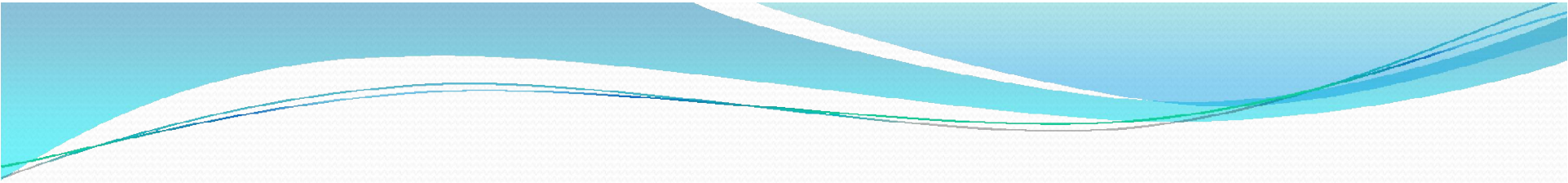


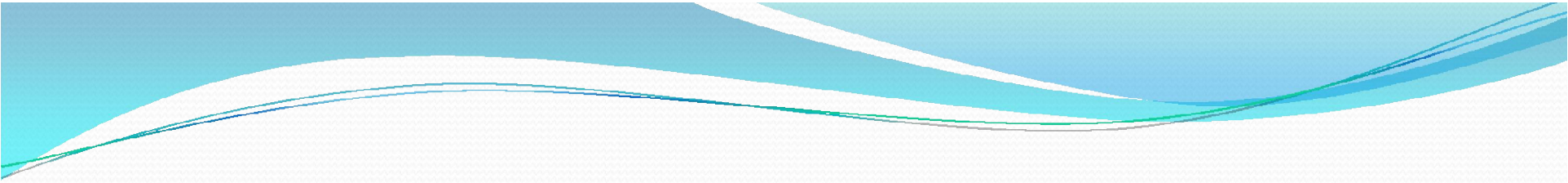
STC

Charbagh, Lucknow



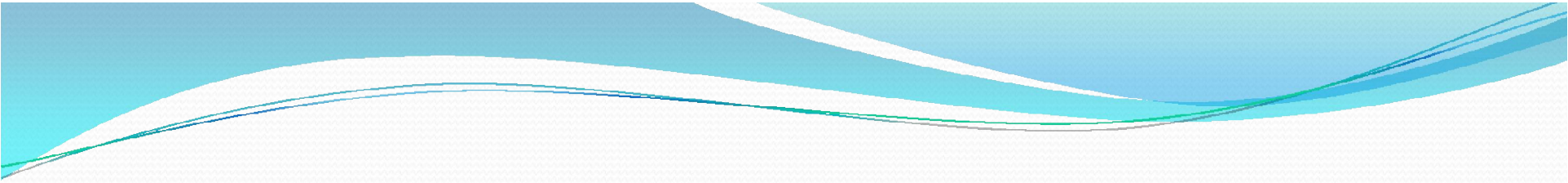
Introduction

- The subject Machine Design is the creation of new and better machines and improving the existing ones. A new or better machine is one which is more economical in the overall cost of production and operation



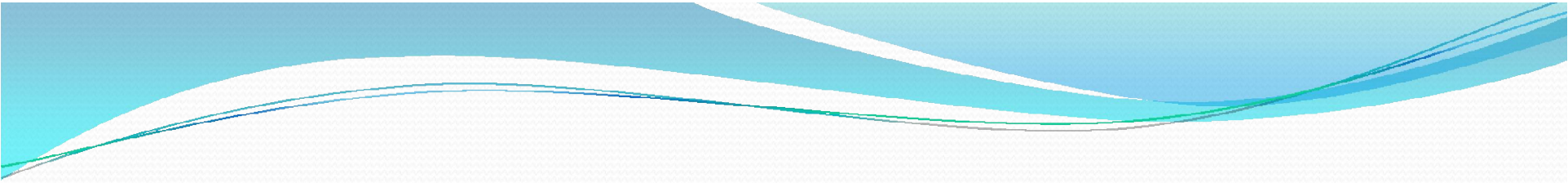
Classifications of Machine Design

- Adaptive design: In most cases, the designer's work is concerned with adaptation of existing designs.
- Development design: This type of design needs considerable scientific training and design ability in order to modify the existing designs into a new idea by adopting a new material or different method of manufacture
- New design: This type of design needs lot of research, technical ability and creative thinking.



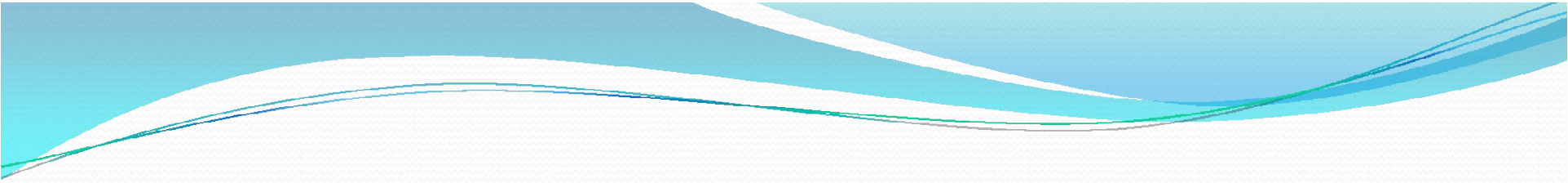
General Considerations in Machine Design

- 1. Type of load and stresses caused by the load.
- 2. Motion of the parts or kinematics of the machine
- 3. Selection of materials
- 4. Form and size of the parts
- 5. Frictional resistance and lubrication
- 6. Convenient and economical feature
- 7. Use of standard parts
- 8. Safety of operation
- 9. Workshop facilities

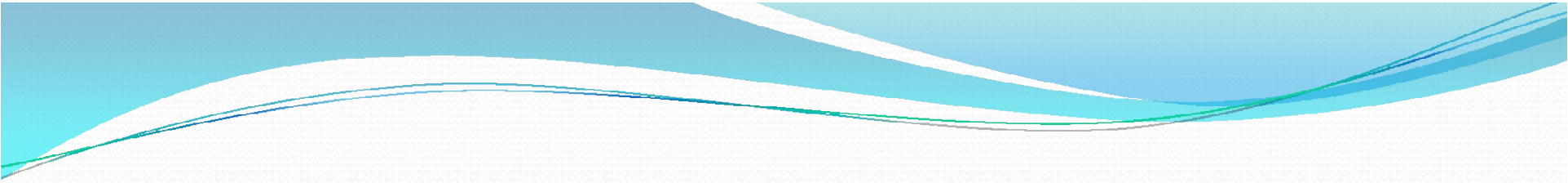


General Considerations in Machine Design

- 10. Number of machines to be manufactured
- 11. Cost of construction
- 12. Assembling

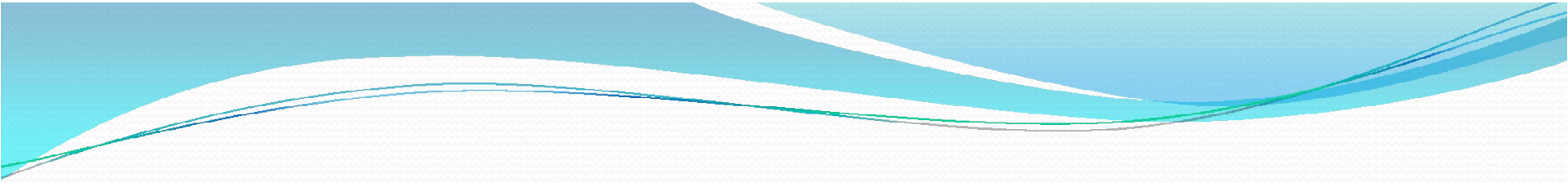


Design of Keys



Design of Keys

- A key is a piece of mild steel inserted between the shaft and hub or boss of the pulley 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 and are subjected to considerable crushing and shearing stresses. A keyway is a slot or recess in a shaft and hub of the pulley to accommodate a key.



Types of Keys

- 1. Sunk keys
- 2. Saddle keys
- 3. Tangent keys
- 4. Round keys

Sunk Keys

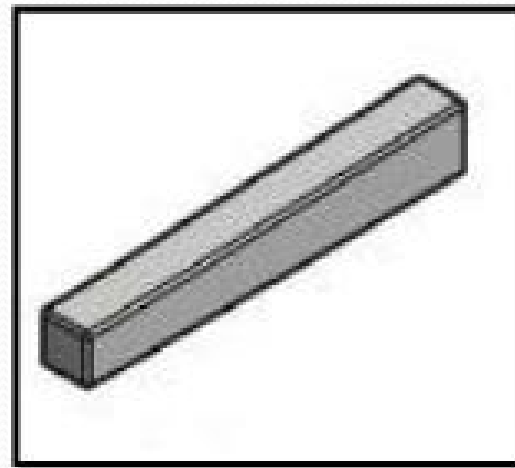
1. Rectangular sunk key:

The usual proportions of this key are :

Width of key $w = d / 4$

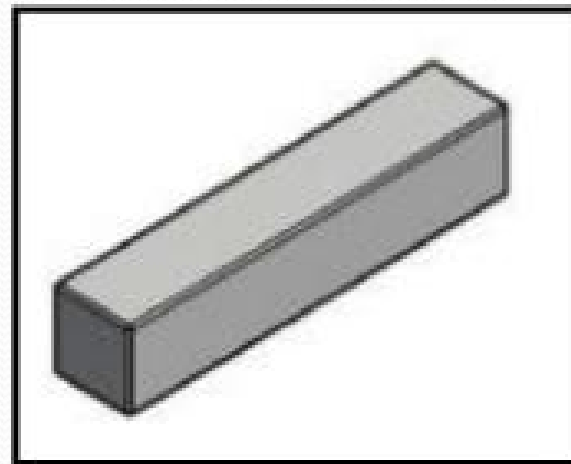
Thickness of key $t = 2w / 3 = d / 6$

d is diameter of shaft



Square sunk key:

The only difference between a rectangular sunk key and a square sunk key is that its width and thickness are equal, i.e. $w = t = d / 4$



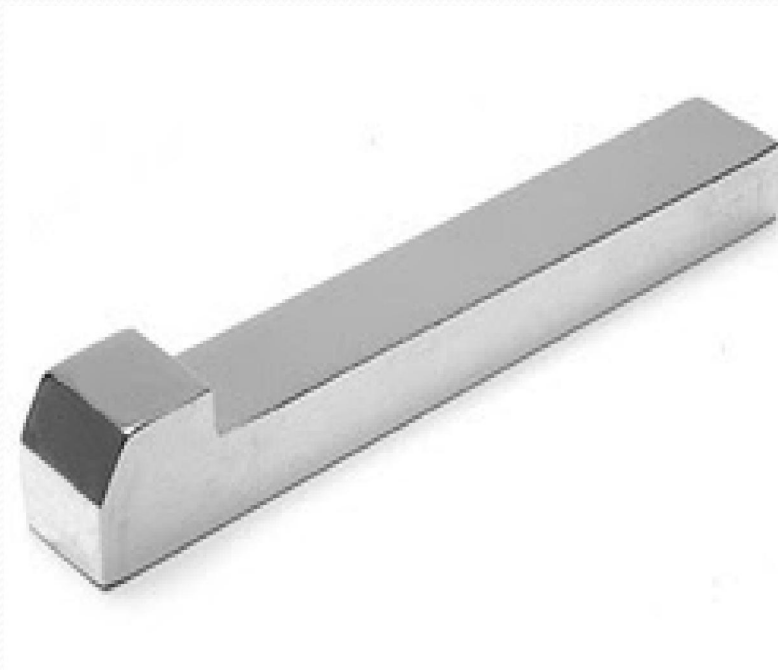
Parallel sunk key:

The parallel sunk keys may be of rectangular or square section uniform in width and thickness throughout. It may be noted that a parallel key is a taperless and is used where the pulley, gear or other mating piece is required to slide along the shaft



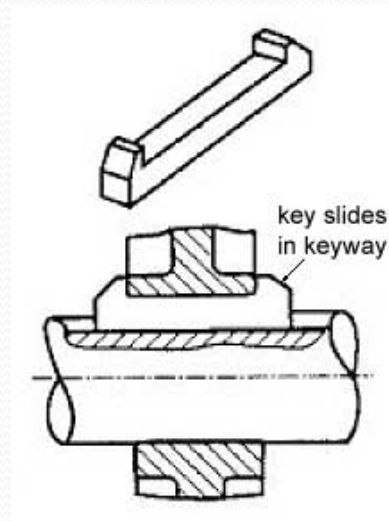
Gib-head key:

It is a rectangular sunk key with a head at one end known as gib head. It is usually provided to facilitate the removal of key.



