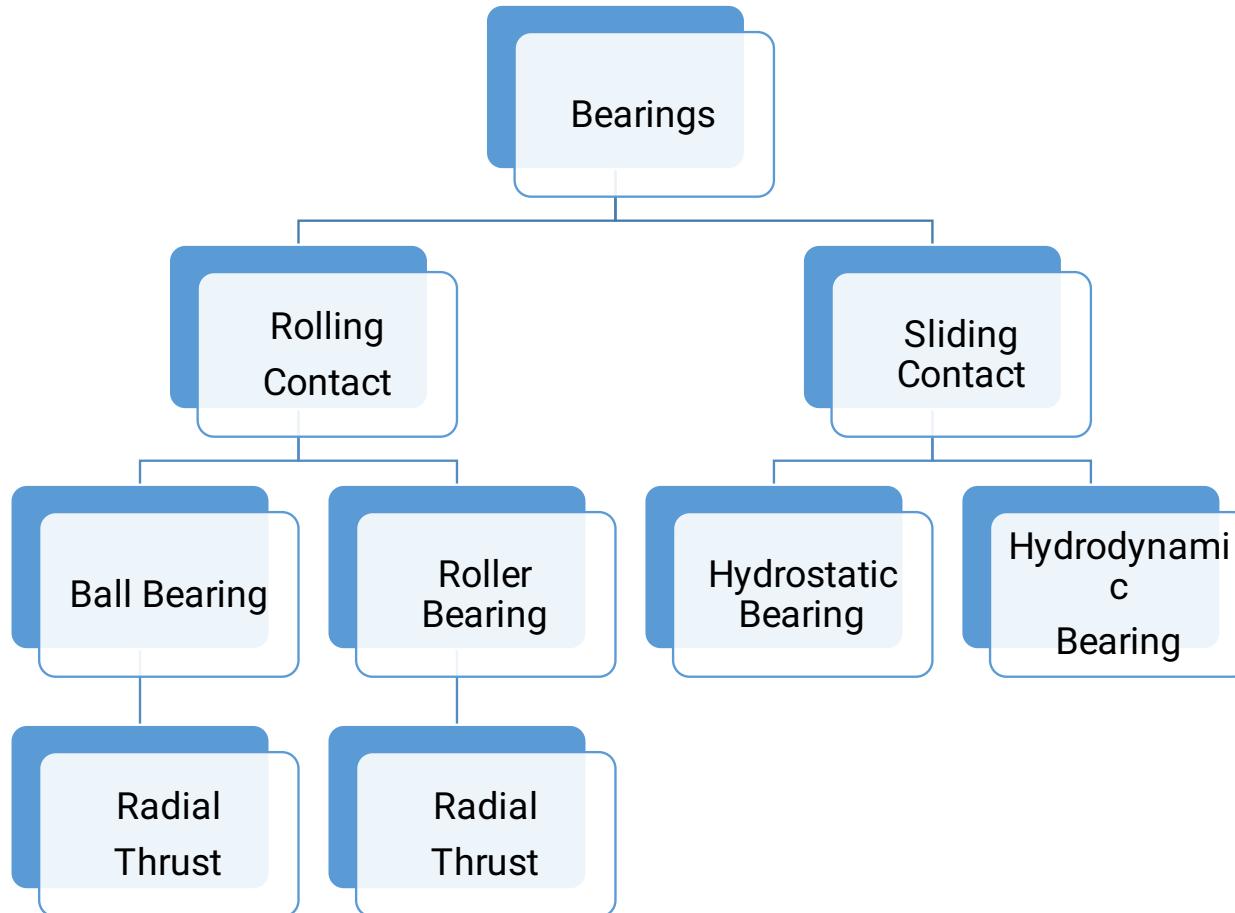
- Bearing is a device that **allows relative motion** between two parts, such as shaft and housing **with low friction** as well as it **restricts** that motion in one **desired direction only.**
- It also supports the rotating shaft or axel and carries the load applied on them.
- Relative motion, sets up frictional force and certain amount of power loss to overcome this frictional force.
- The frictional force generates heat.

Bearings

Functions:

- I. It ensures **free rotation** of the shaft or the axle **with minimum friction**.
- II. It supports shaft or axle and holds it in the correct position.
- III. It takes the **forces** acting on the shaft or the axle in both working as well rest condition and **transfers them to frame** on which it is mounted.

Classification of Bearings



Classification of Bearings

- The bearings are generally classified into **sliding contact bearings** and **rolling contact (antifriction) bearings**.
 - A. **Sliding Contact bearings**
 - The bearing in which the contacting surface makes sliding contact or are separated by a film of lubricant are known as sliding contact bearings.
 - a. Journal Bearing
 - b. Thrust Bearing
 - B. **Rolling contact bearings**
 - The bearings in which the contacting surfaces make a rolling contact are known as rolling contact bearings.
 - a. Ball bearing
 - b. Roller bearing

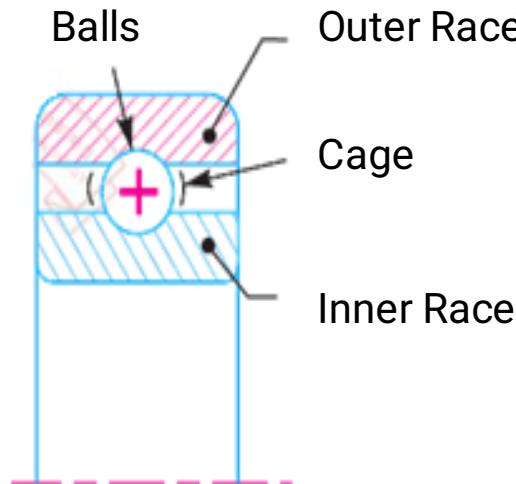
Rolling contact bearing

- The rolling contact bearings are **ball bearing** and **roller bearings**.
- The purpose **to support a load while permitting relative motion between two elements of a machine.**
- The ball and roller contact bearing consist of an inner race which is mounted on shaft or journal and an outer race which is carried out by the housing or casing.
- In between inner and outer race there are balls or rollers, these are held at proper distances so that they will not touch each other.
- In **ball bearings** the contact between balls and inner & outer race is **point contact**.
- Whereas in **roller bearings** the contact between rollers and inner & outer race is **line contact**.

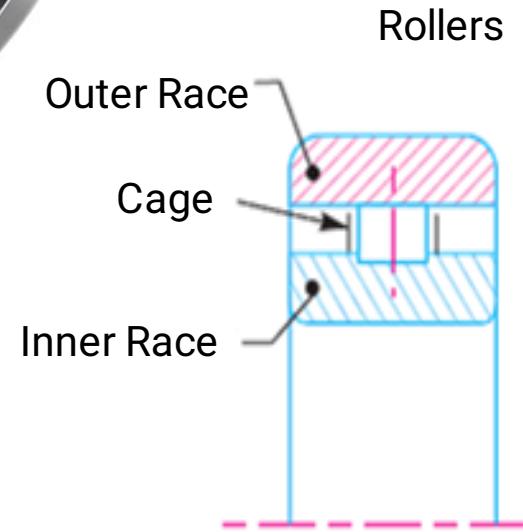
Rolling contact bearing



Ball Bearing



Roller Bearing



Rolling contact bearing

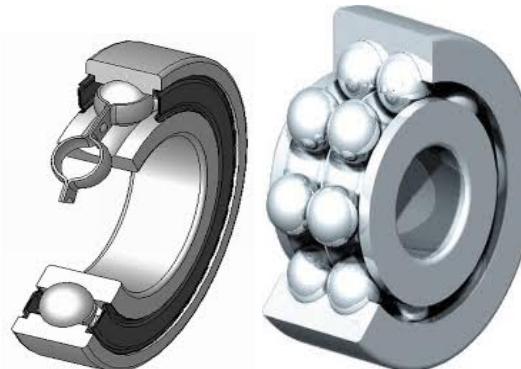
- Due to low rolling friction these bearings are aptly called “antifriction” bearing.
- Frictional resistance considerably less than as in plain bearings.
- Ball has rolling contact and sliding friction is eliminated and replaced by much lower rolling friction.
- In plain bearing the starting resistance is much larger than the running resistance due to absence of oil film.
- In ball and rolling bearings the initial resistance to motion is only slightly more than their resistance to continuous running.
- Hence ball and rolling bearing are more suitable to drives subject to frequent starting and stopping as they save power.
- Owing to the low starting torque, a low power motor can be used for a line shaft running in ball bearing.

Types of Ball Bearing

- The different types of ball bearings are:

1. **Single row deep groove ball bearing:-**

- Take radial as well as thrust load.
- Carry high radial load and moderate thrust (axial) load.



2. **Double row deep groove ball bearing:-**

- Carries heavier radial and axial loads.
- Used instead of using two single row deep groove ball bearings.

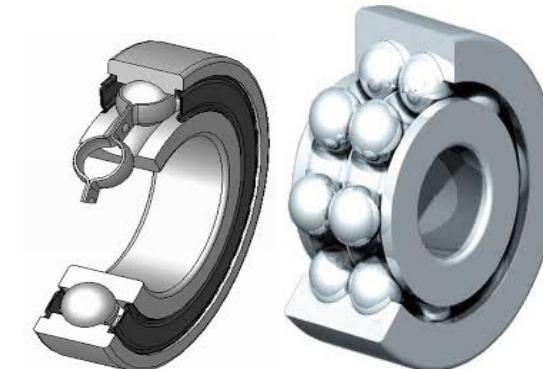
3. **Angular contact ball bearing:-**

- Carries substantial thrust (axial) load in addition to radial load.



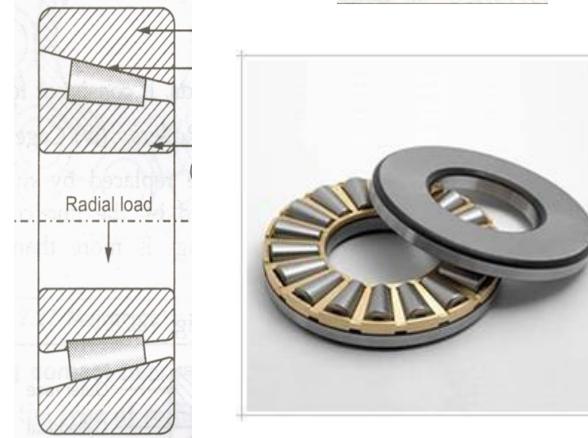
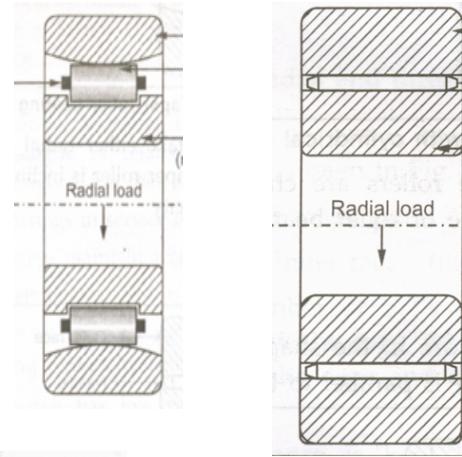
4. **Thrust ball bearing:-**

- Used to take pure thrust (axial) loads.



Types of Roller Bearing

- The different types of roller bearings are:
 1. **Cylindrical roller bearing:-**
 - Take greater radial load.
 - Cannot take thrust (axial) load.
 2. **Needle roller bearing:-**
 - Carries heavier radial loads.
 - Used where radial space is limited.
 3. **Taper roller bearing:-**
 - Carries high radial and thrust (axial) load.
 4. **Thrust roller bearing:-**
 - Used to take pure thrust (axial) loads.



Materials for Bearings:

The desirable properties of a good bearing material are as:

- I. High **compressive strength** to withstand high pressures without distortion.
 - II. High **endurance strength** to avoid pitting
 - III. High **corrosion resistance**.
- There are essentially two choices for the material used in ball bearings are as Chrome Steel or Stainless Steel.

Chrome steel : 1) Good Load Capacity 2) Smooth and low noisy working conditions

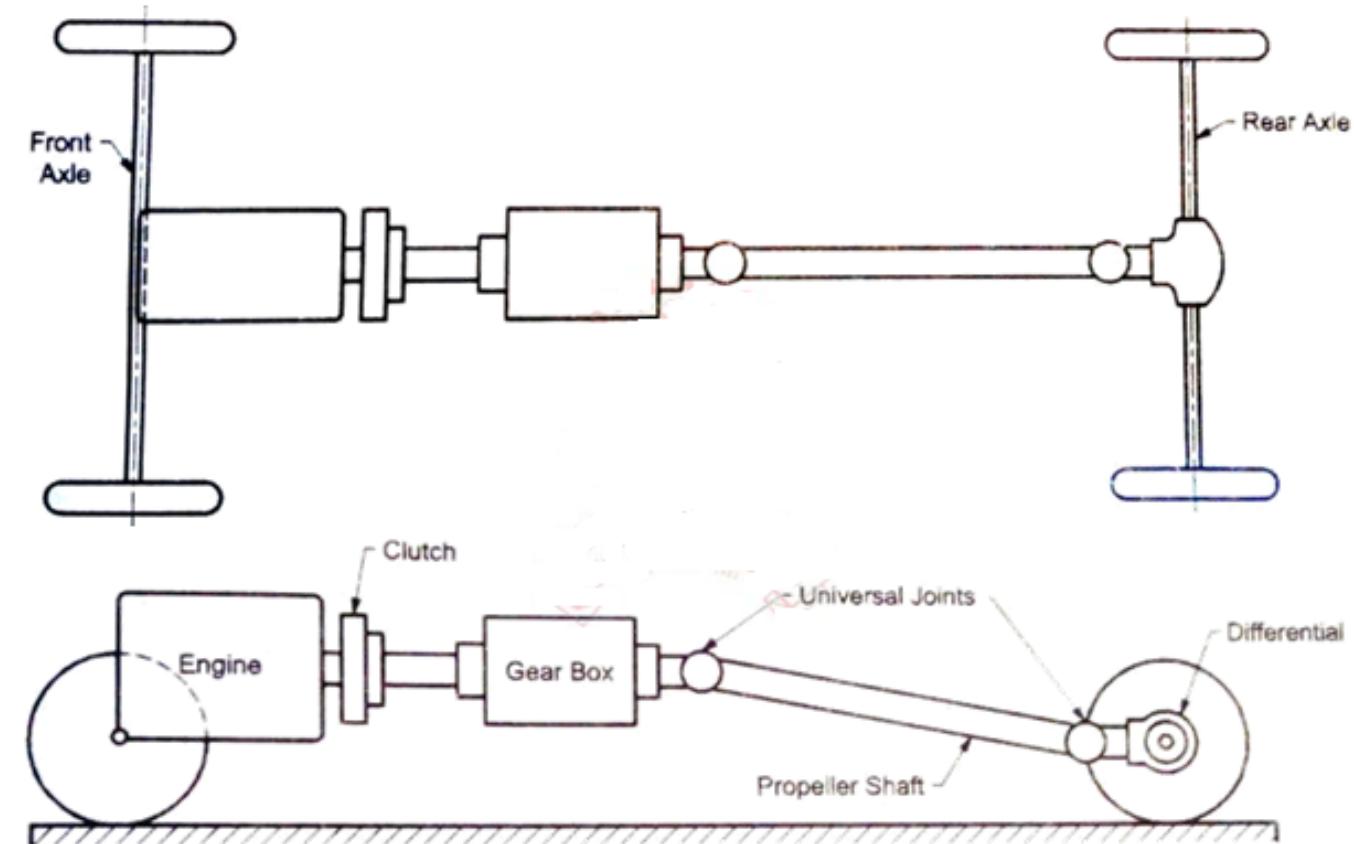
3) Good Machinability 4) Long life 5) Low Corrosion Resistance

Stainless Steel : (Martensitic stainless steel) 1) High Corrosion Resistance 2) Excellent Lifetime 3) Low noise characteristics

Comparison between Ball & Roller bearing

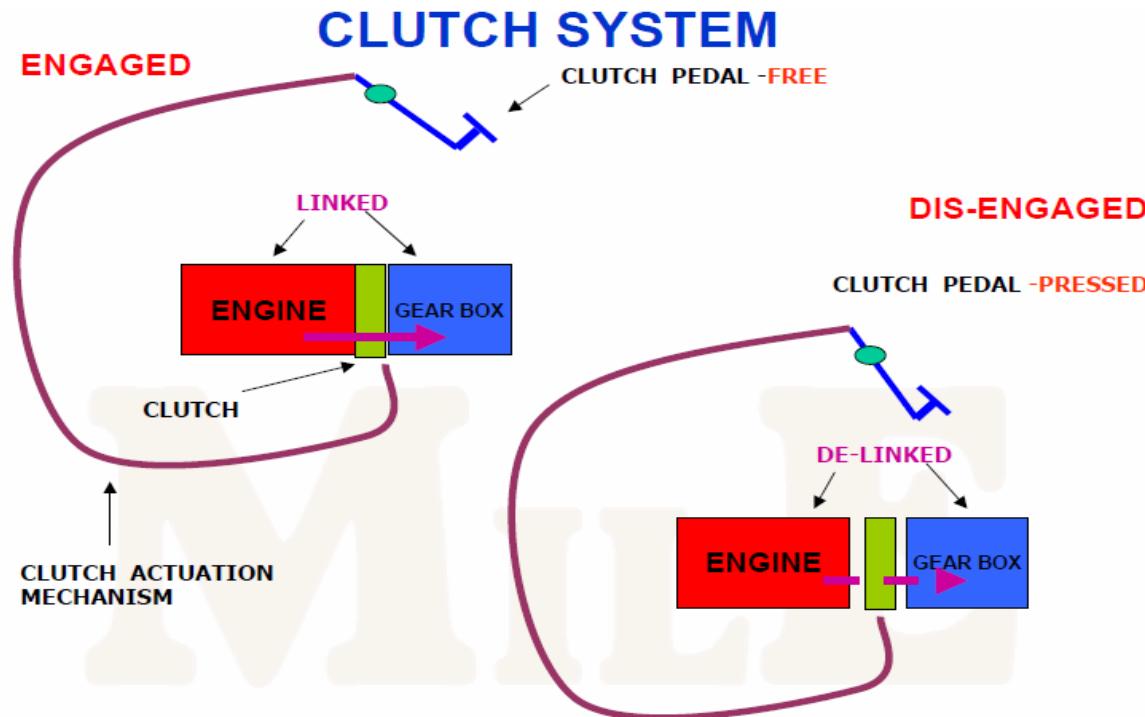
Sr. No.	Comparison parameter	Ball Bearing	Roller Bearing
1	Rolling Element	Spherical balls	Cylindrical rollers, Taper rollers.
2	Nature of contact	Point contact	Line contact
3	Load carrying capacity	Due to point contact load carrying capacity is low	Due to line contact load carrying capacity is high
4	Radial dimensions	Radial dimensions are more	Radial dimension is less
5	Axial Dimensions	Axial dimensions is less	Axial dimension is more

