Unit-2

Topics Covered

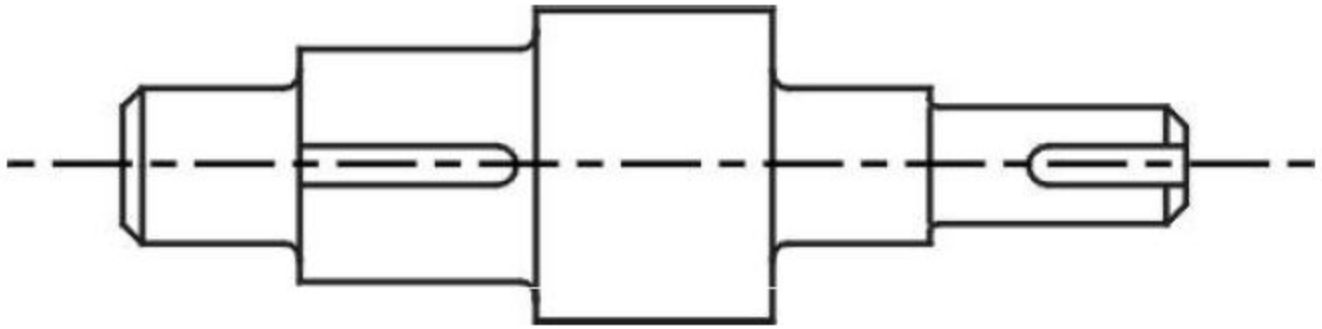
- Machine Elements
- Mechanisms
- Power transmitting devices

Mechanical Machine Elements

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

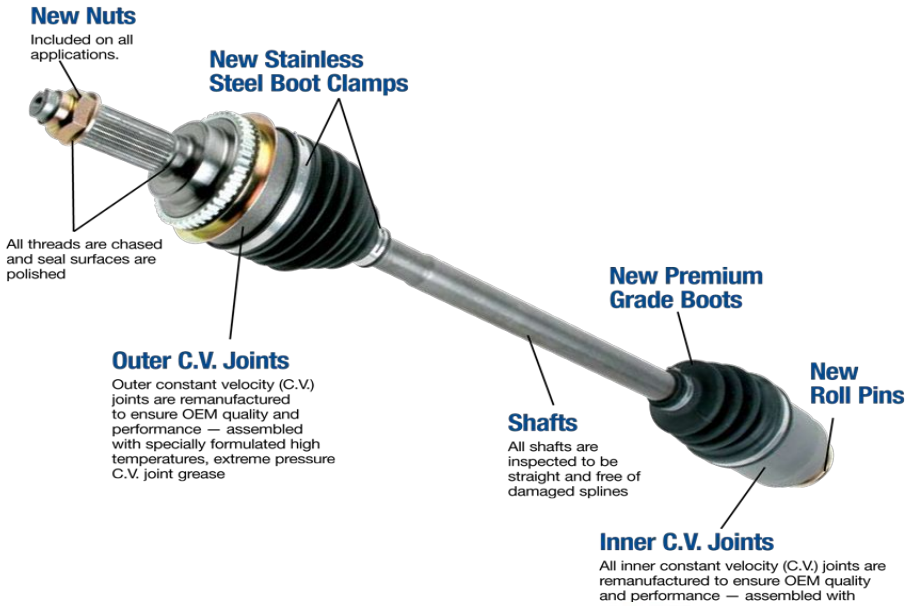
Shafts

- 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.

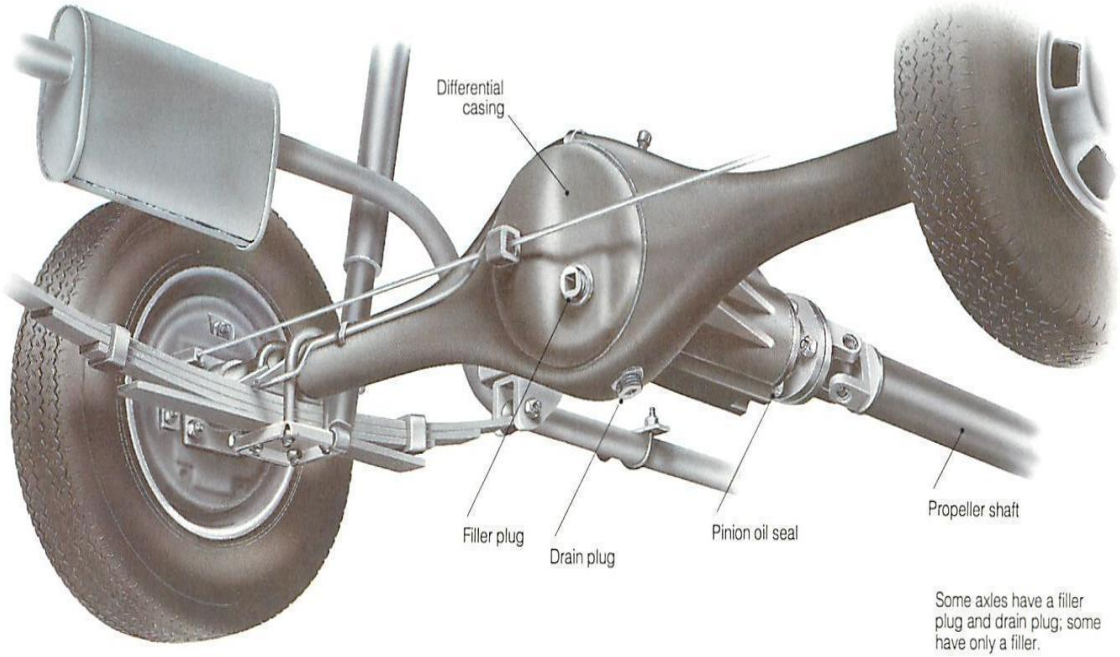


Shafts

- 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 *lineshaft, headshaft, stub shaft, transmission shaft, countershaft,* and *flexible shaft* are names associated with special usage.



Identify, Which is shaft and Which is Axle?



Uses of Shaft

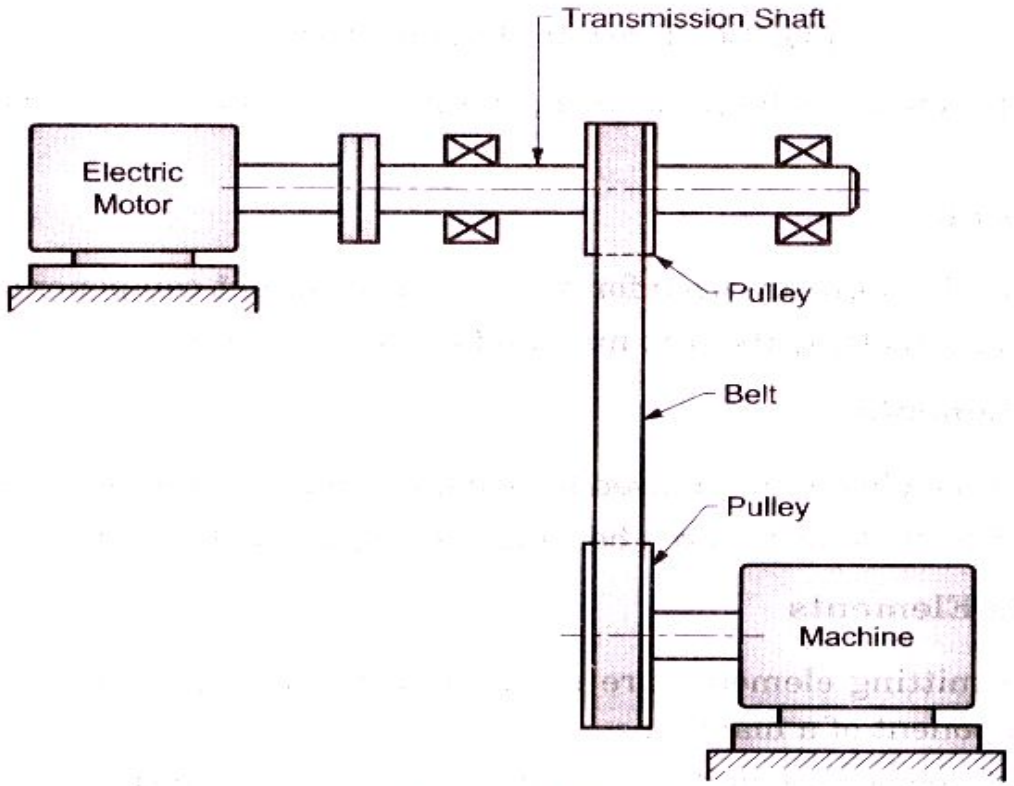
- Usually, Shaft is used for power transmission from one point to another such as,
- Automobile Drive Shafts
- Marine Drive Shafts
- Locomotive Drive Shafts
- Machine Shafts
- Aeroplanes etc.

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 s

Transmission Shaft

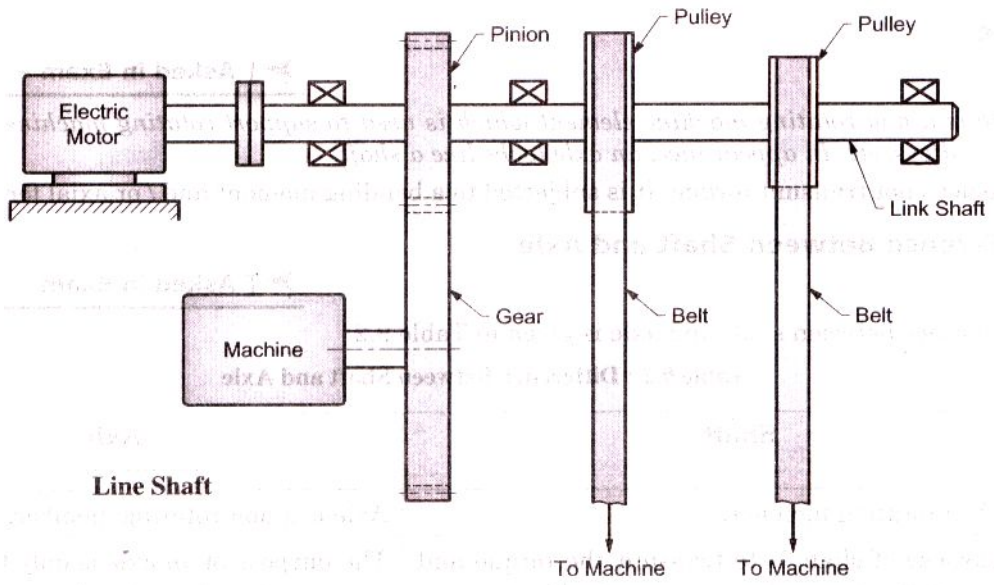
The shaft which is directly connected to power producing device is called transmission shaft



Transmission Shaft

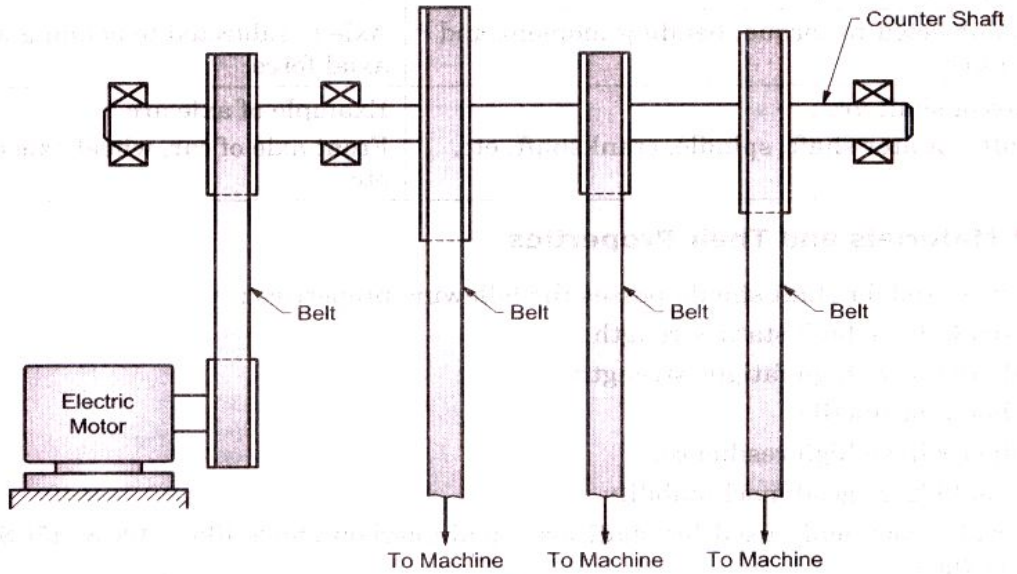
Line Shaft

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

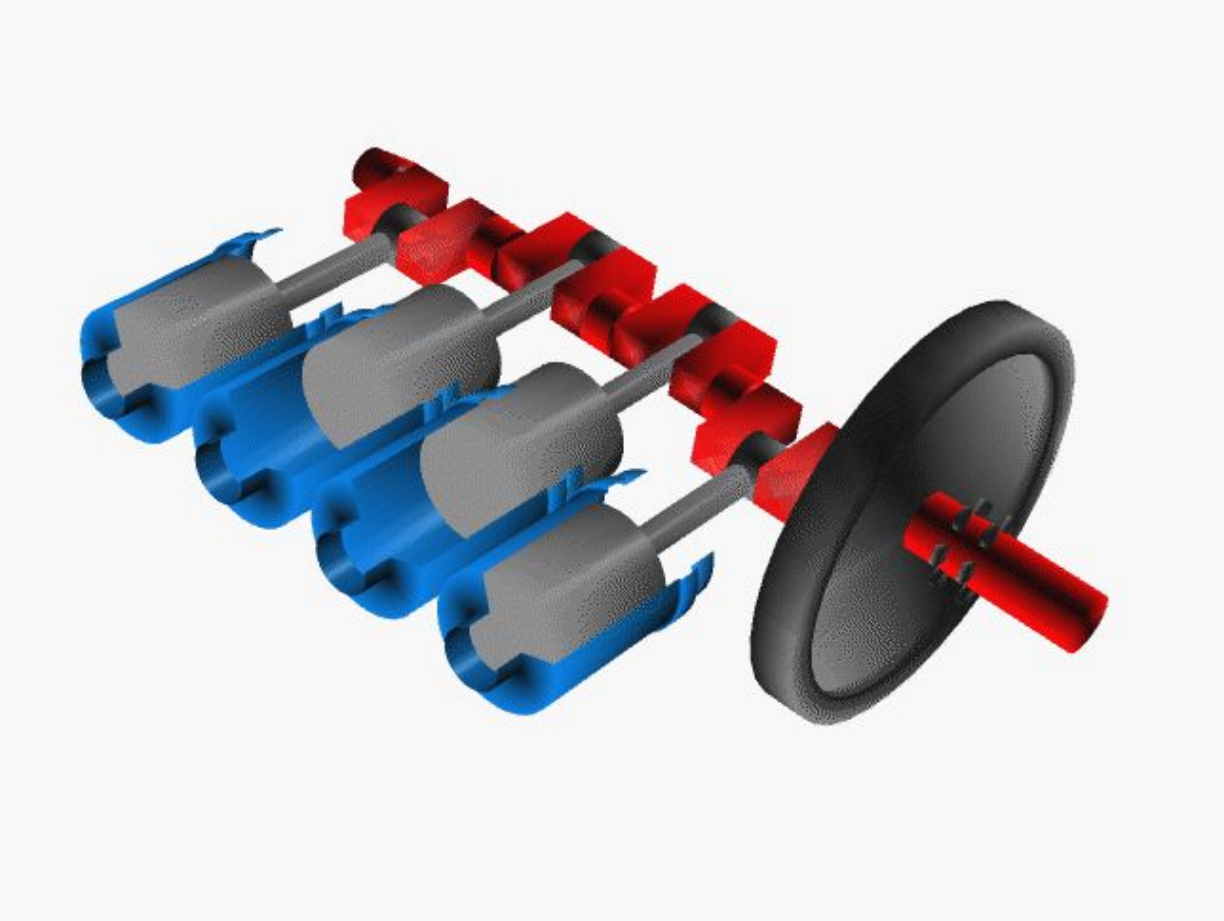
Counter shaft is a secondary shaft which is driven by the main shaft through belt, chain or gear drive and from which the power is supplied to the different machines.



Counter Shaft

Crankshaft

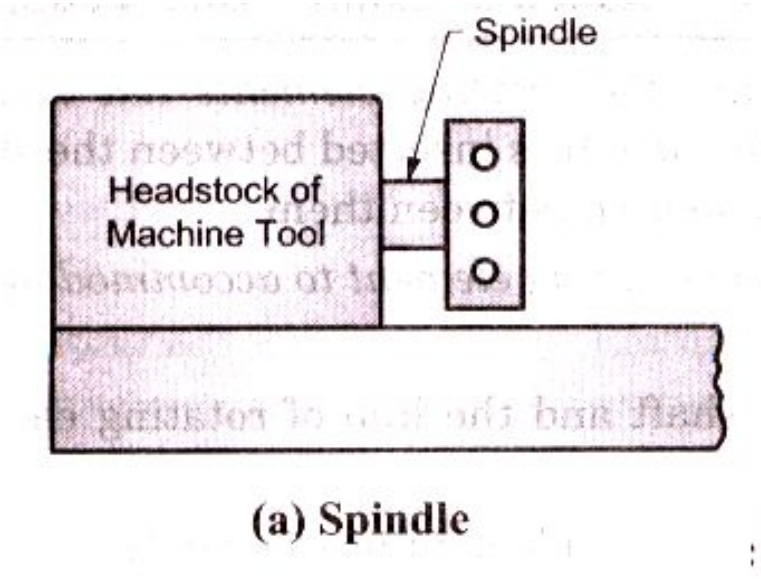
The shaft which used in multi cylinder IC engine to which cranks are embedded is called crankshaft.



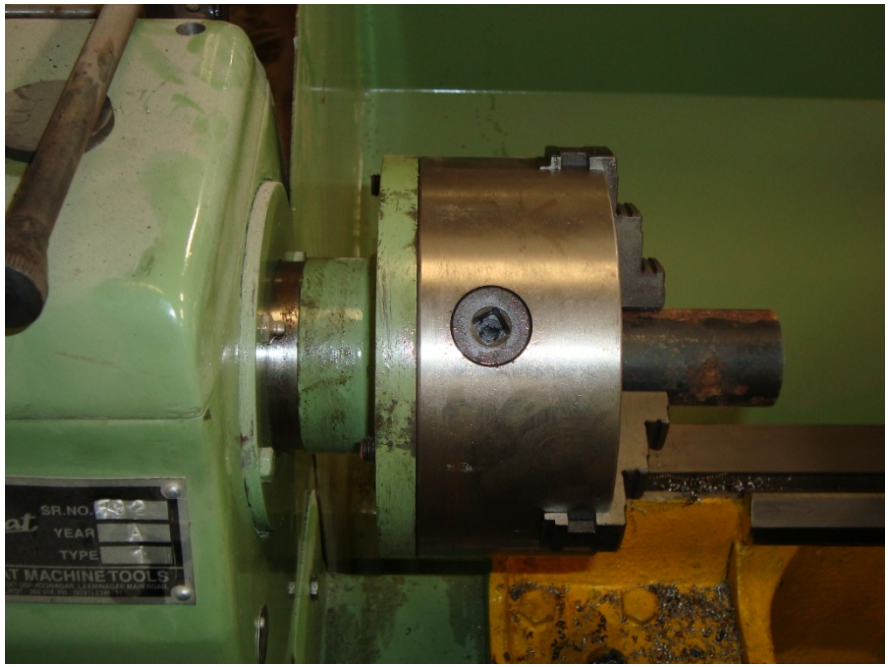
Spindle

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

.

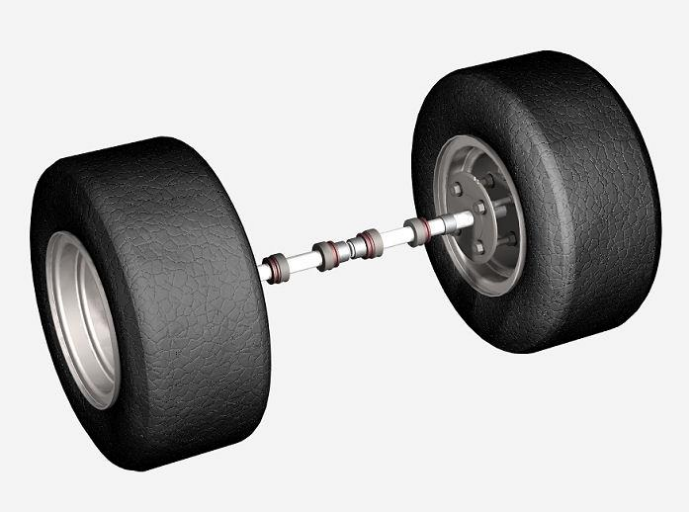


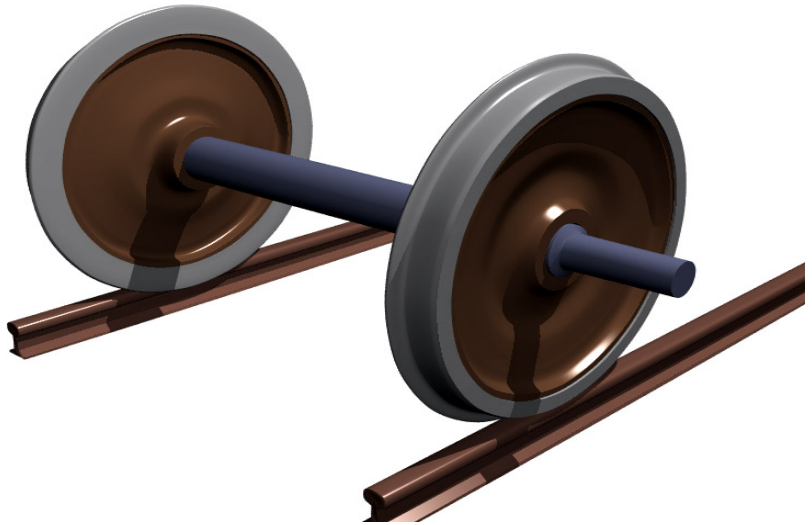
(a) Spindle



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.