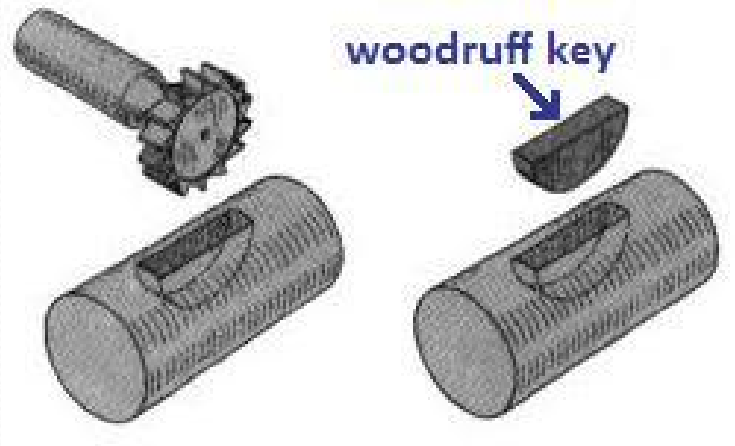
Feather key:

A key attached to one member of a pair and which permits relative axial movement is known as feather key. It is a special type of parallel key which transmits a turning moment and also permits axial movement. It is fastened either to the shaft or hub, the key being a sliding fit in the key way of the moving piece.



Woodruff key:

The woodruff key is an easily adjustable key. It is a piece from a cylindrical disc having segmental cross-section. A woodruff key is capable of tilting in a recess milled out in the shaft by a cutter having the same curvature as the disc from which the key is made.

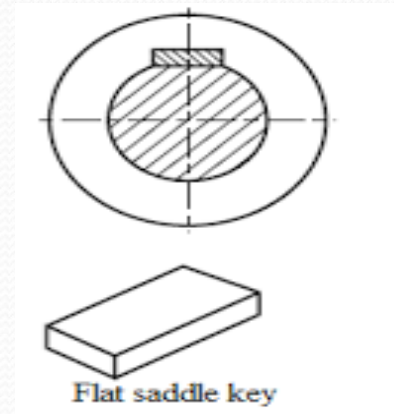


Saddle keys

- 1. Flat saddle key

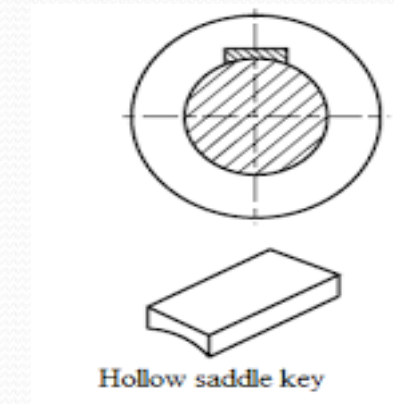
flat saddle key is a taper key which fits in a keyway in the hub and is flat on the shaft.

It is likely to slip round the shaft under load.



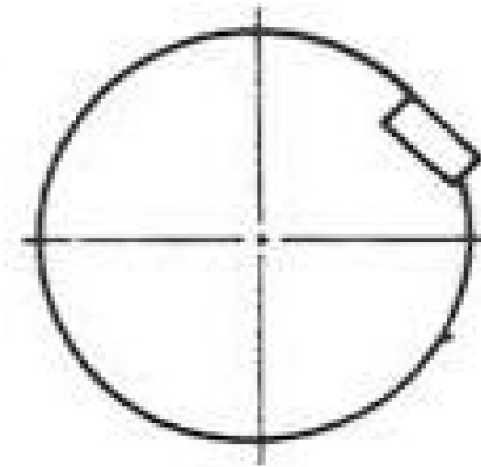
- 2. Hollow saddle key

fits in a keyway in the hub and the bottom of the key is shaped to fit the curved surface. Since hollow saddle keys hold on by friction, therefore suitable for light loads.



Tangent Keys

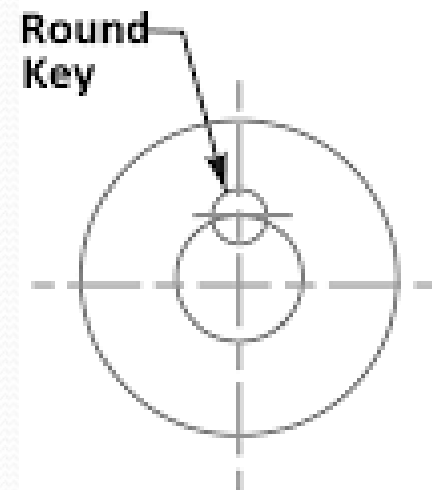
The tangent keys are fitted in pair at right angles. Each key is to withstand torsion in one direction only. These are used in large heavy duty shafts.



RECTANGULAR TANGENT KEY

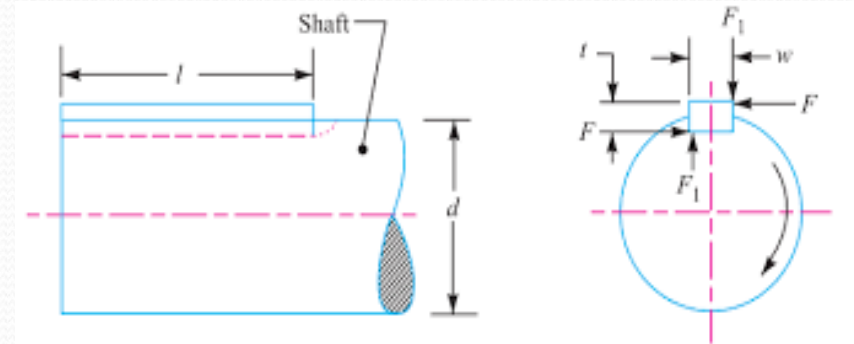
Round Keys

The round keys are circular in section and fit into holes drilled partly in the shaft and partly in the hub. They have the advantage that their keyways may be drilled and reamed after the mating parts have been assembled.



Strength of a Sunk Key

A key connecting the shaft and hub is shown in Fig.



Let T = Torque transmitted by the shaft

F = Tangential force acting at the circumference of the shaft

d = Diameter of shaft

l = Length of key,

w = Width of key

t = Thickness of key

and τ and σ = Shear and crushing stresses for the material of key.

Considering shearing of the key, the tangential shearing force acting at the circumference of the shaft

F = Area resisting shearing $\times$ Shear stress $= l \times w \times \tau$

$\therefore$ Torque transmitted by the shaft $T = F \times d/2 = l w \tau d/2$

Considering crushing of the key, the tangential crushing force acting at the circumference of the shaft

$$F = \text{Area resisting crushing} \times \text{Crushing stress} = l \times t/2 \times \sigma$$

∴ Torque transmitted by the shaft,

$$T = F \times d/2 = l \cdot t/2 \cdot \sigma \cdot d/2$$

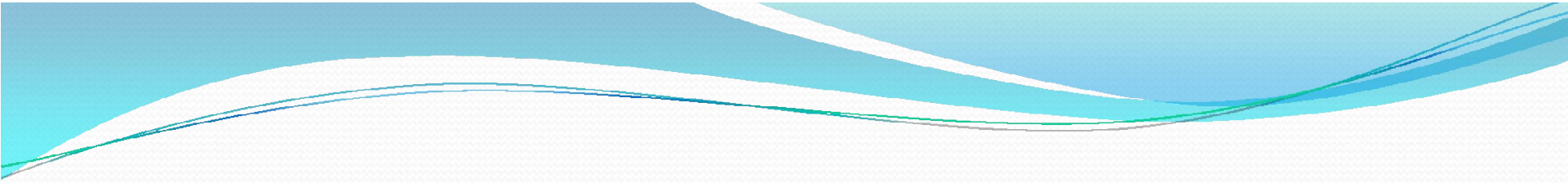
The key is equally strong in shearing and crushing, if

$$l \cdot w \cdot \tau \cdot d/2 = l \cdot t/2 \cdot \sigma \cdot d/2$$

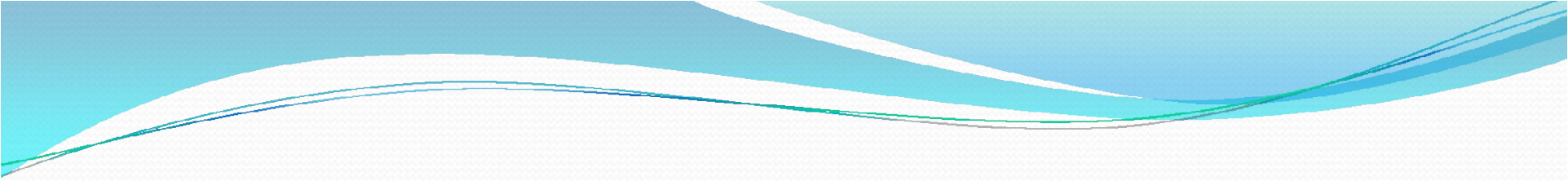
$$w/t = \sigma/2 \tau$$

The permissible crushing stress for the usual key material is at least twice the permissible shearing stress. Therefore we have $w = t$.

In other words, a square key is equally strong in shearing and crushing.