CLUTCH



CLUTCH

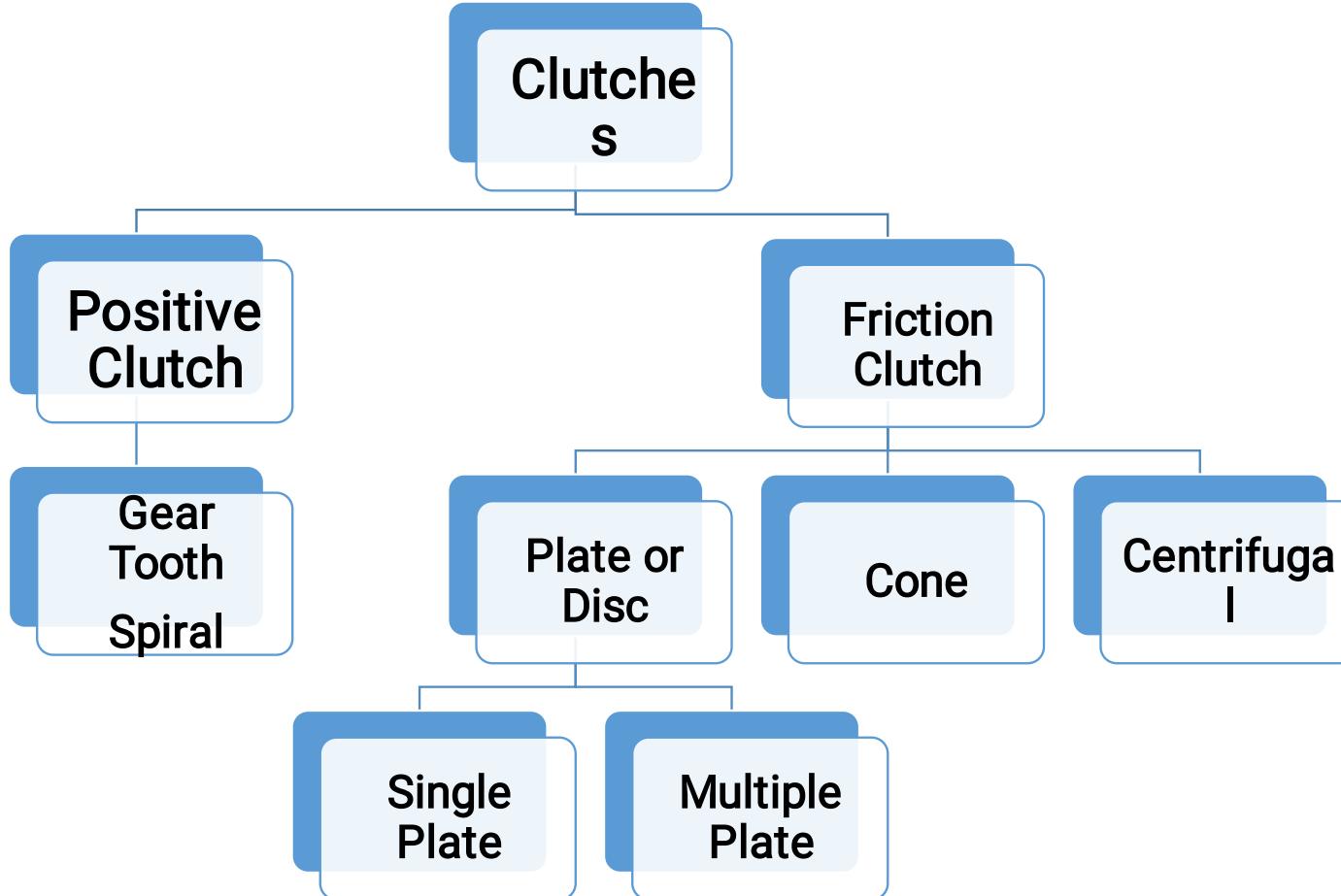
- It connects or disconnects the source of power from the remaining parts of the power transmission system at the will of the operator.
- It is mounted between driving and driven shaft.



Requirement of Good CLUTCH

- A good clutch should fulfil the following requirements:
 1. The force required to disengage should be as minimum as possible.
 2. It should transmit torque from driving shaft to driven shaft.
 3. The operation of engaging should be possible at any speed of the driving shaft. And it should have gradual engagement
 4. The heat generation during engaging should be minimum and heat dissipation should be faster.
 5. The engaging mechanism should not rupture or should not introduce more stresses in the clutch material.
 6. It should be dynamically balanced and should have ability to damp vibration.

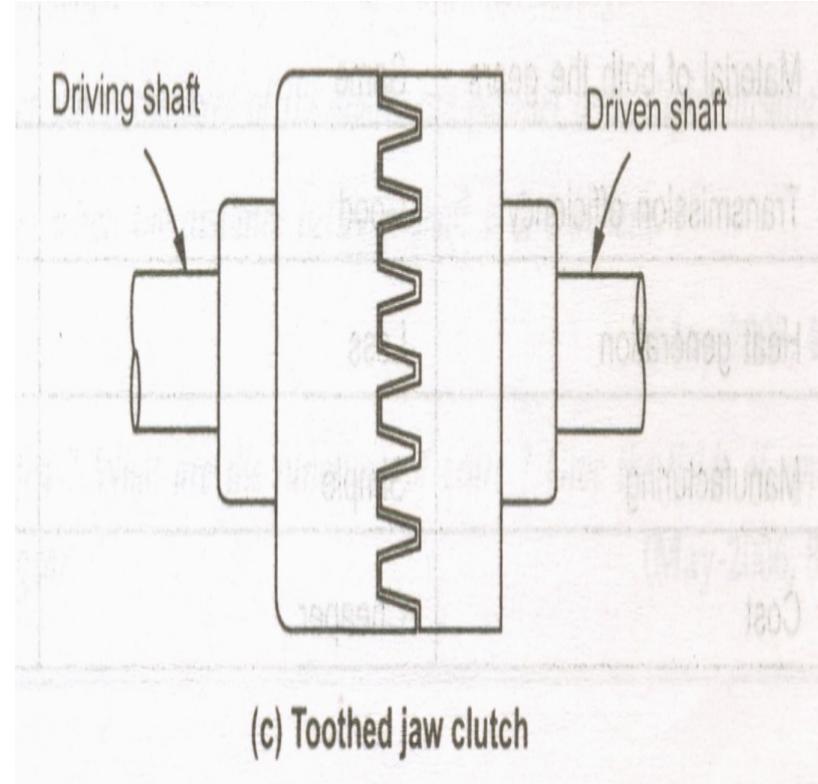
Classification of Clutch



Positive contact clutches

Transmit power from the driving shaft to the driven shaft by means of jaws or teeth

- **Square jaw clutch:**
- Positive clutches are used when positive drive is required.
- The Jaw clutch is the simplest type of positive clutch.
- It permits one shaft to drive another shaft through a direct contact of interlocking jaws.
- Used for transmitting power from electric motor to ball mill, pumps etc.



(c) Toothed jaw clutch

Square jaw toothed clutch

Positive contact clutches

Transmit power from the driving shaft to the driven shaft by means of jaws or teeth

➤ Advantages

- 1) They do not slip.
- 2) Less heat is generated.
- 3) Requires little or no maintenance.
- 4) Design is simple.

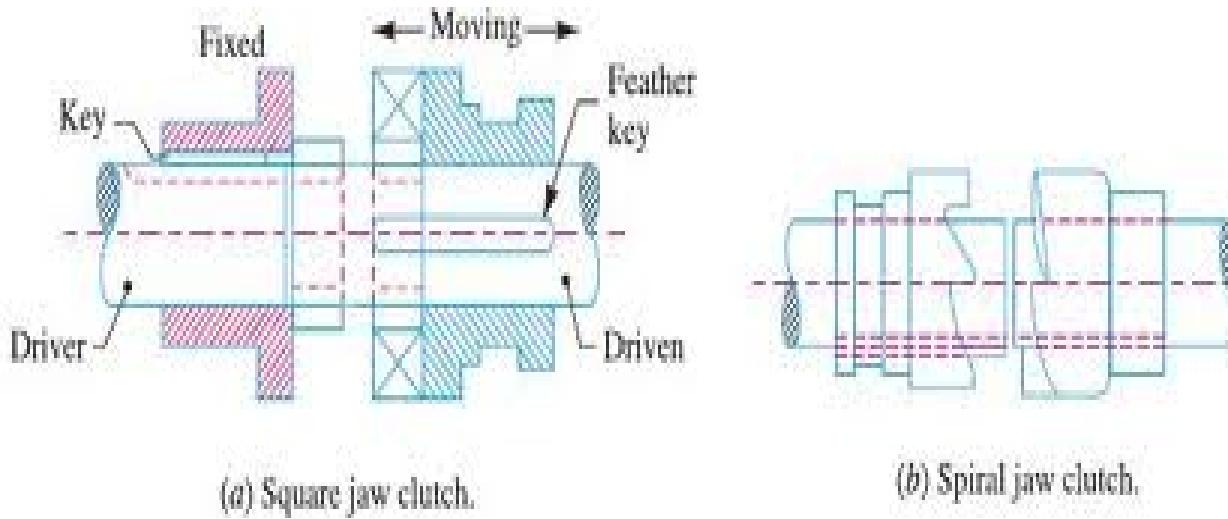
➤ Disadvantages

- 1) They can not be engaged at high speeds. Maximum 60 rpm for jaw clutch and 300 rpm for toothed clutch.
- 2) Sometimes, they cannot be engaged when both shafts are at rest unless the jaws are aligned.
- 3) Engagement at any speed is accompanied by shock or jerk.
- 4) Frequent engagement and disengagement cause wearing of jaws, which affects their performances.

➤ Applications

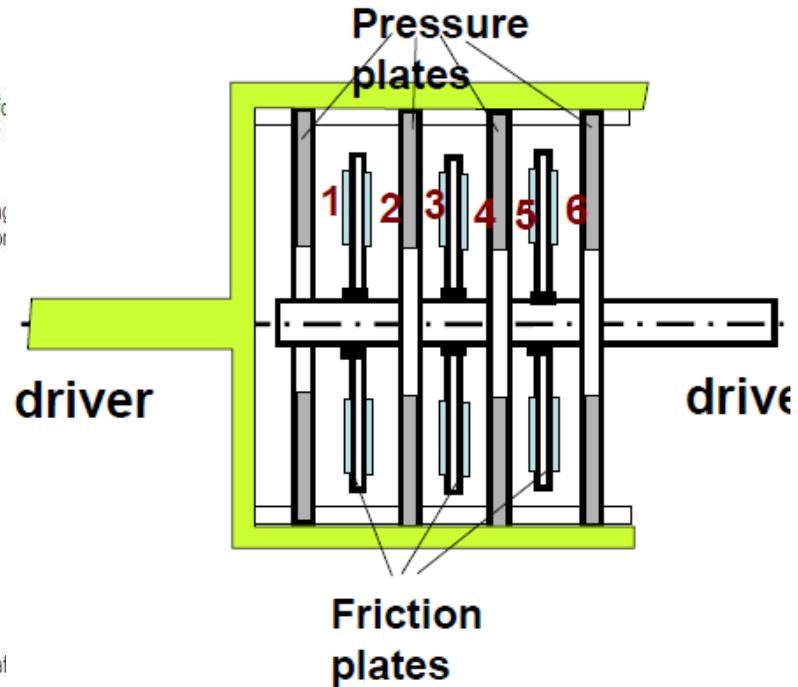
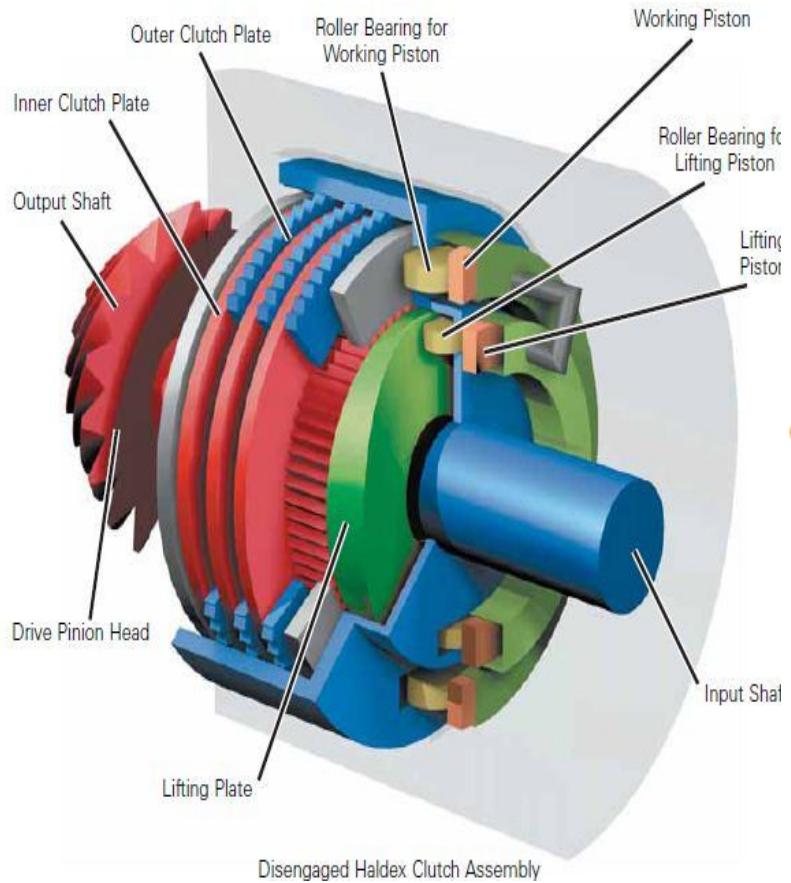
Automotive transmission, presses, punches and household appliances like kitchen grinding machine.

Positive Type Clutch

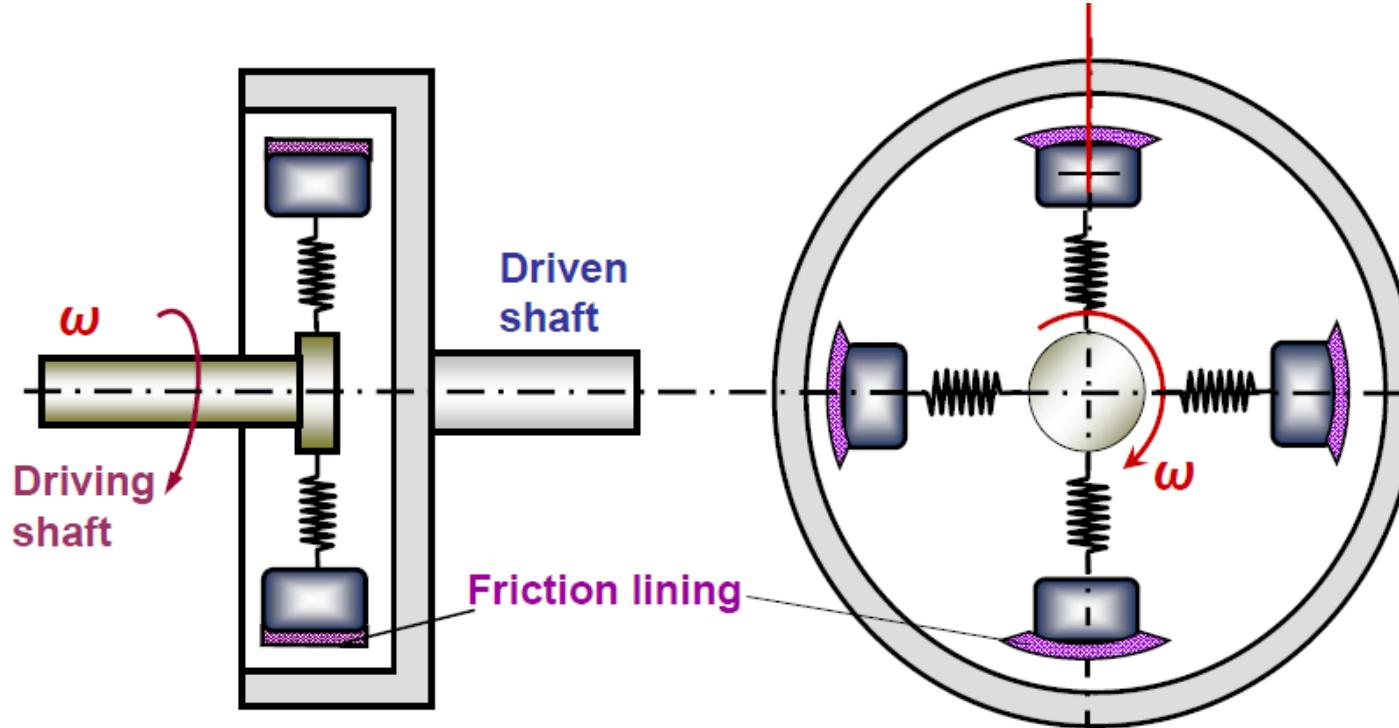


Frictional Clutch

- Transmit power or motion by friction between contacting surfaces.
- **Uses:**
- Transmission of power of shaft and machines which must be started and stopped frequently.
- **Requirements:**
- The contact surface should develop sufficient frictional force that may pick up and hold the load.
- The heat of friction should be rapidly dissipated and tendency to grab should be minimum.
- The surface should be backed by a material stiff enough to ensure a reasonably uniform distribution of pressure
 - **Torque capacity of the clutch depends on,**
- Coefficient of friction
- The diameter of the driven plate
- Spring thrust applied by the pressure plate