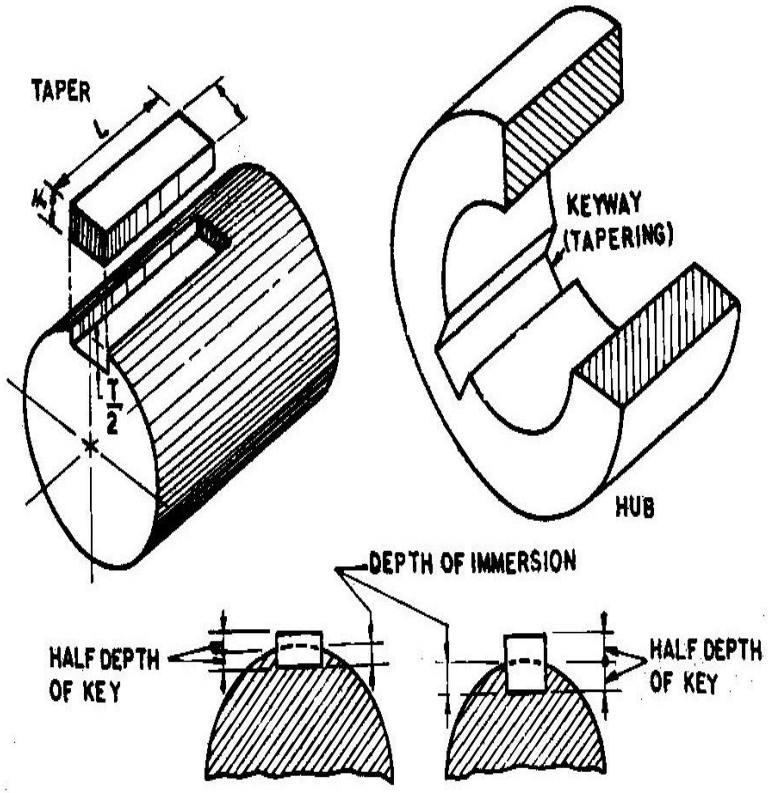


Difference between Axle and Shaft

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 electirc motor, shaft of IC engine

Keys n Couplings

- 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.



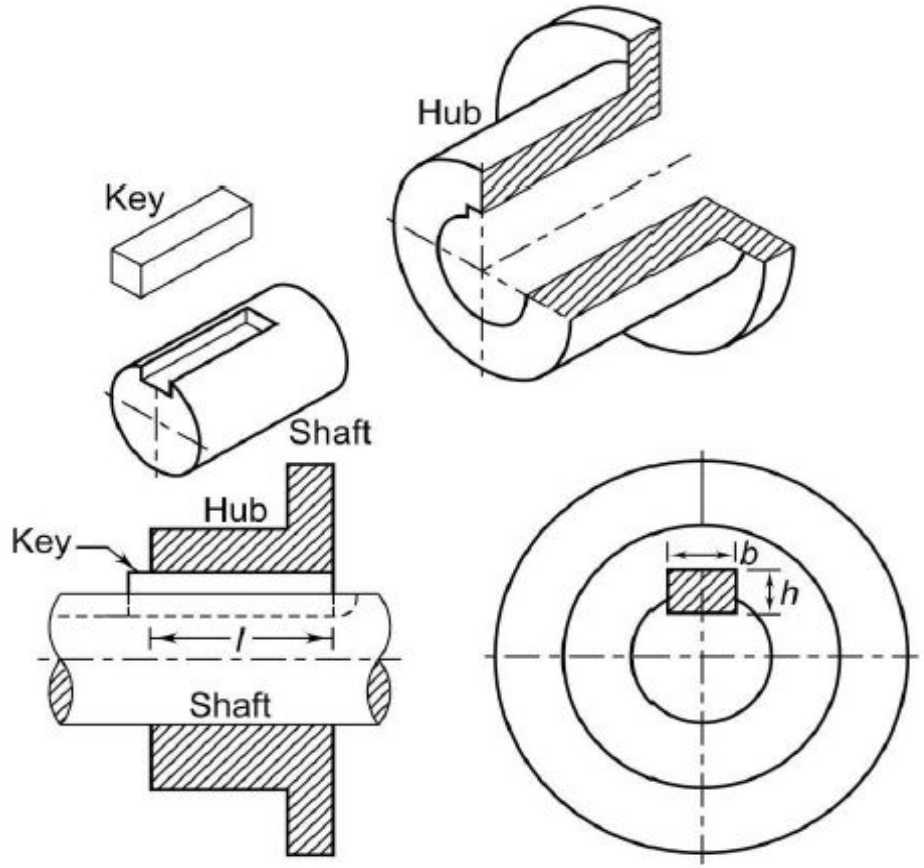


Fig. 9.16 Key-joint

- 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

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

Classification of Keys

- Saddle keys
  - Hollow saddle key
  - Flat saddle key
- Sunk keys
  - Taper sunk keys
  - Parallel sunk keys
  - Father keys
  - Woodruff key (adjustable key)
- Round keys
  - Parallel pin
  - Taper pin

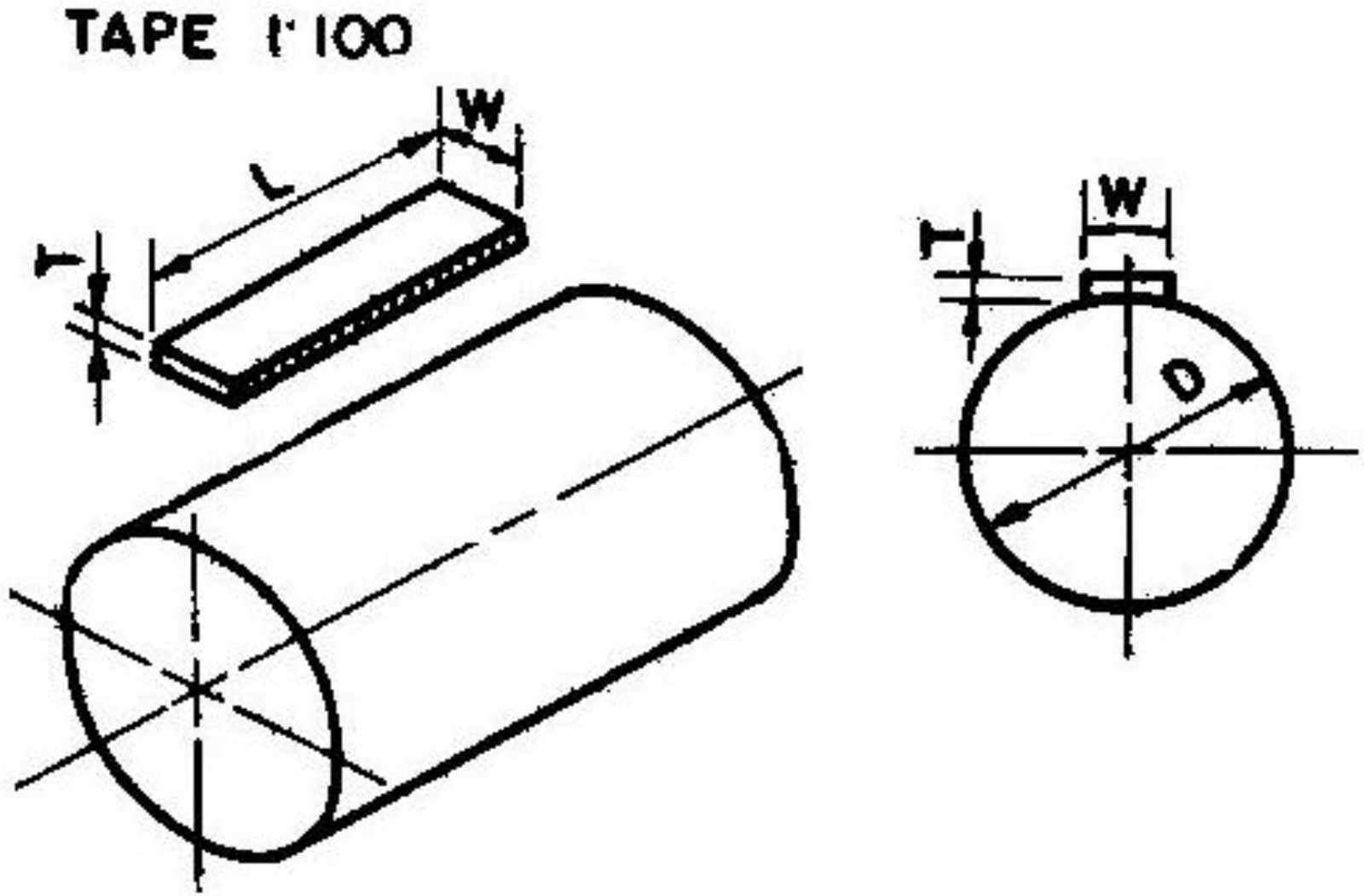
Saddle keys

- Saddle key are taper keys which are sunk into the hub only.(note: a taper key in 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).
- 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.

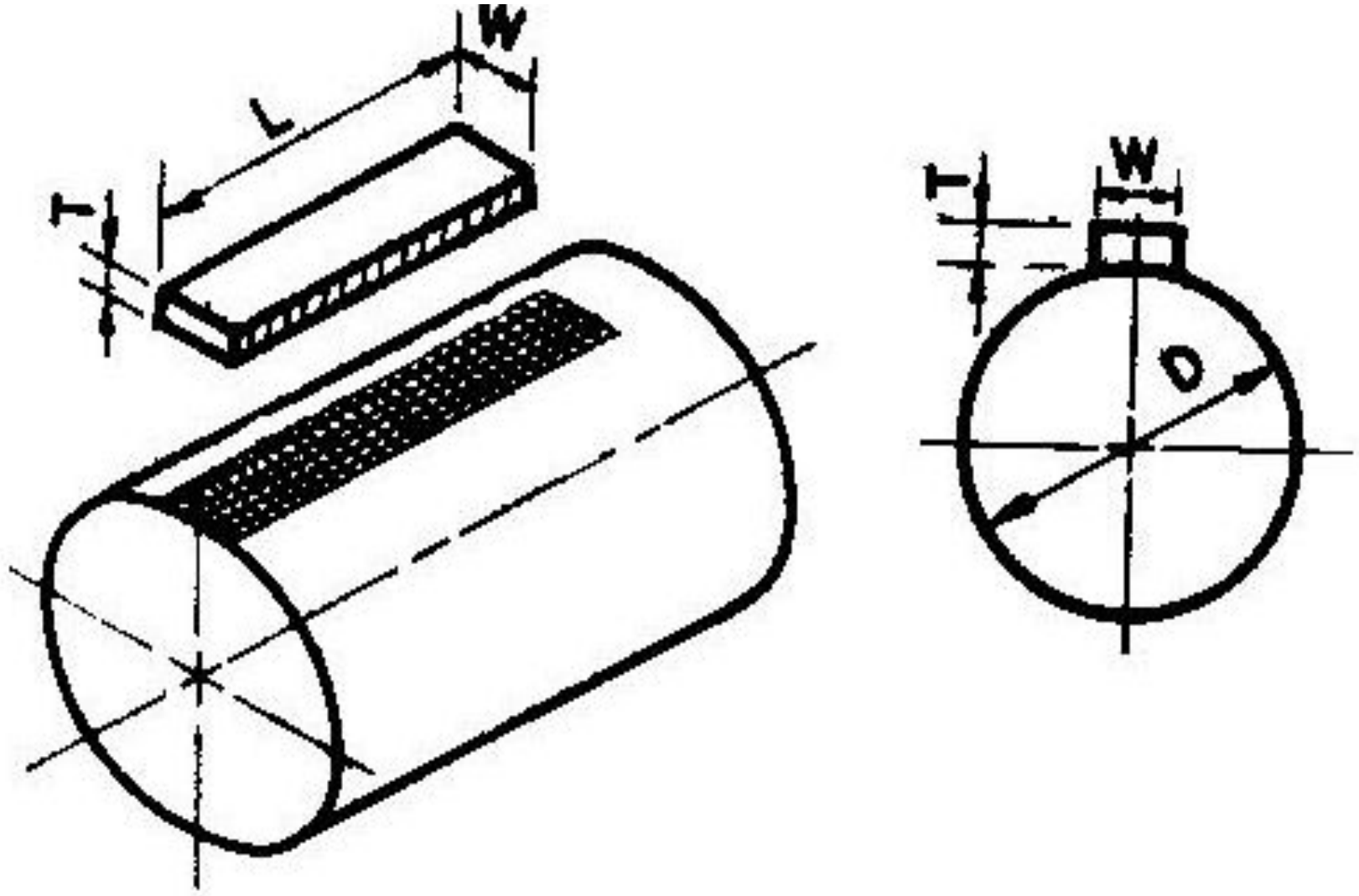
Type of the saddle key

- 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.
- 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.

Hollow Saddle Key



Flat Saddle Key

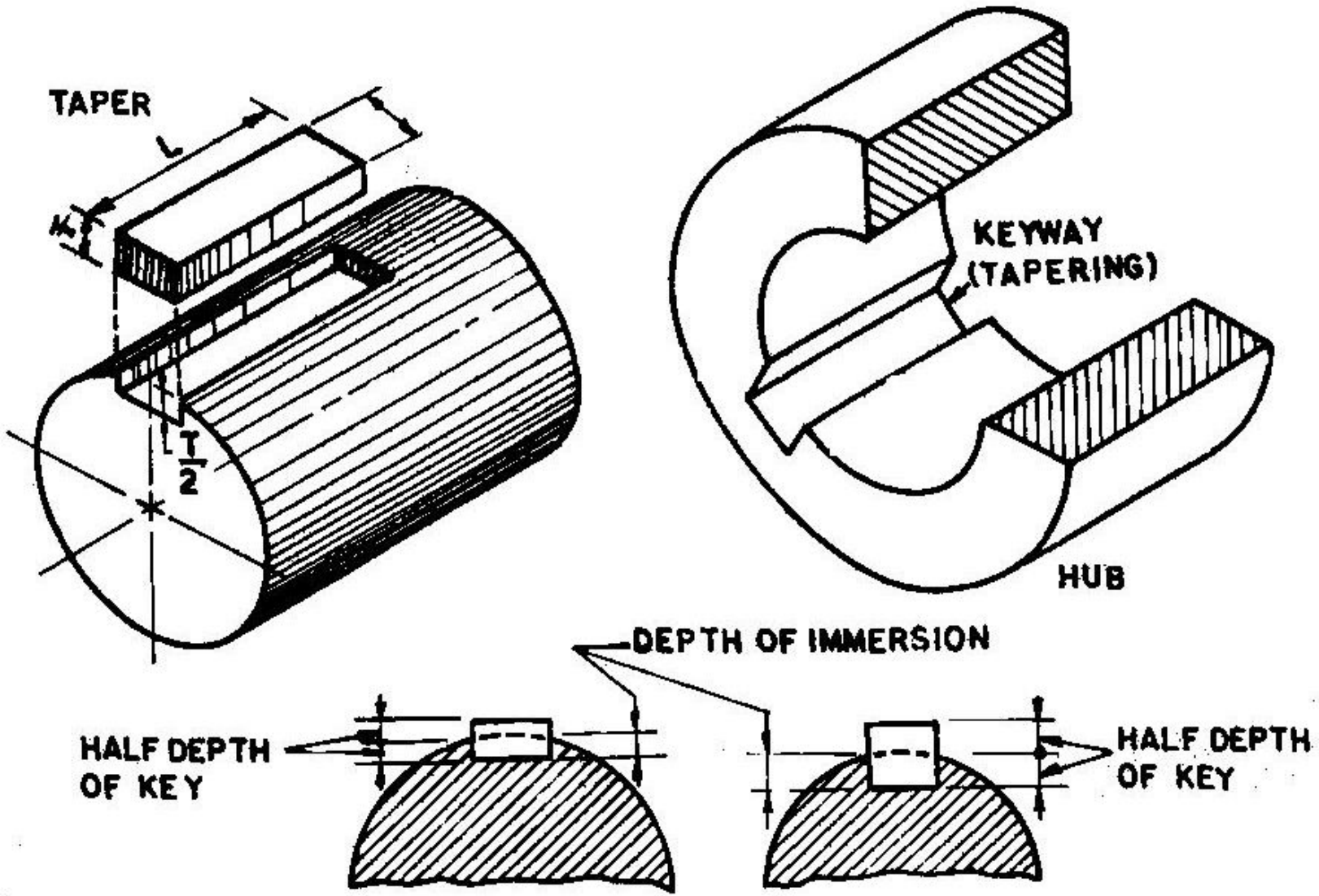


Sunk keys

- Sunk keys are sunk into the shaft and into the hub. These keys are suitable for heavy duty since they rely on positive drive.

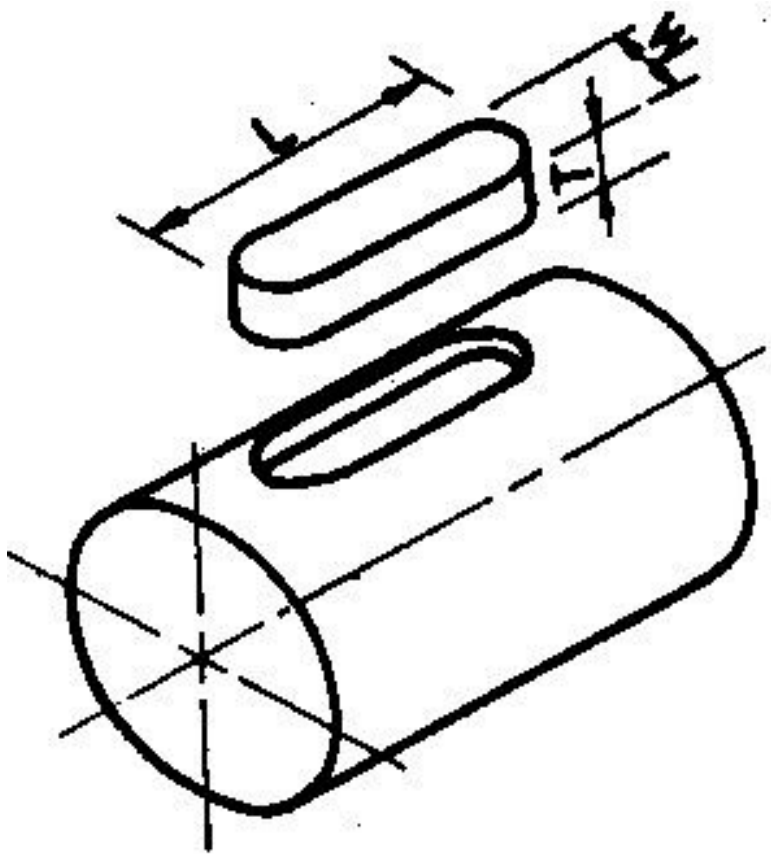
- Taper sunk keys:
  - This is the standard form of the key and may be either of rectangular or square cross-section. The key is sunk in the shaft to a depth of half its nominal thickness when measured at the side.
  - This key gives a very sound fastening without any fear of slipping between the two parts, unless , of course, the key shears. Such a key can be safely used for heavy duty work.

Sunk taper key



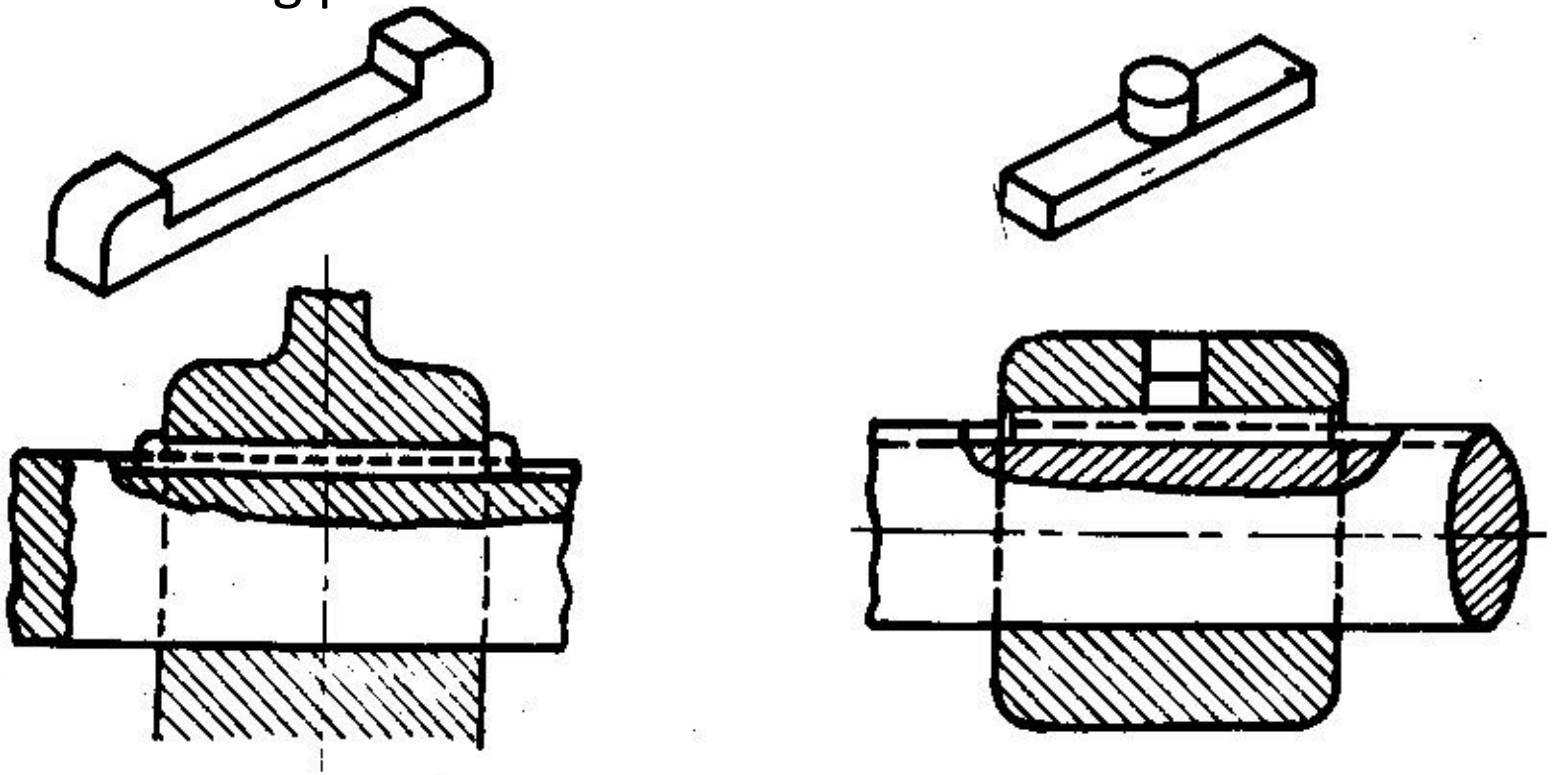
Parallel sunk key

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.