Threads



Threaded fasteners

Advantages of Threaded fasteners:

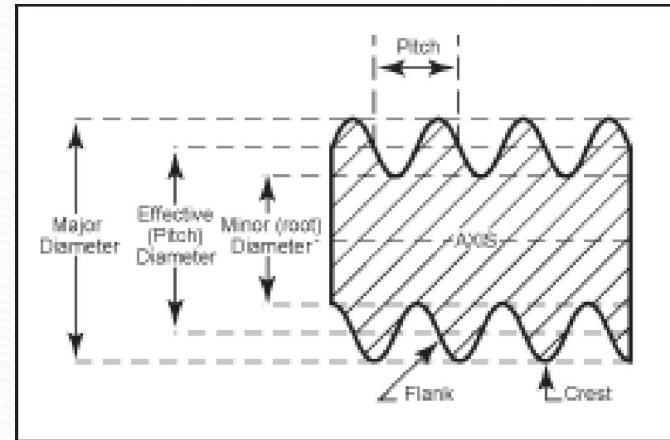
- Ease in assembling and disassembling
- Reliability due to self locking
- Manufacturability

Disadvantages:

- Large stress concentration
- Wear and tear

Geometric property of threads:

- Major diameter
Out side diameter of the fastener
- Minor diameter
Inside diameter of the fastener
- Pitch diameter
Average of the major and minor diameter
- Pitch
Distance between two consecutive tips
- Lead
Advancement of screw in one complete revolution



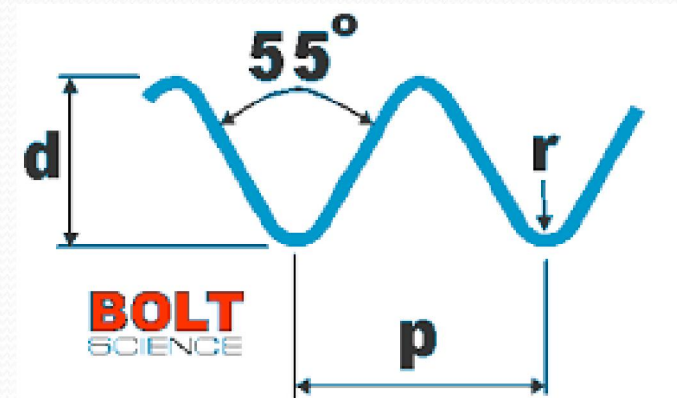
Types of threads

- BSW(British Standard whitworth)

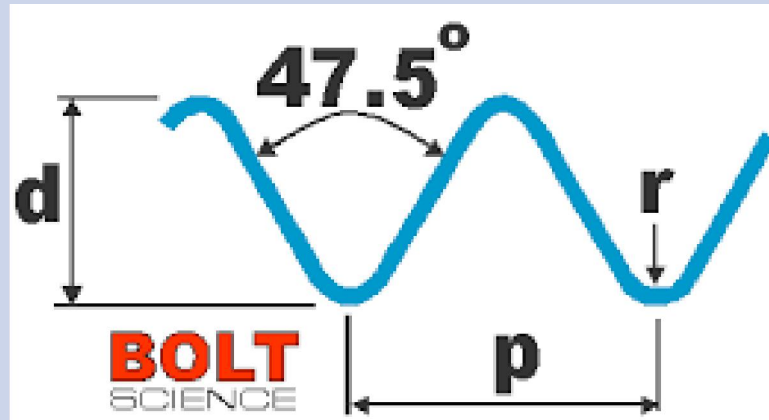
Special purpose

Adjustment screws

Aeroplane and auto parts

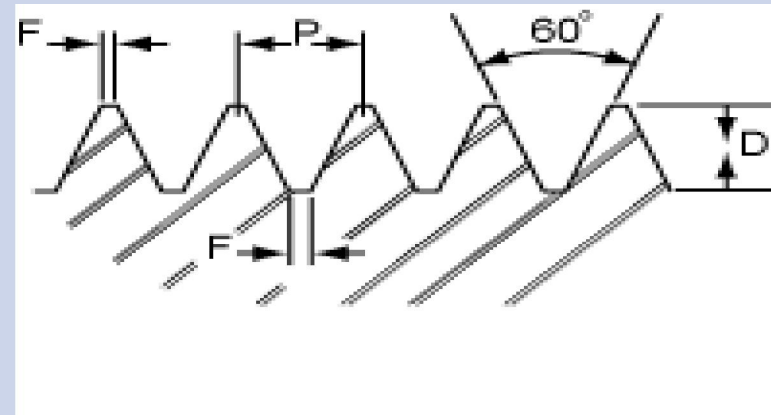


British Association threads



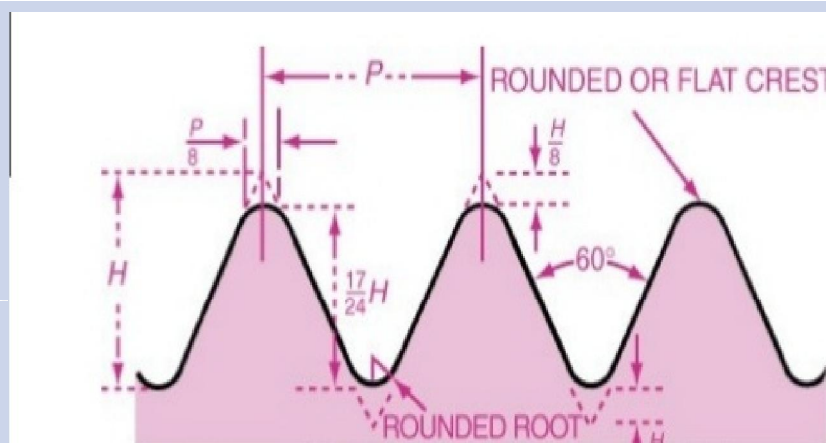
Angle is 47°
For Precision works

American National Standard thread



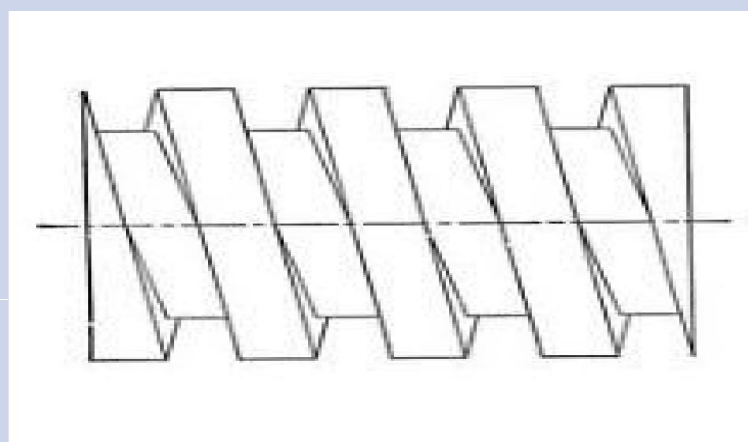
Angle is 60°
Used in fabrication and machine construction

Unified Standard (1948)



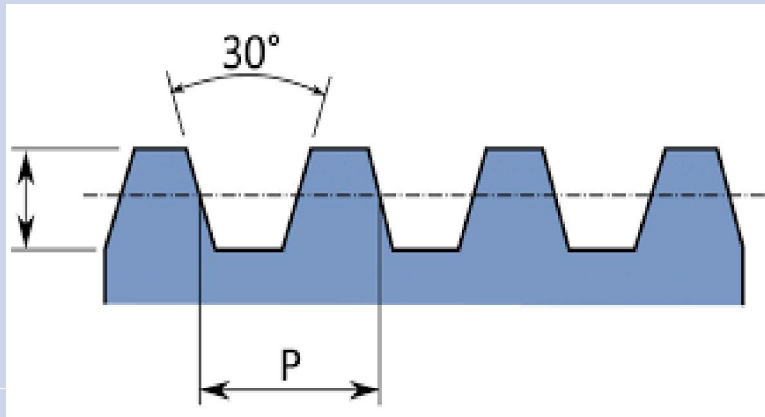
Angle is 60°
Rounded root

Square Thread



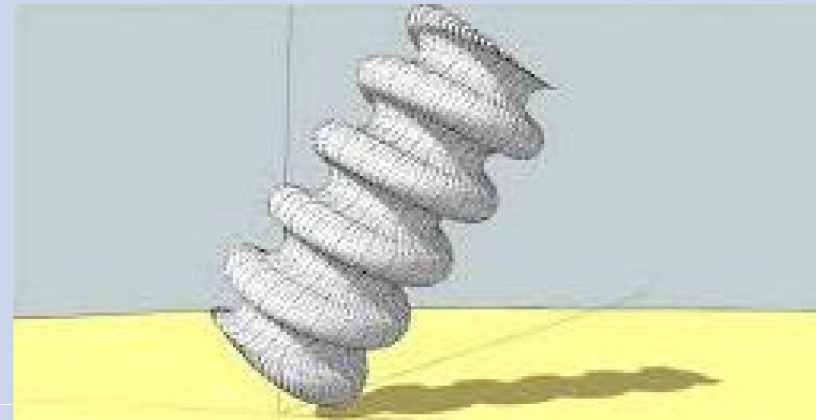
Angle is 90°
Higher efficiency, low root strength
Feedback mechanism
Valves and spindles
Screw jack

Acme thread



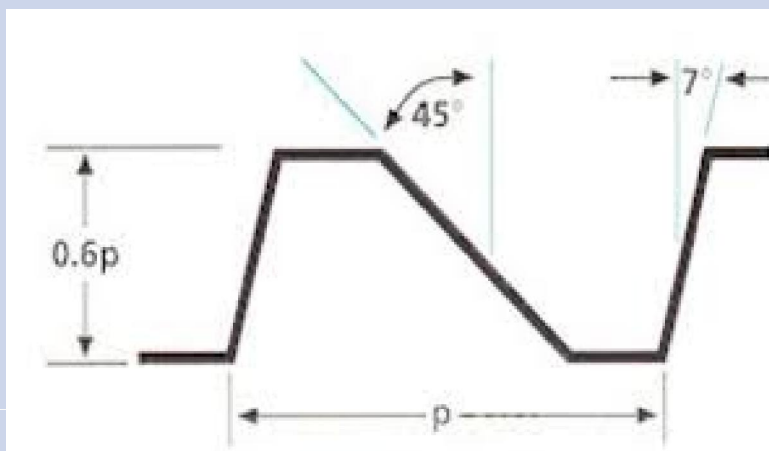
Angle is 30°
Screw cutting lathe
Brass valves
Bench vice

Knuckle Thread



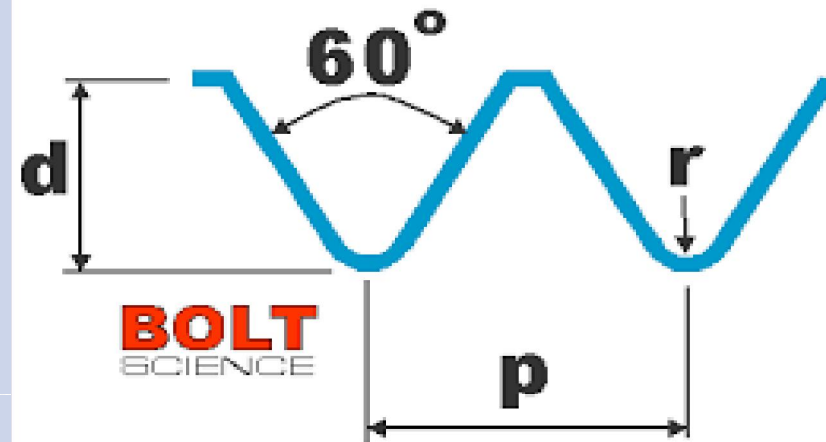
Easy to manufacture
Not for precision operation
Rail carriage coupling
Glass bottle
Large electrical connectors

Buttress thread



To transmit power in one direction
Large root strength

Metric Thread (IS)

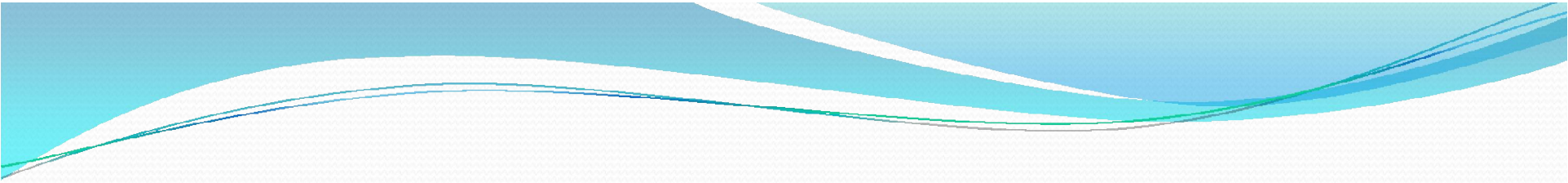


Designation of threads

- As per IS4218 part –IV
- Size designation
- Tolerance designation

M 6 - 8 d

Metric	6 mm	Normal	With tolerance
H- unit thread	nominal dia	7- fine	d- with tolerance
		9- coarse	h- without tolerance



Shaft Couplings

Purpose?