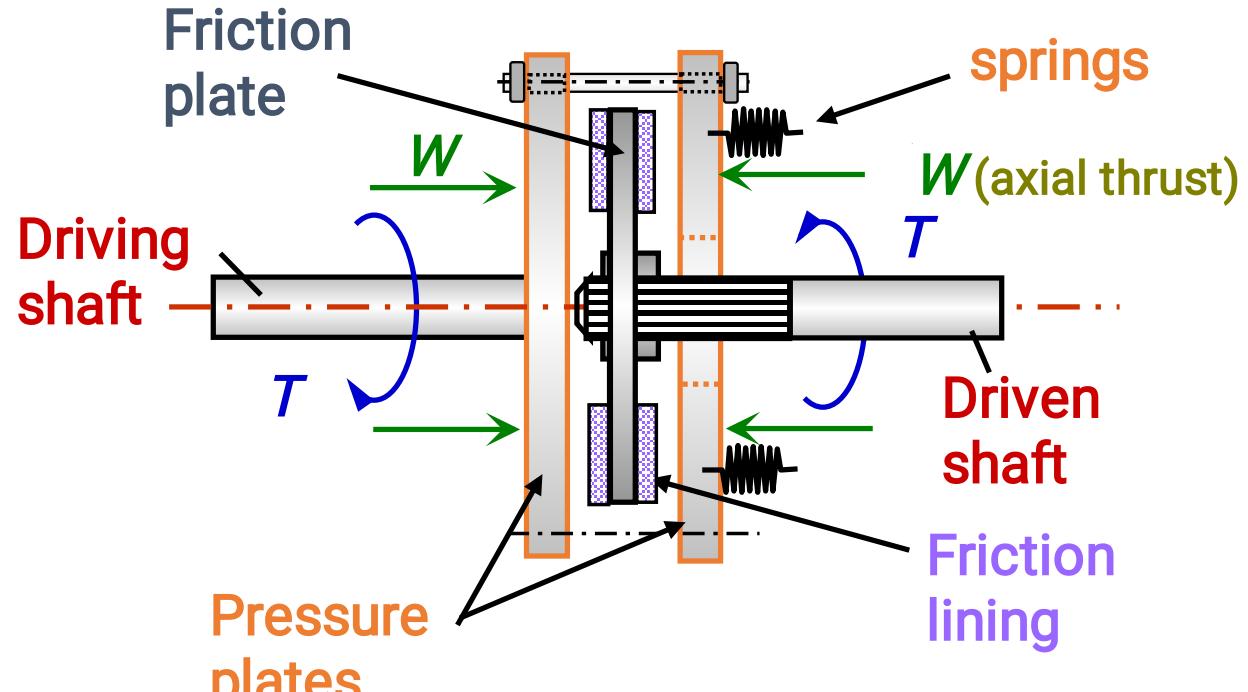


Multi- plate Clutch



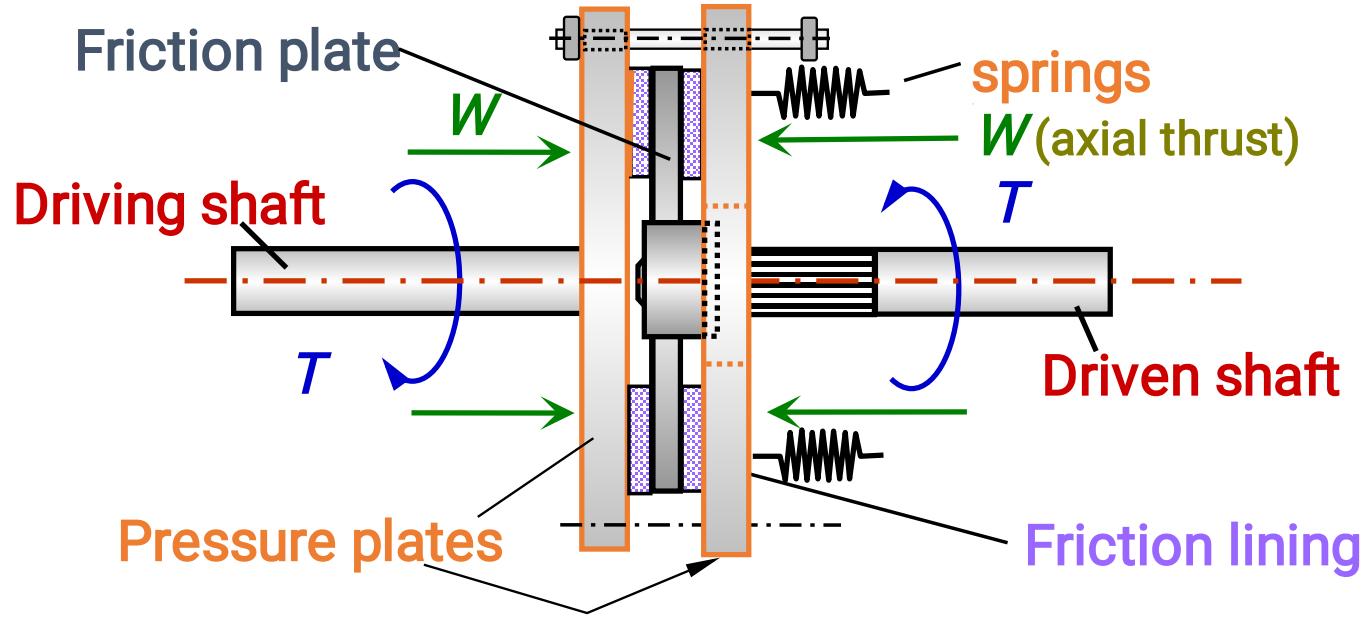
Centrifugal Clutch

Flat-plate friction clutches



Single-plate Friction Clutch (Disengaged position)

Flat-plate friction clutches

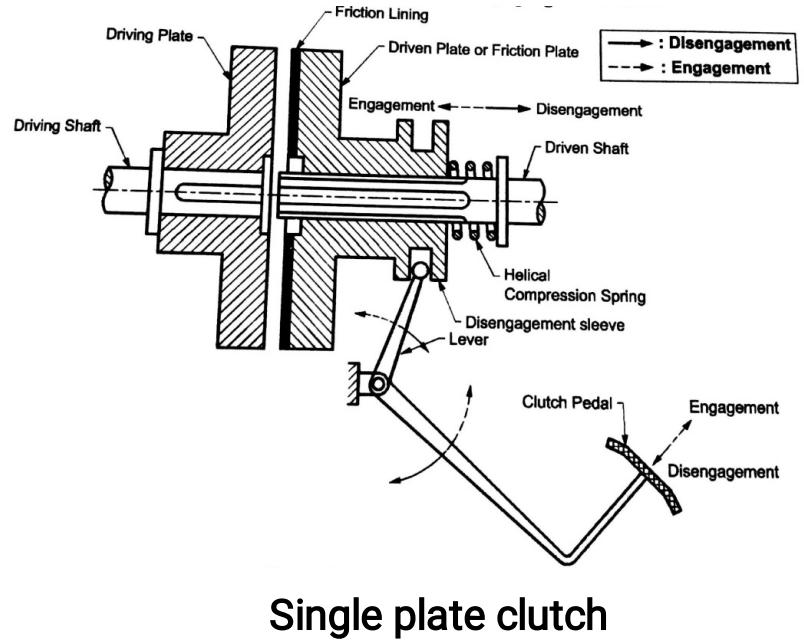


Single-plate Friction Clutch (Engaged position)

Flat-plate friction clutches

Construction:

- A single plate clutch consist of one driving plate and driven plate (Friction plate).
- The driving plate is rigidly keyed to the driving shaft, while driven plate is free to slide axially on the splined driven shaft.
- The friction lining, made of friction material like asbestos is either riveted or pasted to the driven plate.
- The helical compression spring exerts the axial force on the driven plate or friction plate.
- The disengagement sleeve, lever and clutch pedal is used for disengaging the clutch.

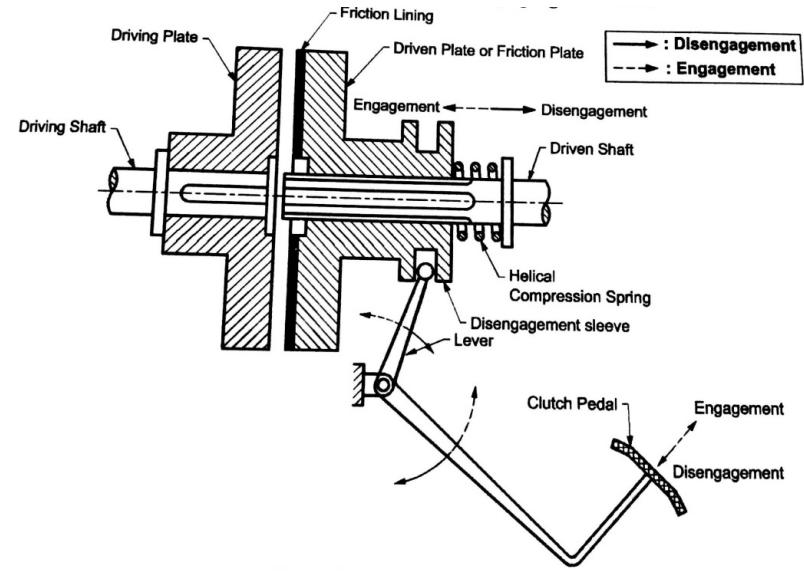


Single plate clutch

Flat-plate friction clutches

Working:

- The helical compression spring presses the driven plate (friction plate) against the driving plate.
- The spring creates an axial force between the driven plate (friction plate) and driving plate.
- The frictional force between the two plates is responsible for transmitting the torque or power.
- In engaged condition, the torque is transmitted from driving shaft through key to driving plate, from driving plate to driven plate due to frictional force.
- Finally from driven plate through the splines to the driven shaft.

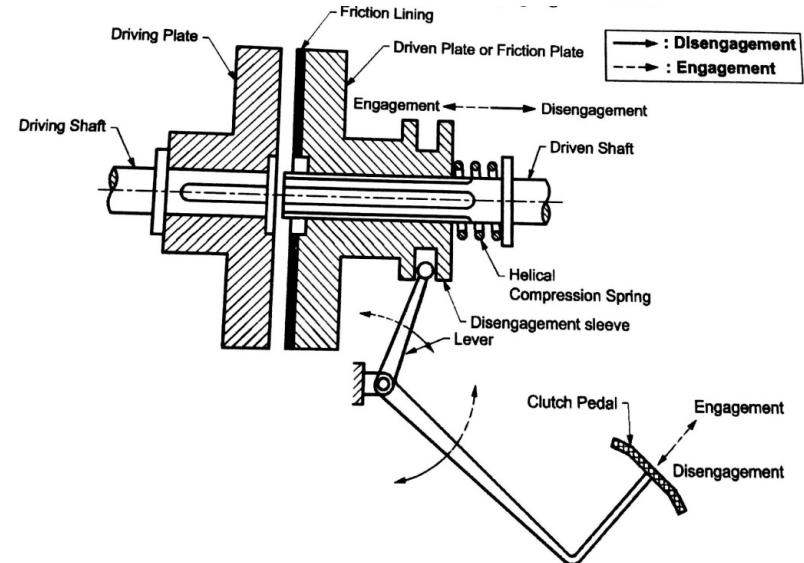


Single plate clutch

Flat-plate friction clutches

Working:

- Due to force exerted by the helical spring, the clutch is normally in engaged position.
- The friction clutch is not positive type and hence can slip under certain conditions.
- In order to disengage the clutch, the clutch pedal is pressed downward. Due to this, the lever displaces the disengagement sleeve to the right.
- Due to sufficient area is available for heat dissipation in single plate clutches, no cooling oil is required.
- The single plate clutch are of **dry** type.



Single plate clutch

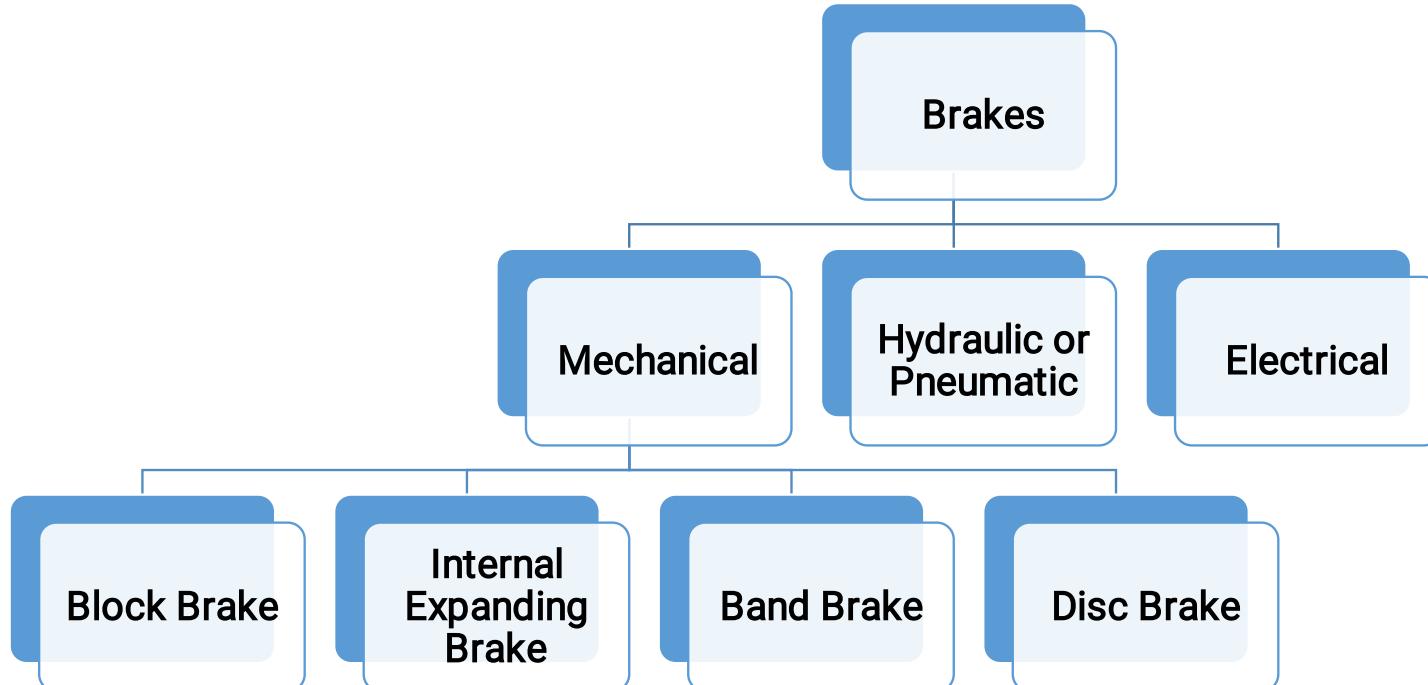
Applications:

Truck, Buses, Cars

BRAKES

- Brake is a mechanical device used to **absorb the energy possessed by a moving system by friction**.
- Its basic purpose is to apply a force against to **slowing or stopping** the motion of a machine or vehicle. It is also used to **hold** the system in **rest**.
- The energy absorbed by the brakes can be **KE or PE or both**. The energy lost by the moving part is usually translated to heat by friction and **dissipated** to the surroundings.

Classification of Brakes



Braking System

❑FUNCTIONS OF THE BRAKING SYSTEM

- To stop the moving vehicle in a shortest possible distance/time.
- To help in controlling the speed of the vehicle during cornering etc.
- To hold the vehicle in stationary position, after it has been brought to stop.

❑REQUIREMENTS OF THE BRAKING SYSTEM :

- The brakes should stop the vehicle within a reasonable distance. The retardation shall be smooth and free from jerk.
- The braking system should not be affected by water, heat, dust etc.
- Pedal effort required by the driver must be optimum so as not to strain the driver.
- The wear and tear of the material of the brake lining should be minimum for longer life
- The brake system capable of dissipating heat generated very quickly.

Disc Brake

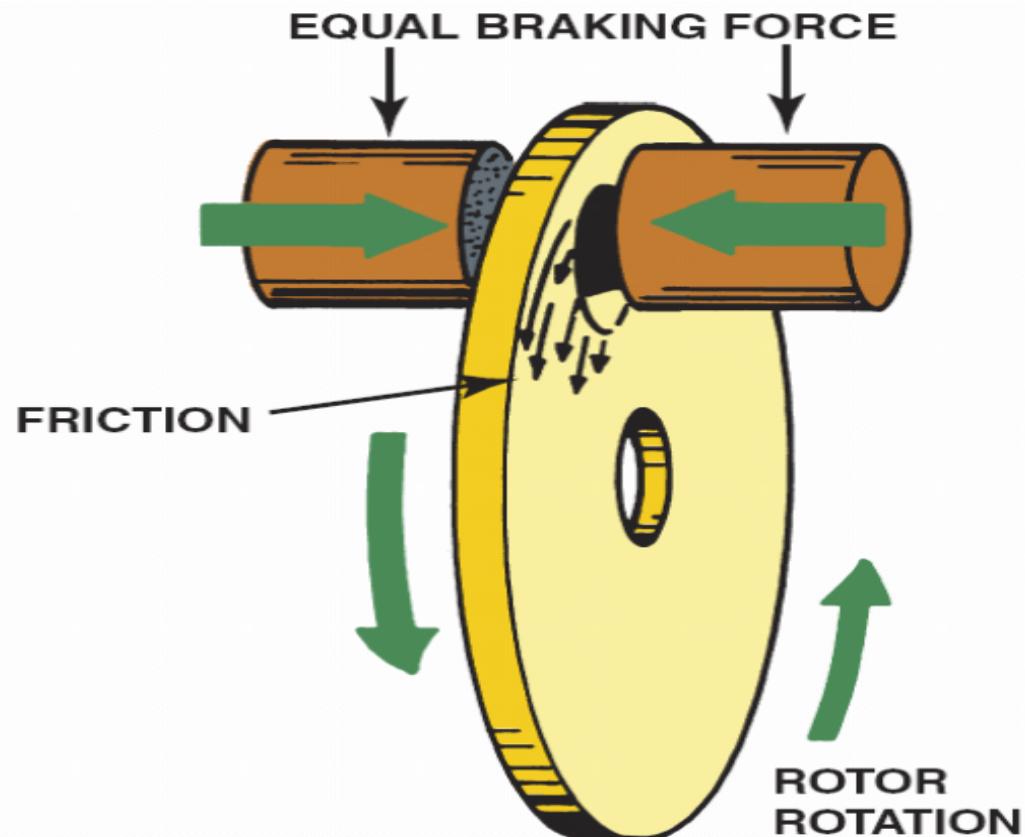
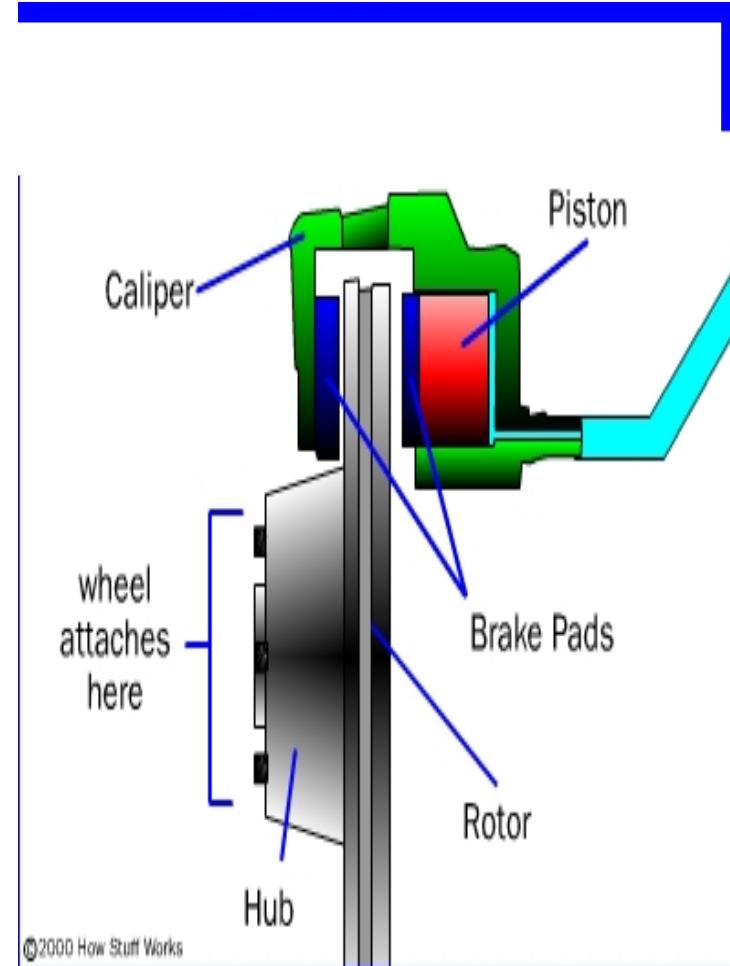


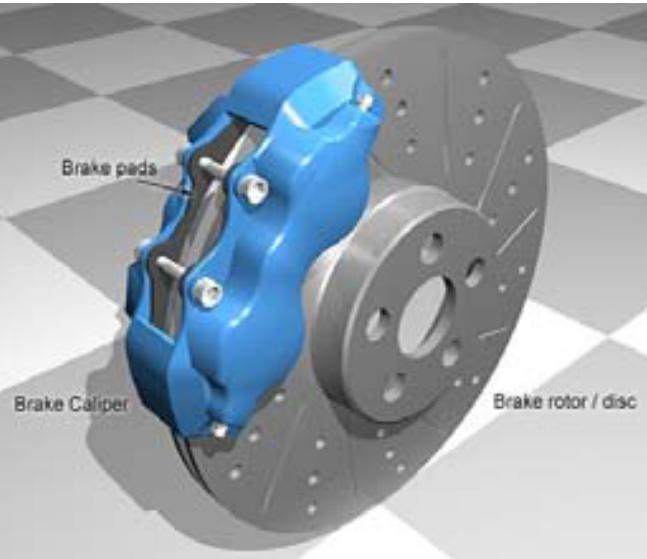
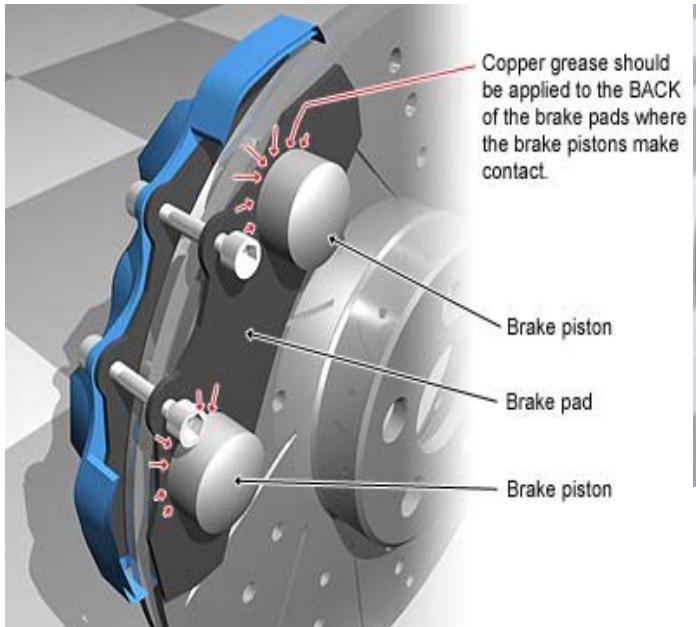
FIGURE . Braking force is applied equally to both sides of the brake rotor.