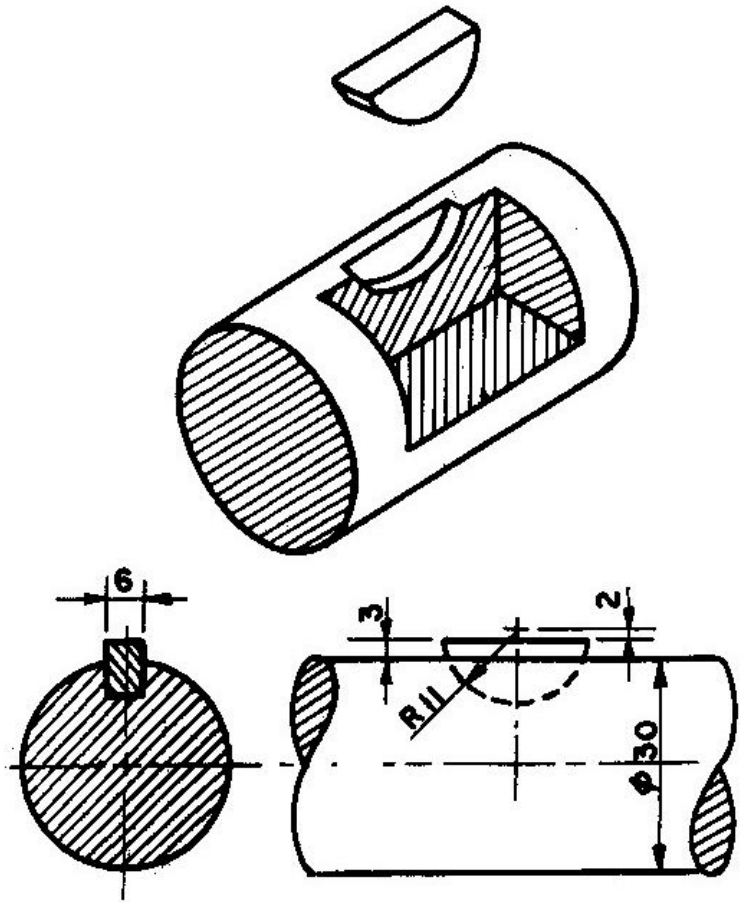
Feather keys

It is a key attached to one member 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.



Woodruff keys

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.



COUPLING

Coupling is the mechanical element used to connect two shafts of a transmission system and transmit the torque from one shaft to another.

Functions of Coupling :

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

Classification of Couplings

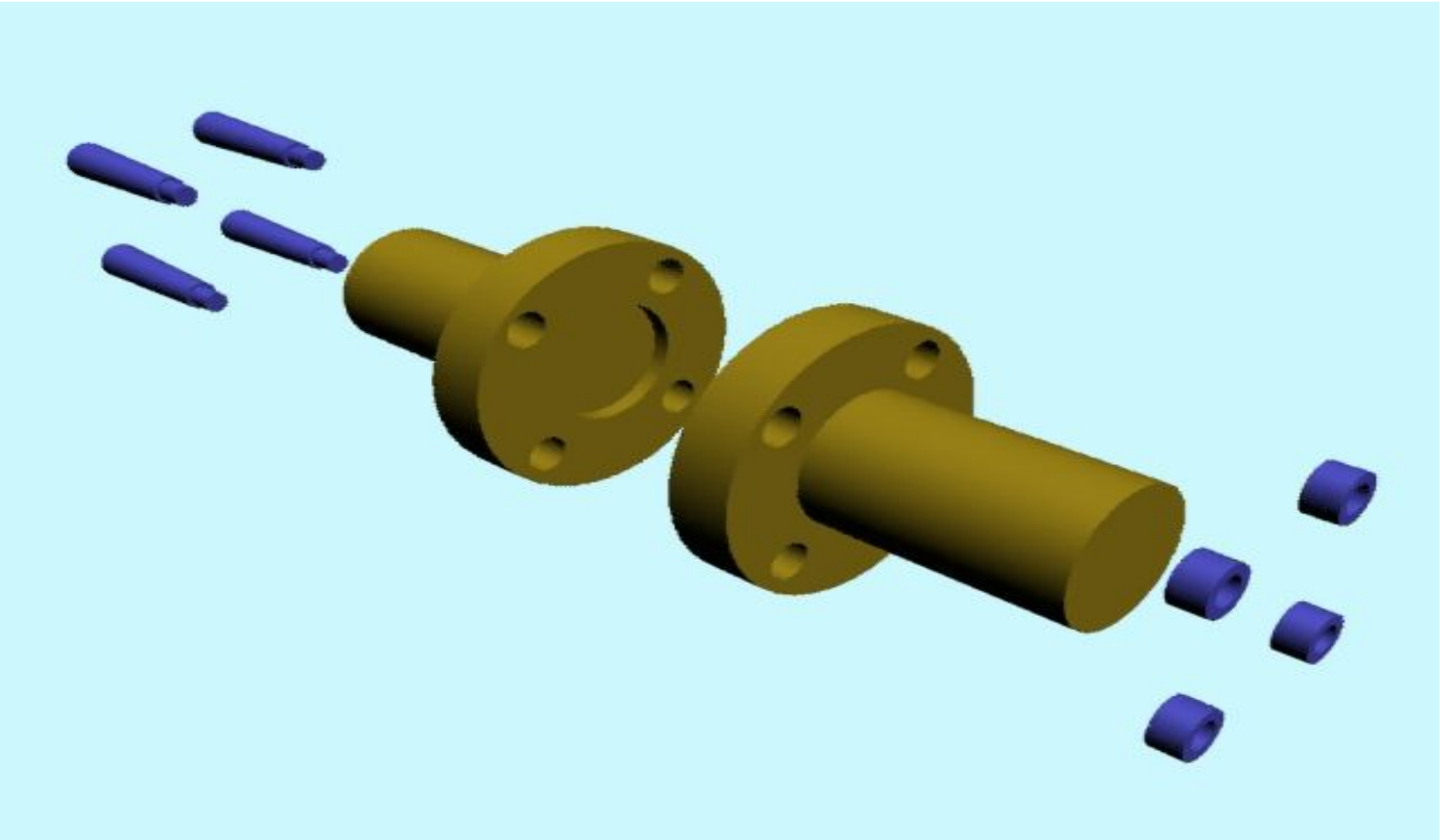
- **Sleeve or Muff**
- **Split Muff**
- **Flange**
  - **Un-Protected type**
  - **Protected type**

- **Flexible**
  - **Bushed – Pin**
  - **Universal**
  - **Oldham**

Rigid Couplings

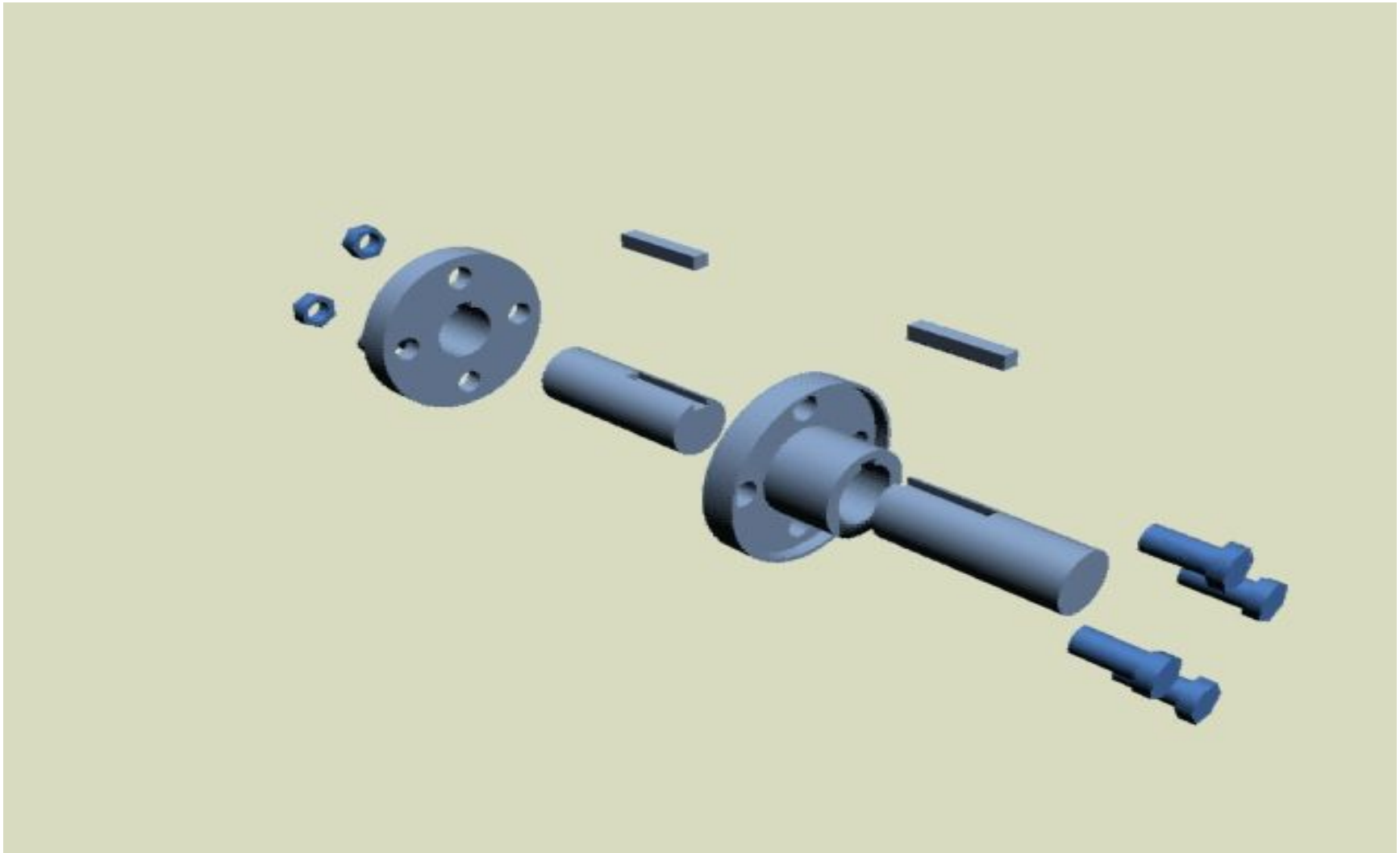
- Rigid couplings are used to connect two shafts which are perfectly aligned.
- These couplings are not capable of tolerating any misalignment between two shafts.
- These couplings are not capable of absorbing shocks and vibrations.
- These are simple and inexpensive.

NON-PROTECTED TYPE FLANGE COUPLING

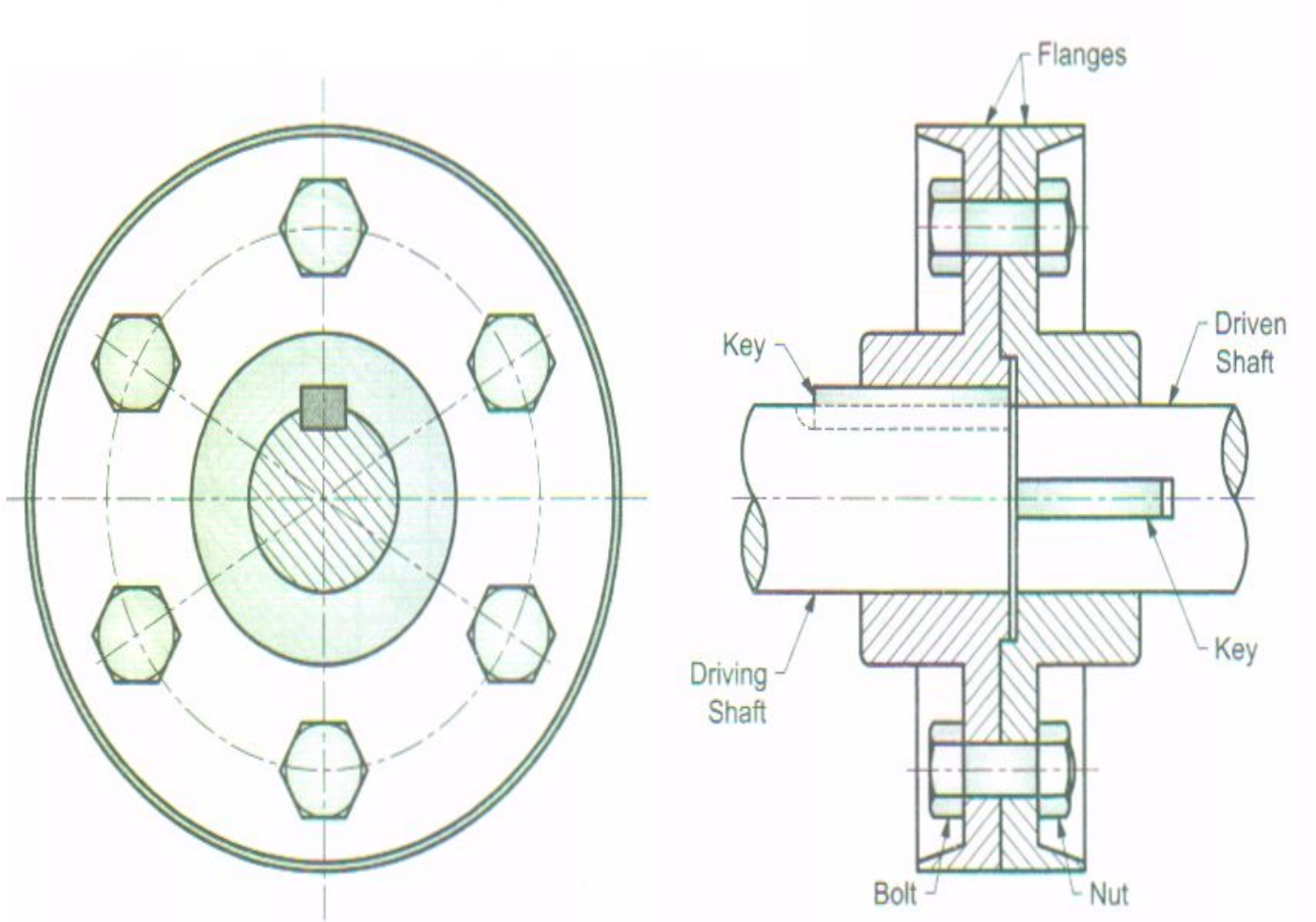


youtube.com

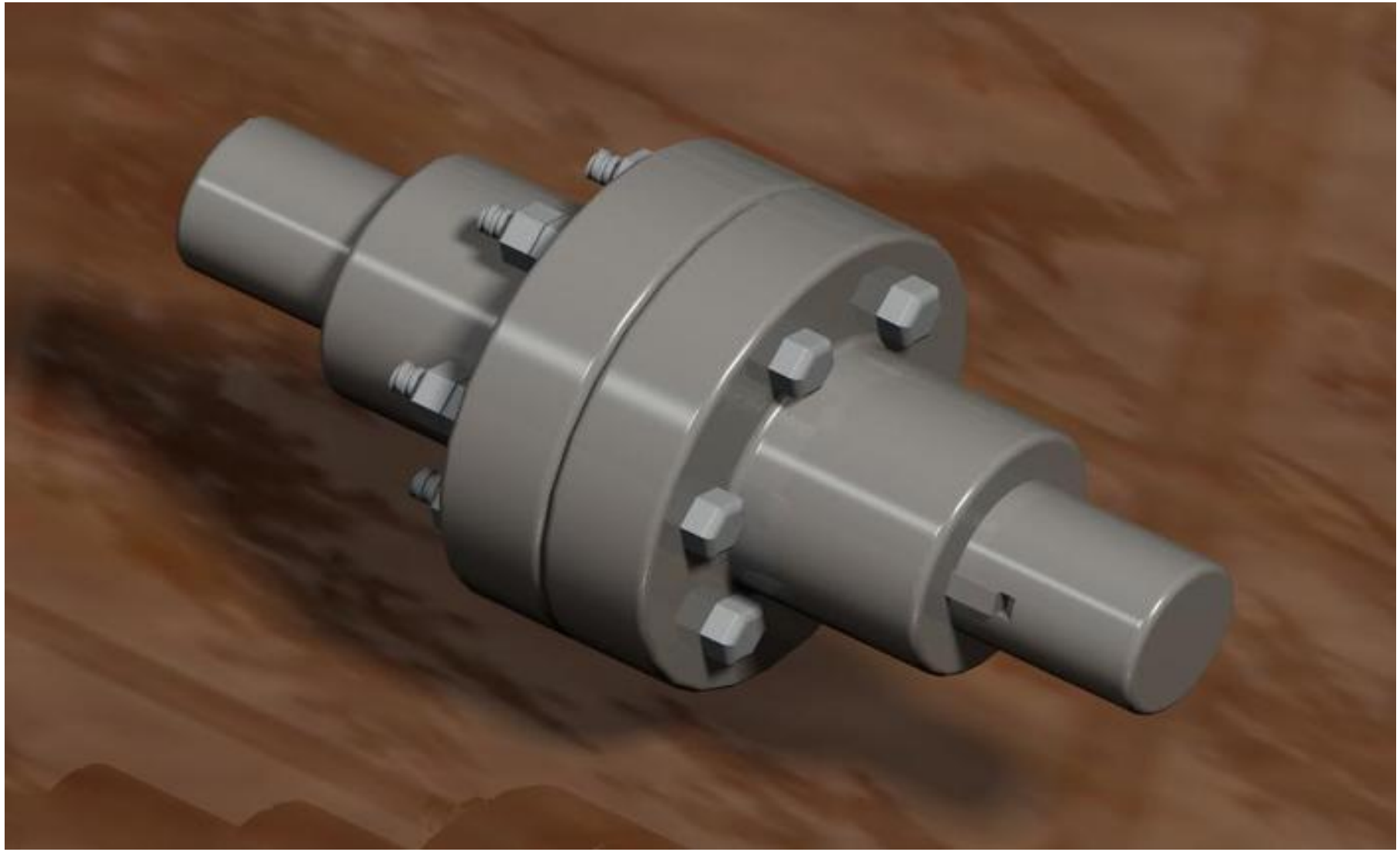
PROTECTED FLANGE COUPLING



youtube.com



Protected Type Rigid Flange Coupling



Un – protected Flange Coupling

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.

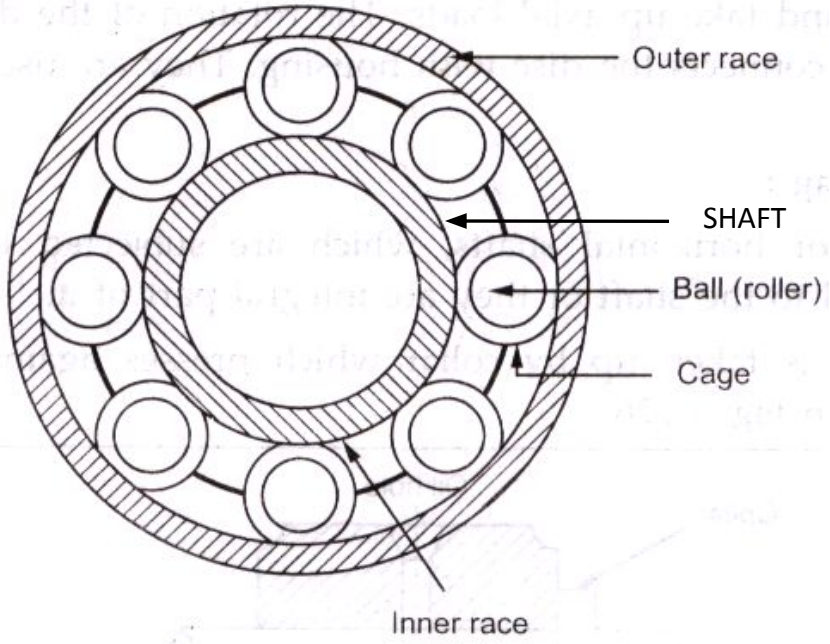
Functions:

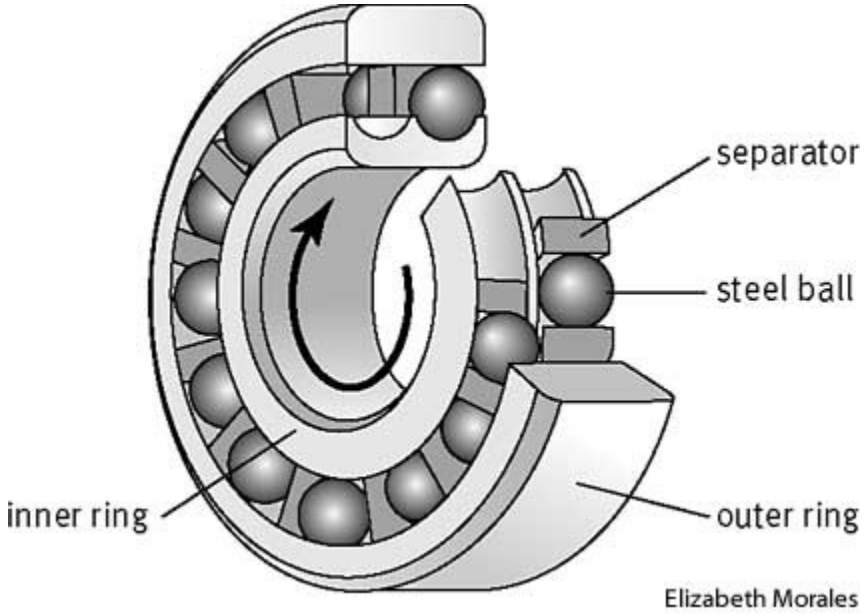
I. It ensures **free rotation** of the shaft or the axle **with minimum friction.**
II. It **supports** shaft or axle and holds it in the correct position.
III. It **takes the forces** acting on the shaft or the axle in both working as well rest condition and **transfers them to frame** on which it is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

- Bearings
  - Rolling
  - Contact
    - Ball Bearing
      - Radial
      - Thrust
    - Roller Bearing
      - Radial
      - Thrust
  - Sliding Contact
    - Hydrostatic Bearing
    - Hydrodynamic
    - Bearing

BALL BEARING

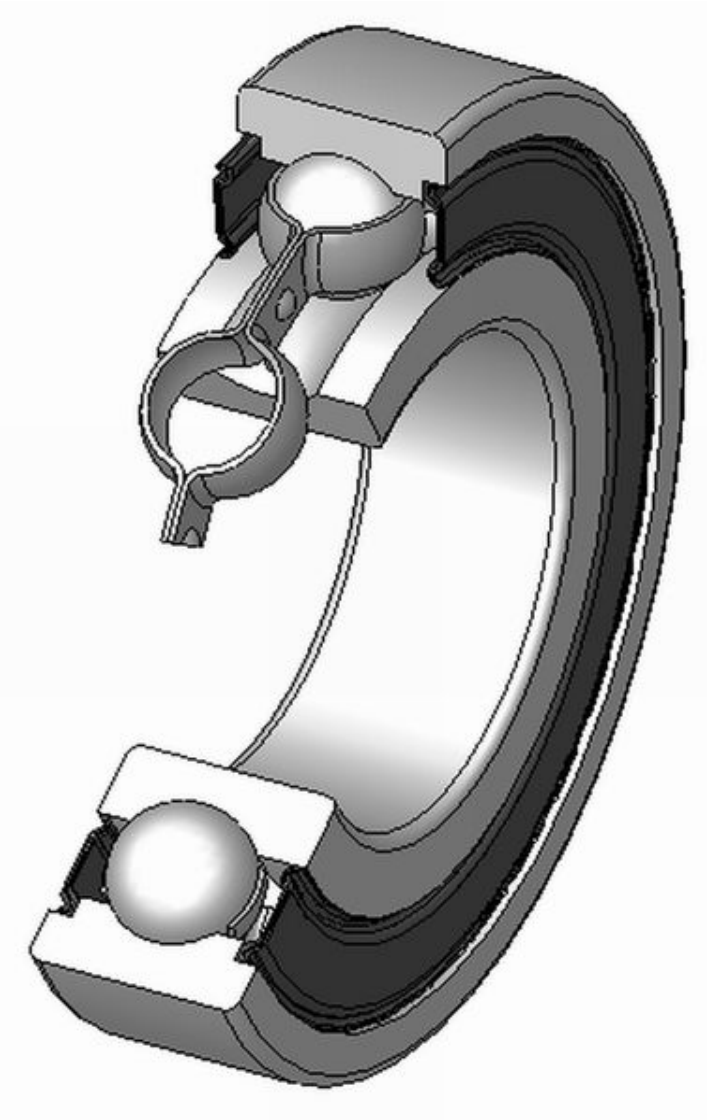
- *Rolling Friction - Antifriction Bearings or Ball Bearings*
- *The purpose to support a load while permitting relative motion between two elements of a machine.*
- *The components of a typical rolling contact bearing are the inner race, the outer race, cage and the rolling elements.*





BALL BEARING

- Due to low rolling friction these bearings are aptly called “antifriction” bearing.
- Frictional resistance considerably less than as in plain bearings
- Rotating – non-rotating pairs separated by balls.
- 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.