Requirement of a good coupling?

Type of coupling?



Shafts are available upto 7 meter length. To join two or more pieces of shaft couplings are required.

- Purpose:
 - ❖ to connect separately manufactured units and disconnect for alteration
 - ❖ to provide mechanical flexibility
 - ❖ to reduce transmission shock loads from one to other
 - ❖ to introduce protection against overload



Requirement of good shaft coupling :

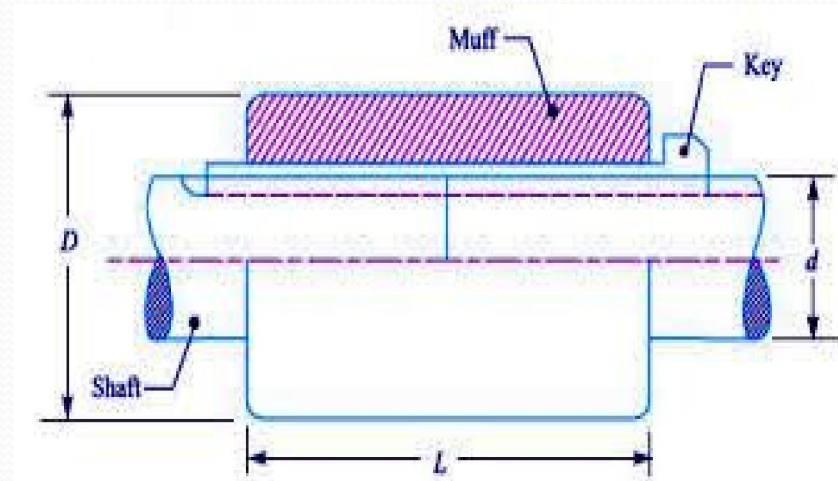
- Easy to connect and disconnect
- Transmit full power without loss
- Hold the shaft in perfect alignment
- Should reduce transmission of shock load
- Should have no projecting parts

Type of shaft coupling

Rigid coupling	Flexible coupling
Sleeve/muff coupling	Bush pin coupling
Clamp/ split muff coupling	Universal coupling
Flange coupling	Oldham coupling

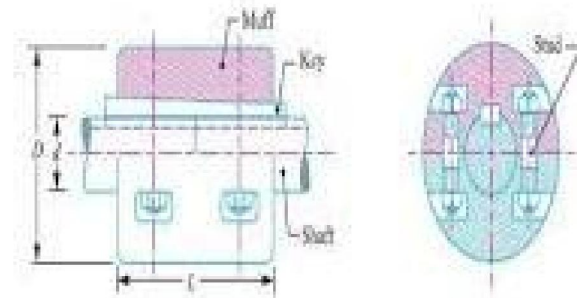
Sleeve/muff coupling

- Simplest, cast iron construction, made up of hollow cylinder
- ID as OD of the shaft
- Fitted by gibhead key
- Power transmitted by key and shaft
sleeve OD = $2d + 13$ mm
length = $3.5 d$



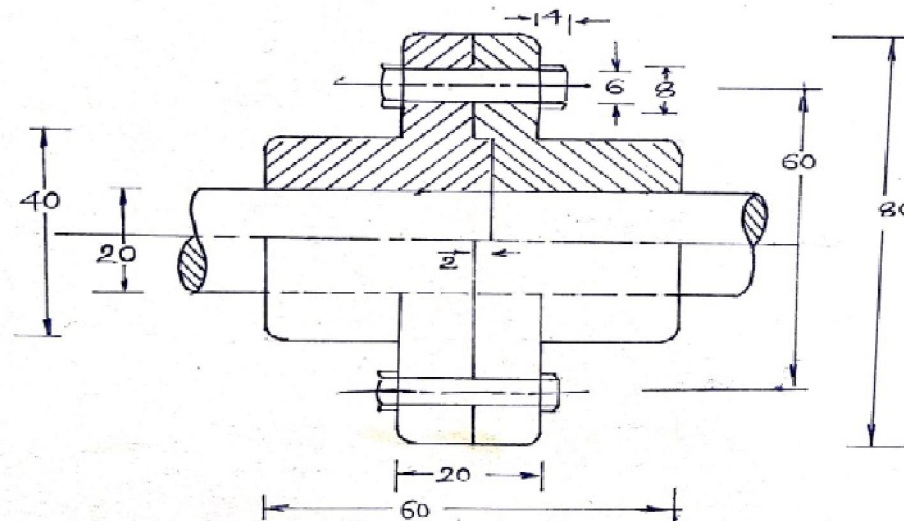
Clamp/compression/split muff coupling

- Sleeve made in two halves
 - ID as OD of the shaft
 - Made up of cast iron
 - Single key fitted in both shaft
-
- used for heavy duty moderate speed
 - Shaft position not to be changed during replacement
- sleeve OD = $2d + 13$ mm
- length = $3.5 d$



Flange coupling

- Has two separate cast iron flanges
- Each flange mounted on shaft or keyed
- One has projected portion and other has recess

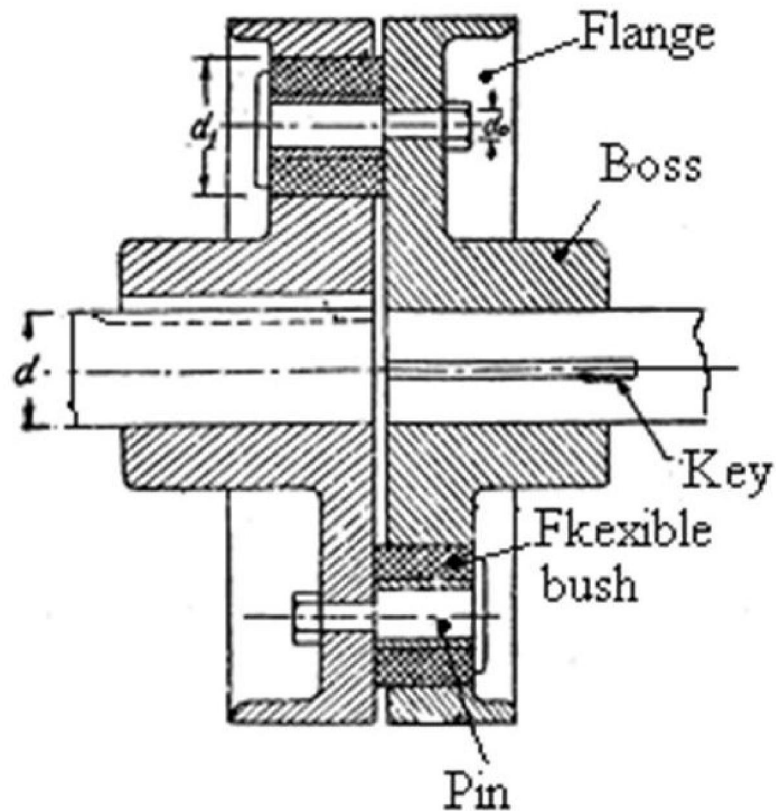


FLANGE COUPLING

ALL DIMENSION IN MM

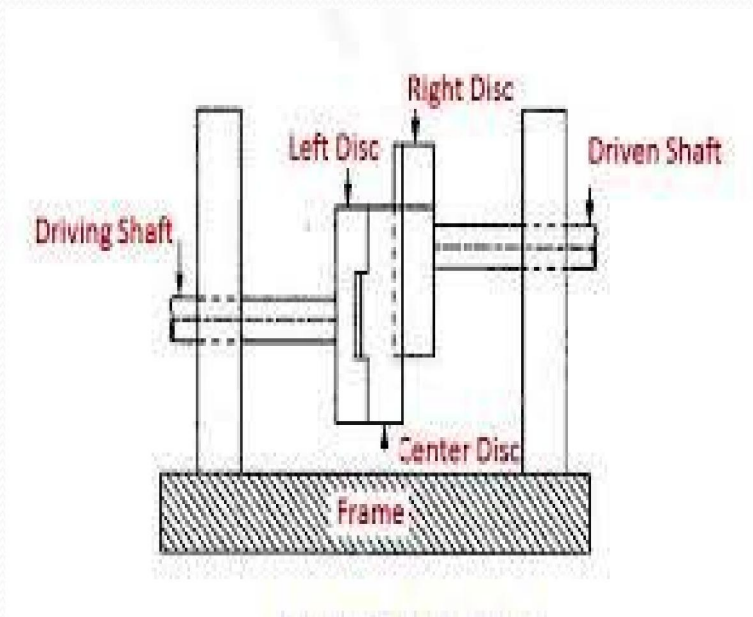
Flexible coupling (Bush –pin)

- When ends of joining shaft are not in exact alignment
- Used to permit axial misalignment without absorption of power



Oldham coupling

- Axis are at a smaller distance apart
- Power transmission because of +ve connection.

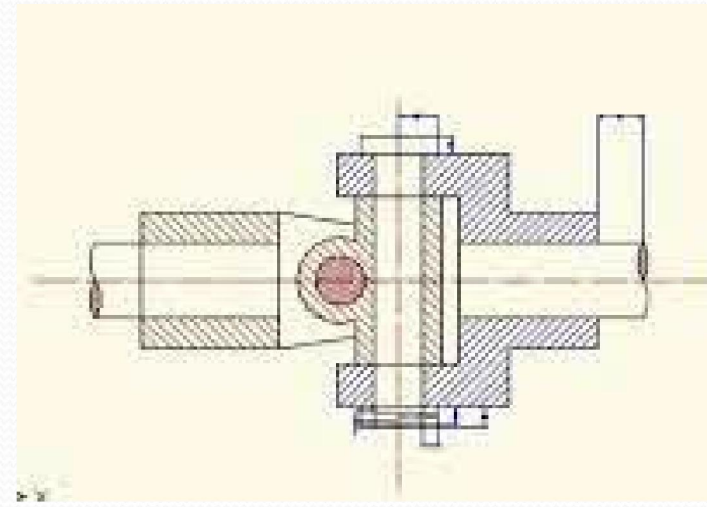


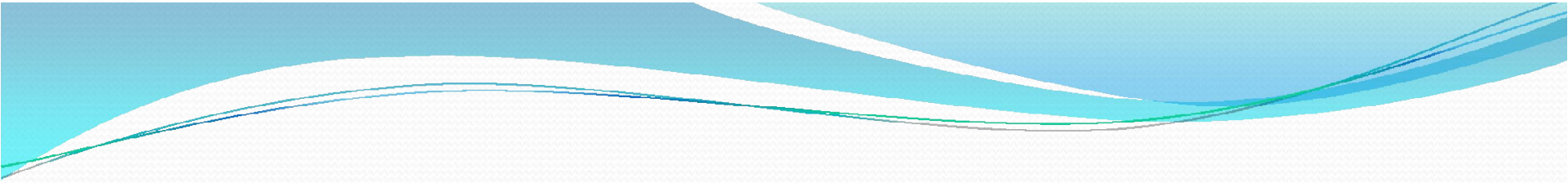
Universal Coupling (Hooke's)