Disc Brake

Disc Brake Assembly

- Absorbs more heat than a drum brake assembly
- When the brake pedal is pushed, brake fluid from the master cylinder compresses the brake pads against the rotors attached to the vehicle's front wheels.
- The friction between the stationary pads and the revolving rotors causes the rotors and wheel to slow and stop.





Basic Difference between Clutch and Brake

Clutch

Initial Condition : The driving member is rotating and the driven member is at rest.

Final Condition : Both members rotate at the same speed and have no relative motion.

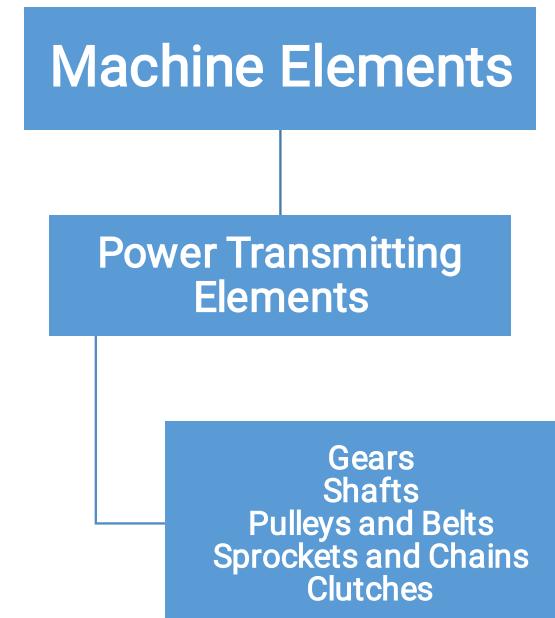
Brake

Initial Condition : one member such as brake drum is rotating and the braking member such as brake shoe is at rest.

Final Condition : Both members are at rest and have no relative motion.

Power Transmitting Elements

- Machine is a device consisting of various elements arranged together so as to perform the prescribed task to satisfy human needs.
- Power transmission is the movement of energy from its place of generation to a location where it is applied to perform useful work. Power is defined formally as units of energy per unit time.



Power transmitting elements: Drives

Drive is a link between *Prime mover* and *Driven machinery*.

Prime movers, power producing devices.

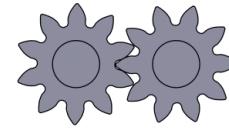
Power Transmitting link

Driven Machinery, Power absorbing devices

- I.C. Engines
- Steam Engines.
- Gas Turbines.
- Steam Turbines.
- Water Turbines.
- Wind Mills.
- Electric Motors.

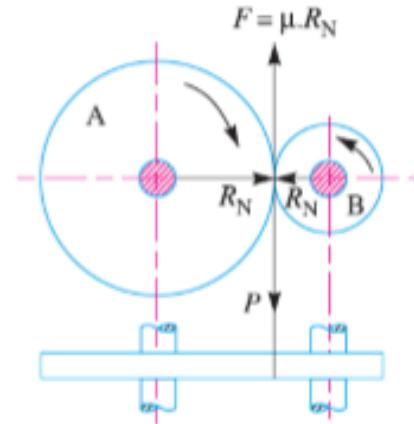
- Chain drive.
- Belt Drive.
- Rope Drive.
- Gear Drive.
- Shaft Drive

- Flour Mill
- Oil Mill.
- Vehicle propulsion.
- Machine Tools.
- Compressors, pumps.
- Material handling Equipments.
- House hold gadgets.

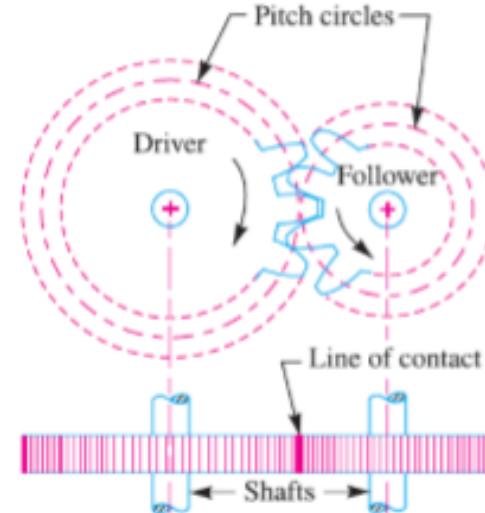


GEAR

- The motion and power transmitted by gears is kinematically equivalent to that transmitted by frictional wheels or discs.



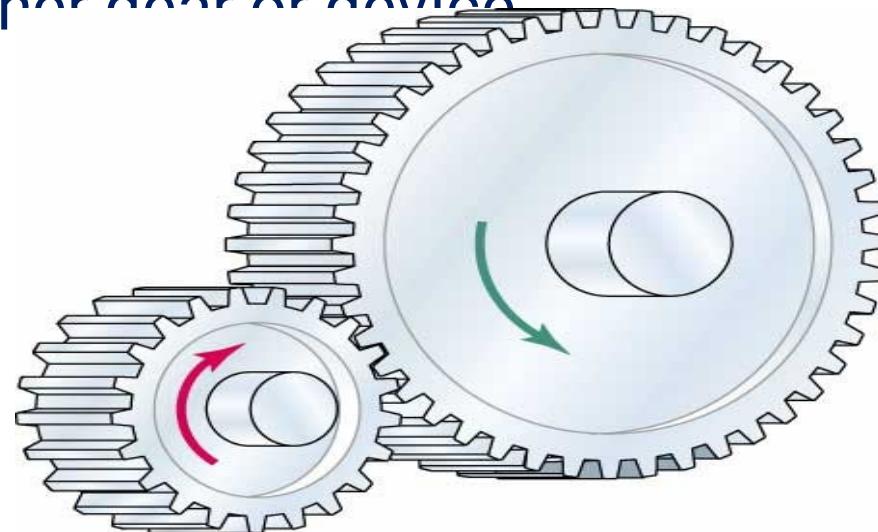
(a) Friction Wheels



(b) Gears

GEAR

- Power transmission is the movement of energy from its place of generation to a location where it is applied to performing useful work
- A gear is a component within a transmission device that transmits rotational force to another gear or device



Academy Artworks

GEAR

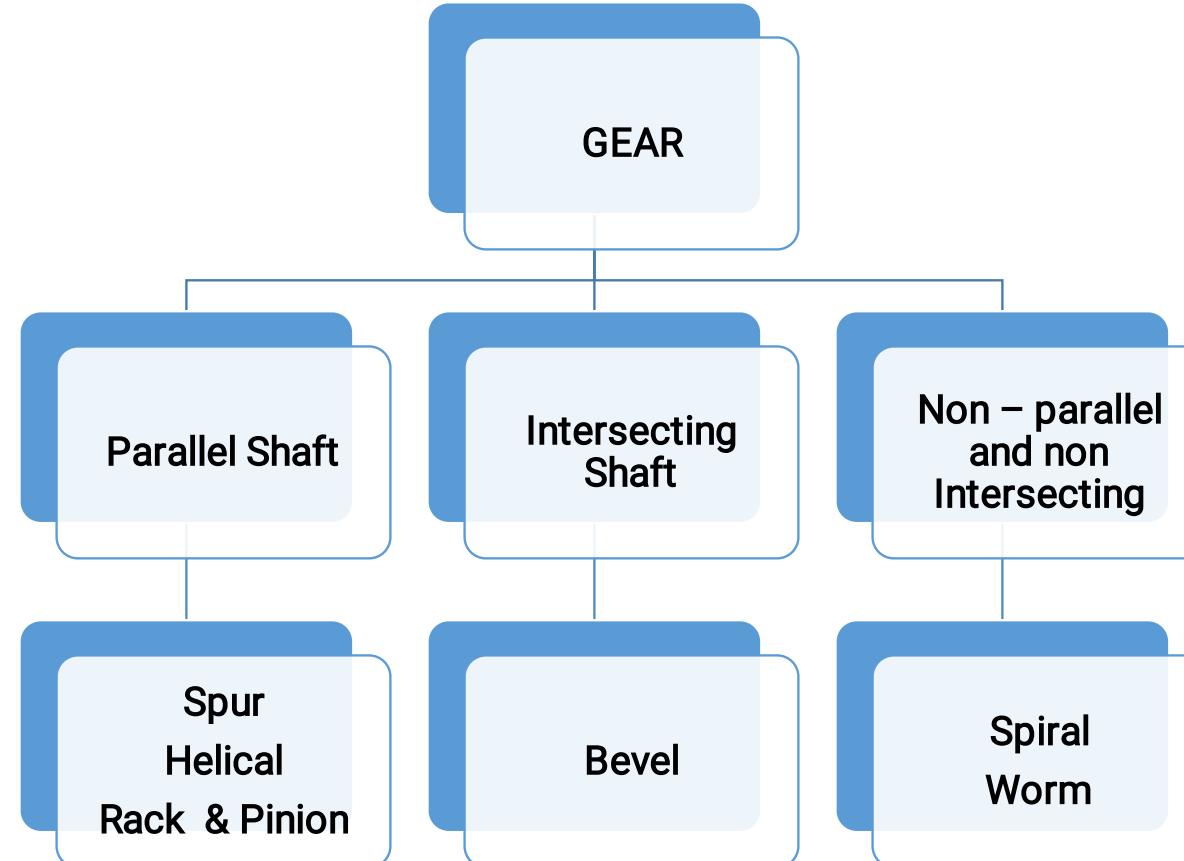
- **Advantages of gear drives:**

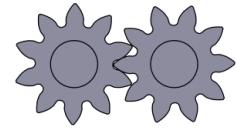
1. It transmits exact velocity ratio.
2. It may be used to transmit large power.
3. It may be used for small center distances of shafts.
4. It has high efficiency.
5. It has compact layout.

- **Disadvantages of gear drives:**

1. Since the manufacture of gears requires special tools and equipment, therefore it is costlier than other drives.
2. The error in cutting teeth may cause vibrations and noise during operation.
3. It requires suitable lubricant and reliable method of applying it, for the proper operation of gear drives.

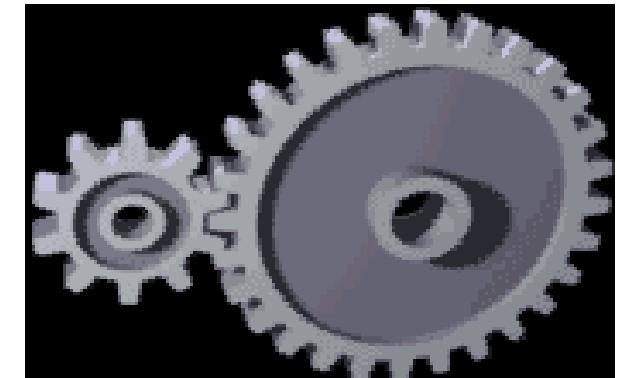
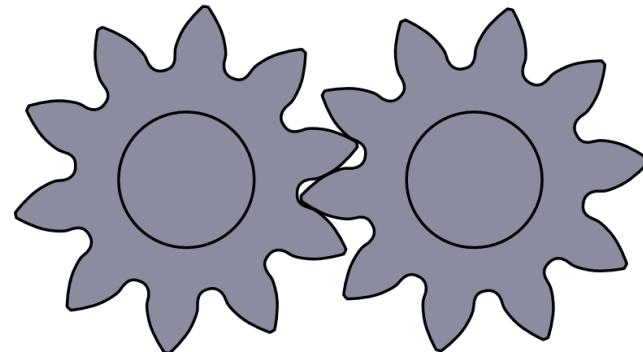
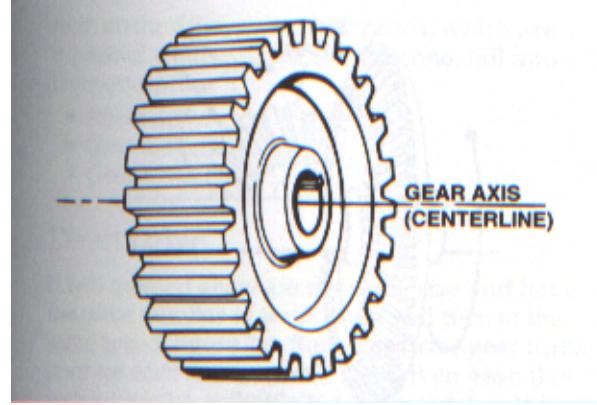
Classification of the Gears based upon position of shaft axes





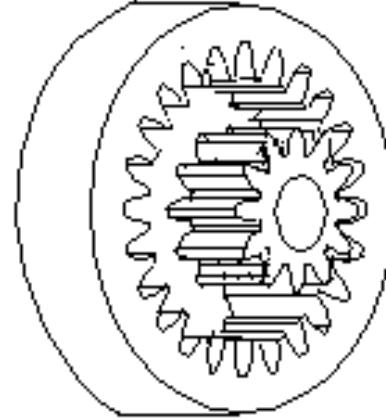
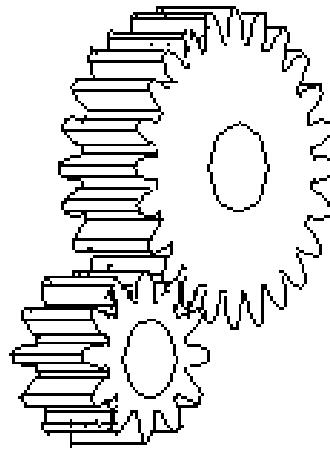
Spur Gears

- Teeth is parallel to axis of rotation
- Transmit power from one shaft to another parallel shaft
- Used in Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer





External and Internal Spur Gear...



Advantages

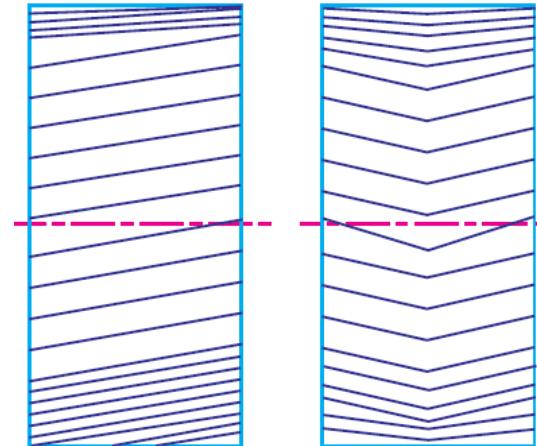
1. It transmits exact velocity ratio.
2. It may be used to transmit large power.
3. It has high efficiency.
4. It has reliable service.
5. It has compact layout.

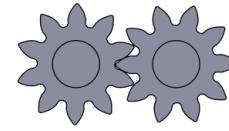
Disadvantages

1. The manufacture of gears require special tools and equipment.
2. The error in cutting teeth may cause vibrations and noise during operation.

Helical Gear

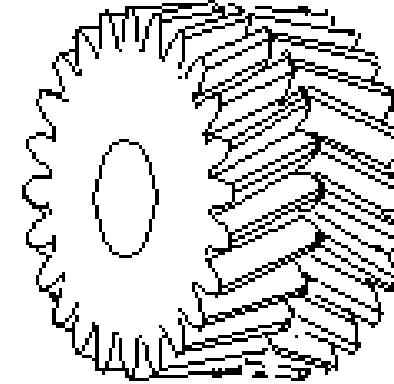
- The teeth on helical gears are cut at an angle to the face of the gear
- This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears
- One interesting thing about helical gears is that if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees





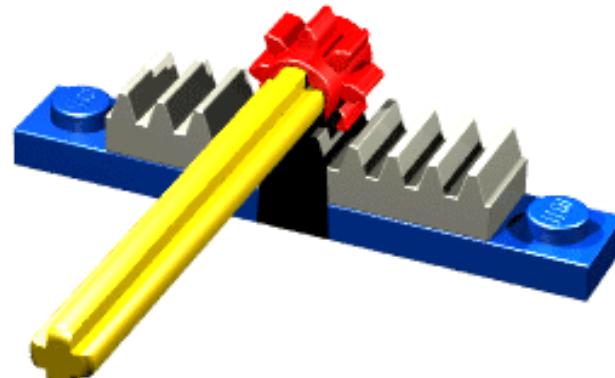
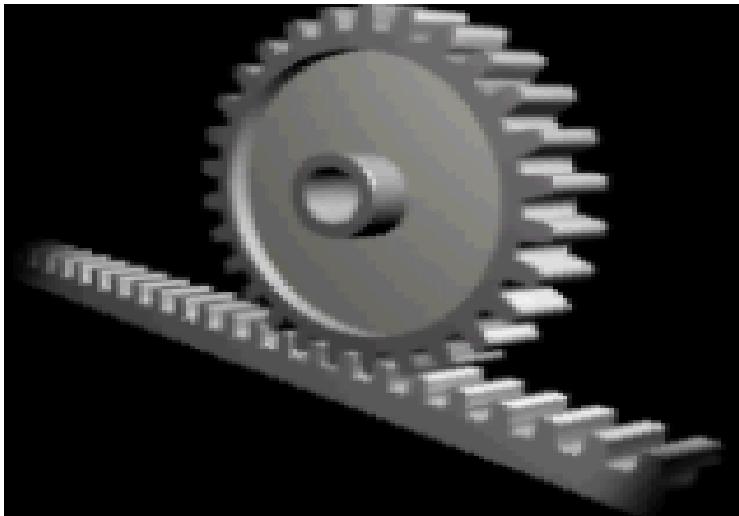
Herringbone gears

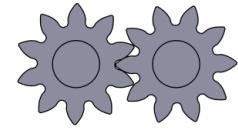
- To avoid axial thrust, two helical gears of opposite hand can be mounted side by side, to cancel resulting thrust forces
- Herringbone gears are mostly used on heavy machinery.