The ball bearing consists of following parts:

- Inner ring or race which fits on the shaft.
- Outer ring or race which fits inside the housing.
- Balls arranged between the surfaces of two races. These provide rolling action between the races.
  - the radius of the track for balls is slightly greater 5 to 10 % than that of the ball themselves.
- Cage which separates the balls or rollers from one another.

The disadvantage of the ball bearings are high cost, they cannot be used in half, and greater noise.

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**.

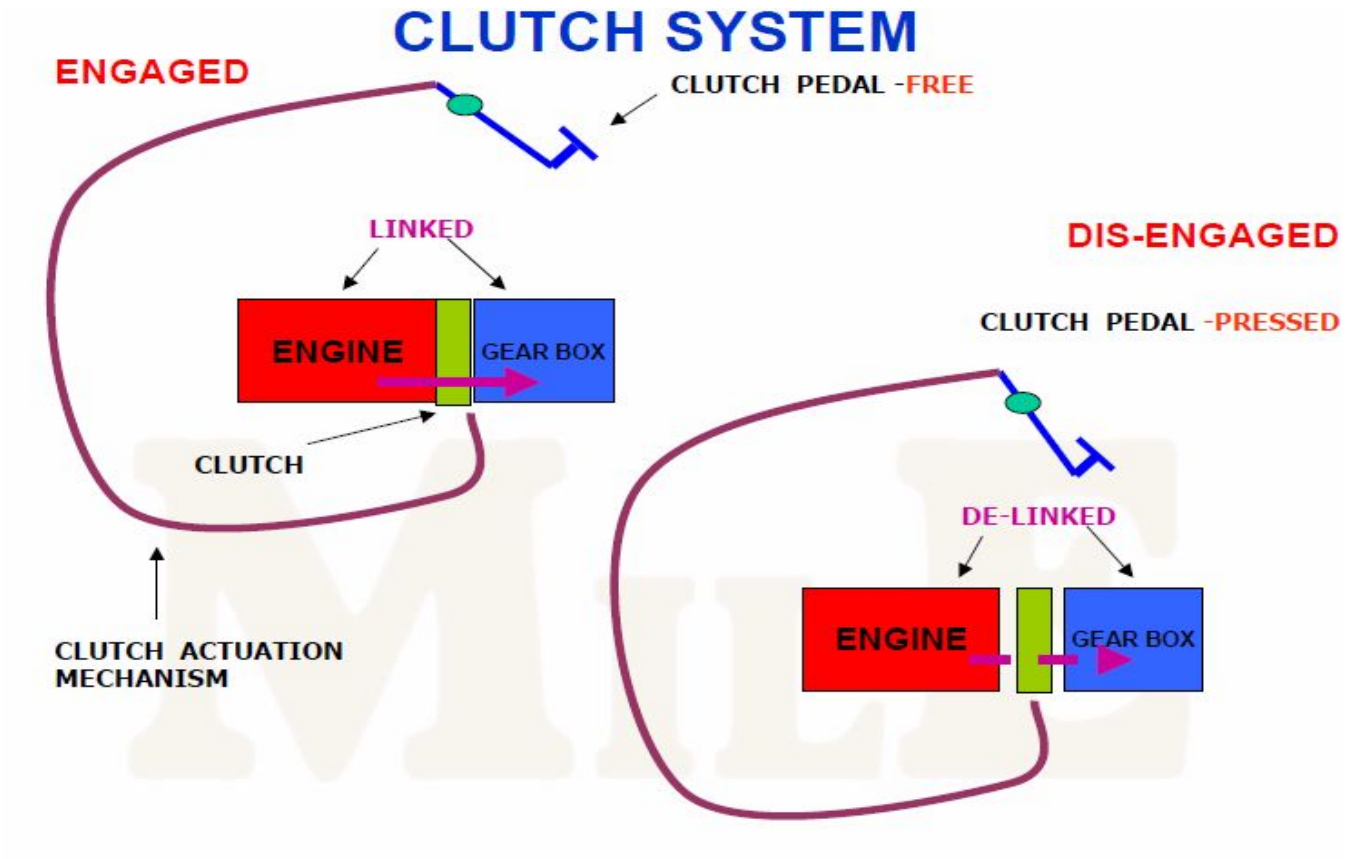
There are essentially two choices for the material used in ball bearings are as Chrome Steel or Stainless Steel.

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

CLUTCH

It connects or disconnects the source of power from the remaining parts of the power transmission system at the will of the operator.



Classification of Clutch

- Clutches
  - Positive Clutch
    - Gear Tooth
    - Spiral
  - Friction Clutch
    - Plate or Disc
      - Single Plate
      - Multiple Plate
    - Cone
    - Centrifugal

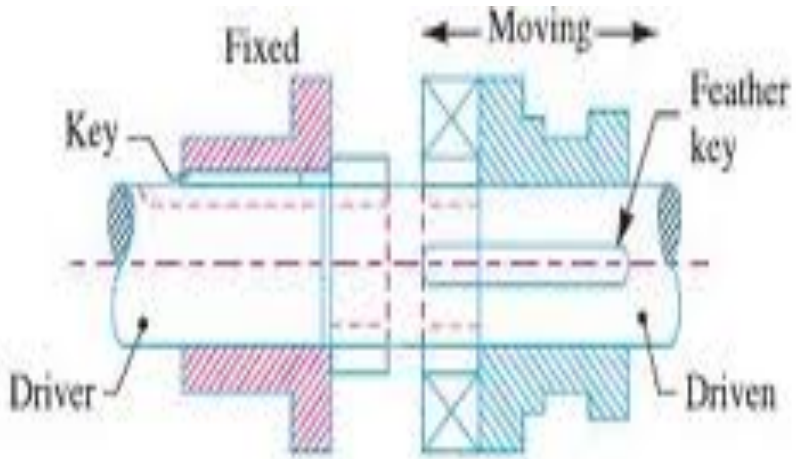
Positive contact clutches

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

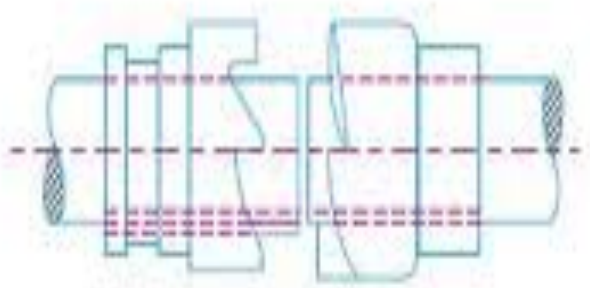
- Transmit large torque with no slip
- Develop very little heat, because they do not depend upon friction.
- Generally lighter.
- Less costly than a friction clutches of similar torque capacity.

- Can not be engaged at high speeds, max 60 rpm for jaw clutches, and 300 rpm for toothed clutches
- Shock accompanies engagement at any speed
- Require some relative motion in order to engage when both driving and driven shafts are at rest

Positive Type Clutch

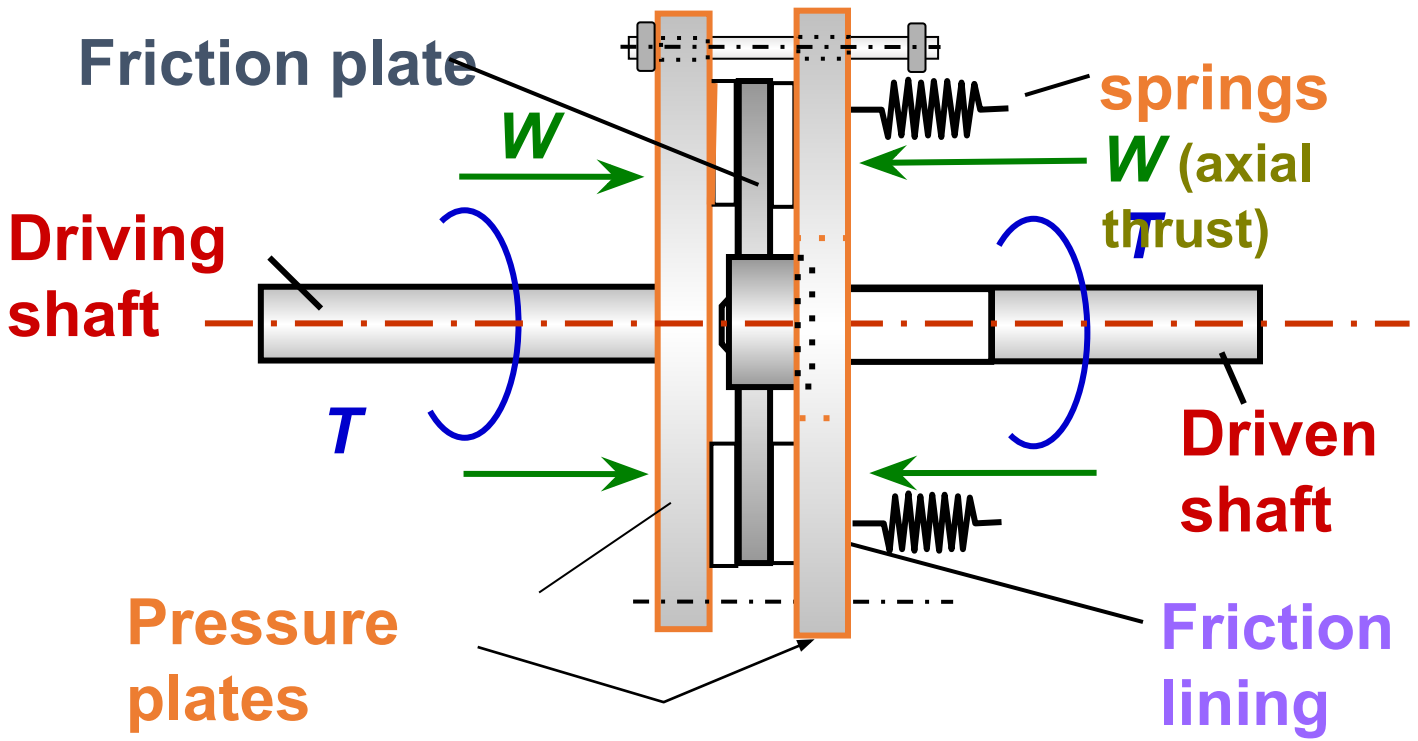


(*a*) Square jaw clutch.



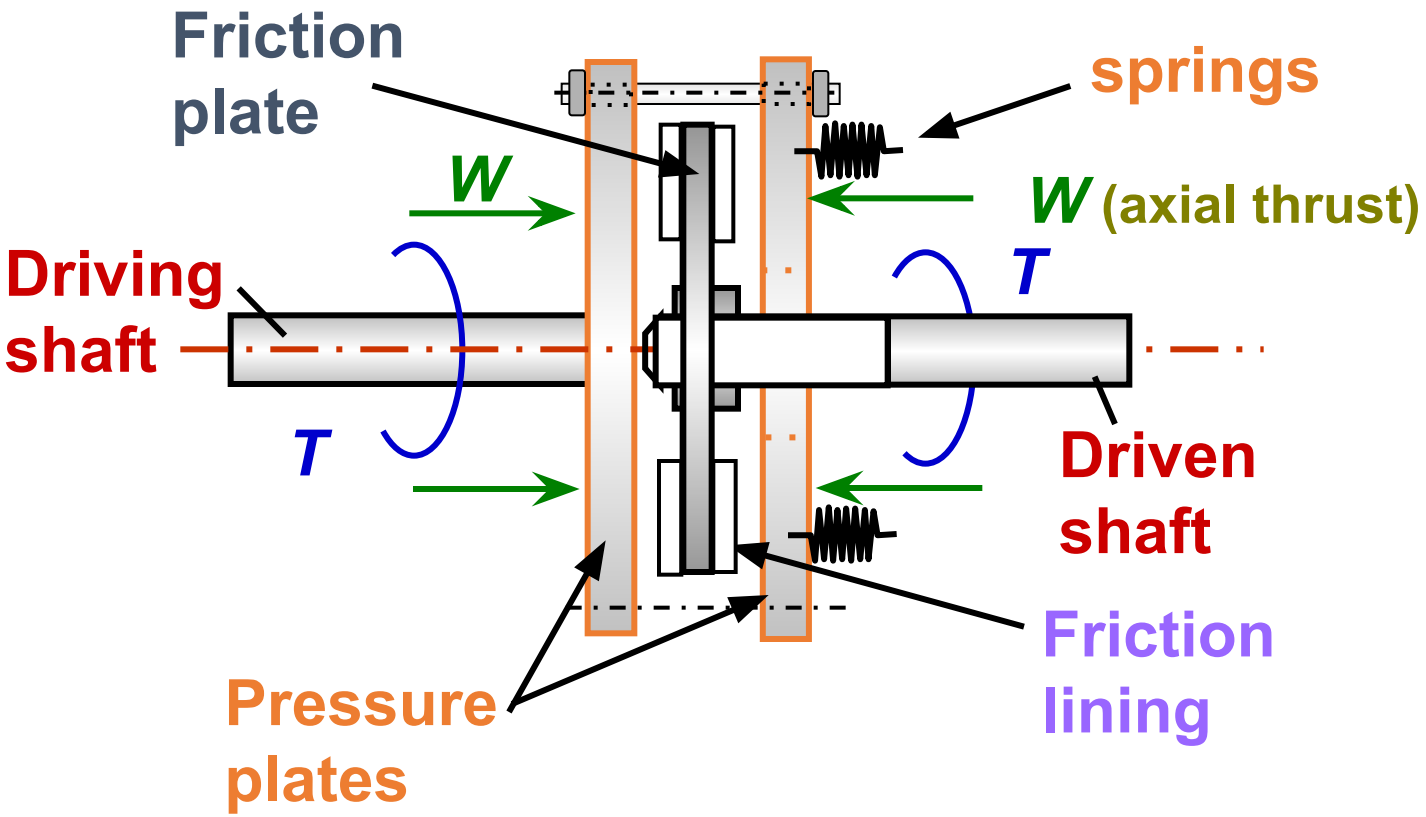
(*b*) Spiral jaw clutch.

Flat-plate friction clutches

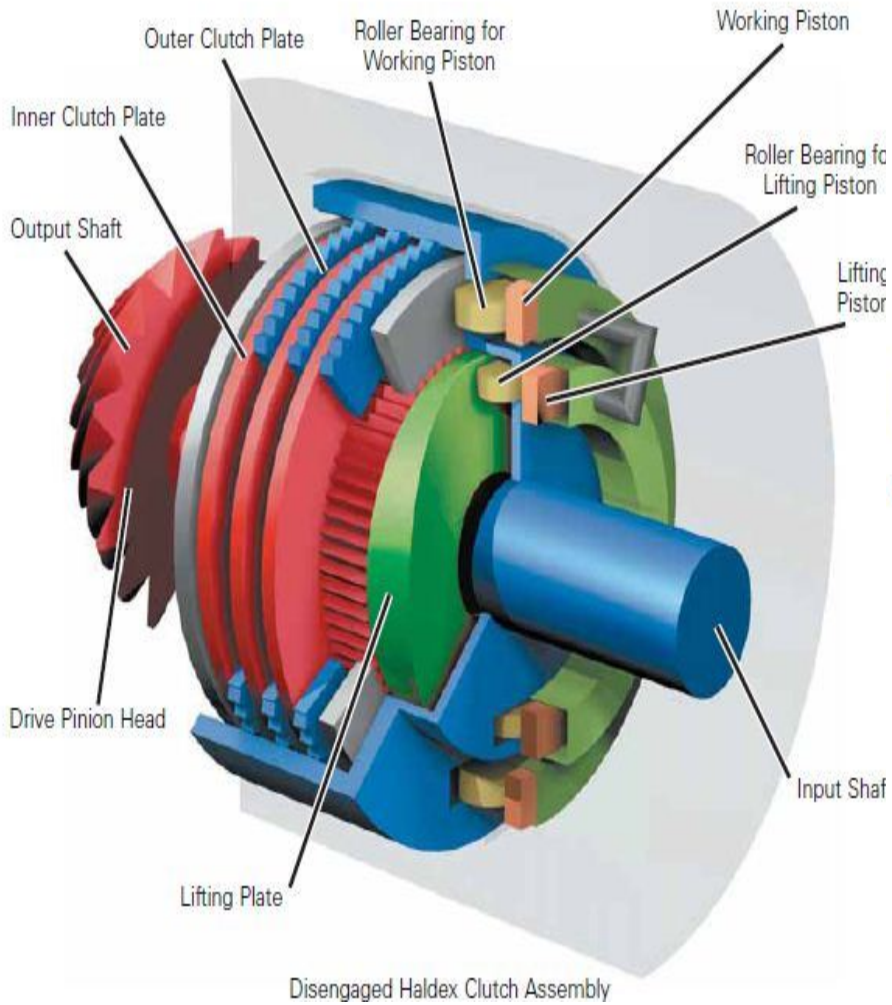


Single-plate Friction Clutch (Engaged position)