- Axis intersect at a small angle
- Inclination of shaft varies with motion

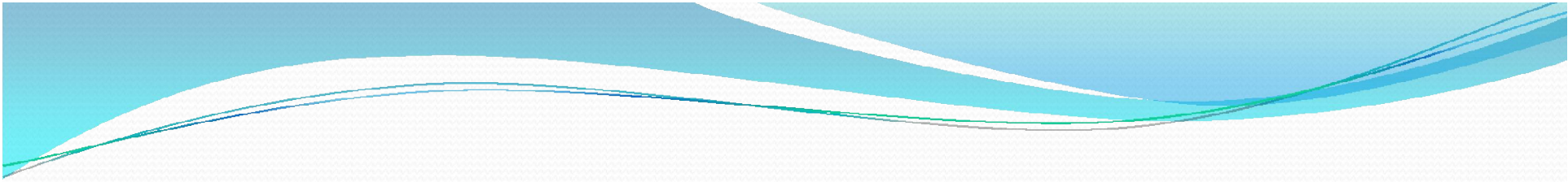
Use- gear box of back axle

Knee joint in Milling machine

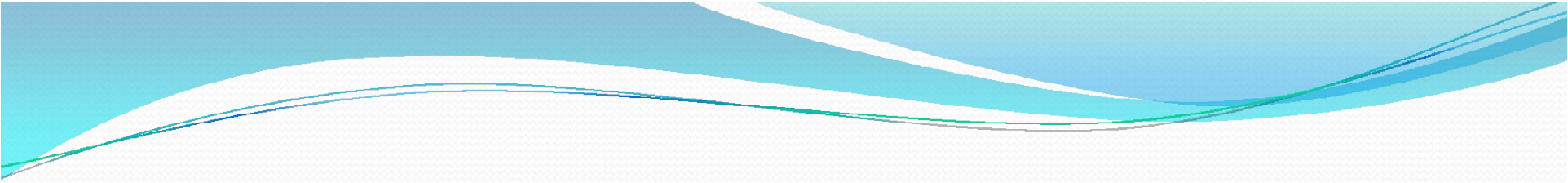




Welding joints

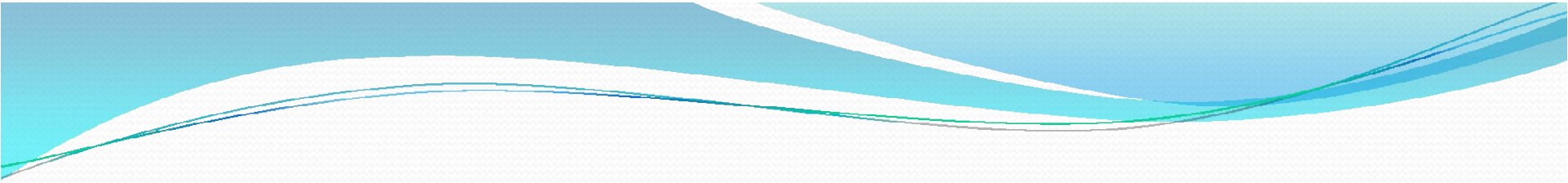


A welding joint is a permanent joint which is obtained by fusion of the edges of two parts to be joined together, with or without application of pressure and a filler material. Heat required for fusion of material may be obtained by burning of gases or by an electric arc. The latter is extensively used because of greater speed of welding. It is extensively used in fabrication as a replacement for bolted or rivet joint.



Advantages:

- Lighter than riveted structure
- Maximum efficiency of joints (100%)
- Alteration and addition can be easily done
- Smooth in appearance, pleasing
- The tension members are not weakened as in case of riveted joint
- A welded joint has great strength
- Some members of typical shape can be easily welded
- Possible to weld any part at any point but rivet require clearance

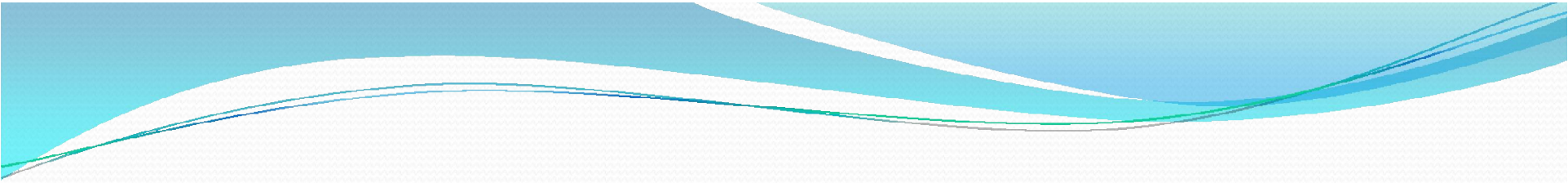


Disadvantages:

- Uneven heating and cooling during fabrication members may get distorted or stress may developed
- Require highly skilled labour and supervision
- Inspection of welding work is more difficult than riveting work

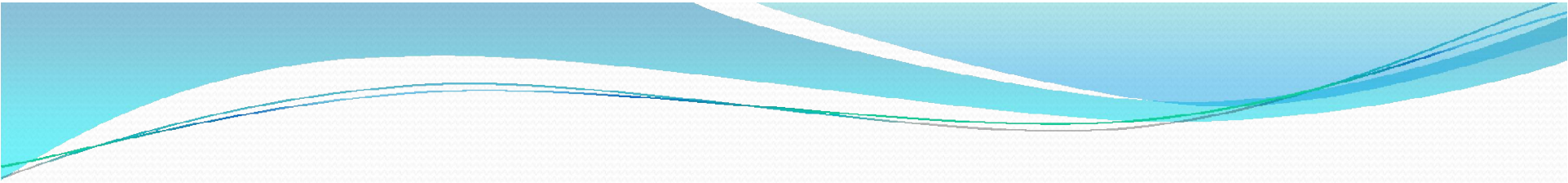
Class of welding

Fusion welding	Forge welding
Heat alone	Heat and pressure
Parts to be joined are held together and molten metal is supplied to the joint. Molten metal may come from filler metal or parent metal.	Parts to be joined are first heated at a proper temp. In a furnace or forge and then hammered. Now rarely used. process of simultaneous heat and press. is used in spot, seam, projection, upset and flash welding.



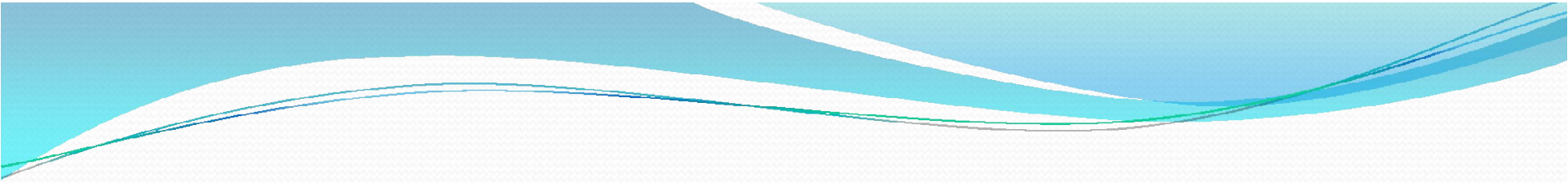
Thermit welding:

- Mixture of iron oxide and aluminium called thermit is ignited and iron oxide is reduced to molten iron. The molten iron is poured into a mould made around joint and fuses with parts to be welded. A major advantage is that all parts are molten at same time and weld almost uniformly. It has minimum residual stress.



Gas welding:

- Applying flame of oxy acetylene or hydrogen gas from a welding torch.
- Intense heat at white cone of flame heats up the local surface to fusion point
- Operator manipulates a welding rod to supply the metal for weld



Electric arc welding:

- The filler metal is supplied by metal welding electrode
- Operator strike an arc by touching the work of base metal with electrode
- Base metal in path of arc stream is melted, forming a pool of molten metal
- Small depression is formed in base metal and the molten metal is deposited around the edge of this depression, which is called arc crater
- Slag is brushed off after cooling of joint.

- Arc welding does not require the metal to be pre-heated and since the temp. of arc is quite high, the fusion is almost instantaneous.

Unshielded arc welding

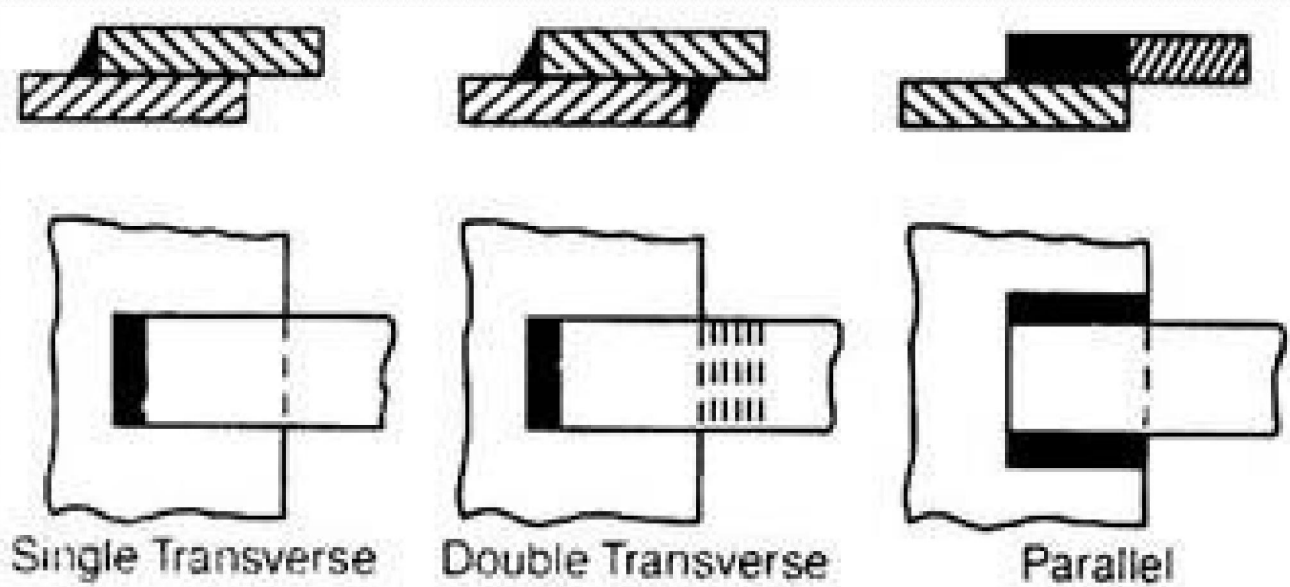
A large electrode or filler rod is used for welding. It is unshielded, deposit weld metal when hot absorb O_2/N_2 from atmosphere which decreases strength of weld.

Shielded arc welding

Welding rod is coated with solid material are used, thus resulting projection of coating focuses a concentrated arc stream which protects air and prevents absorption of O_2 and N_2 .