Rack and pinion

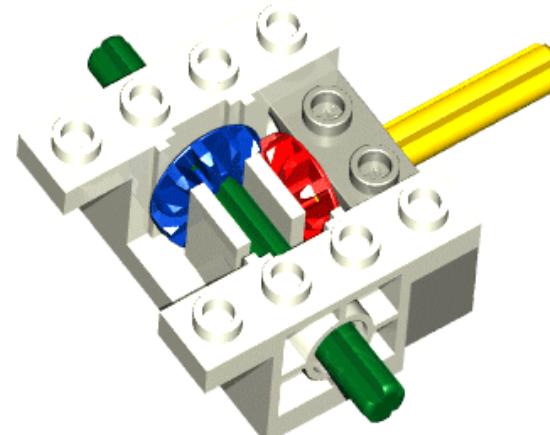
- **Rack and pinion gears** are used to convert rotation (From the pinion) into linear motion (of the rack)
- A perfect example of this is the steering system on many cars

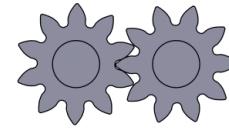




Bevel gears

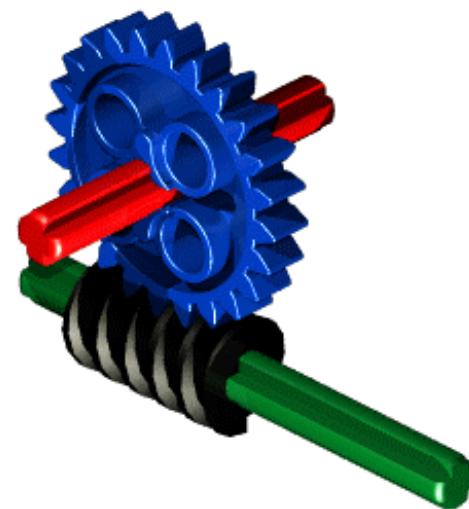
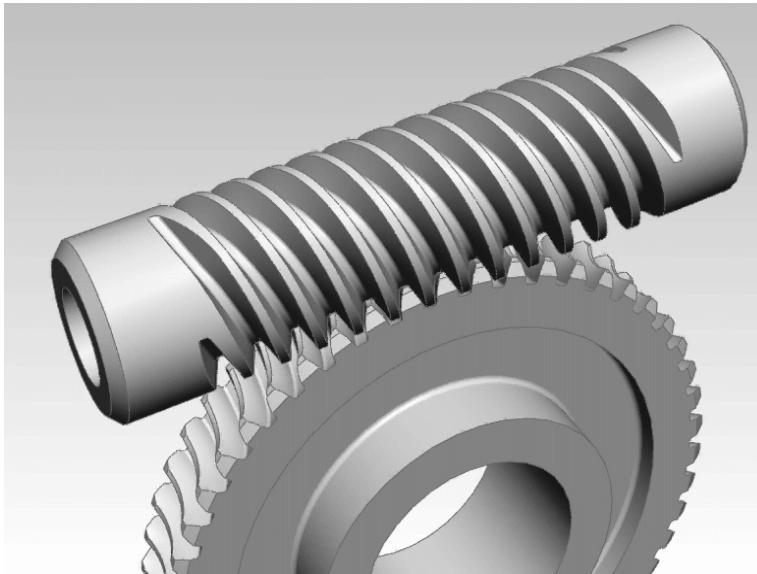
- Bevel gears are useful when the direction of a shaft's rotation needs to be changed.
- They are usually mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well.
- The teeth on bevel gears can be **straight, spiral or hypoid**.
- locomotives, marine applications, automobiles, printing presses, cooling towers, power plants, steel plants, railway track inspection machines, etc.

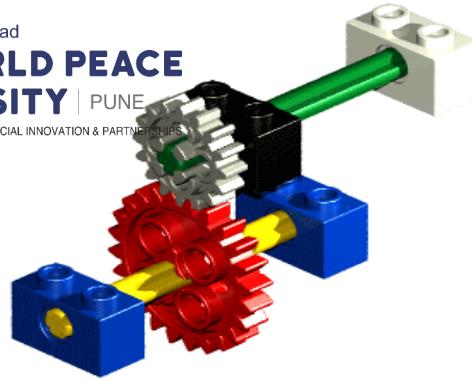




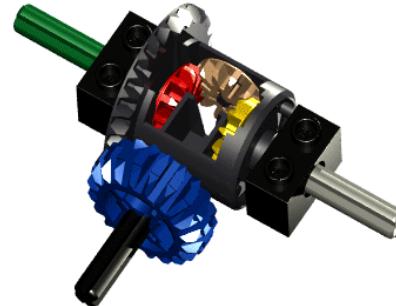
Worm And Worm Gear

- **Worm gears** are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater
- Many worm gears have an interesting property that no other gear set has: the worm can easily turn the gear, but the gear cannot turn the worm
- Worm gears are used widely in material handling and transportation machinery, machine tools, automobiles etc

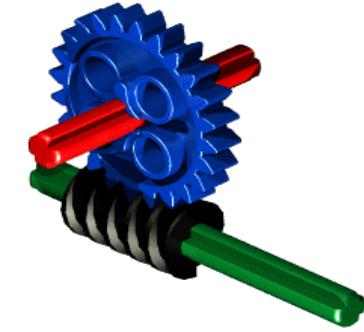




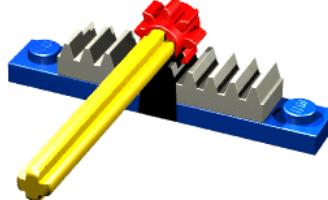
Spur Gears



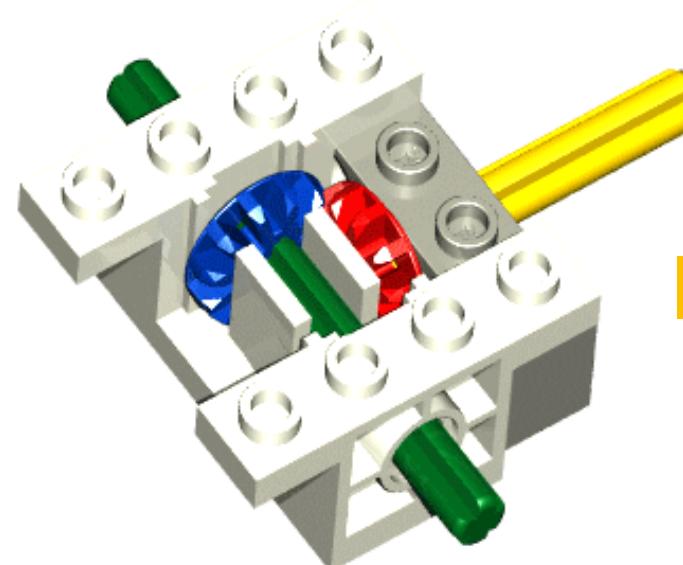
Bevel Gears



Worm and Worm wheel



Rack and Pinion



Bevel Gears

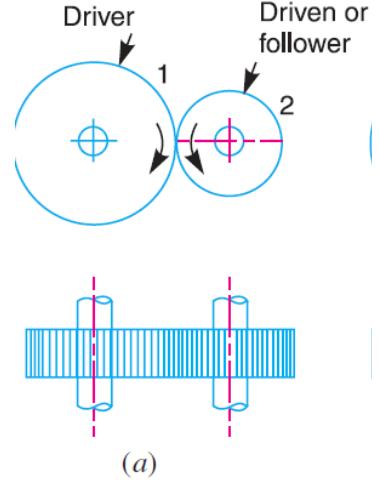


Gear Trains

- Sometimes, two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called ***gear train or train of toothed wheels.***
- The nature of the train used depends upon the velocity ratio required and the relative position of the axes of shafts.
- A gear train may consist of spur, bevel or spiral gears.

Simple Gear Train

- When there is only one gear on each shaft, as shown in Fig., it is known as *simple gear train*.
- The gears are represented by their pitch circles.*
- When the distance between the two shafts is small, the two gears 1 and 2 are made to mesh with each other to transmit motion from one shaft to the other, as shown in Fig. (a).
- Since the gear 1 drives the gear 2, therefore gear 1 is called the driver and the gear 2 is called the driven or follower.*
- It may be noted that the motion of the driven gear is opposite to the motion of driving gear.*



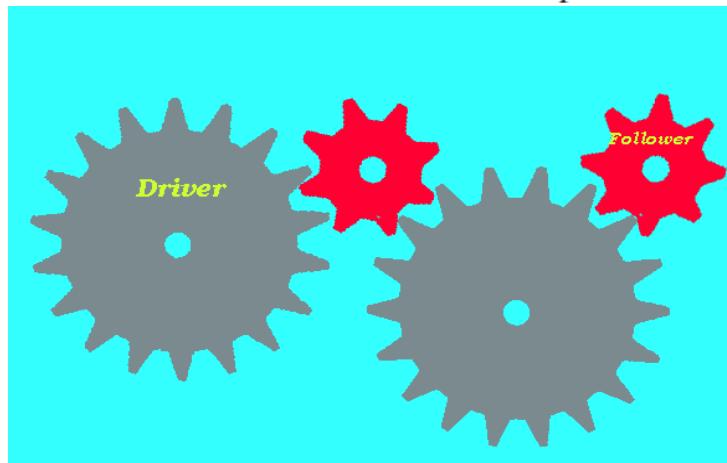
Since the speed ratio (or velocity ratio) of gear train is the ratio of the speed of the driver to the speed of the driven or follower and ratio of speeds of any pair of gears in mesh is the inverse of their number of teeth, therefore

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1} \quad \text{also} \quad \frac{N_1}{N_2} = \frac{d_2}{d_1}$$

It may be noted that ratio of the speed of the driven or follower to the speed of the driver is known as **train value** of the gear train. Mathematically,

$$\text{Train value} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$

From above, we see that the train value is the reciprocal of speed ratio.



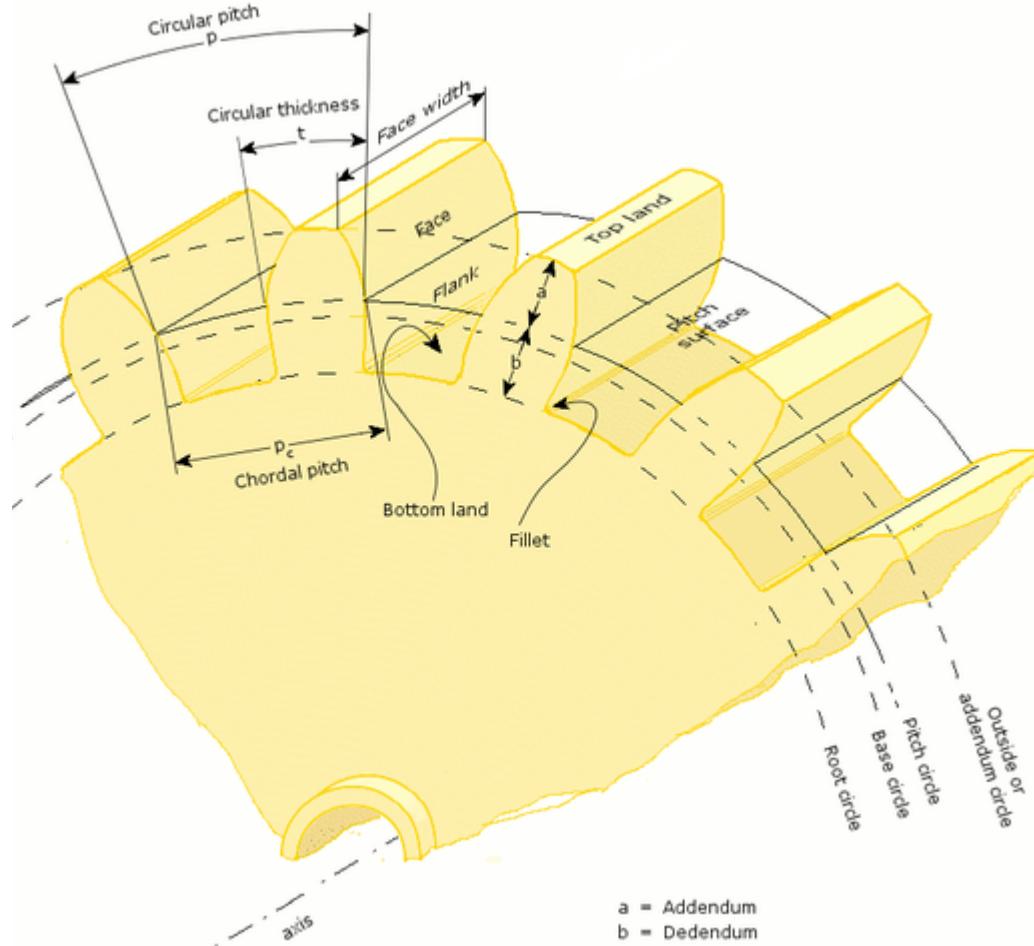
Spur Gear Terminology

1. **Pitch circle.** It is an imaginary circle which by pure rolling action, would give the same motion as the actual gear. Pitch circle diameter Pitch point. Pitch surface.
2. **Pressure angle or angle of obliquity** - angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point. It is usually denoted by ϕ . The standard pressure angles are $14\frac{1}{2}^\circ$ and 20° .
3. **Addendum.** It is the radial distance of a tooth from the pitch circle to the top of the tooth.
4. **Dedendum.** It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.
Addendum circle. **Dedendum circle.**
5. **Circular pitch.** It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth

Material used for - cast iron, steel and bronze.

Spur Gear Terminology

Gear tooth profile





Dr. Vishwanath Karad

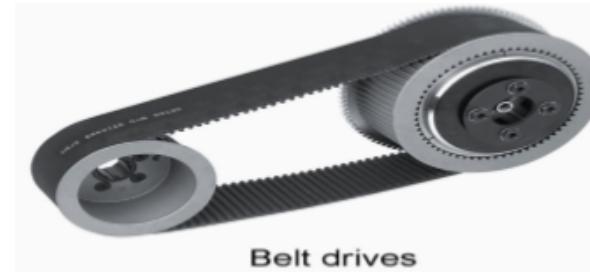
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Numericals

1. A pinion gear with 22 teeth and has a rotational speed of 1200 rpm and drives a gear at 660 rpm. Calculate the number of teeth on gear.
2. A gear drive consists of two gears, A and B, and has a velocity ratio of 1.50. Gear A, the smaller of the two gears, revolves at 126 rpm in the clockwise direction, and has 28 teeth. Calculate the speed and number of teeth on gear B.
3. A pair of gears has been designed with a velocity ratio of 3.20. The pinion has 20 teeth. Find the number of teeth on gear. Also find the train value.

Belts Drives

- A belt is a looped strip of flexible material used to mechanically link two or more rotating shafts. A belt drive offers smooth transmission of power between shafts at a considerable distance.
- Belt drives are used as the source of motion to transfer to efficiently transmit power or to track relative movement.





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Functions of Belts

- Transmit motion between shafts that are located at a considerable distance from each other
- They are not used for exact fixed speed ratio slipping
- They are very flexible
 - distance or
 - the angle between the two shafts.

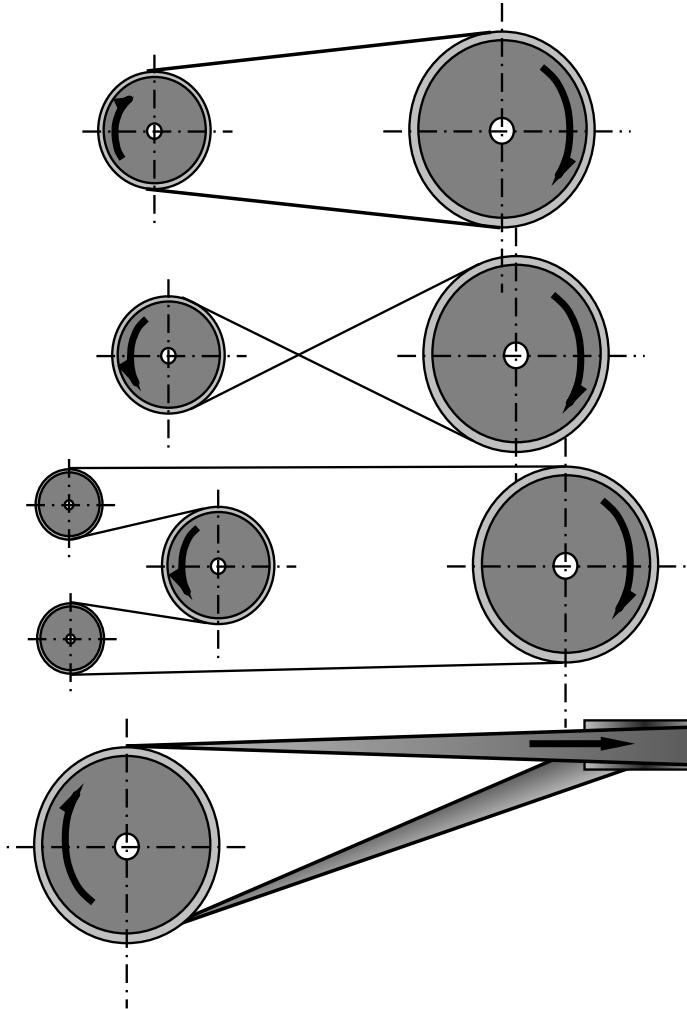
Layout of Flat belt drive :

Non-reversing Open Belt

Reversing Crossed Belt

Reversing Open Belt

Quarter Twist Belt drive



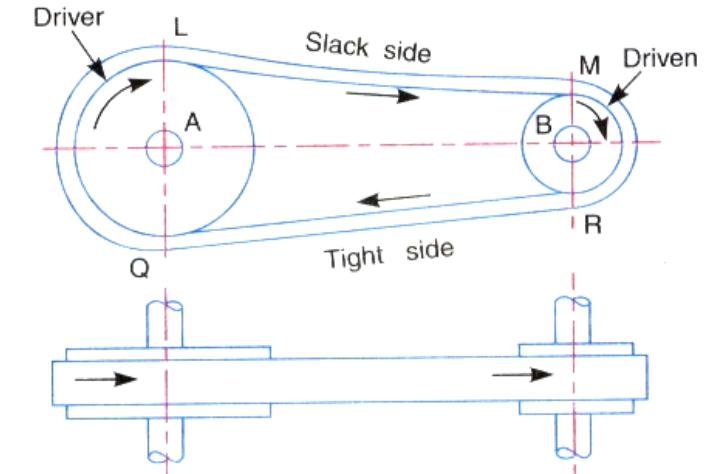
Types of Belt Drive [According to its Arrangement]

- ◆ The power from one pulley to another can be transmitted by different arrangement of the belts.

◆ Open Belt Drive :

It is used, when shafts are arranged parallel and rotating in the same direction. In this case, the driver A pulls the belt from one side (i.e. lower side) and delivers it to the other side (i.e. upper side).