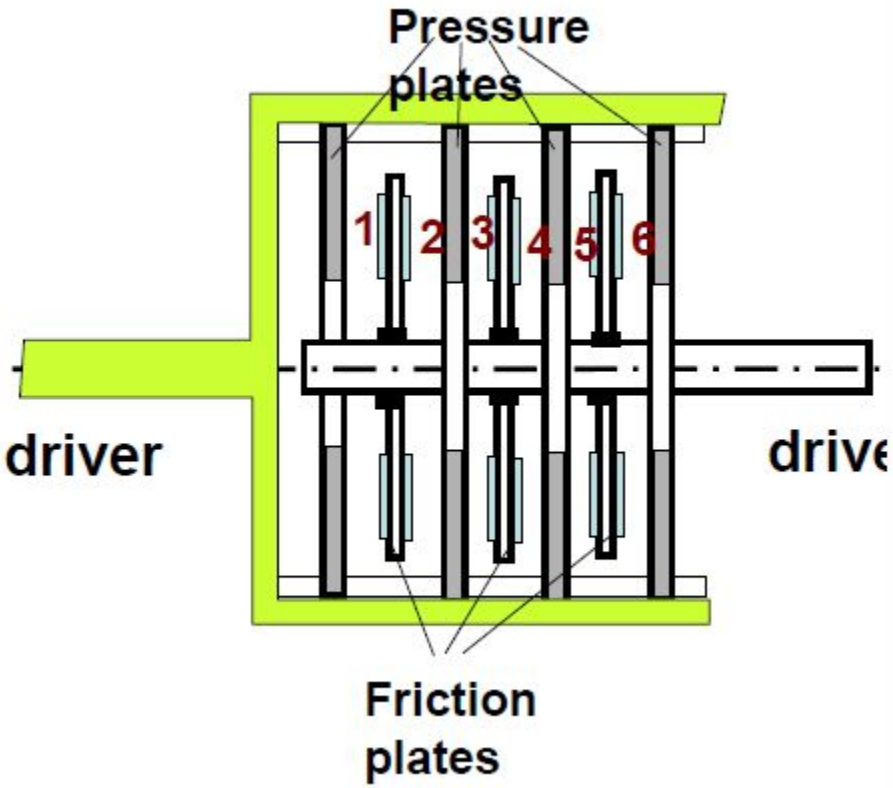
Flat-plate friction clutches



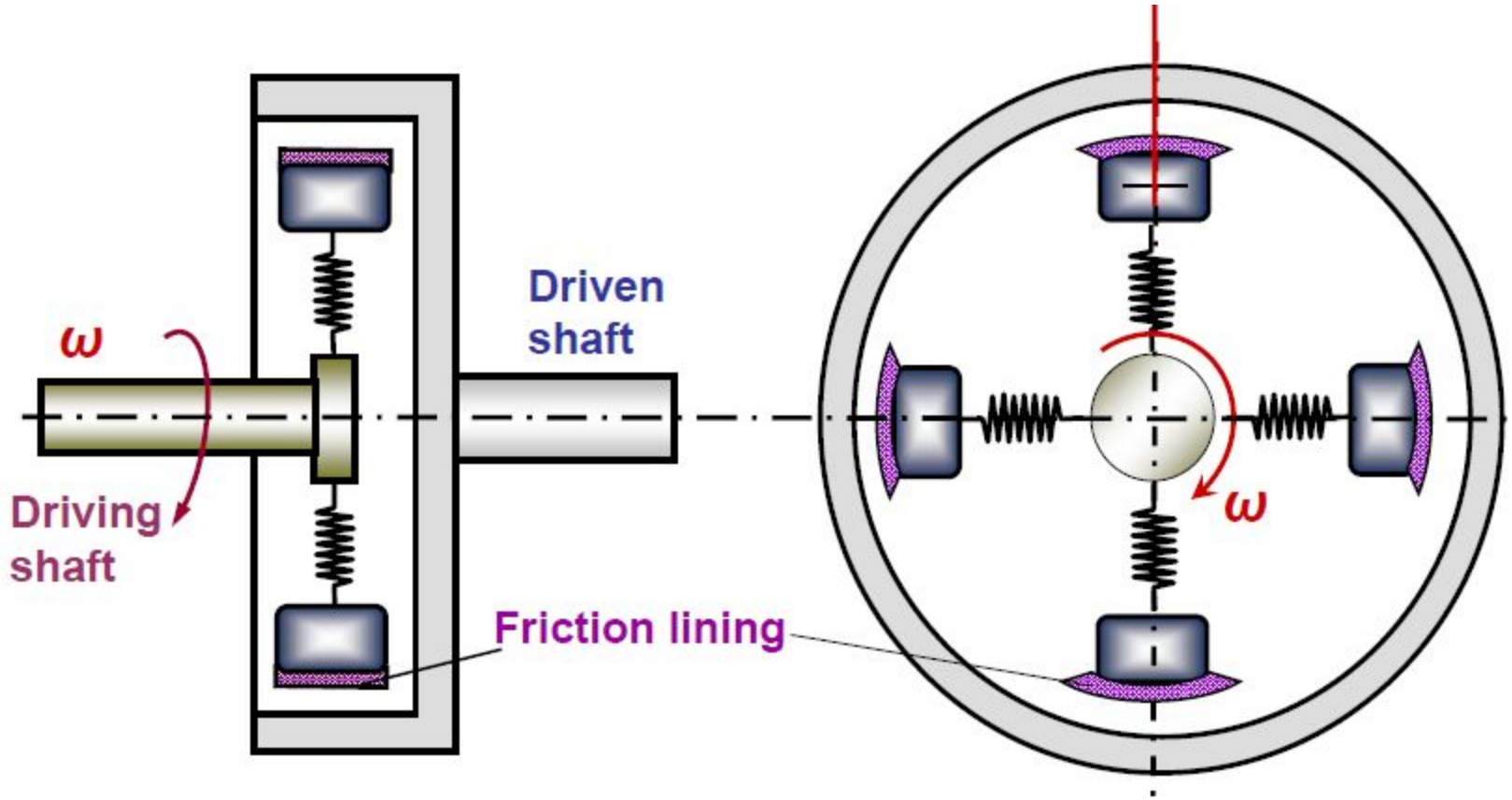
Single-plate Friction Clutch (Disengaged position)



Disengaged Haldex Clutch Assembly



Multi- plate Clutch



Centrifugal Clutch

Clutch

- Requirements of the clutch
  - Torque transmission
  - Gradual engagement
  - Heat dissipation
  - Dynamic balancing
  - Vibration damping
  - Inertia
- Torque capacity of the clutch depends on
  - Coefficient of friction
  - The diameter of the driven plate
  - Spring thrust applied by the pressure plate

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.

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

- Brakes
  - Mechanical
    - Block Brake
    - Internal Expanding Brake
    - Band Brake
    - Disc Brake
  - Hydraulic or Pneumatic
  - Electrical

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

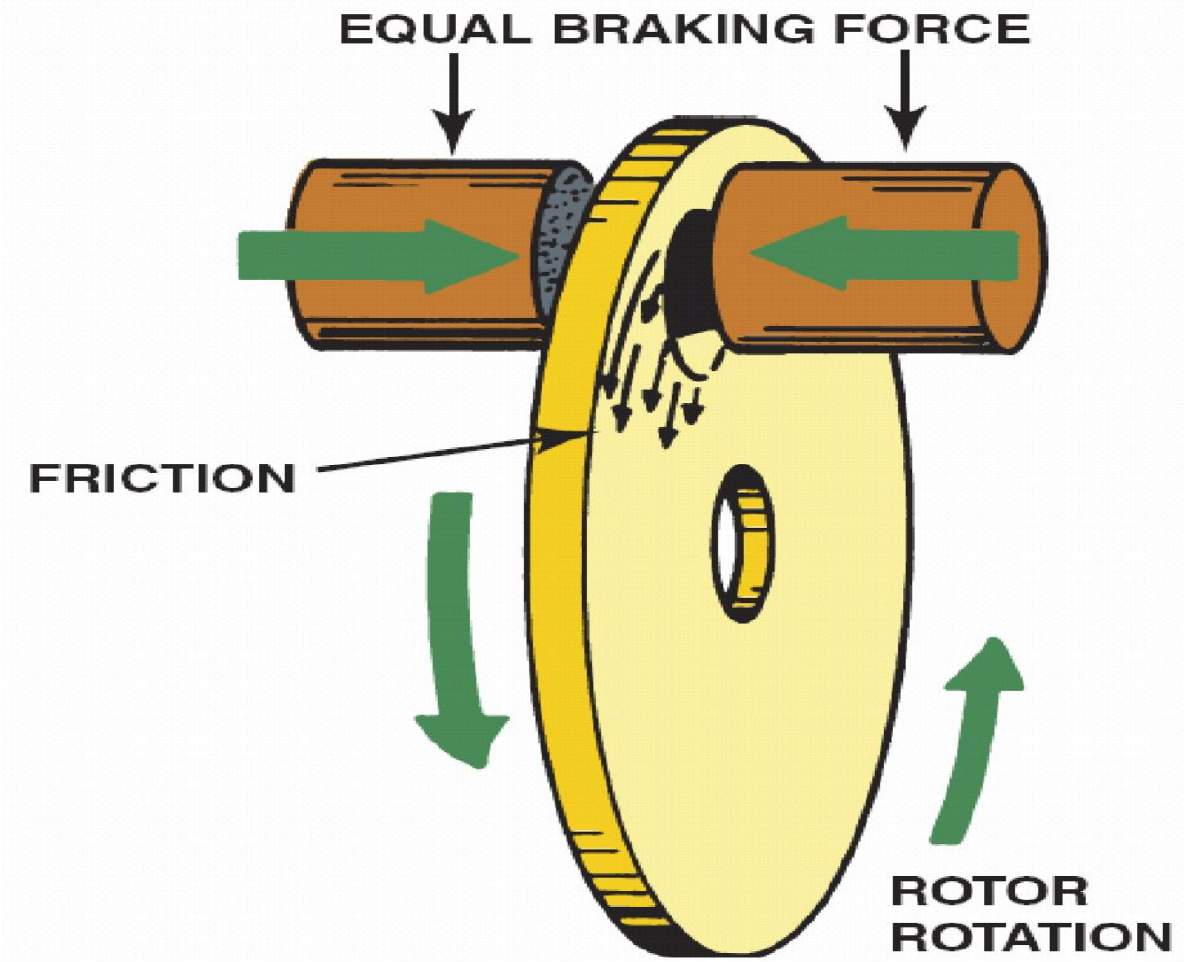
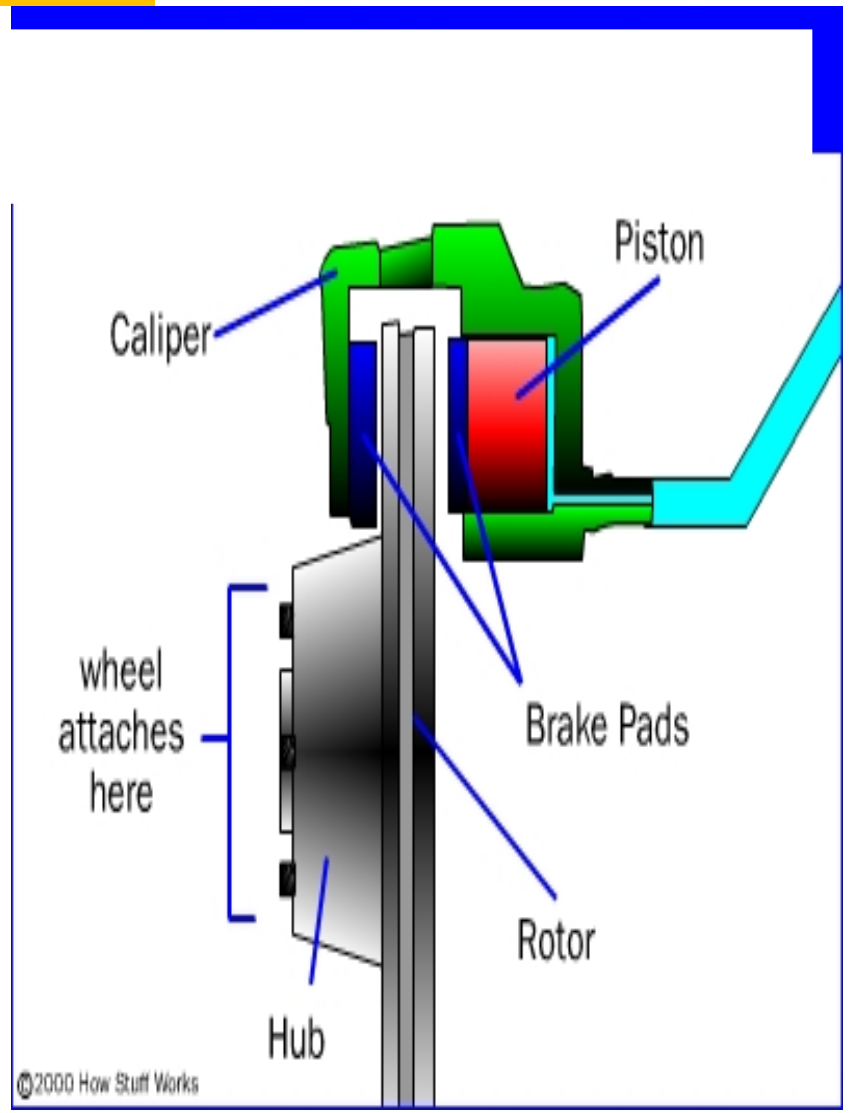


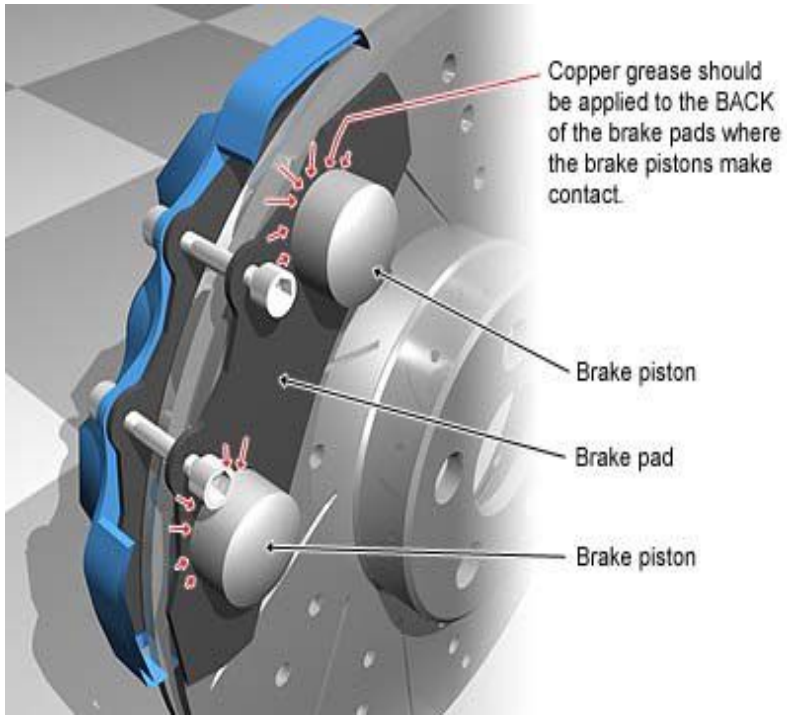
FIGURE . Braking force is applied equally to both sides of the brake rotor.

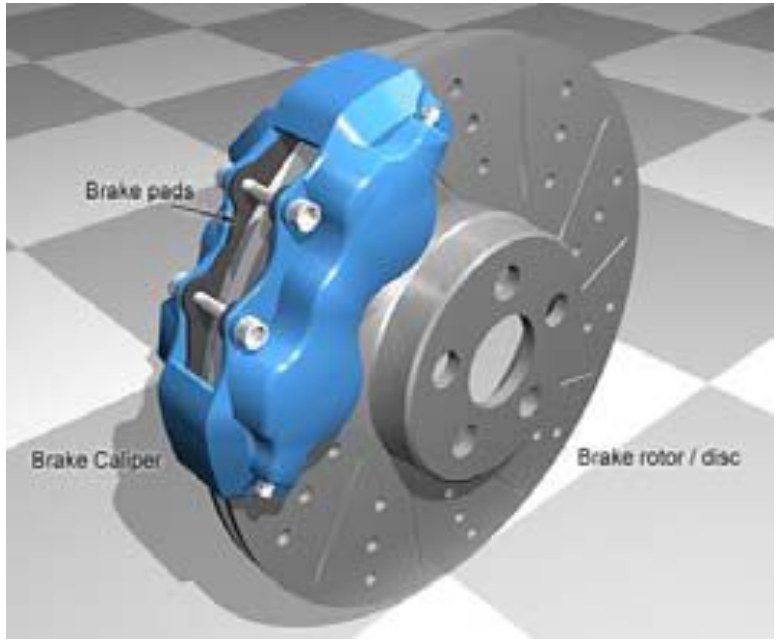
Disc Brake

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.




Copper grease should be applied to the BACK of the brake pads where the brake pistons make contact.
Brake piston
Brake pad
Brake piston


Brake pads
Brake Caliper
Brake rotor / disc

Power transmitting elements: Drives

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

Prime movers, power producing devices.

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

Power Transmitting link

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

Driven Machinery, Power absorbing devices

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

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.***

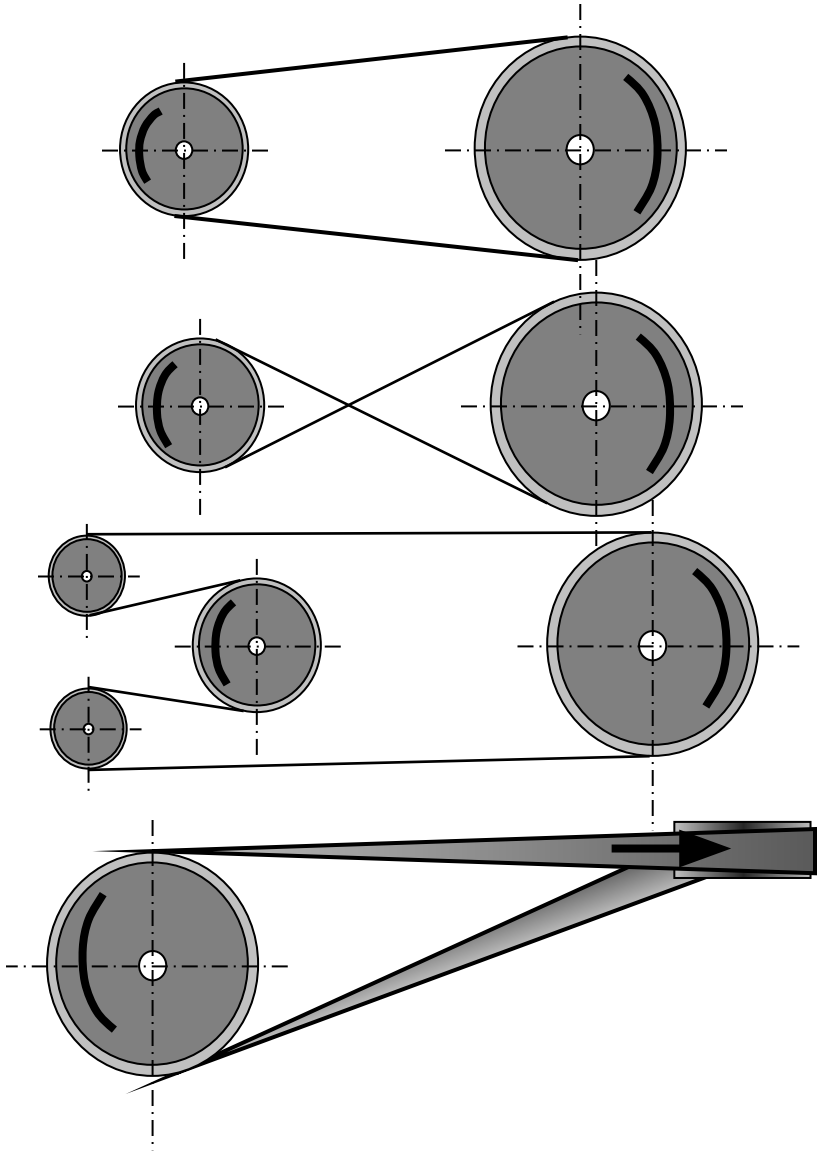
Layout of Flat belt drive :

Non-reversing Open Belt

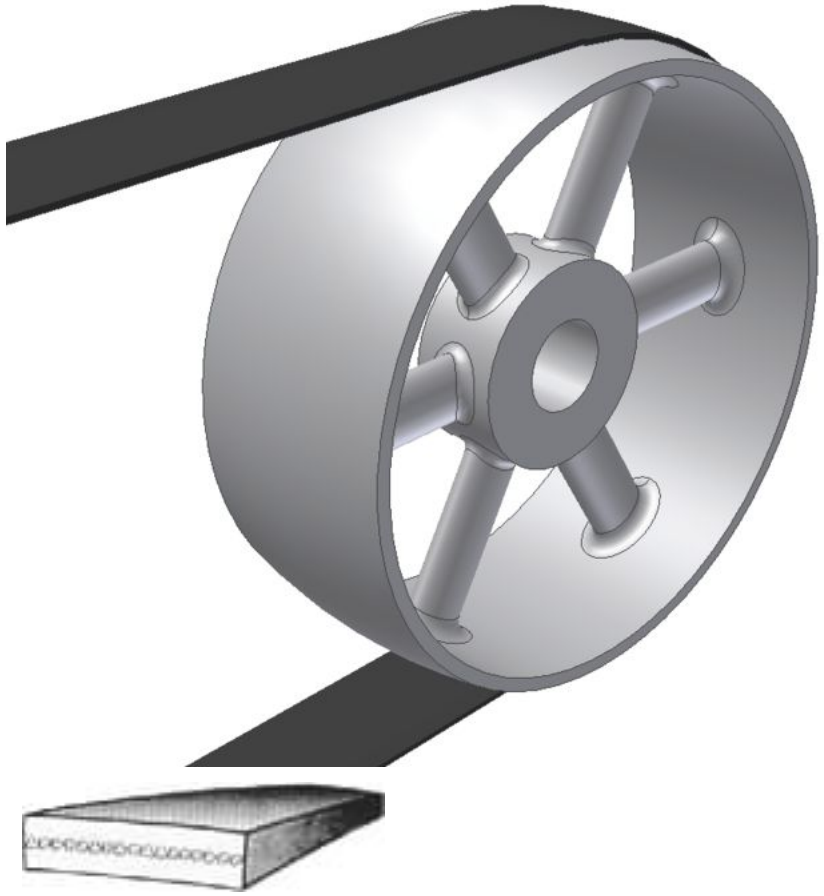
Reversing Crossed Belt

Reversing Open Belt

Quarter Twist Belt drive

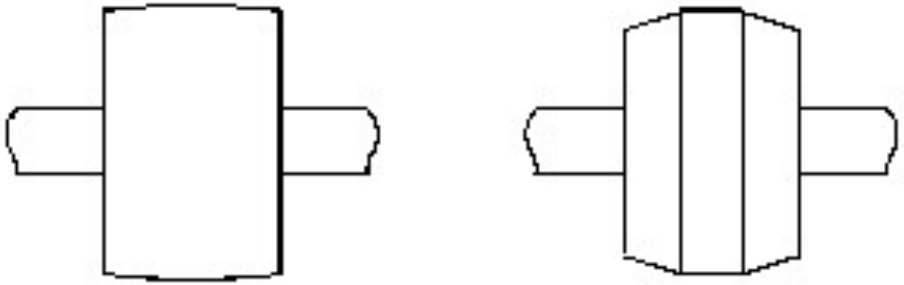


Flat Belt Drive



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

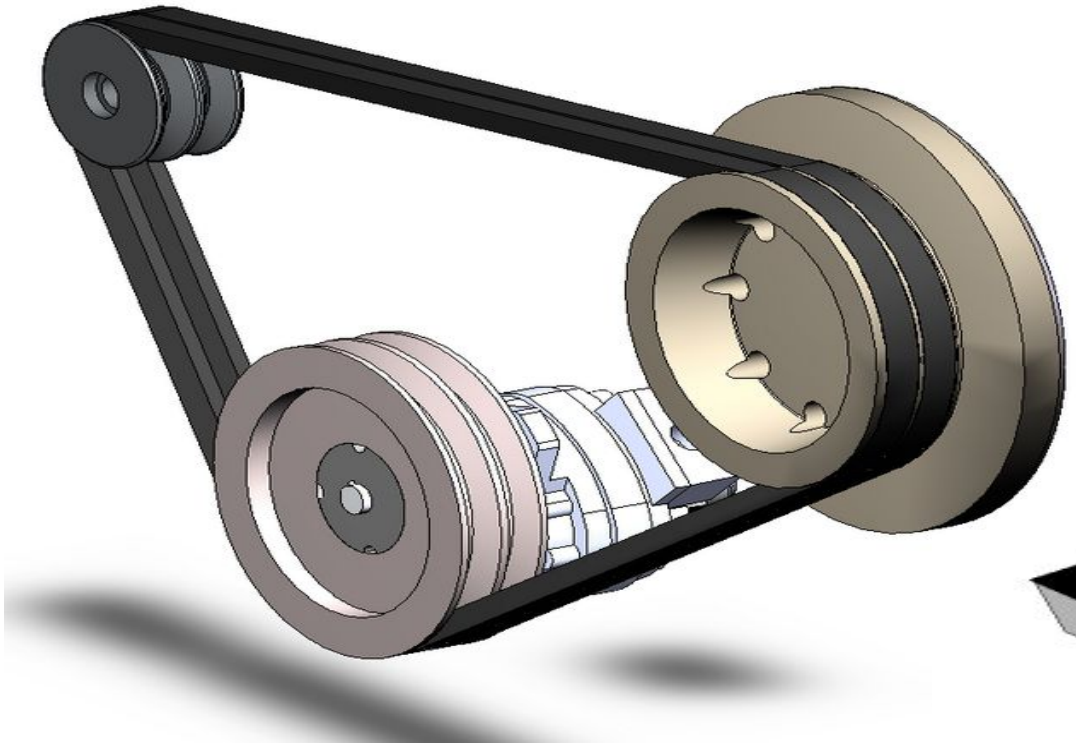
Flat belts:

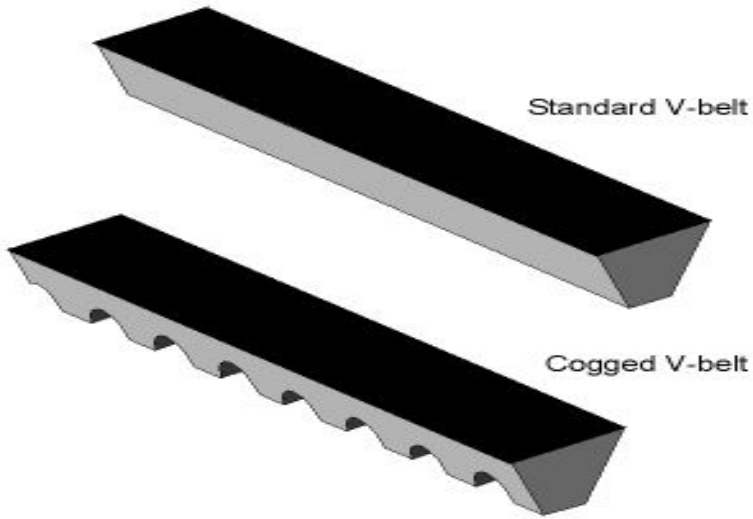
+Simple construction
+Low cost
+High flexibility
+High tolerance to overload
+Good resistance in abhrasive environments

-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

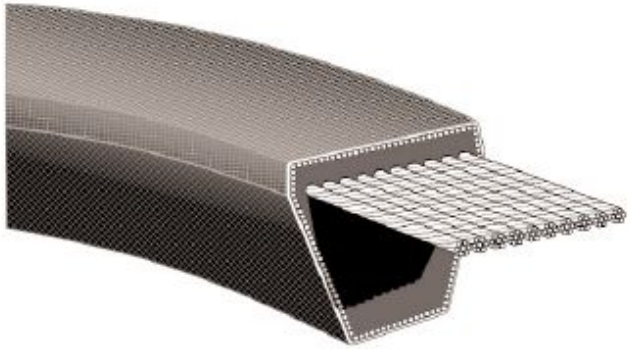




wikipedia.com

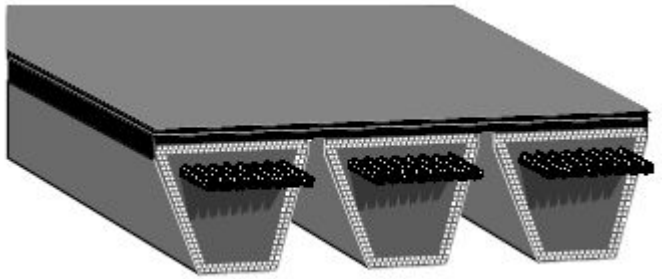
V Belt Drive

- 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

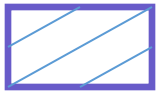
SYNCHRONOUS BELTS (TIMING BELTS)

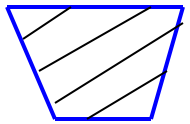
Synchronous belts are toothed belts where timing is guaranteed by the presence of the teeth. Load is transferred both by the teeth and the belt core.

Synchronous drives employ the positive engagement of two sets of meshing teeth. Due to this design, they do not slip and there is no relative motion between the two elements in mesh. The positive nature of these drives makes them capable of transmitting large torques and withstand large accelerations. However, chain drives are often used where positive synchronization between shafts and transmission of substantial torque is required.

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	Dives are compact
Wide range of materials, leather, cotton, fabric, balata	Only rubber and fabric materials are used.

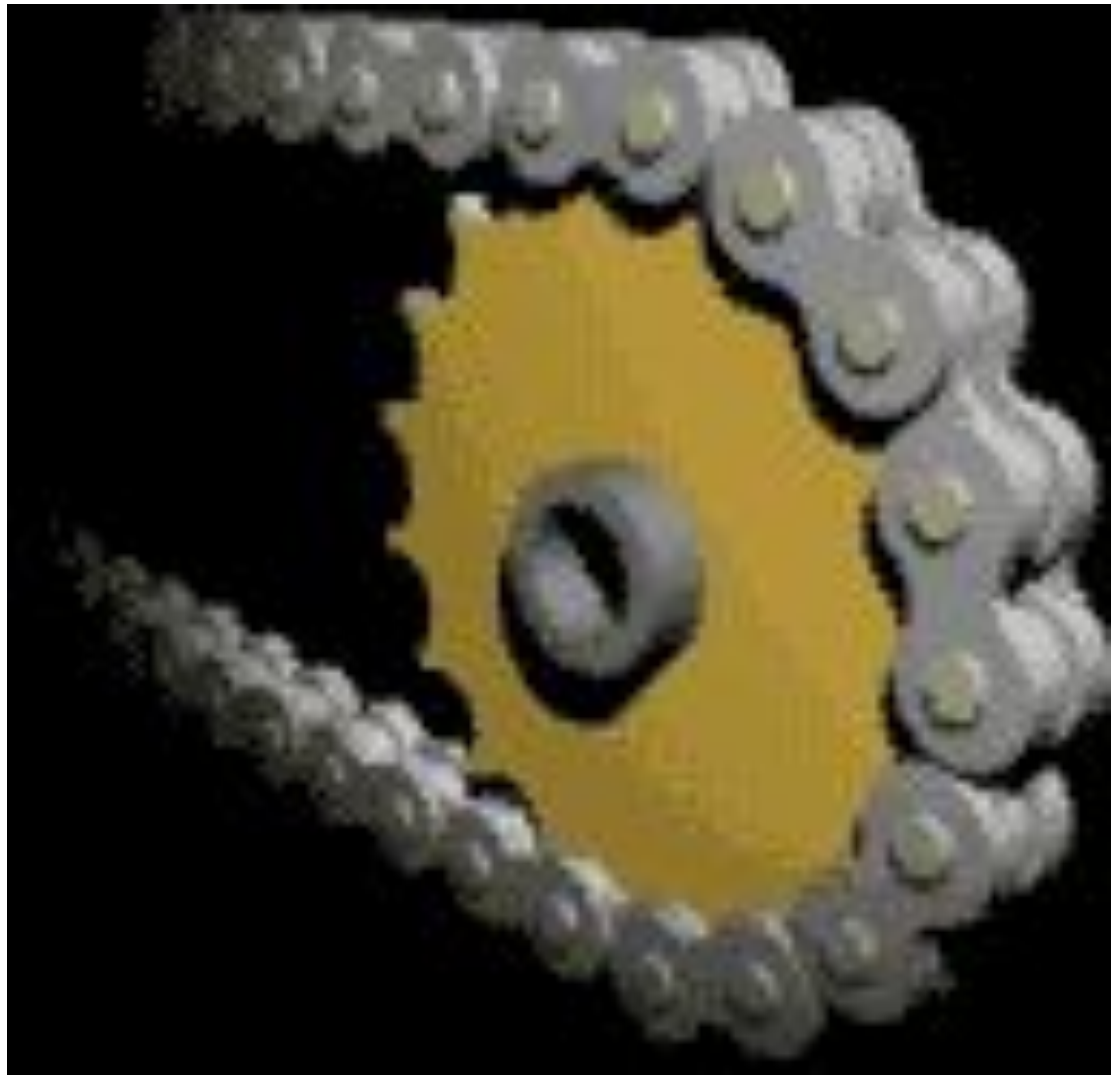




Belts vs. Chains

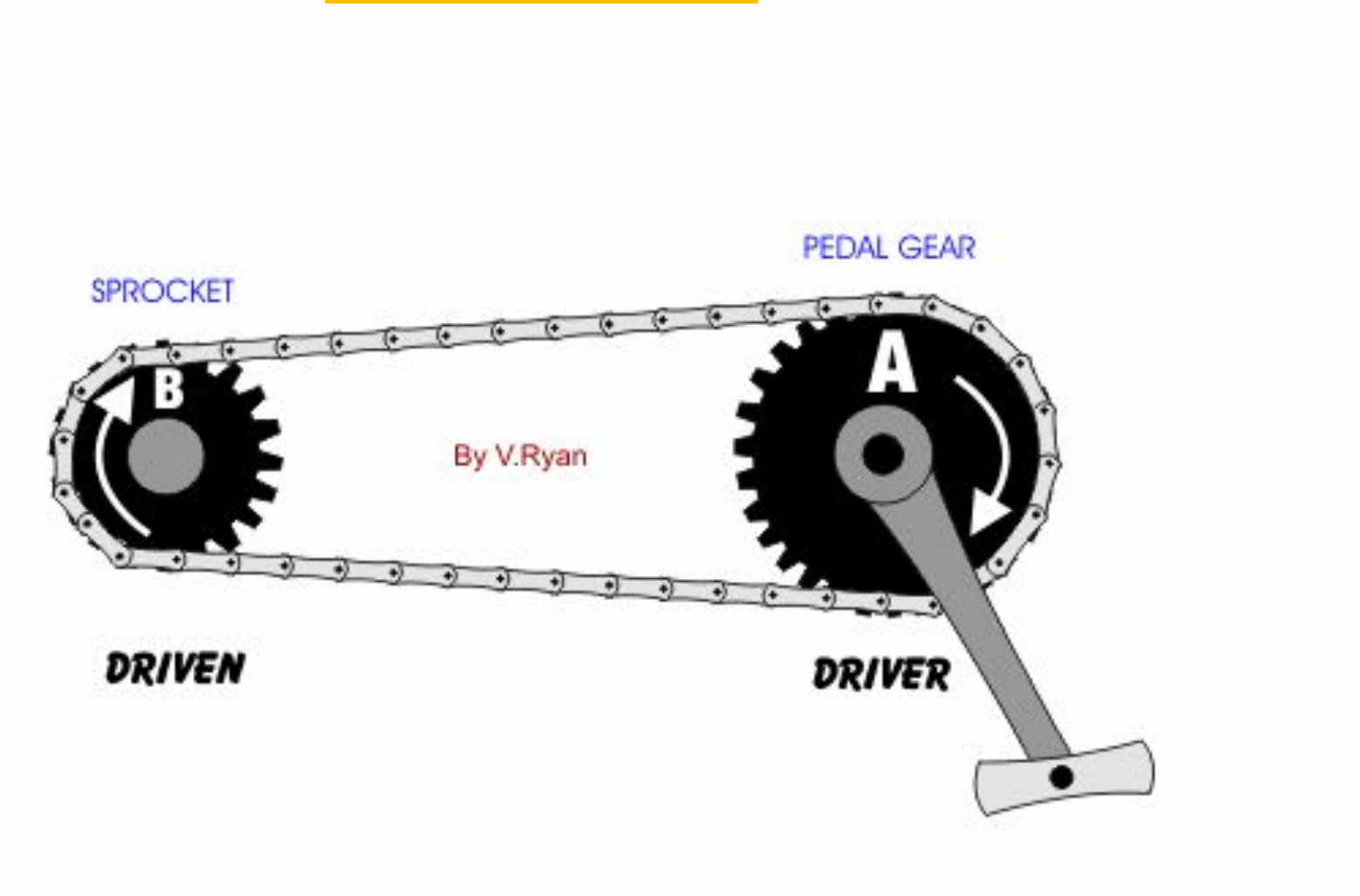
	Belts	Chains
Type of Drive	Friction Drive	Positive Drive
Use When:	High Speed, Low Torque	High Torque, Low Speed
Speed:	$2500 < V_t < 7000$ ft./min.	$V < 1500$ ft./min.
Disadvantages:	Must design with standard lengths, wear, creep, corrosive environment, slip, temp., when must have tension need idler	Must be lubricated, wear, noise, weight, vibration
Advantages:	Quiet, flexible, cost	Strength, length flexibility

Chain Drive



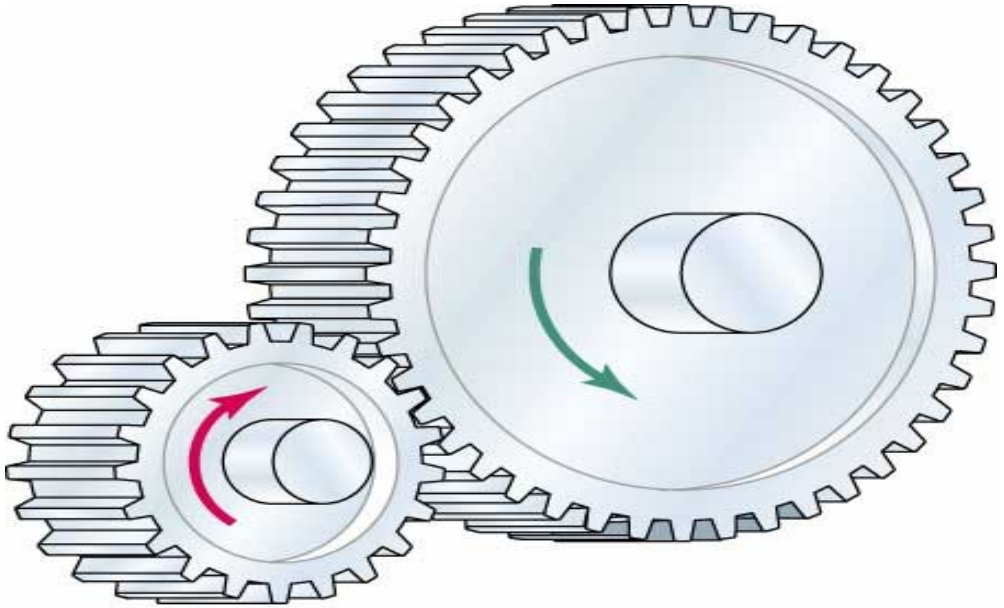
- Positive drives
- Large torque transmitting
- No slip results into constant velocity ratio
- Higher efficiency
- Speed ratios up to 10:1 are possible.
- They are costly, and noisy.
- Precise alignment is required.

Chain Drive



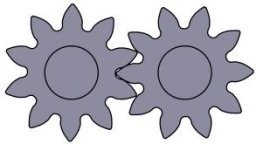
GEAR

- 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



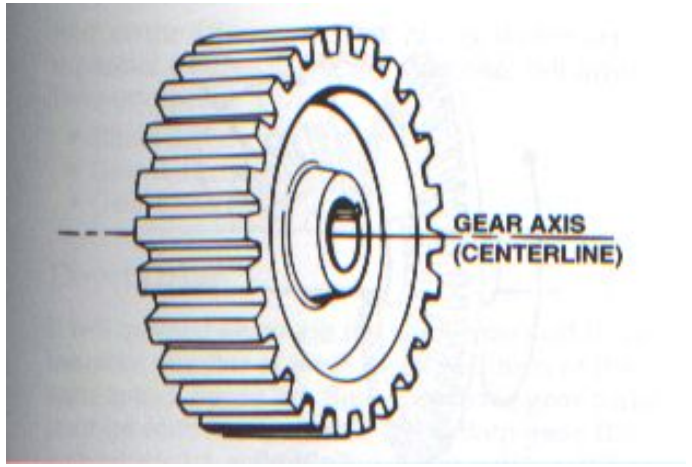
Classification of the Gears based upon position of shaft axes

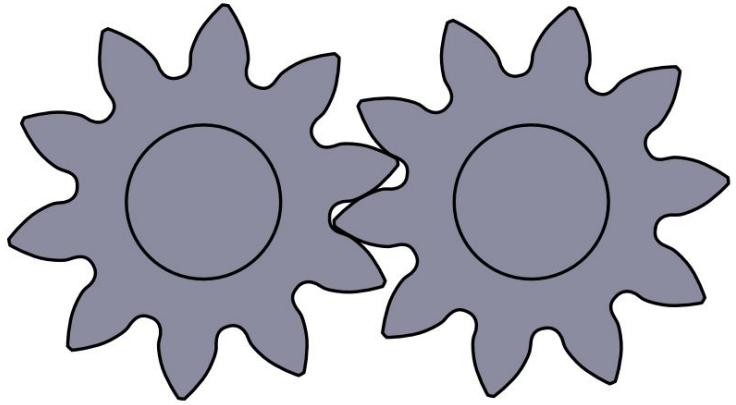
- **GEAR**
  - **Parallel Shaft**
    - **Spur**
    - **Helical**
    - **Rack & Pinion**
  - **Intersecting Shaft**
    - **Bevel**
  - **Non – parallel and non Intersecting**
    - **Spiral**
    - **Worm**



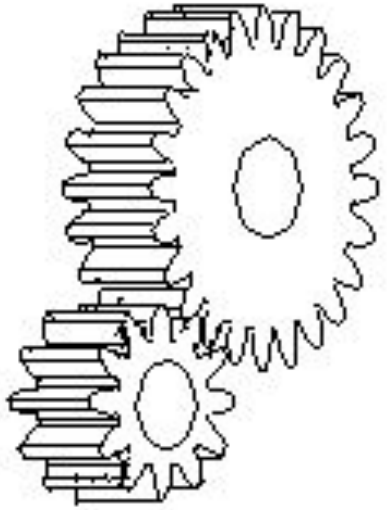
Spur Gears

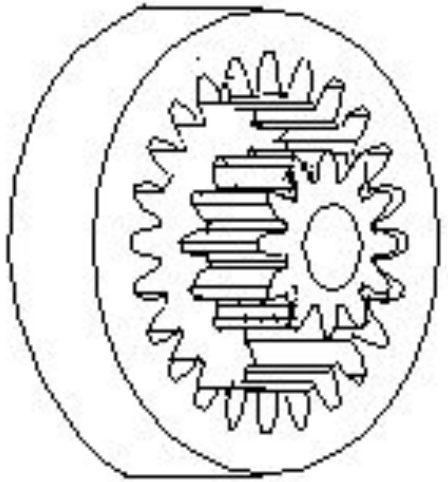
- Teeth is parallel to axis of rotation
- Transmit power from one shaft to another parallel shaft
- Used in Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer





External and Internal Spur Gear…





Advantages

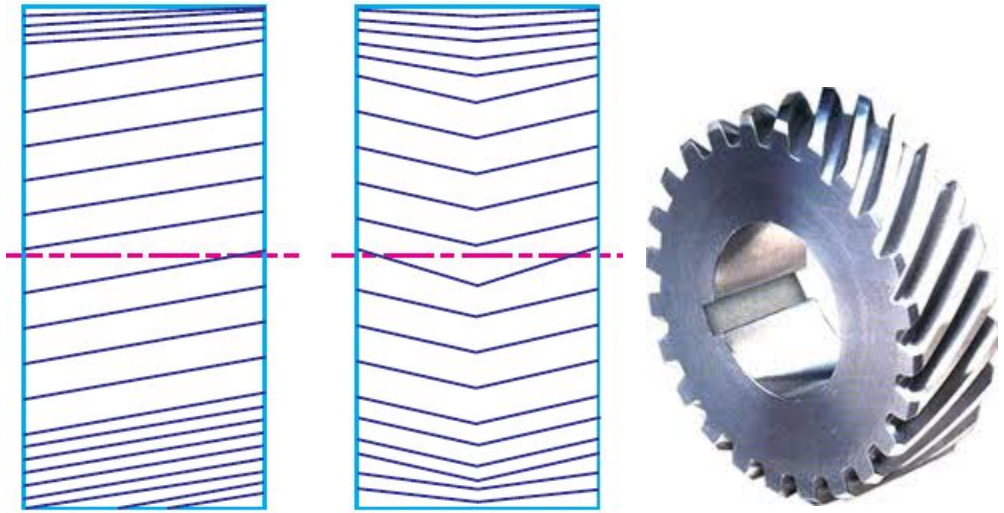
1. It transmits exact velocity ratio.
2. It may be used to transmit large power.
3. It has high efficiency.
4. It has reliable service.
5. It has compact layout.

Disadvantages

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

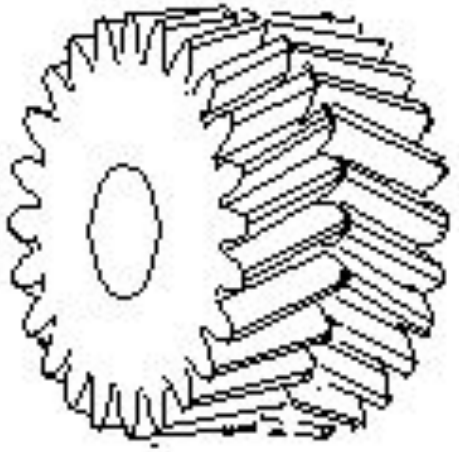
Helical Gear

- 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

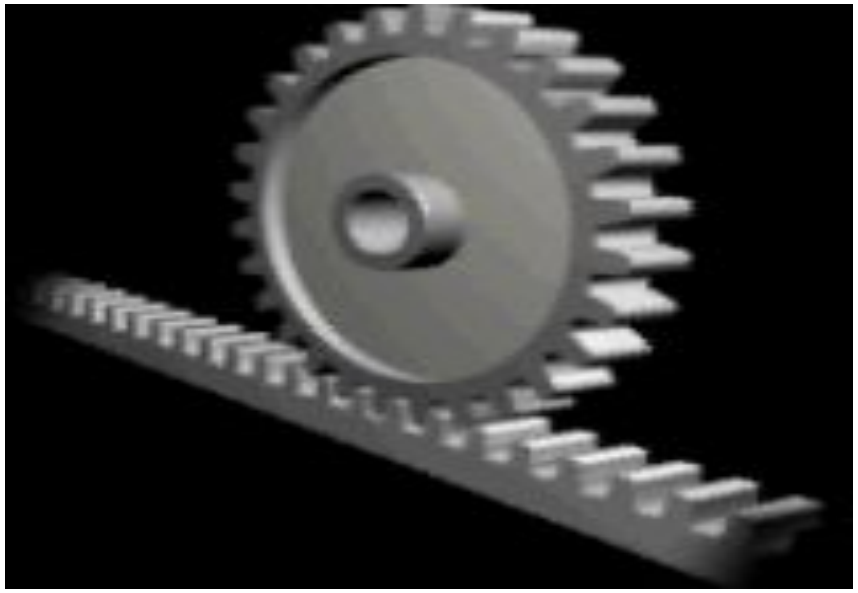


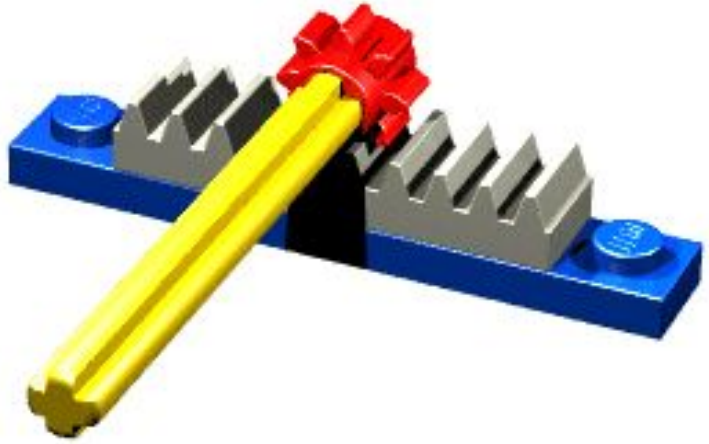
- Herringbone gears are mostly used on heavy machinery.