Types of weld joints

- Lap joint:



Types of weld joints

- Butt joint:



Single Square Groove



Single Bevel Groove



Double Bevel Groove



Single-V Groove



Double-V Groove



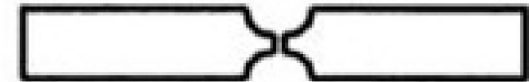
Single-J Groove



Double-J-Groove



Single-U Groove



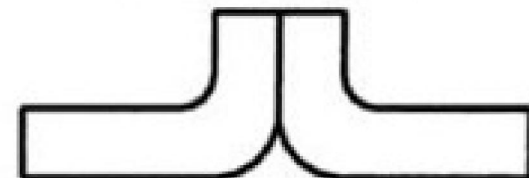
Double-U Groove



Flare Bevel Groove



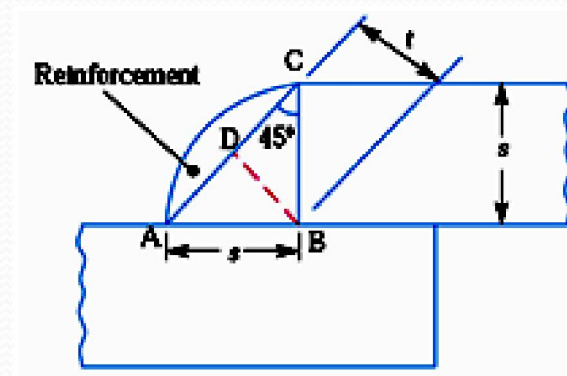
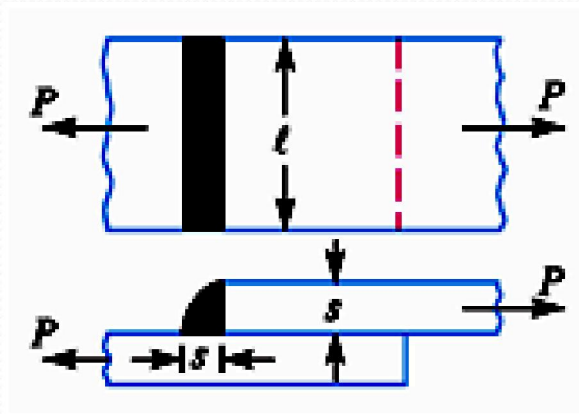
Flare-V Groove



Flanged Butt Joint

Strength of a transverse fillet joint:

- It is assumed that section of fillet joint is a right angle triangle.
- BD- is known as throat thickness



Strength of a transverse fillet joint:

$t = BD$

$s =$ leg or size of weld

$l =$ length of weld

$t = s \times \sin 45^\circ = .707 s$

- Minimum area of weld or throat

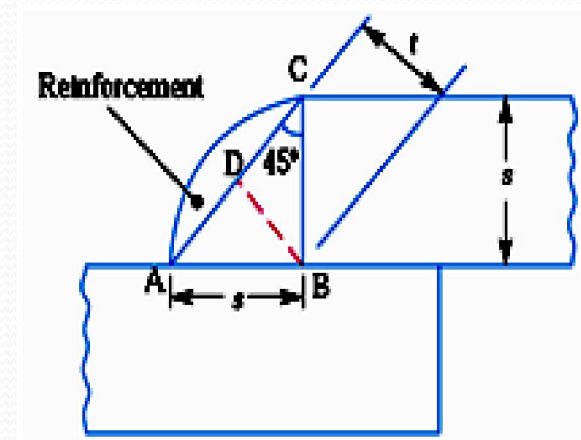
area = length x thickness = $.707 \times s \times l$

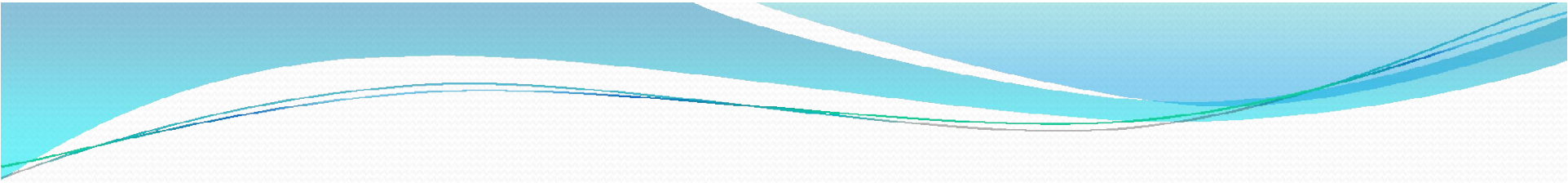
$\sigma =$ allowable tensile stress

$P =$ area x allowable stress = $.707.s.l.\sigma$

Tensile strength of a double transverse fillet joint = $2 \times .707 s l \sigma$

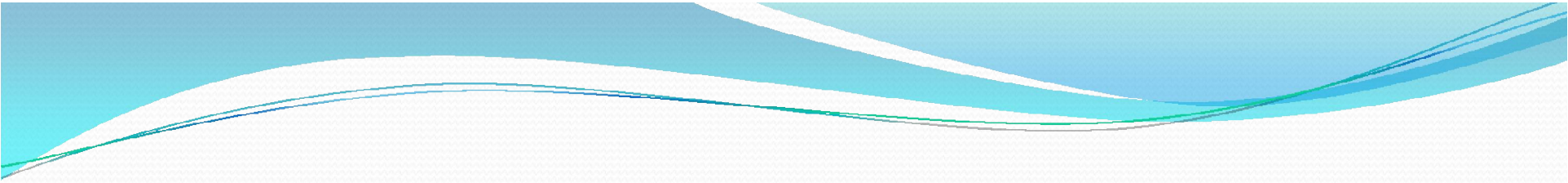
$$P = 1.414 s l \sigma$$





Cotter joints

- What is a cotter joint
- Parts of a cotter joint
- Cases of failure

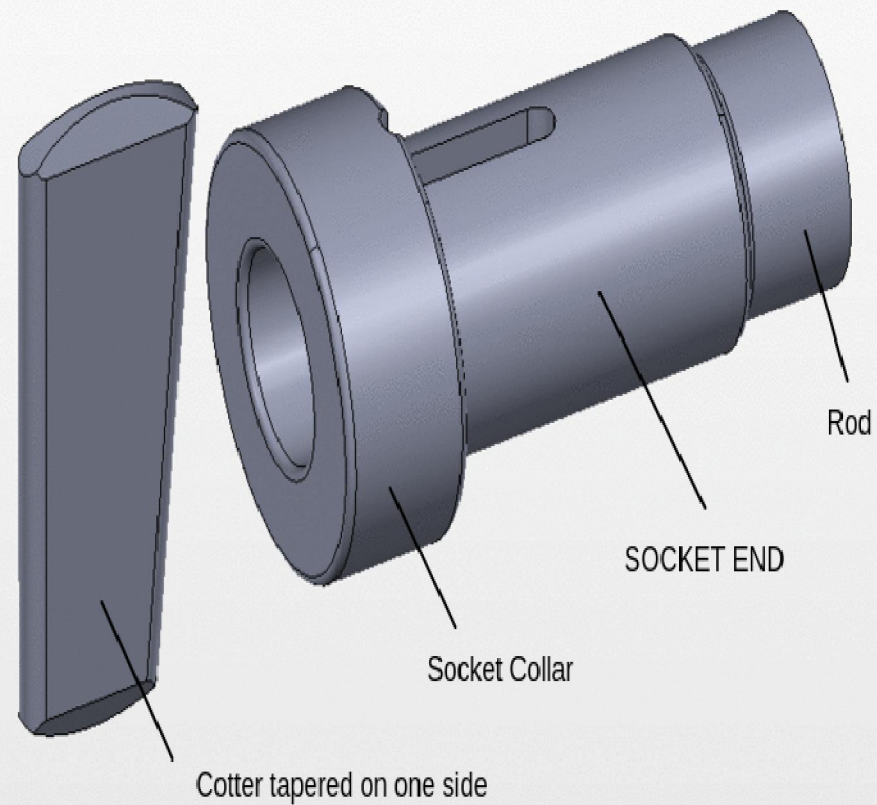
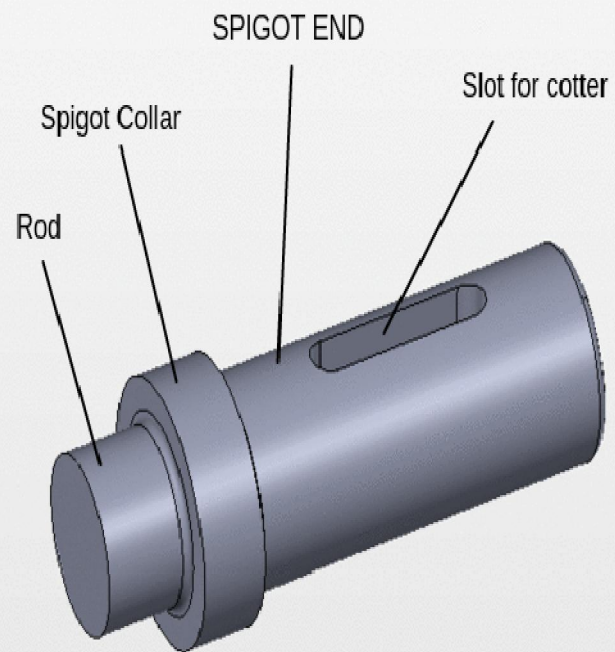


Cotter Joints:

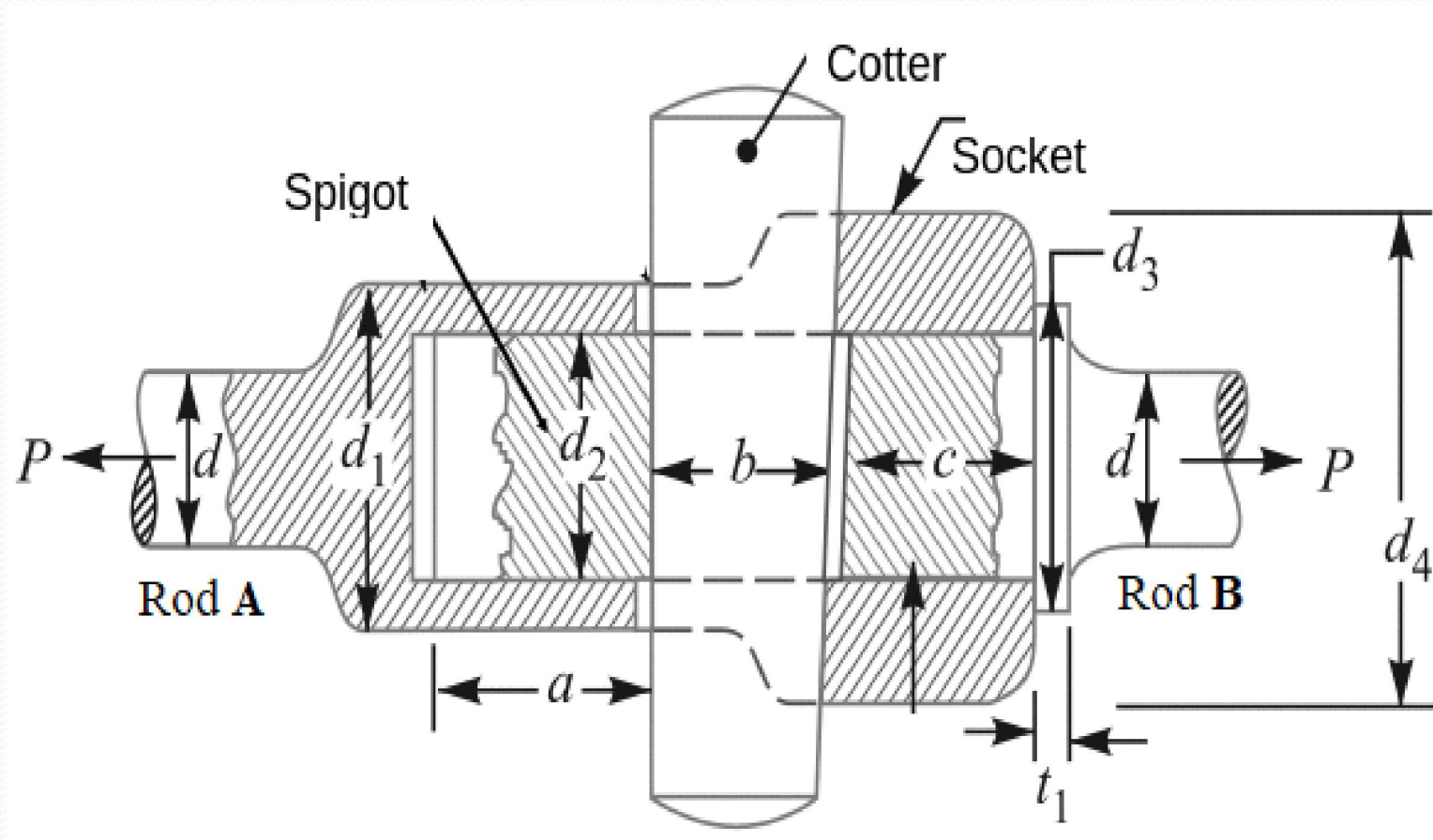
A cotter is a flat wedge shaped piece of rectangular cross-section and its width is tapered for an easy adjustment.