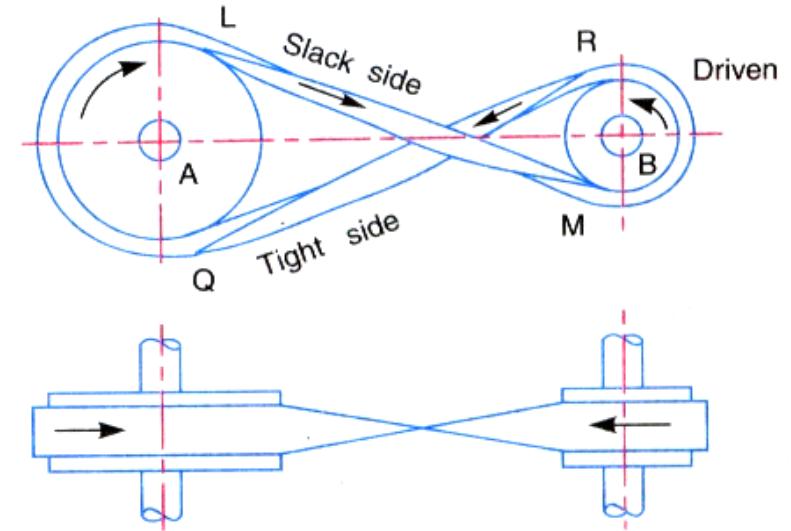
Thus the tension in the lower side belt will be more than that in the upper side belt. Hence lower side belt is known as tight side, whereas the upper belt is known as slack side,



Types of Belt Drive [According to its Arrangement]

◆ Cross Belt Drive :

This belt drive is used when shaft are arranged parallel and rotating in the opposite direction. A crossed belt drive can transmit more power than open belt drive, as the angle of wrap is more. However, the belt has to bend in two different planes and it wears out more.



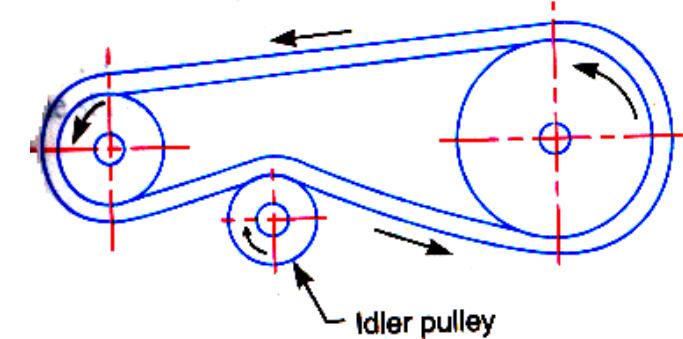
Types of Belt Drive [According to its Arrangement]

◆ Belt Drive with idler Pulleys :

A belt drive with an idler pulley, used with shafts arrangement parallel and when an open belt drive can not be used due to small angle of contact on the smaller pulley. This **type of drive** is **provided to obtain in high velocity ratio** and when **the required belt tension** cannot be obtained by other means.

When it is desired to transmit motion from one shaft to several shafts, all arranged in parallel, a belt drive with many ideal pulleys can be employed.

In conveyer system to avoid slackness of the belt, idler pulleys are used.

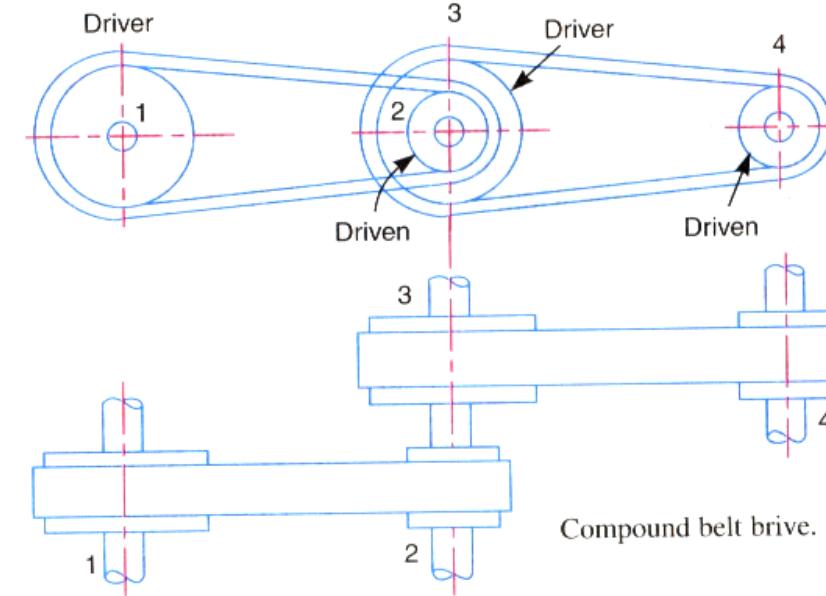


Belt drive with single idler pulley.

Types of Belt Drive [According to its Arrangement]

◆ Compound Belt Drive :

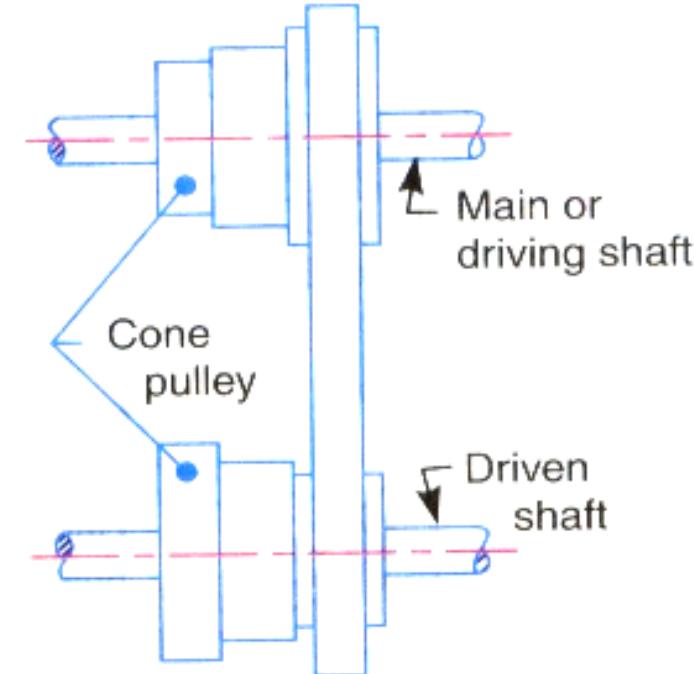
It is used to transmit power from one shaft to another through a number of pulleys.



Types of Belt Drive [According to its Arrangement]

◆ Stepped or Cone Pulley Drive :

A stepped or cone pulley drive, used for changing the speed of the driven shaft while the main or driving shaft runs at constant speed. This is accomplished by shifting the belt from one part of the steps to the another.



Stepped or cone pulley drive.

Advantages and Disadvantages of belt drive.

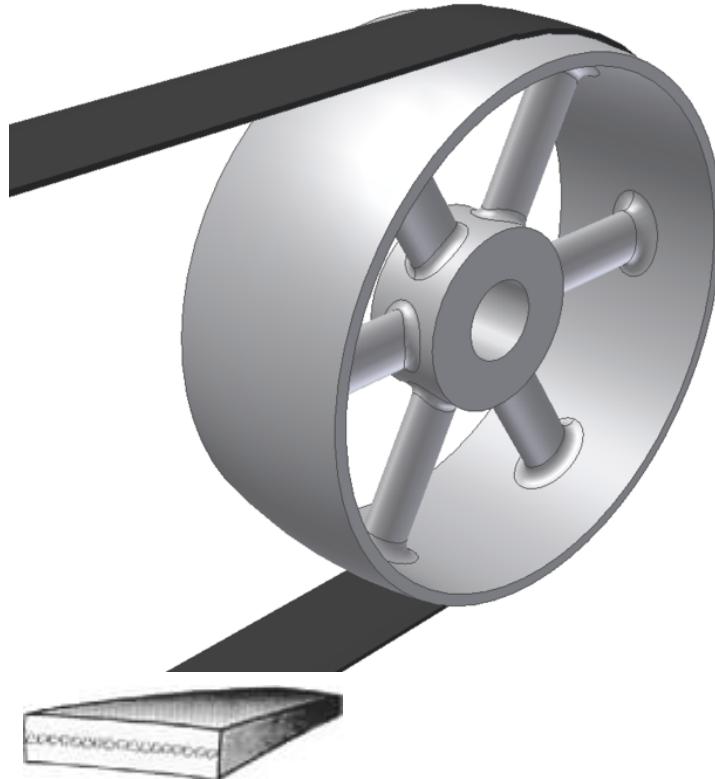
Advantages of belt drives:

- ☒ Belt drives are simple and economical.
- ☒ They don't need parallel shafts.
- ☒ Belts drives are provided with overload and jam protection.
- ☒ Noise and vibration are damped out. Machinery life is increased because load fluctuations are shock-absorbed.
- ☒ They are lubrication-free. They require less maintenance cost.
- ☒ Belt drives are highly efficient in use (up to 98%, usually 95%).
- ☒ They are very economical when the distance between shafts is very large.

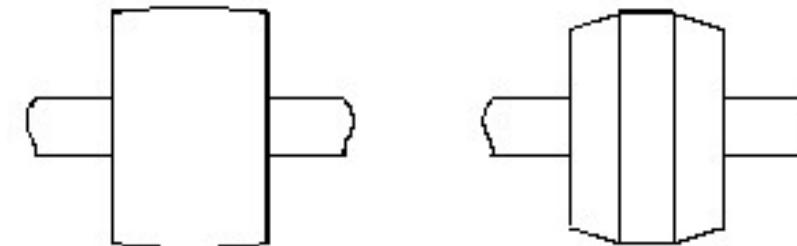
Disadvantages of belt drives:

- ☒ In Belt drives, angular velocity ratio is not necessarily constant or equal to the ratio of pulley diameters, because of slipping and stretching.
- ☒ Heat buildup occurs. Speed is limited to usually 35 meters per second. Power transmission is limited to 370 kilowatts.
- ☒ Operating temperatures are usually restricted to -35 to 85°C.
- ☒ Some adjustment of center distance or use of an idler pulley is necessary for wearing and stretching of belt drive compensation.

Flat Belt Drive



Cross section



- Large distance between shafts
- cheaper compared to 'V' belts.
- The slip is more.
- Cross belts are used to reverse direction of rotation.
- Flat belts provide only small speed ratios.
- Main problem for flat belts is the belt to go off the pulley.
- Crowned pulleys are used to prevent off tracking

Flat Belt Drive

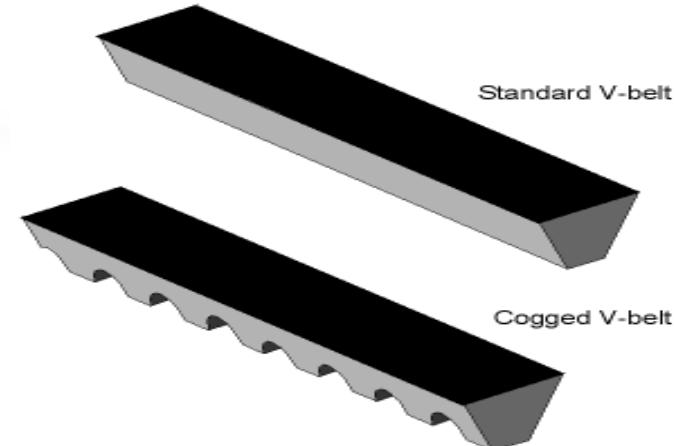
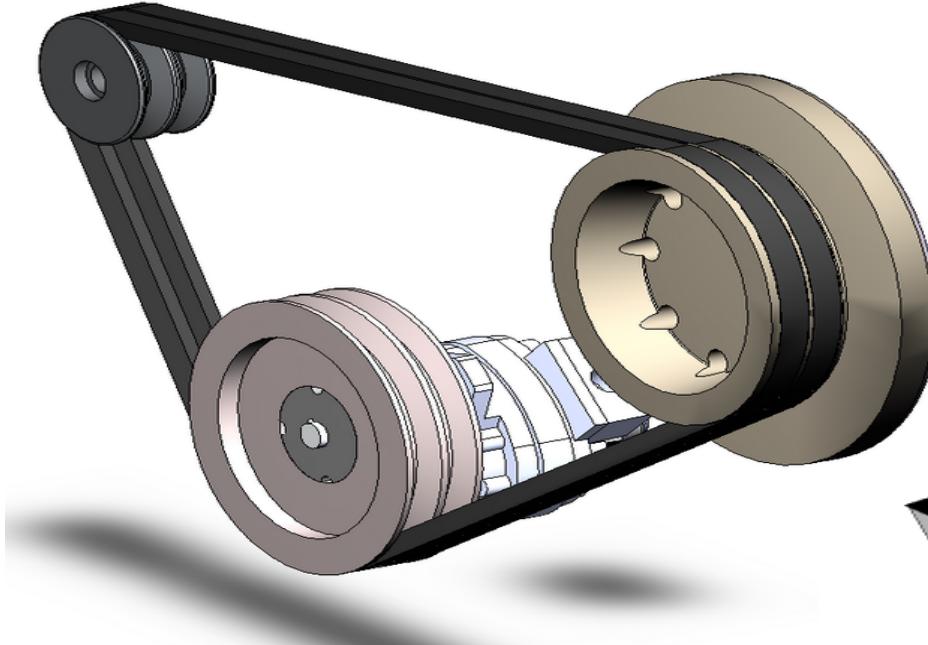
Flat belts:

- +Simple construction
- +Low cost
- +High flexibility
- +High tolerance to overload
- +Good resistance in abrasive environments

- Noisy
- Sliding is possible
- Low efficiency at low speeds
- Tensioning is required



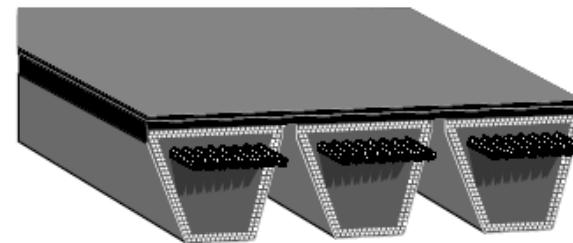
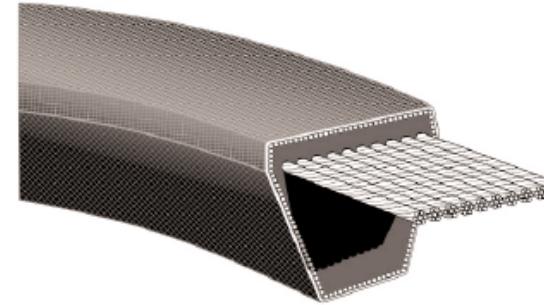
V Belt Drive



- Trapezoidal cross section
- Better grip by wedge action .
- The slip is very small

V Belt Drive

- ➔ The "V" shape of the belt tracks in a mating groove in the pulley (or sheave), with the result that the belt cannot slip off.
- ➔ The belt also tends to wedge into the groove as the load increases – the greater the load, the greater the wedging action – improving torque transmission and making the vee belt an effective solution.
- ➔ For high-power requirements, two or more vee belts can be joined side-by-side in an arrangement called a multi-V, running on matching multi-groove sheaves.
- ➔ Good resistance to overloads



SYNCHRONOUS BELTS (TIMING BELTS)



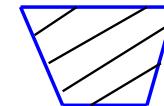
Synchronous belts are toothed belts where timing is guaranteed by the presence of the teeth. Load is transferred both by the teeth and the belt core.

Flat and V Belts comparison

Flat Belts

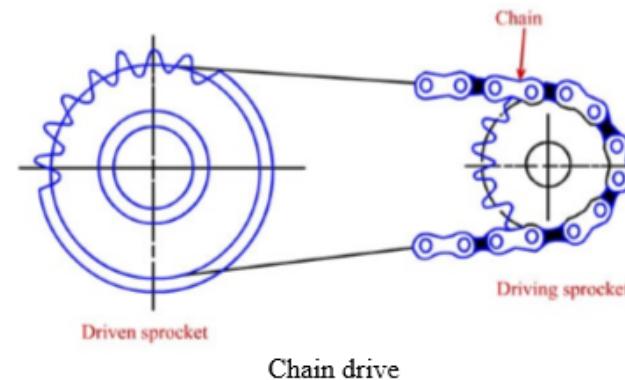
V- Belts

Large centre distances.	Smaller centre distances
More flexibility in centre to centre distance adjustments.	Less flexibility in centre distances
Slip is more.	Slip is very less.
Less costly.	Cost is more.
Cross section is rectangular.	Cross section Trapezoidal.
Lower efficiency.	Higher efficiency.
Pulley sizes are more	Pulleys are smaller
Drives are bulky	Drives are compact
Wide range of materials, leather, cotton, fabric, balata	Only rubber and fabric materials are used.



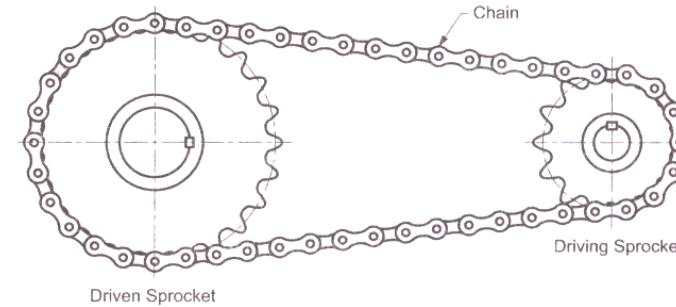
Chain Drive

- A chain drive consists of an endless chain wrapped around sprocket wheels.
- The chain has a number of links connected by pins.
- The sprockets have teeth of special profile.
- Chains are used for power transmission and as conveyors.
- The chain drives have some features of both belt (flexibility of location of driver and driven) and gear drives (ruggedness).
- Chain drives are recommended for velocity ratio below 10:1, chain velocity 1550 m/min and power transmission up to 100 kW.