Rack and pinion

- **Rack and pinion gears** are used to convert rotation (From the pinion) into linear motion (of the rack)

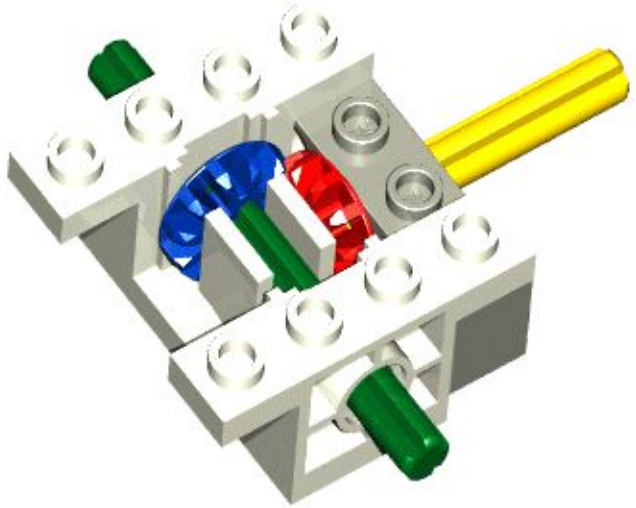
- A perfect example of this is the steering system on many cars





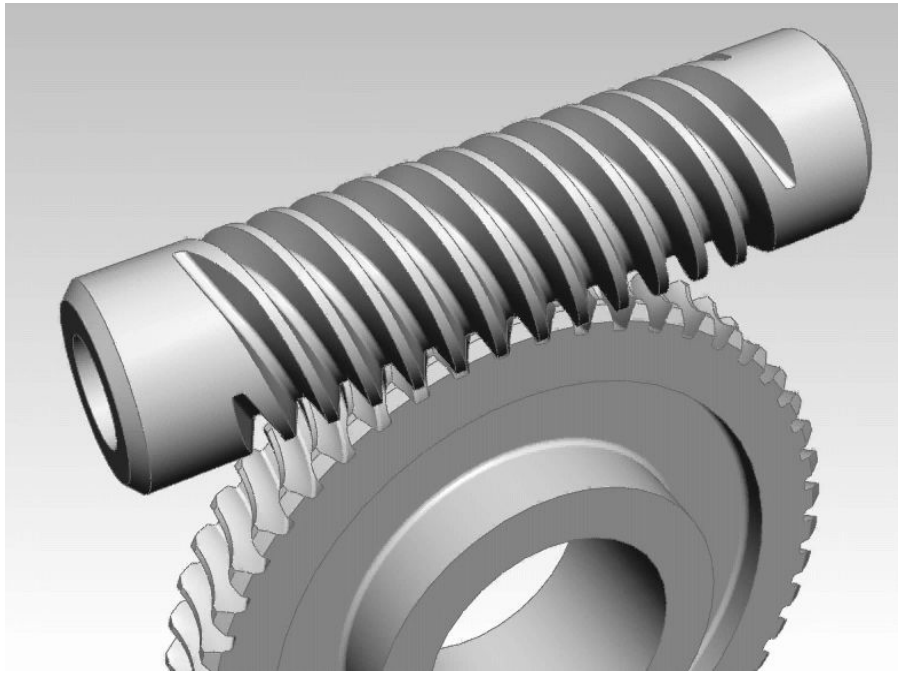
Bevel gears

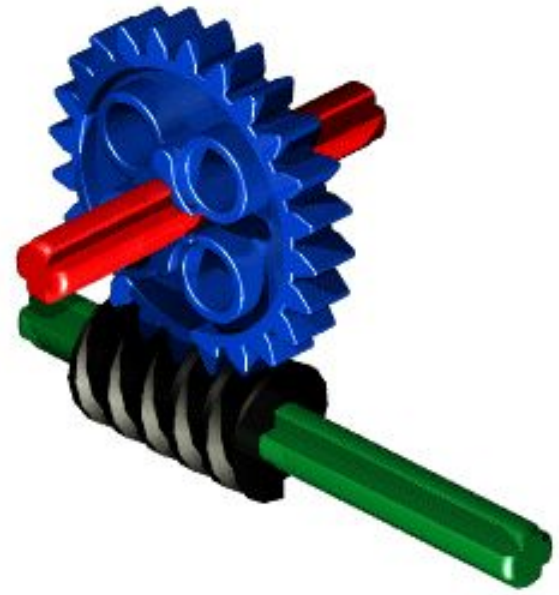
- **Bevel gears** are useful when the direction of a shaft's rotation needs to be changed
- They are usually mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well
- The teeth on bevel gears can be **straight**, **spiral** or **hypoid**
- locomotives, marine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

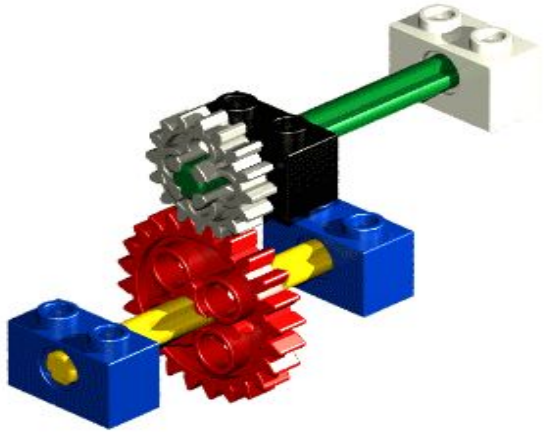


Worm And Worm Gear

- **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

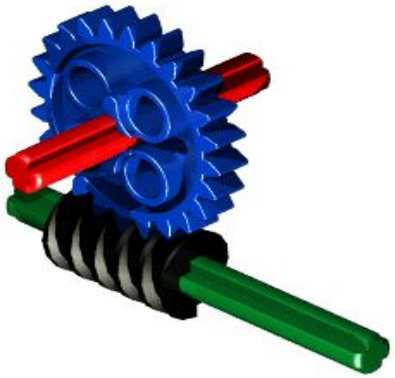




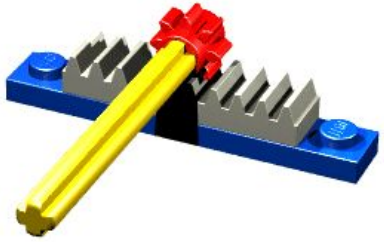


Spur Gears

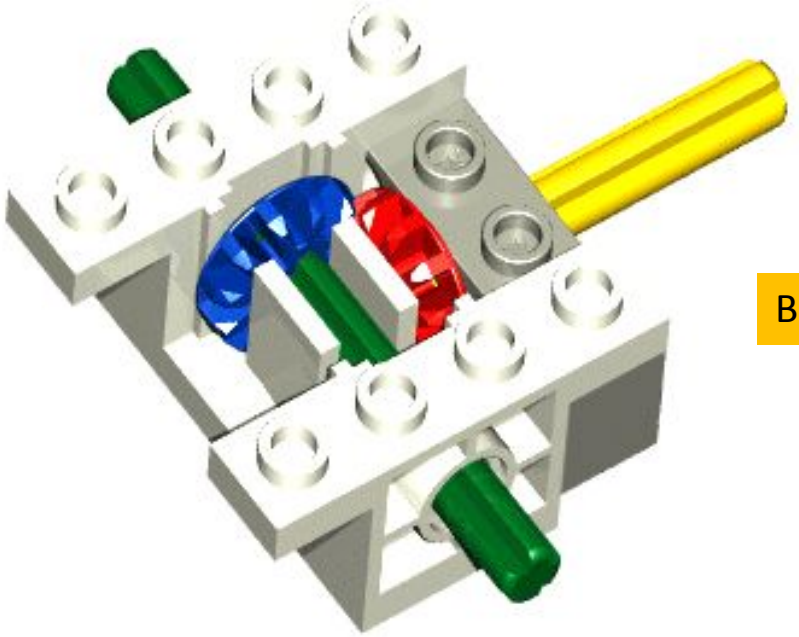
Bevel Gears



Worm and Worm wheel



Rack and Pinion



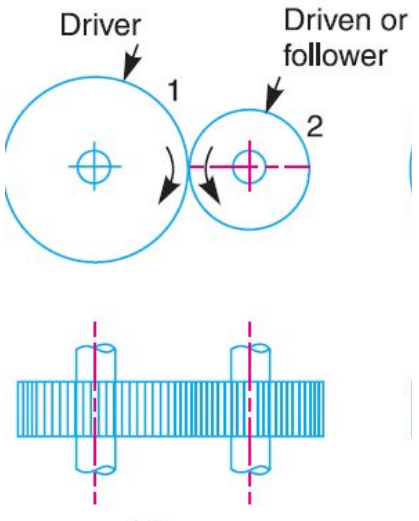
Bevel Gears

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.



(*a*)

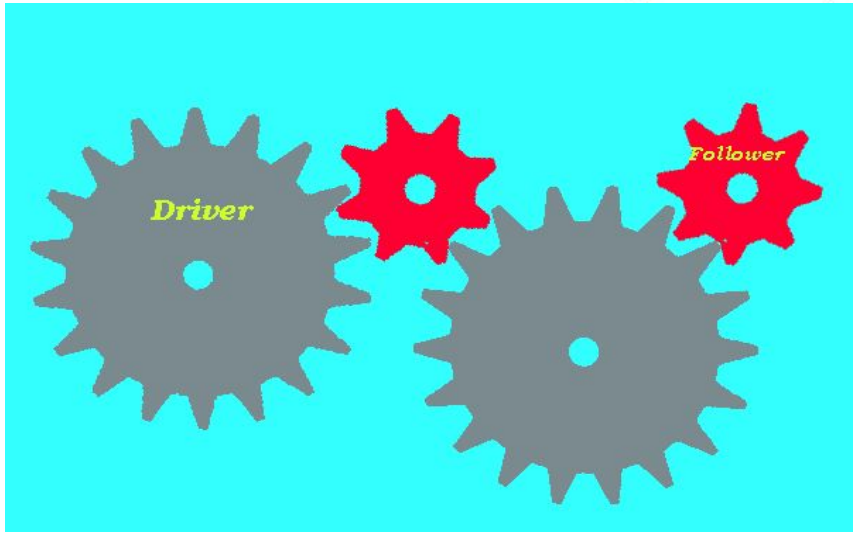
Since the speed ratio (or velocity ratio) of gear train is the ratio of the speed of the driver to the speed of the driven or follower and ratio of speeds of any pair of gears in mesh is the inverse of their number of teeth, therefore

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

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,

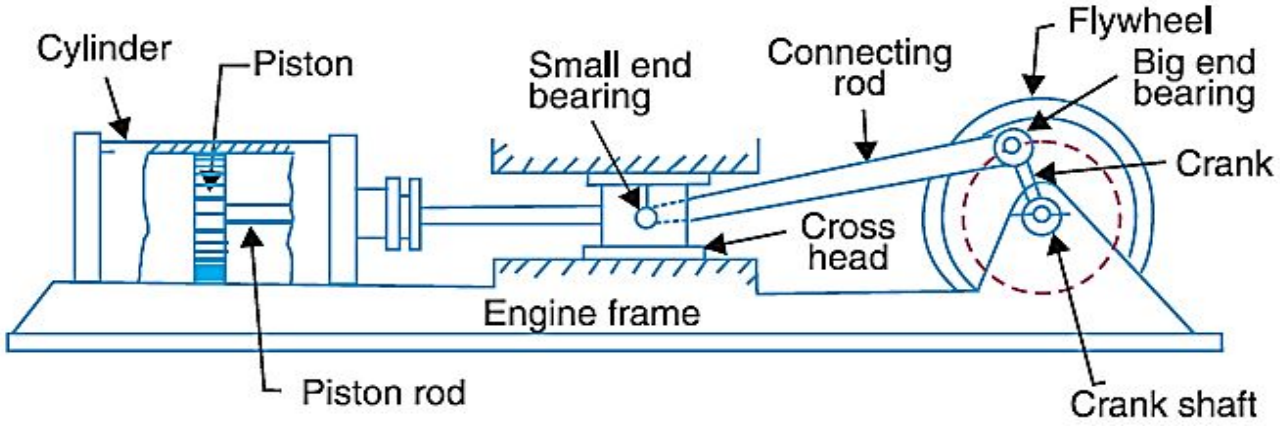
$$\text{Train value} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$

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



Mechanisms: Kinematic Link or Element

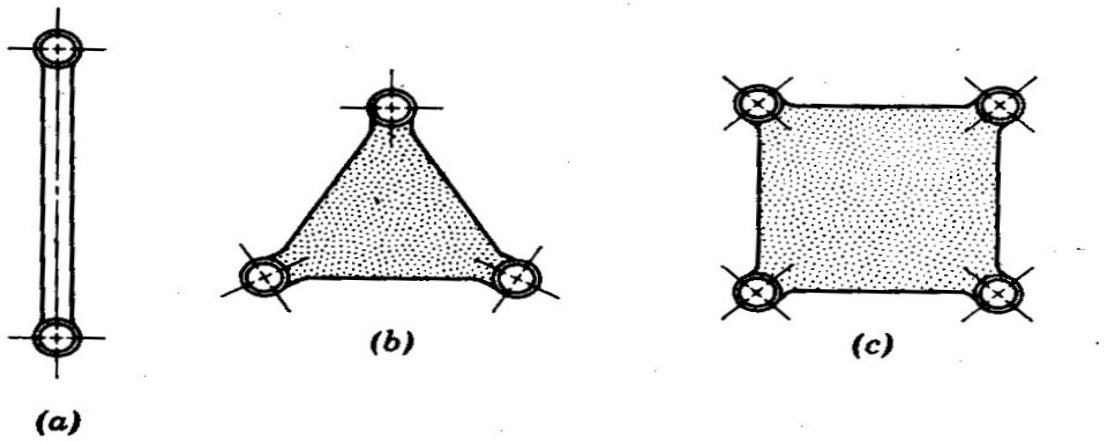
- Each part of a machine, which moves relative to some other part, is known as a *kinematic link (or simply link) or element.*
- *A link may consist of several parts, which are rigidly* fastened together, so that they do not move relative to one another.
- For example, in a reciprocating steam engine, 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.*

Types of Constrained Motions

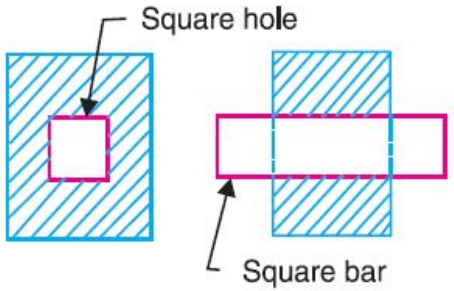
Following are the three types of constrained motions :

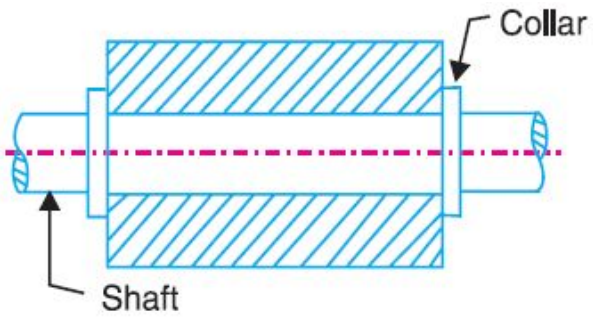
1. ***Completely constrained motion.***

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.



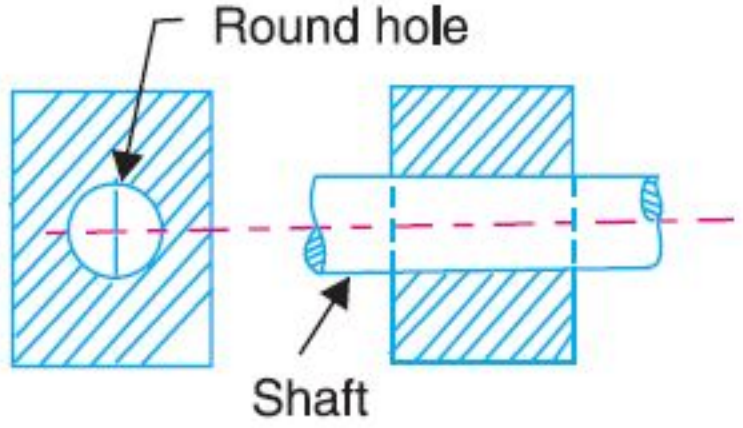


2. *Incompletely constrained motion.*

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.



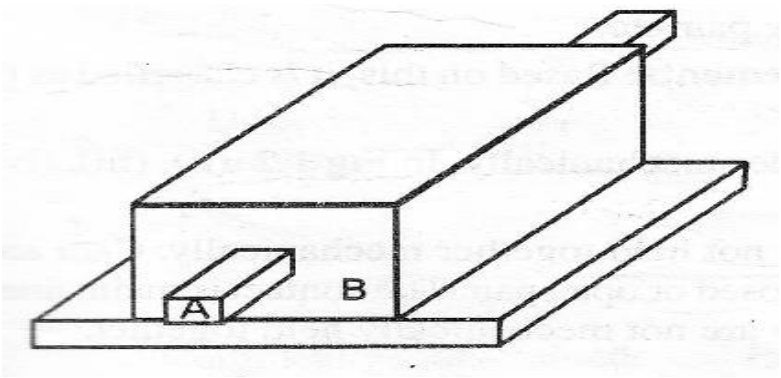
Classification of Kinematic Pairs

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

(a) Sliding pair.

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.

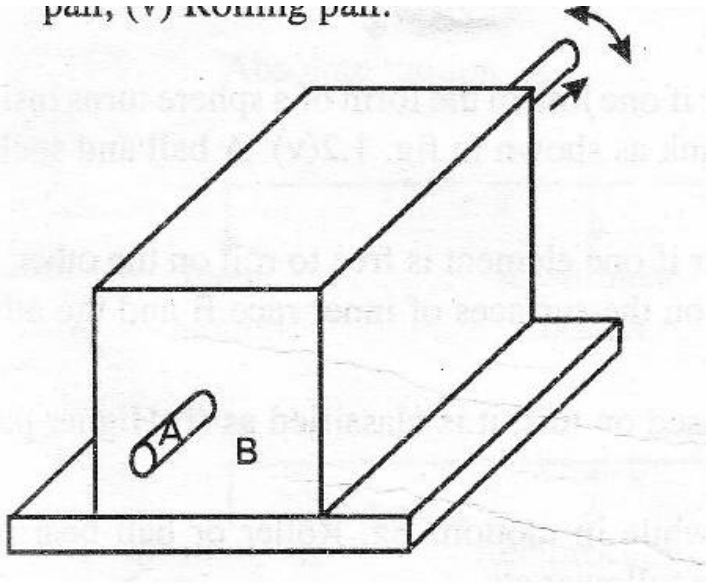


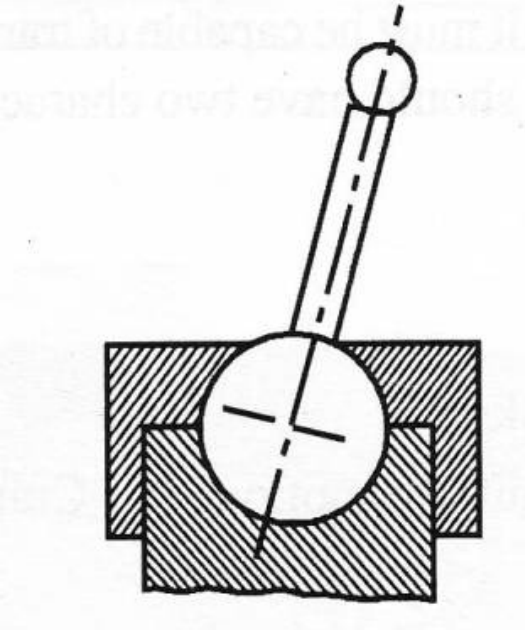
(*b) Turning pair.*

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.*

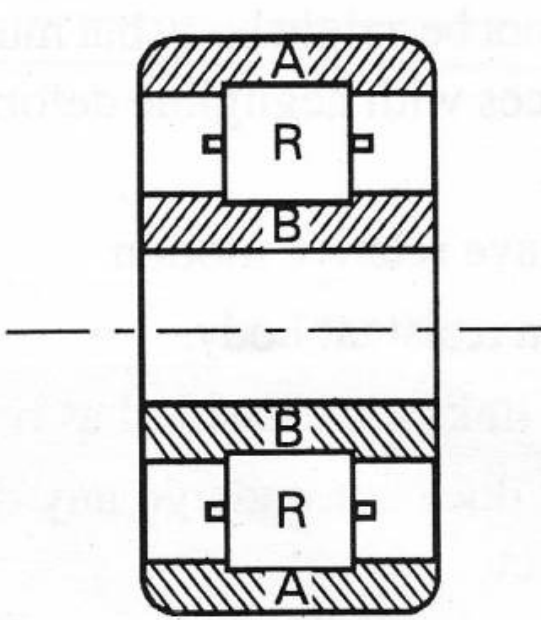
When the two elements of a pair are connected in such a way that one element (with spherical shape) turns or swivels about the other fixed element, the pair formed is called a spherical pair. The ball and socket joint, attachment of a car mirror, pen stand etc., are the examples of a spherical pair.