The cotter is usually made of mild steel or wrought iron. It is a temporary fastening and is used to connect rods or bars subjected to tensile or compressive forces.

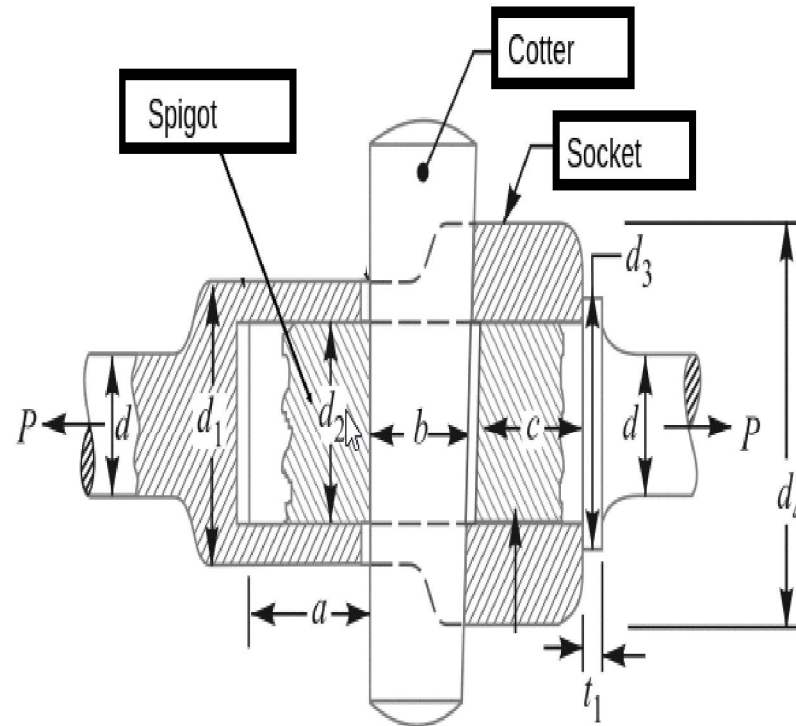
Cotter Joints:



Cases of Failure of Cotter Joint :



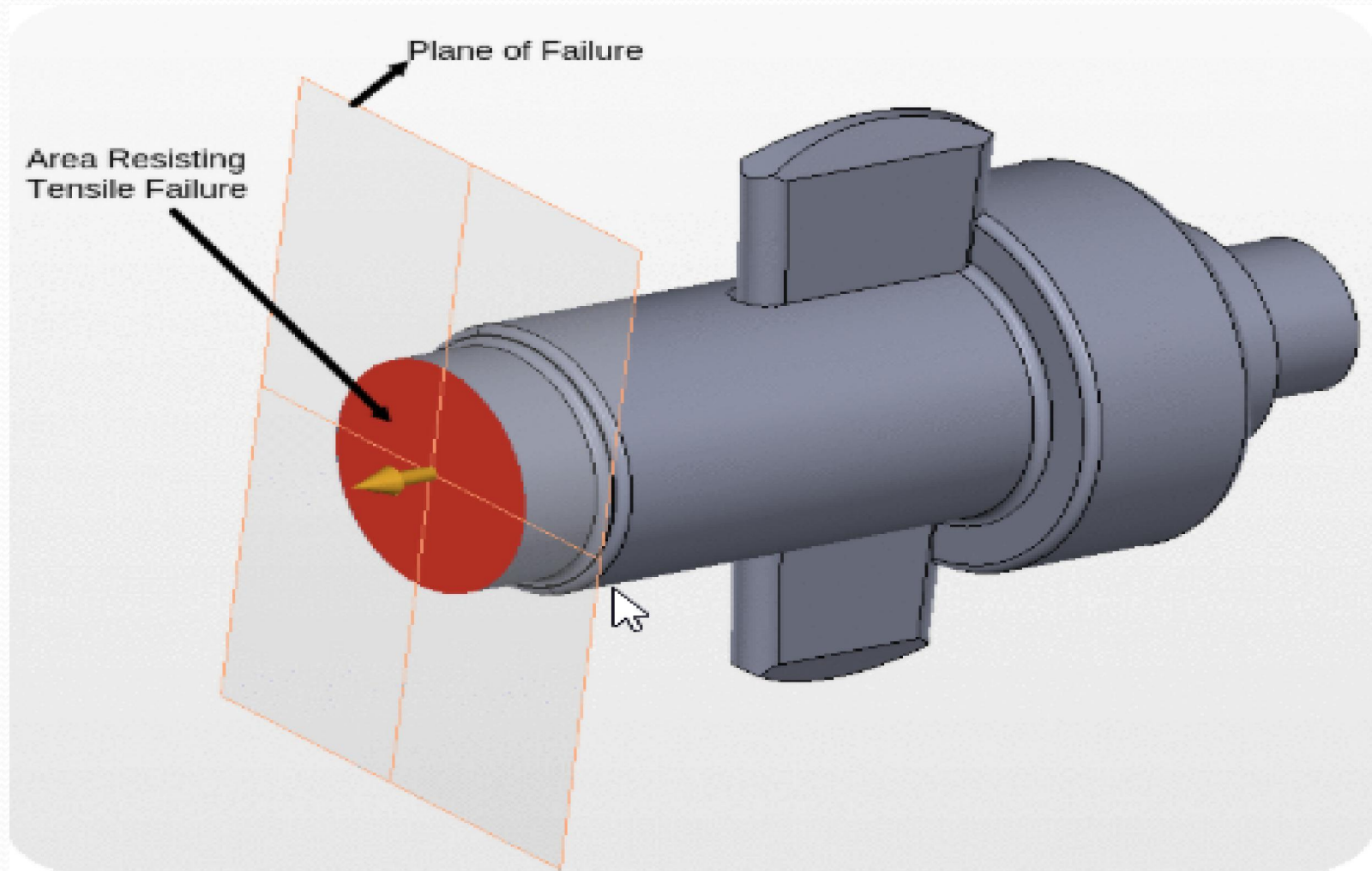
DESIGN PROCEDURE OF COTTER JOINT



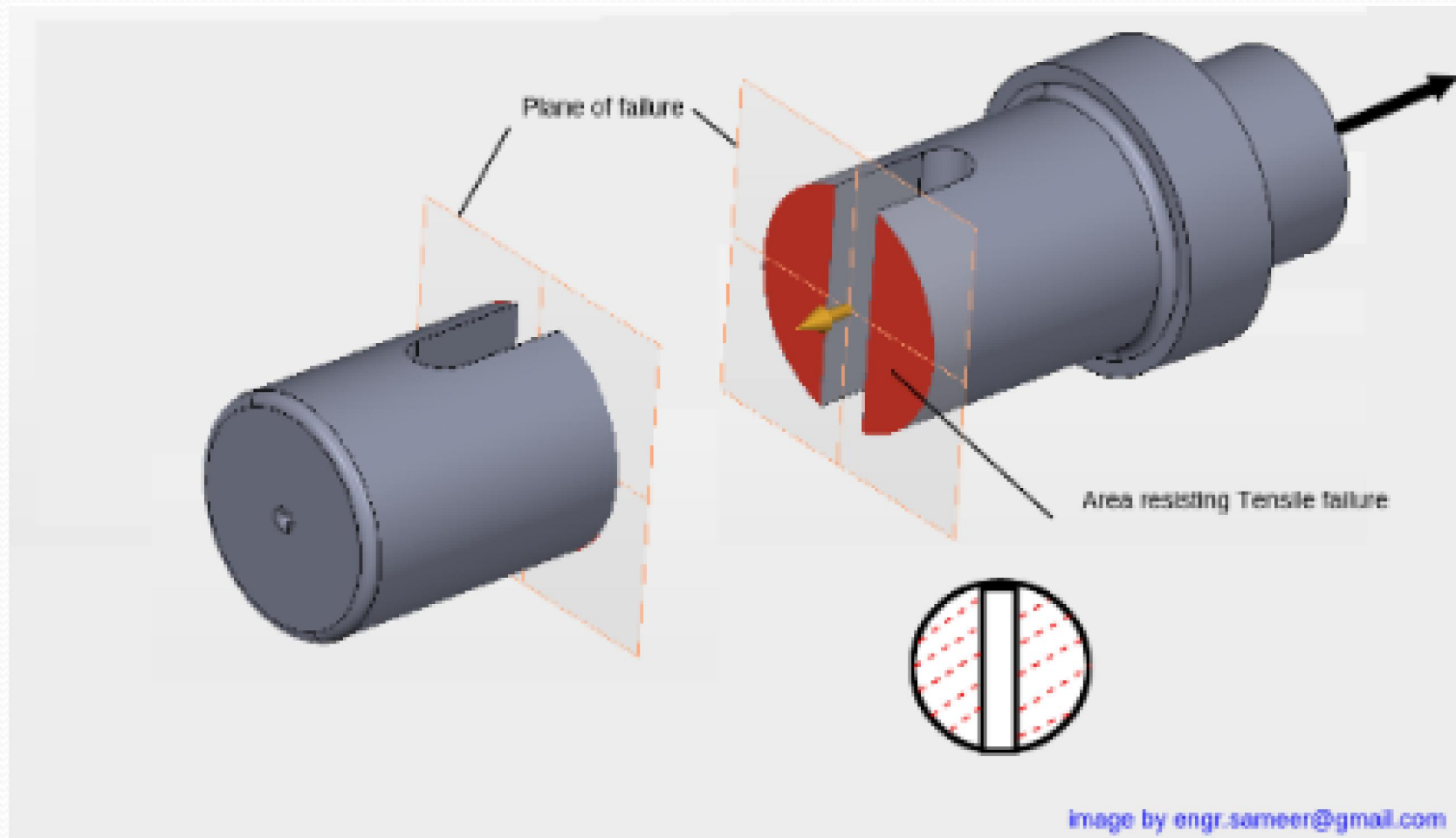
Notations used in design are as follows,

P = Load on the joint or pull acting on rods, d = Diameter of the rod, d_1 = outer diameter of socket, d_2 = Diameter of spigot or inside diameter of socket, d_3 = Outside diameter of spigot collar, d_4 = Diameter of socket collar, t_1 = Thickness of spigot collar, a = Distance from the end of the slot to end of spigot, c = thickness of socket collar, b, t, l = width, thickness and length of cotter