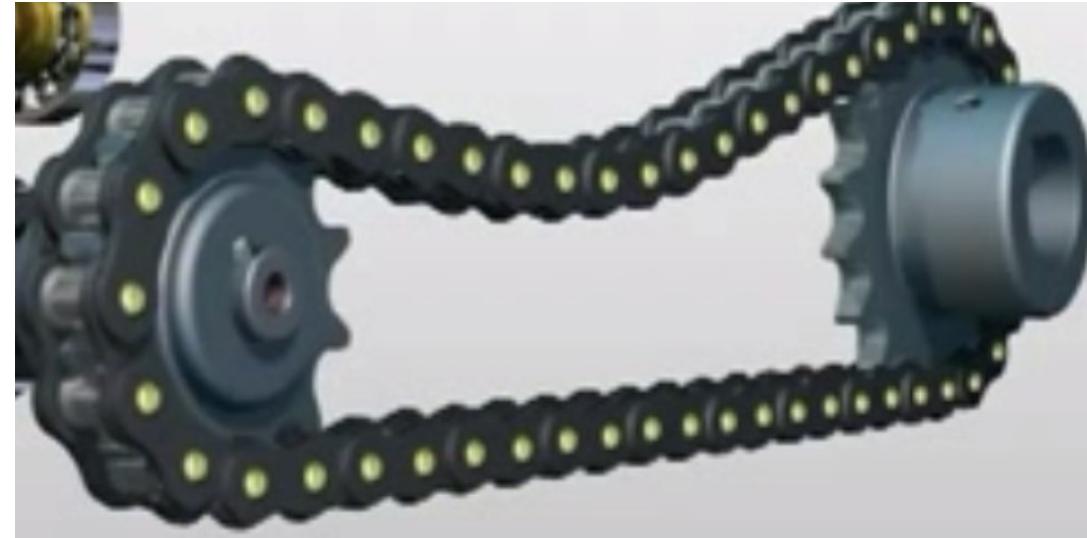
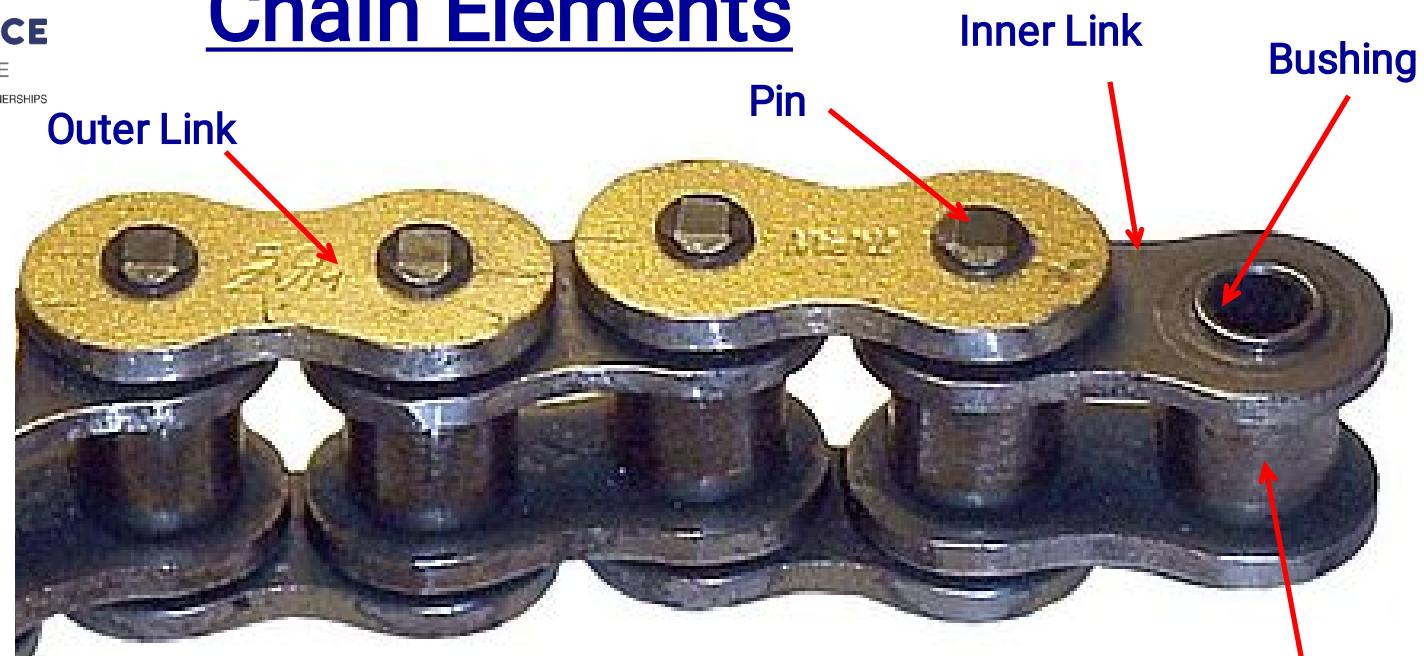


Chain Drive

- ◆ In order to **avoid slipping**, **steel chains are used**,
- ◆ The chains are **made up of rigid links** which are **hinged together** in order to avoid the necessary flexibility for warping around the driving and driven wheels.
- ◆ The wheels have **projecting teeth** and fit into the **corresponding recesses**, in the **links of The chain**.
- ◆ The **wheels and the chain** are constrained to move together without slipping and ensures perfect velocity ratio.
- ◆ The **toothed wheel** are known as **sprocket wheels** or simply **sprockets**.
- ◆ These wheels **resemble to spur gears**



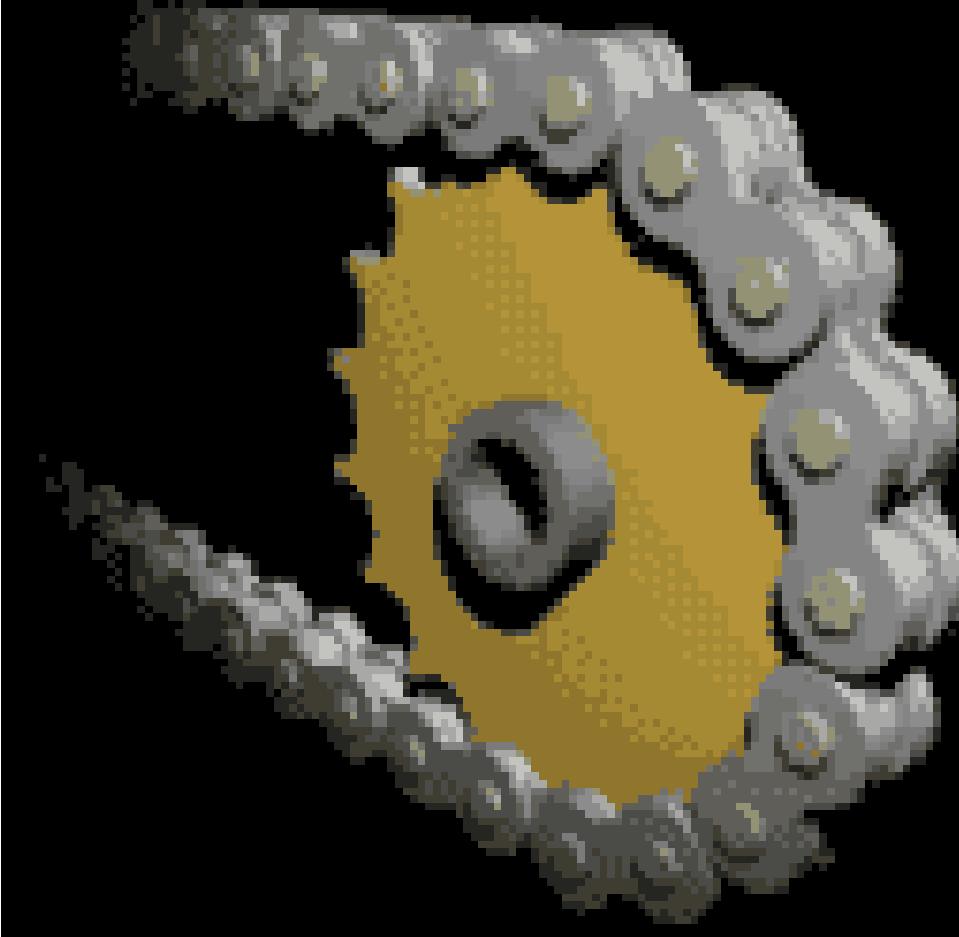
Chain Elements



Chain Elements

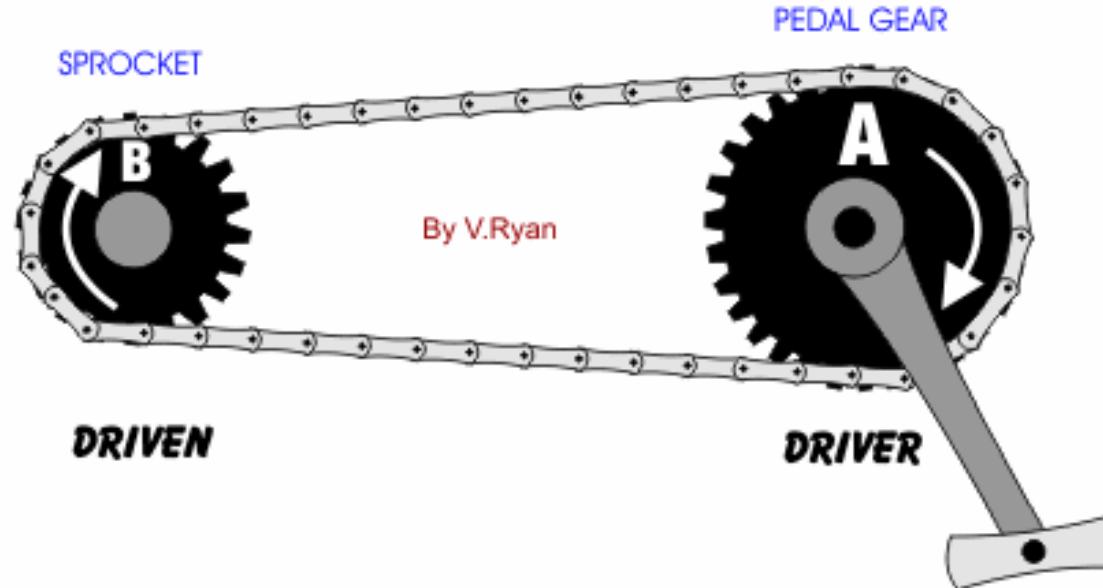
- Inner Link: It has bigger hole diameter
 - Outer Link: It has smaller hole diameter
 - Bush : It is a hollow cylinder and it press fits inside two inner links
 - Pin: It passes through the bush, two outer links are press fitted on it
 - Roller: It is a hollow cylinder which can rotate freely over bush
-
- Bush and pin joint is responsible for **flexibility** of the chain.
 - Roller is added **to reduce the wear of the sprocket**

Chain Drive



- Positive drives
- Large torque transmitting
- No slip results into constant velocity ratio
- Higher efficiency
- Speed ratios up to 10:1 are possible.
- They are costly, and noisy.
- Precise alignment is required.

Chain Drive





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॥ विश्वानात्मकं पूर्वा ॥

Belts vs. Chains

Belts

Type of Drive

Friction Drive

Use When:

High Speed, Low Torque

Speed:

$2500 < V_t < 7000$ ft./min.

Disadvantages:

Must design with standard lengths, wear, creep, corrosive environment, slip, temp., when must have tension need idler
Quiet, flexible, cost

Advantages:

Chains

Positive Drive

High Torque, Low Speed

$V < 1500$ ft./min.

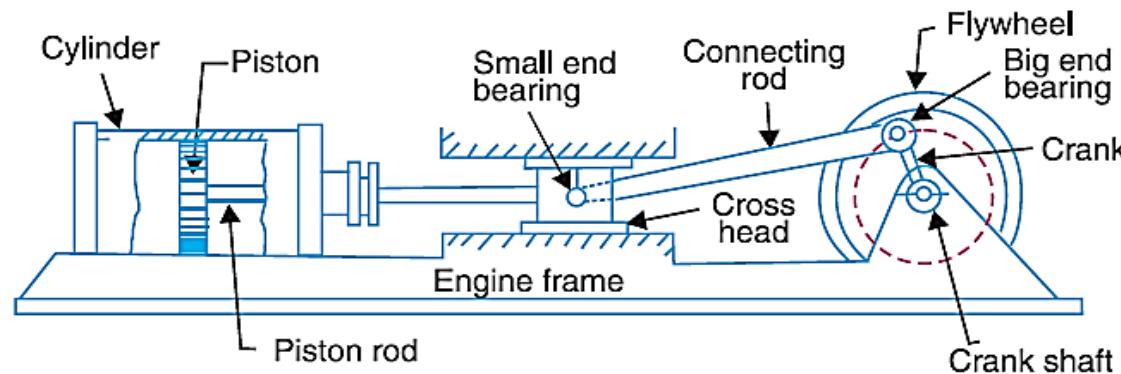
Must be lubricated, wear, noise, weight, vibration

Strength, length flexibility

Mechanisms

Kinematic Link or Element

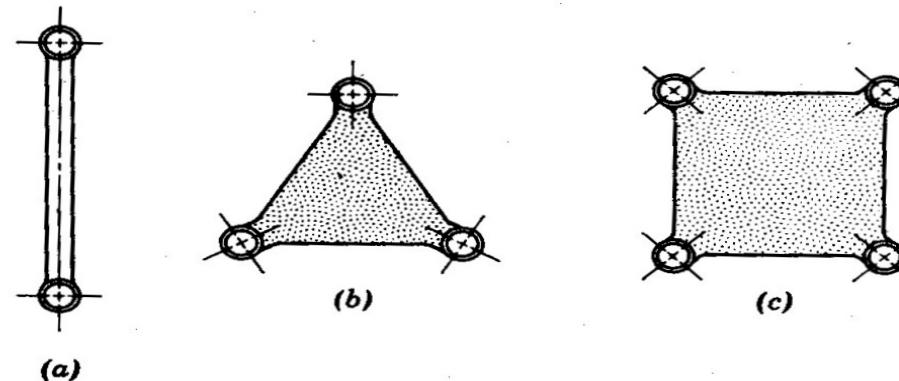
- Each part of a machine, which moves relative to some other part, is known as a *kinematic link (or simply link) or element*.
- *A link may consist of several parts, which are rigidly fastened together, so that they do not move relative to one another.*
- For example, in a reciprocating steam engine, as shown in, piston, piston rod and crosshead constitute one link ; connecting rod with big and small end bearings constitute a second link ; crank, crank shaft and flywheel a third link and the cylinder, engine frame and main bearings a fourth link.



Link or element:

It is the name given to any body which has motion relative to another. All materials have some elasticity. A rigid link is one, whose deformations are so small that they can be neglected in determining the motion parameters of the link.

- **Binary link:** Link which is connected to other links at two points. (Fig.a)
- **Ternary link:** Link which is connected to other links at three points. (Fig.b)
- **Quaternary link:** Link which is connected to other links at four points. (Fig. c)



Kinematic Pair

The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (*i.e. in a definite direction*), the pair is known as *kinematic pair*.

Kinematic Chain

When the number of kinematic links are joined such that first link is in contact with last link, then it is called as kinematic chain.

Types of Constrained Motions

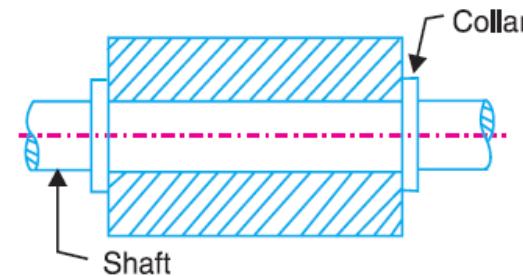
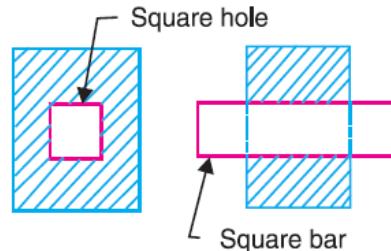
Following are the three types of constrained motions :

1. *Completely constrained motion.*

When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.

For example, the piston and cylinder (in a steam engine) form a pair and the motion of the piston is limited to a definite direction (*i.e. it will only reciprocate relative to the cylinder*) irrespective of the direction of motion of the crank.

The motion of a square bar in a square hole, as shown in Fig. 2, and the motion of a shaft with collars at each end in a circular hole, as shown in Fig. 3, are also examples of completely constrained motion.

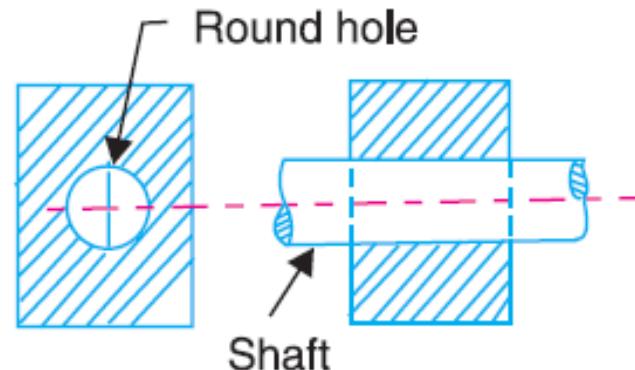


2. Incompletely constrained motion.

When the motion between a pair can take place in more than one direction, then the motion is called an incompletely constrained motion.

The change in the direction of impressed force may alter the direction of relative motion between the pair.

A circular bar or shaft in a circular hole, as shown in Fig. 4, is an example of an incompletely constrained motion as it may either rotate or slide in a hole. These both motions have no relationship with the other.



Classification of Kinematic Pairs

1. According to the type of relative motion between the elements.

- a) Sliding pair. b) Turning Pair
- c) Spherical pair d) Rolling pair
- e) Screw pair

2. According to the type of contact between the elements.

- a) Lower pair. b) Higher Pair

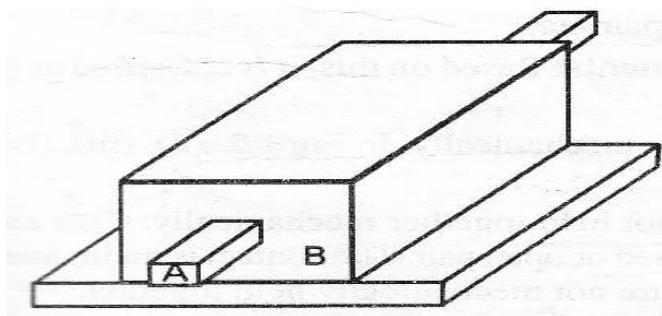
Classification of Kinematic Pairs

1. According to the type of relative motion between the element.

(a) Sliding pair.

When the two elements of a pair are connected in such a way that one can only slide relative to the other, the pair is known as a sliding pair.

The piston and cylinder, cross-head and guides of a reciprocating steam engine, ram and its guides in shaper, tail stock on the lathe bed etc. are the examples of a sliding pair. A little consideration will show, that a sliding pair has a completely constrained motion.

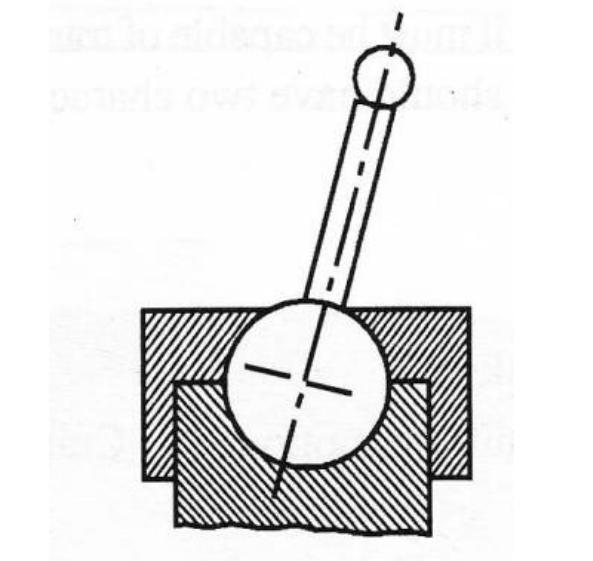
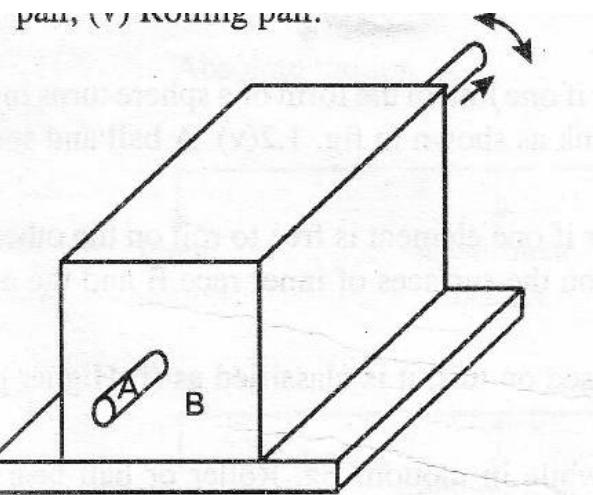


(b) Turning pair.

When the two elements of a pair are connected in such a way that one can only turn or revolve about a fixed axis of another link, the pair is known as turning pair.