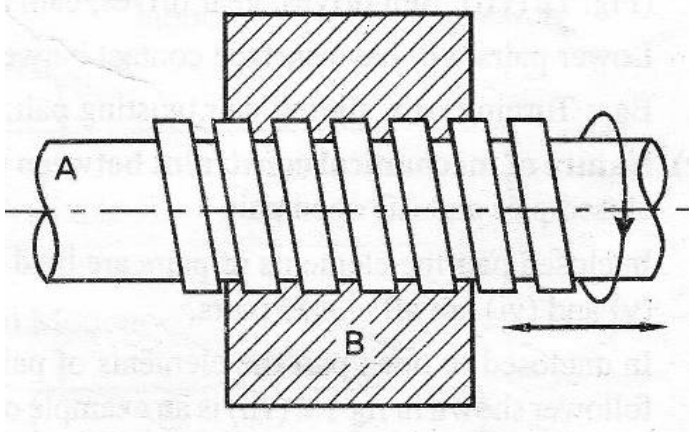
(d) Rolling pair.

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.

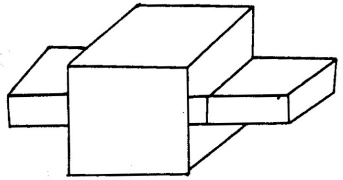
When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads, the pair is known as screw pair. The lead screw of a lathe with nut, and bolt with a nut are examples of a screw pair.

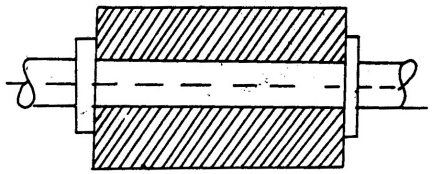


2. *According to the type of contact between the elements.*

(a) Lower pair.

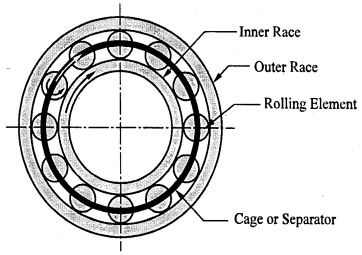
When the two elements of a pair have a surface contact when relative motion takes place and the surface of one element slides over the surface of the other, the pair formed is known as lower pair. It will be seen that sliding pairs, turning pairs and screw pairs form lower pairs.





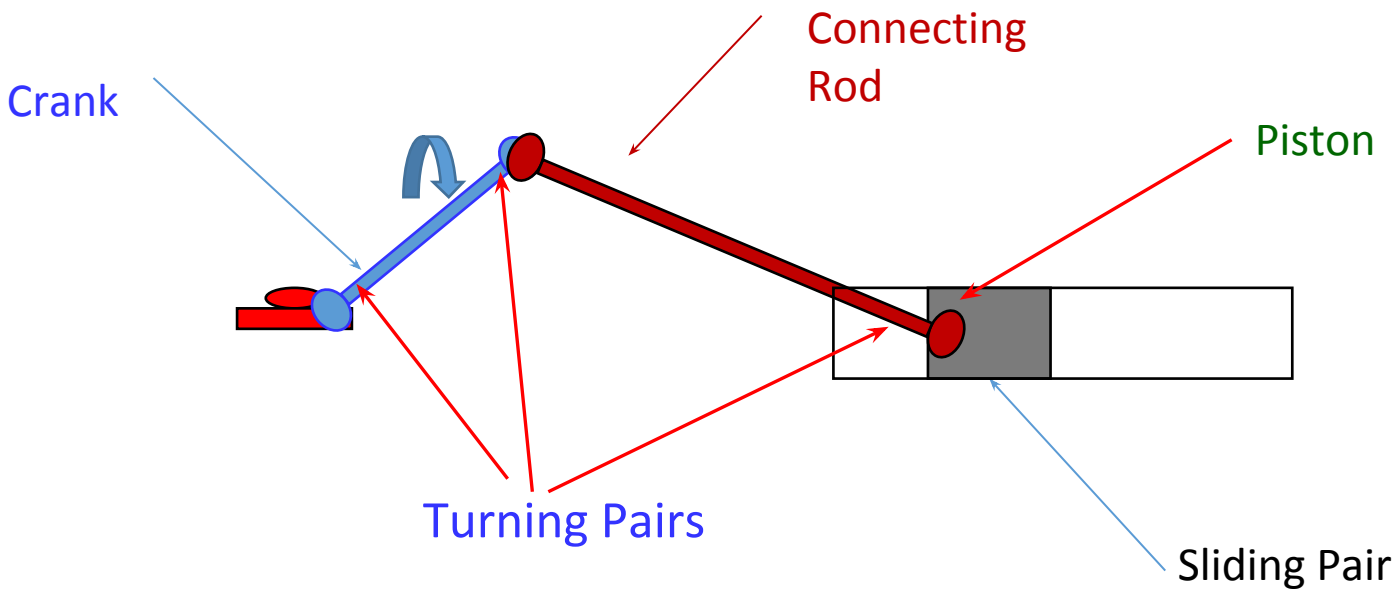
(b) Higher pair.

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:

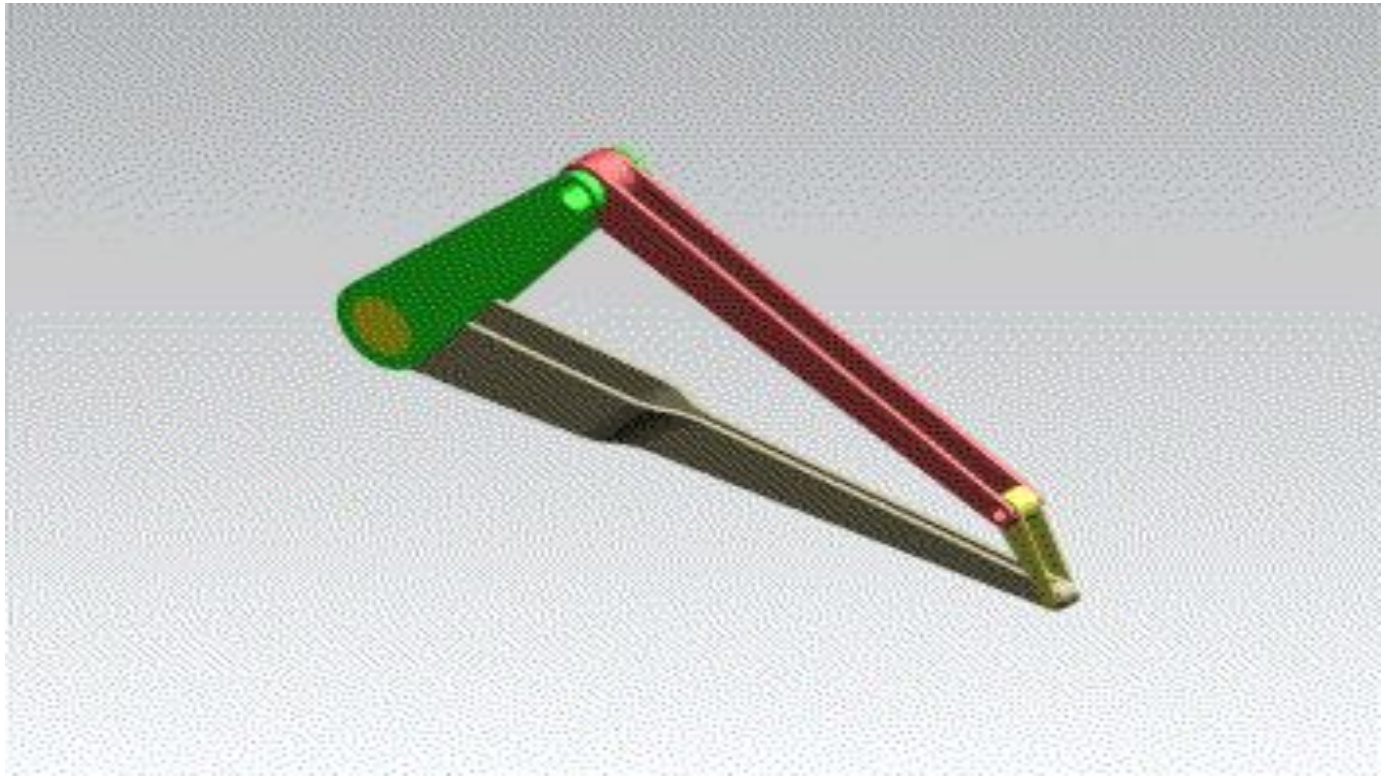
- A mechanism is one in which one of the links of a kinematic chain is fixed.
- Different mechanisms can be obtained by fixing different links of the same kinematic chain.
- These are called as inversions of the mechanism.

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, and**
3. **Double slider crank chain.**

Simple Four Bar Mechanism

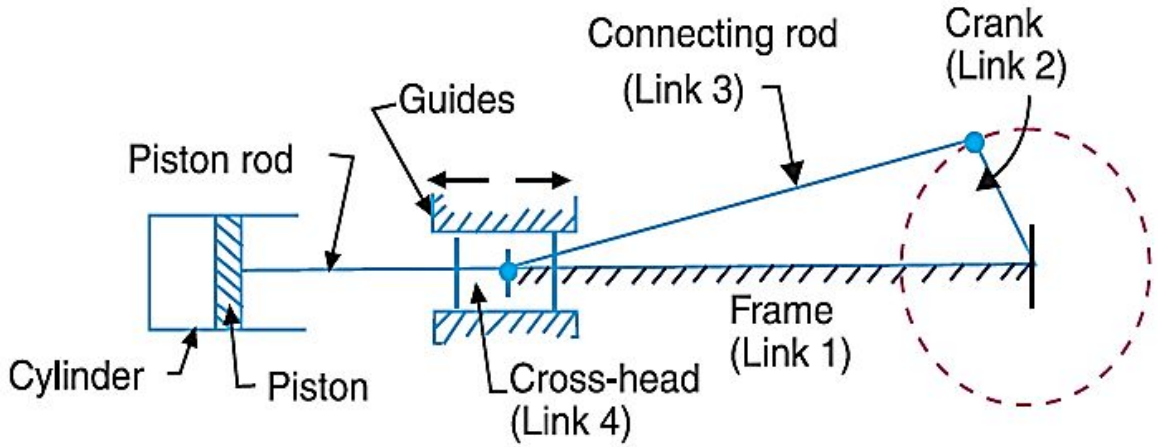


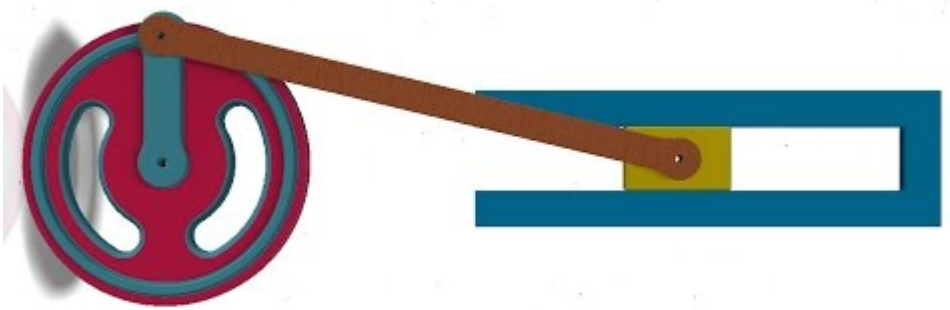
Grashof's Law

- 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.

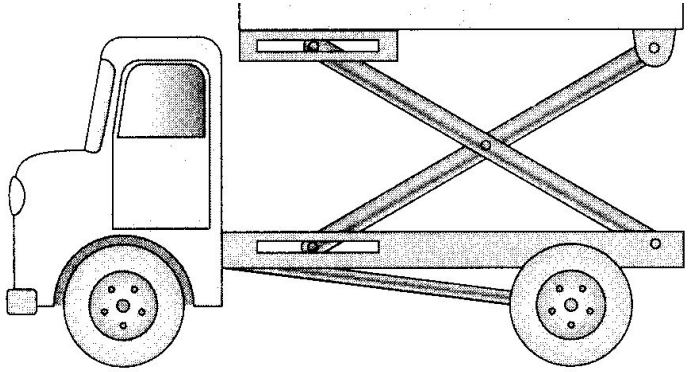
Single Slider Crank Chain

- A single slider crank chain is a modification of the basic four bar chain.
- It consist 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.

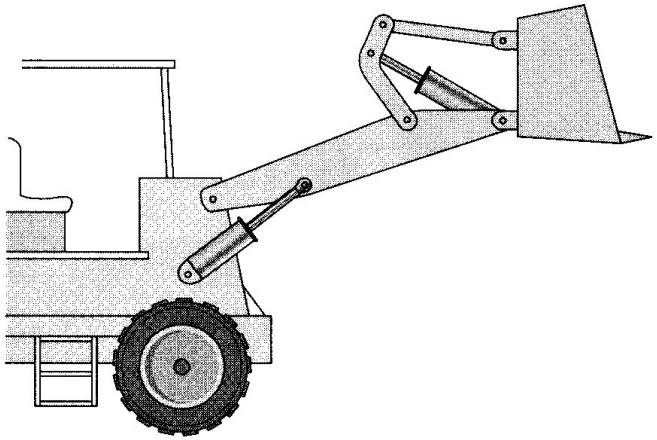




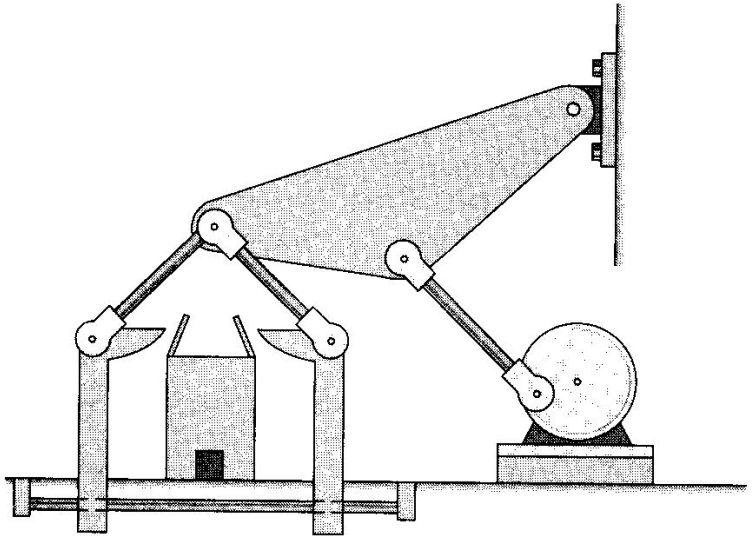
Example of Mechanisms



Lift platform

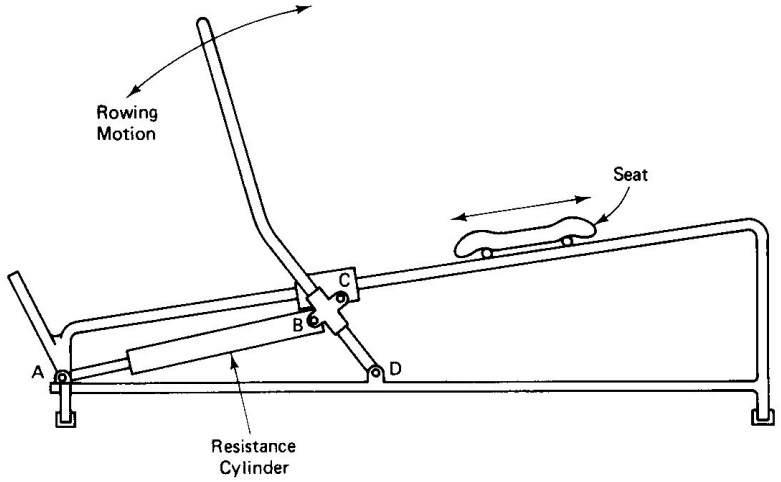


Front loader

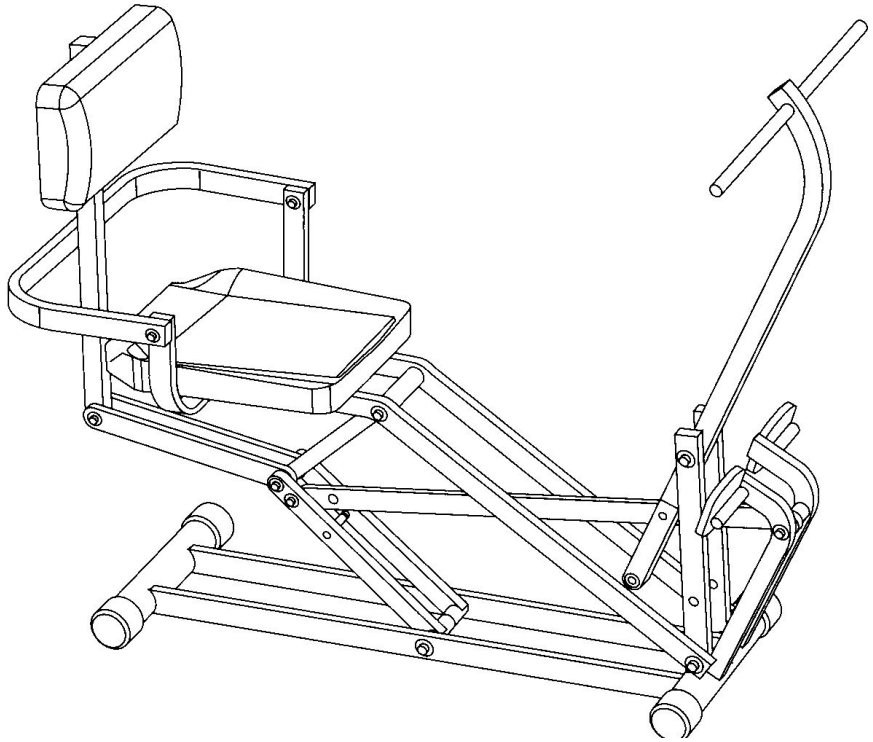


Device to close the top flap of boxes

Example of Mechanisms



Rowing type exercise machine



Conceptual design for an exercise machine

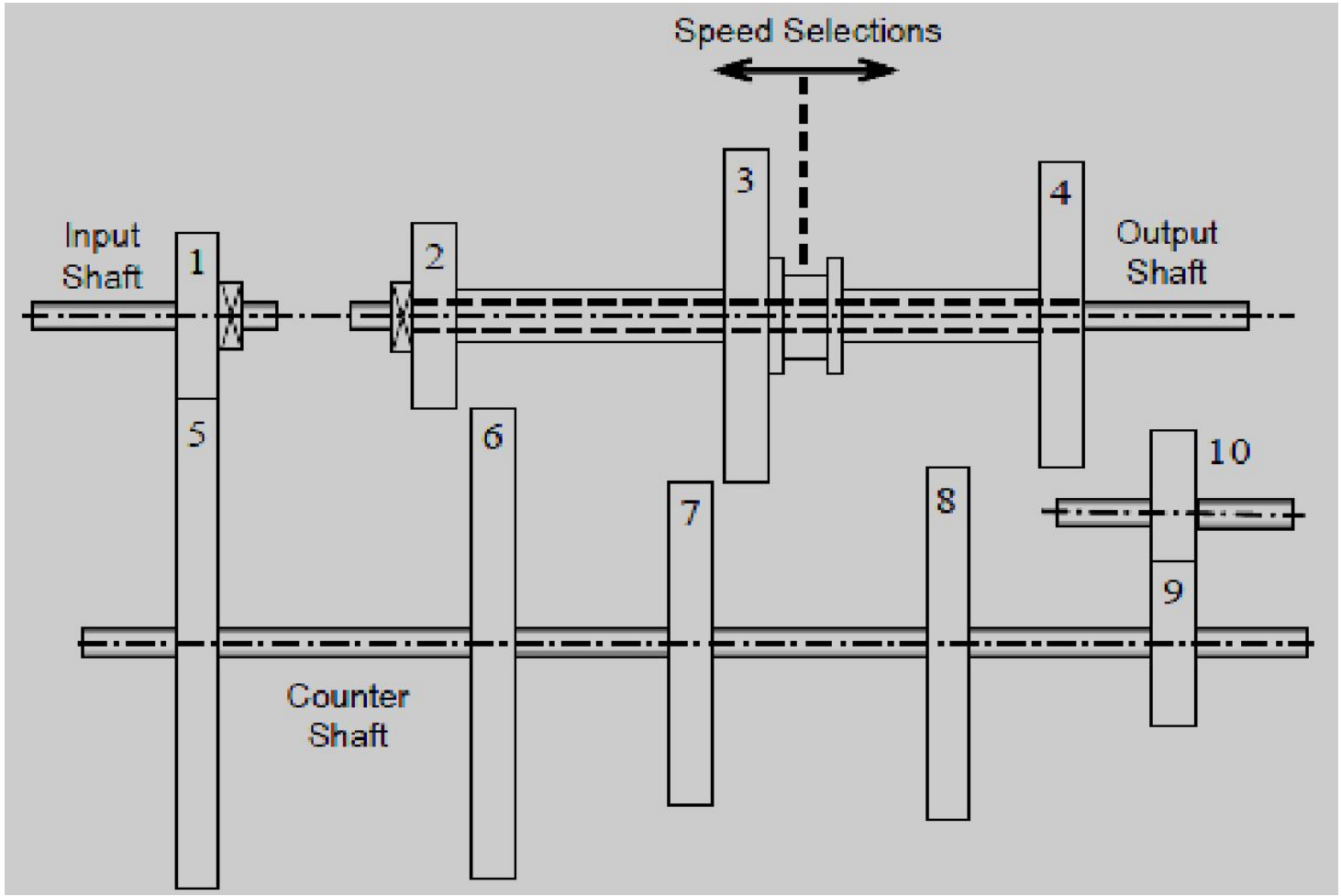
Machine:

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 lockengine, etc.	Examples of machine are: I.C. engine, shaping machine, hand pump, etc.

Numericals :

For the gear train shown below, calculate speed at output shaft:



The numbers of teeth on the various gear wheels are as follows:

Gear Wheel	Number of Teeth	Gear Wheel	Number of Teeth
1	12	6	35
2	15	7	25
3	25	8	30
4	20	9	12
5	38	10	12

Complete the table below

Gear in mesh	Output shaft speed
2 and 6	
3 and 7	
4 and 8	
4 and 10	

Thank You