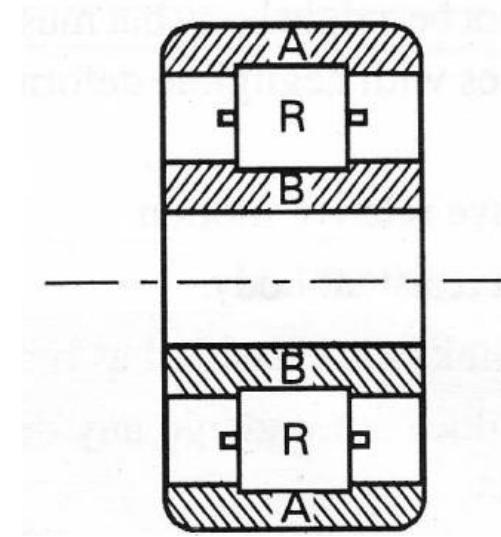
(c) Spherical pair.

When the two elements of a pair are connected in such a way that one element (with spherical shape) turns or swivels about the other fixed element, the pair formed is called a spherical pair. The ball and socket joint, attachment of a car mirror, pen stand etc., are the examples of a spherical pair.



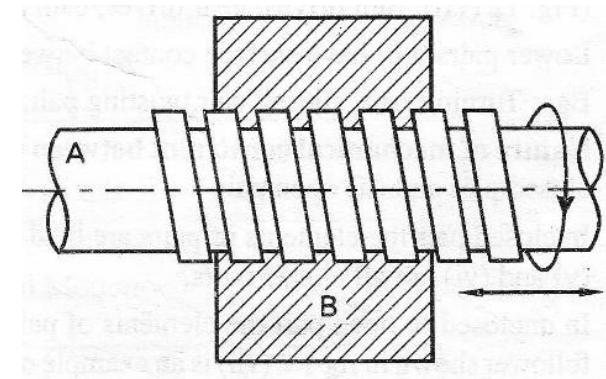
(d) Rolling pair.

When the two elements of a pair are connected in such a way that one rolls over another fixed link, the pair is known as rolling pair. Ball and roller bearings are examples of rolling pair.



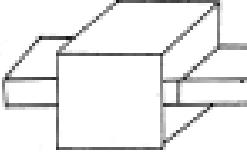
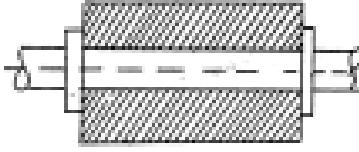
(e) Screw pair.

When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads, the pair is known as screw pair. The lead screw of a lathe with nut, and bolt with a nut are examples of a screw pair.



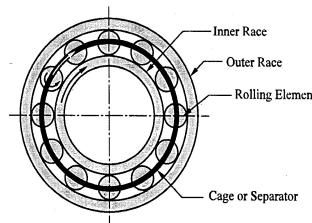
2. According to the type of contact between the elements.

(a) Lower pair.

When the two elements of a pair have a surface contact when relative motion takes place and the surface of one element slides over the surface of the other, the pair formed is known as lower pair. It will be seen that sliding pairs   *are lower pairs.*

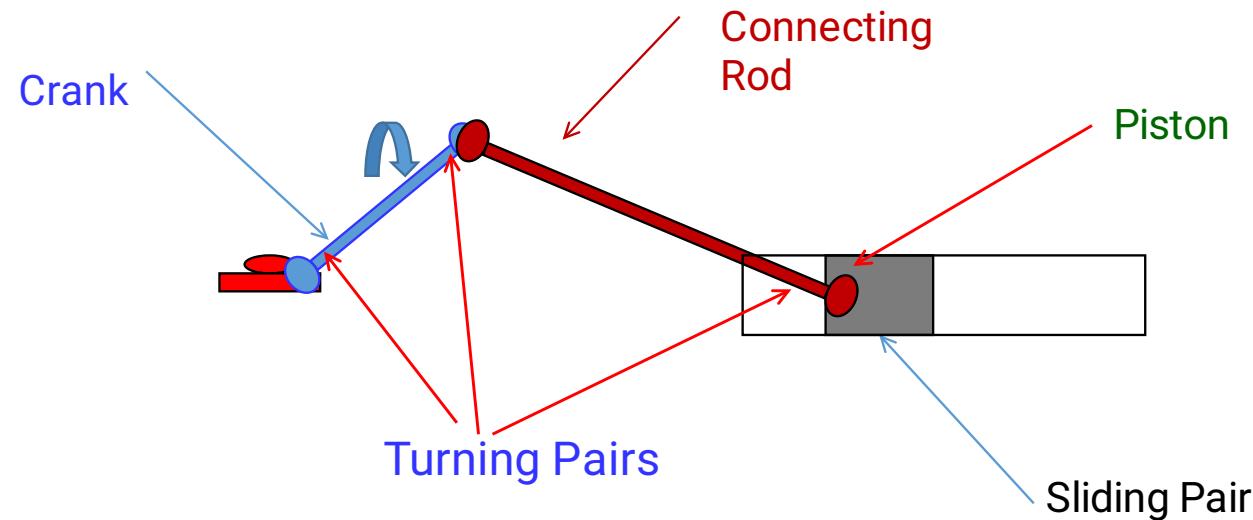
(b) Higher pair.

When the two elements of a pair have a line or point contact when relative motion takes place and the motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair. A pair of friction discs, toothed gearing, belt and rope drives, ball and roller bearings and cam and follower are the examples of higher pairs.



Mechanism

- When one of the links of a kinematic chain is fixed, the chain is known as *mechanism*.
- It may be used for transmitting or transforming motion
- A mechanism with four links is known as *simple mechanism*, and the mechanism with more than four links is known as *compound mechanism*.
- When a mechanism is required to transmit power or to do some particular type of work, it then becomes a *machine*.



Inversions of mechanism:

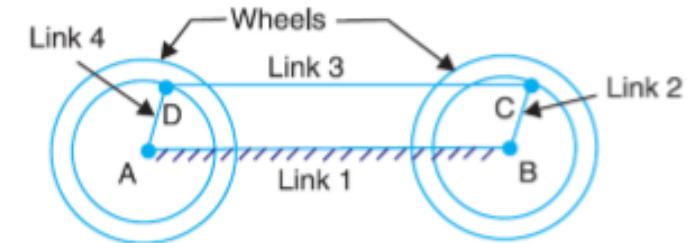
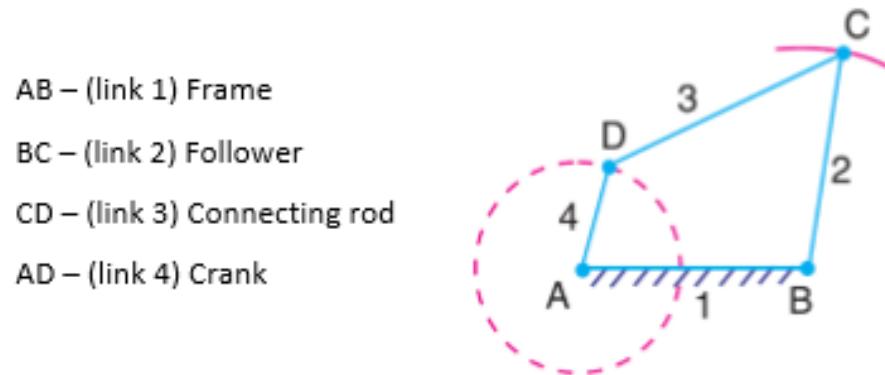
- A mechanism is one in which one of the links of a kinematic chain is fixed.
- Different mechanisms can be obtained by fixing different links of the same kinematic chain.
- These are called as inversions of the mechanism.

Types of Kinematic Chains

- The most important kinematic chains are those which consist of four lower pairs, each pair being a sliding pair or a turning pair.
- The following three types of kinematic chains with four lower pairs are important from the subject point of view :
 1. Four bar chain or quadric cyclic chain.
 2. Single slider crank chain.
 3. Double slider crank chain.

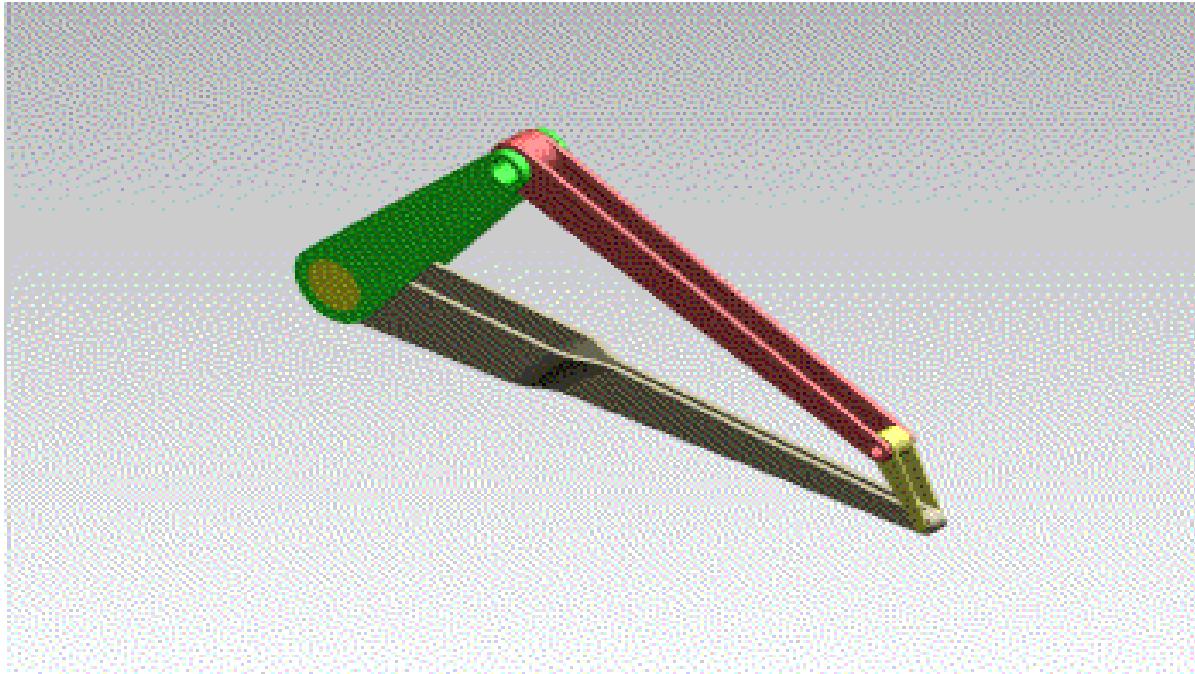
Simple Four Bar Mechanism

- ▶ Four bar chain is simplest type of kinematic chain. It consists of four links, each of them forming a turning pair at joints.
- ▶ The length of the four links may all be different. According to “Grashf’s law” of four bar mechanism the sum of the lengths of the shortest and the longest links should not be greater than of the lengths of the remaining two links.
- ▶ This mechanism transfers rotary motion of one wheel to the other.



Coupling rod of locomotive

Simple Four Bar Mechanism

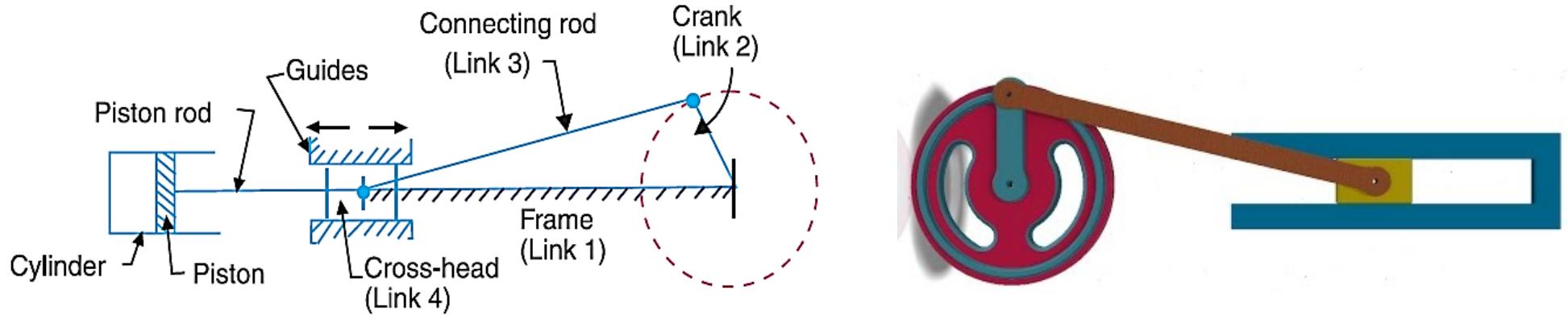


Grashof's Law

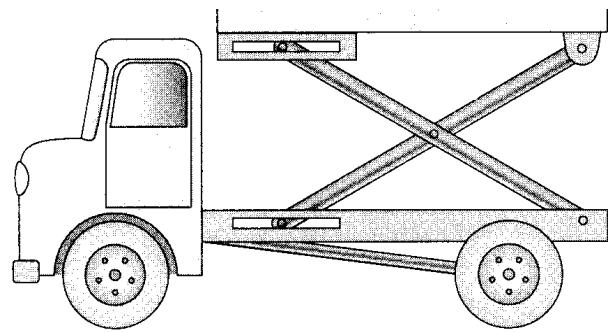
- For Planner Four bar linkage, sum of shortest and longest link lengths can not be grater than sum of remaining two link lengths, if there is to be continuous relative motion between two members.
- If $|l + s| < p + q$, Crank- Rocker Mechanism is Possible.
- If $|l + s| = p + q$, Double Crank Mechanism is Possible.
- If $|l + s| > p + q$, Double Rocker Mechanism is Possible.

Single Slider Crank Chain

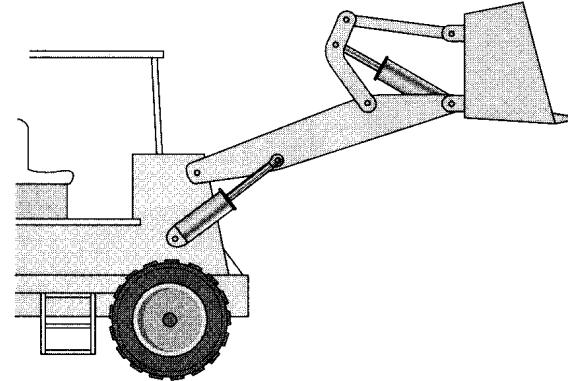
- A single slider crank chain is a modification of the basic four bar chain.
- It consists of one sliding pair and three turning pairs. It is, usually, found in reciprocating steam engine mechanism.
- This type of mechanism converts rotary motion into reciprocating motion and vice versa.
- In a single slider crank chain, as shown in Fig., the links 1 and 2, links 2 and 3, and links 3 and 4 form three turning pairs while the links 4 and 1 form a sliding pair.
- The link 1 corresponds to the frame of the engine, which is fixed. The link 2 corresponds to the crank ; link 3 corresponds to the connecting rod and link 4 corresponds to cross-head.
- As the crank rotates, the cross-head reciprocates in the guides and thus the piston reciprocates in the cylinder.



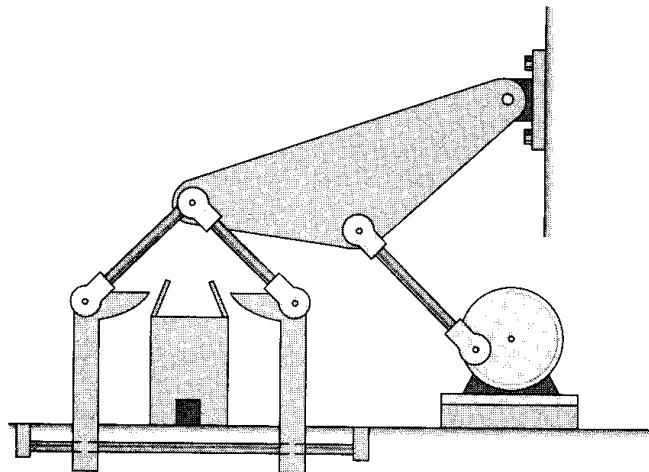
Example of Mechanisms



Lift platform

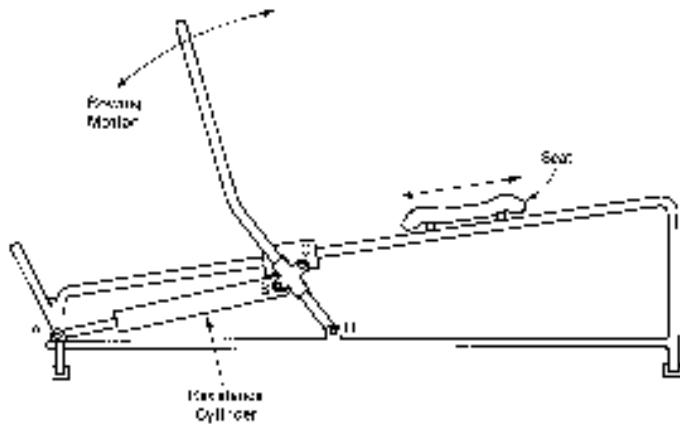


Front loader

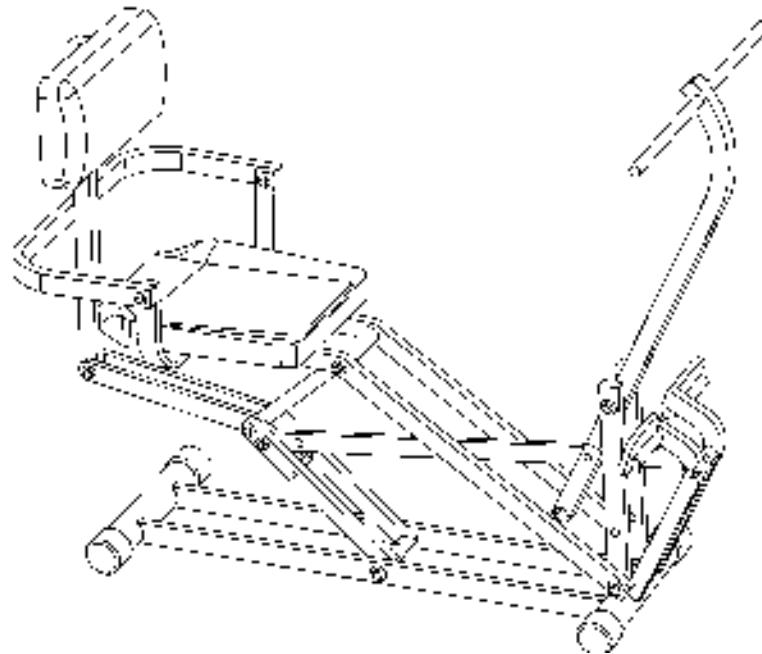


Device to close the
top flap of boxes

Example of Mechanisms



Rowing type exercise machine



Conceptual design for an exercise machine

Machine:

Machine is a combination of resistant bodies, with definite constrained motion, which is used for transmitting or transforming available energy so as to do some particular kind of work.

Sr. No.	Mechanism	Machine
1	If one of the links or elements of a kinematic chain is fixed, the transmitting or transforming the motion. It is then termed as a mechanism.	When a mechanism is required to transmit power or to do some particular kind of work, the various links or elements have to be designed so as to withstand the forces to which they are subjected. The arrangement is then known as a machine.
2	The primary function of mechanism is to transmit or transform the motion.	The primary function of machine is to transmit or transform the energy.
3	Every mechanism is not necessarily a machine.	Every machine is either a mechanism or a combination of more than one mechanisms.
4	Examples of mechanism are: Clock, type-writer,, P.V. diagram indicator of lock engine, etc.	Examples of machine are: I.C. engine, shaping machine, hand pump, etc.

Thank You