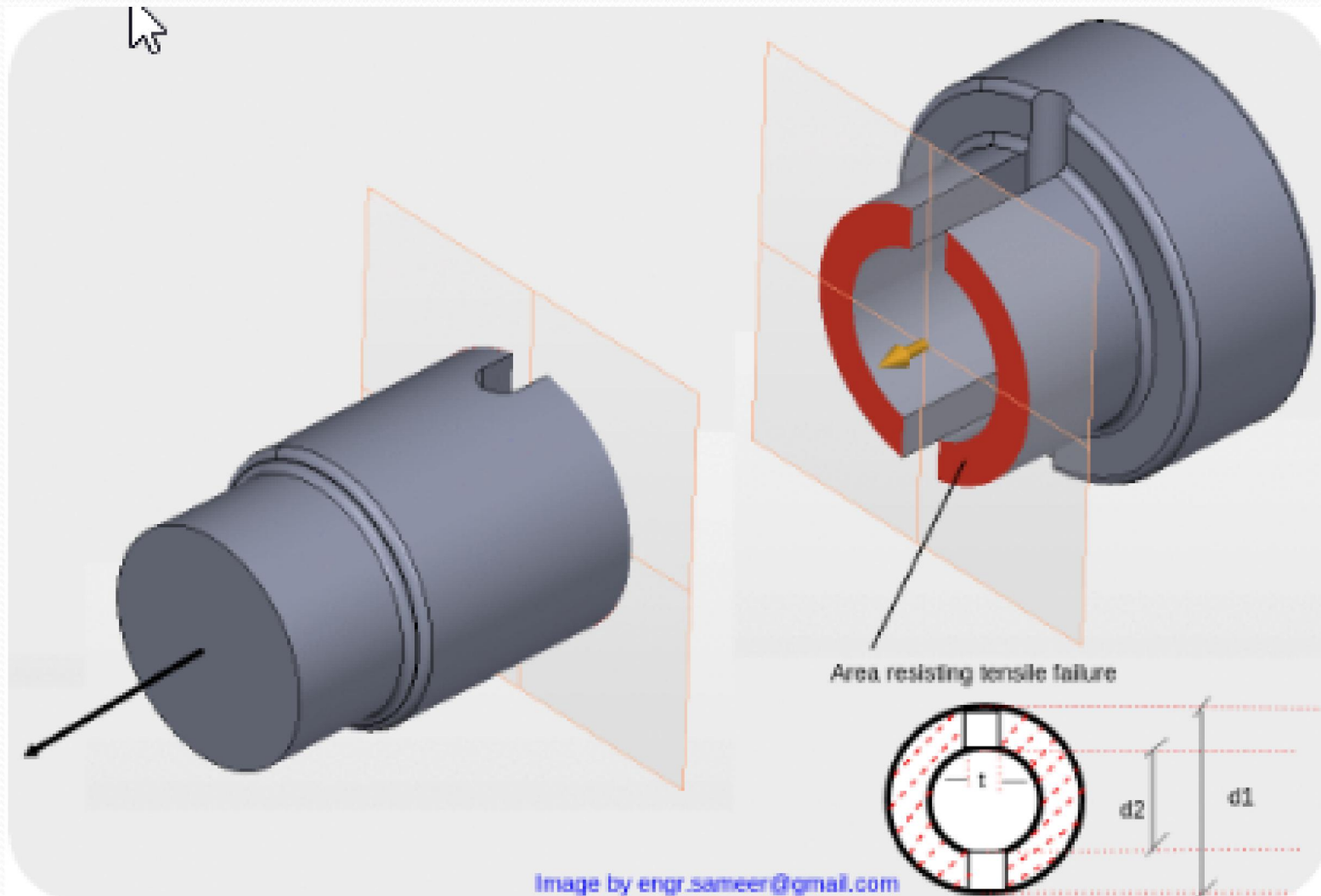
Tensile failure of rod:



Failure of the spigot in tension :

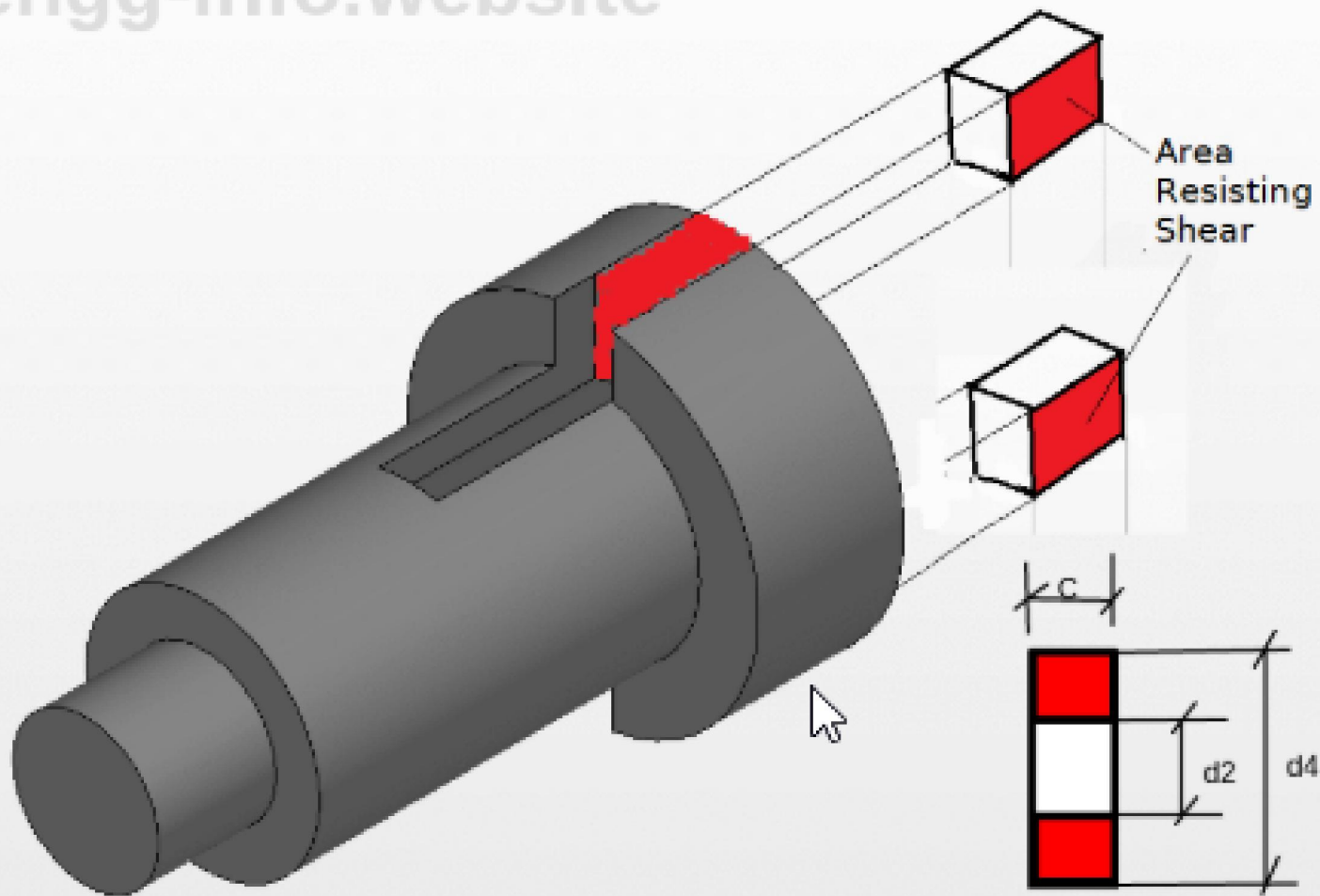


Failure of the socket in tension :

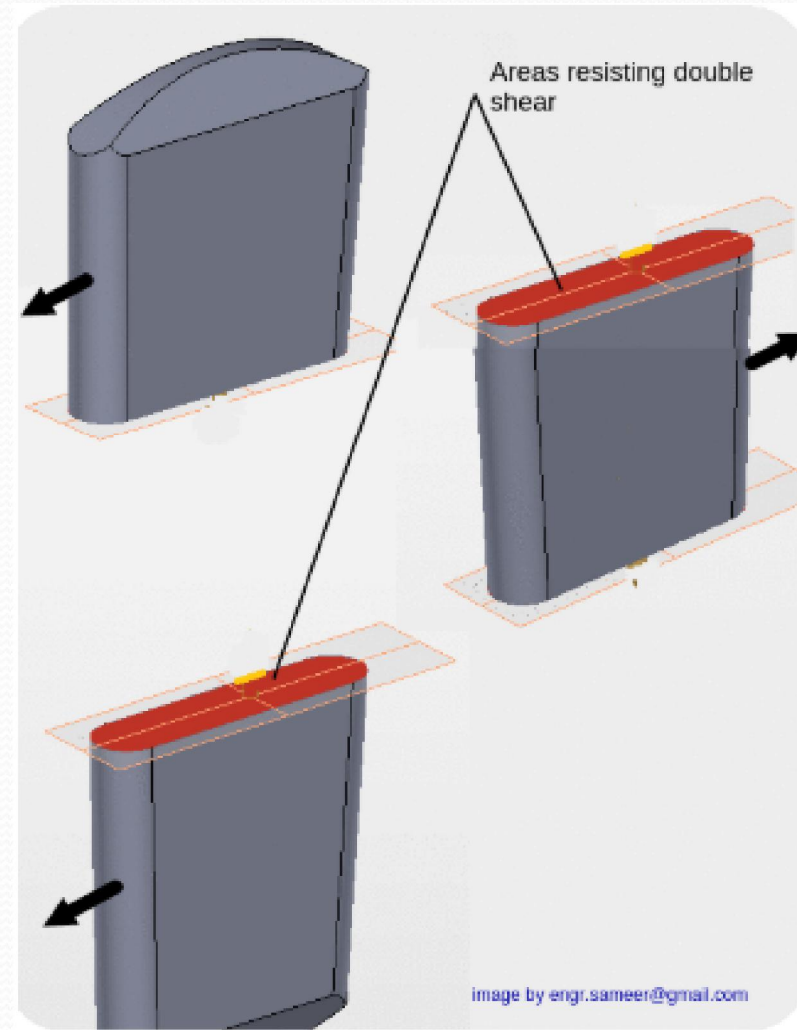


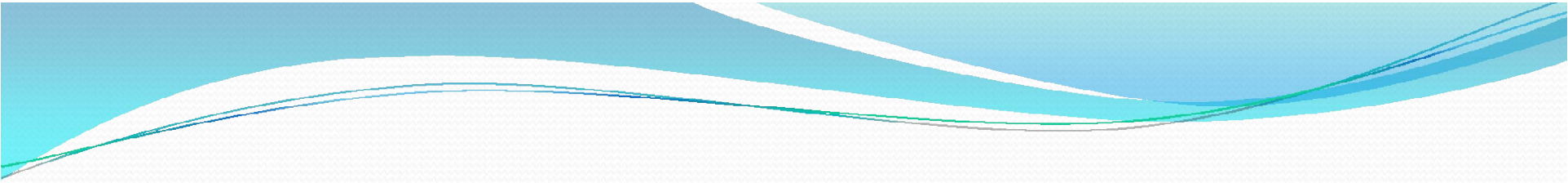
Shear Failure of the socket :

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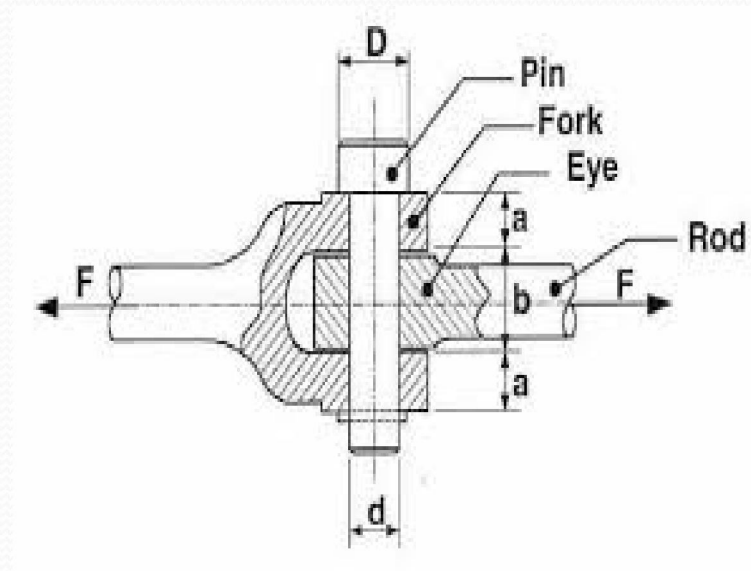
Double Shear failure of the cotter :





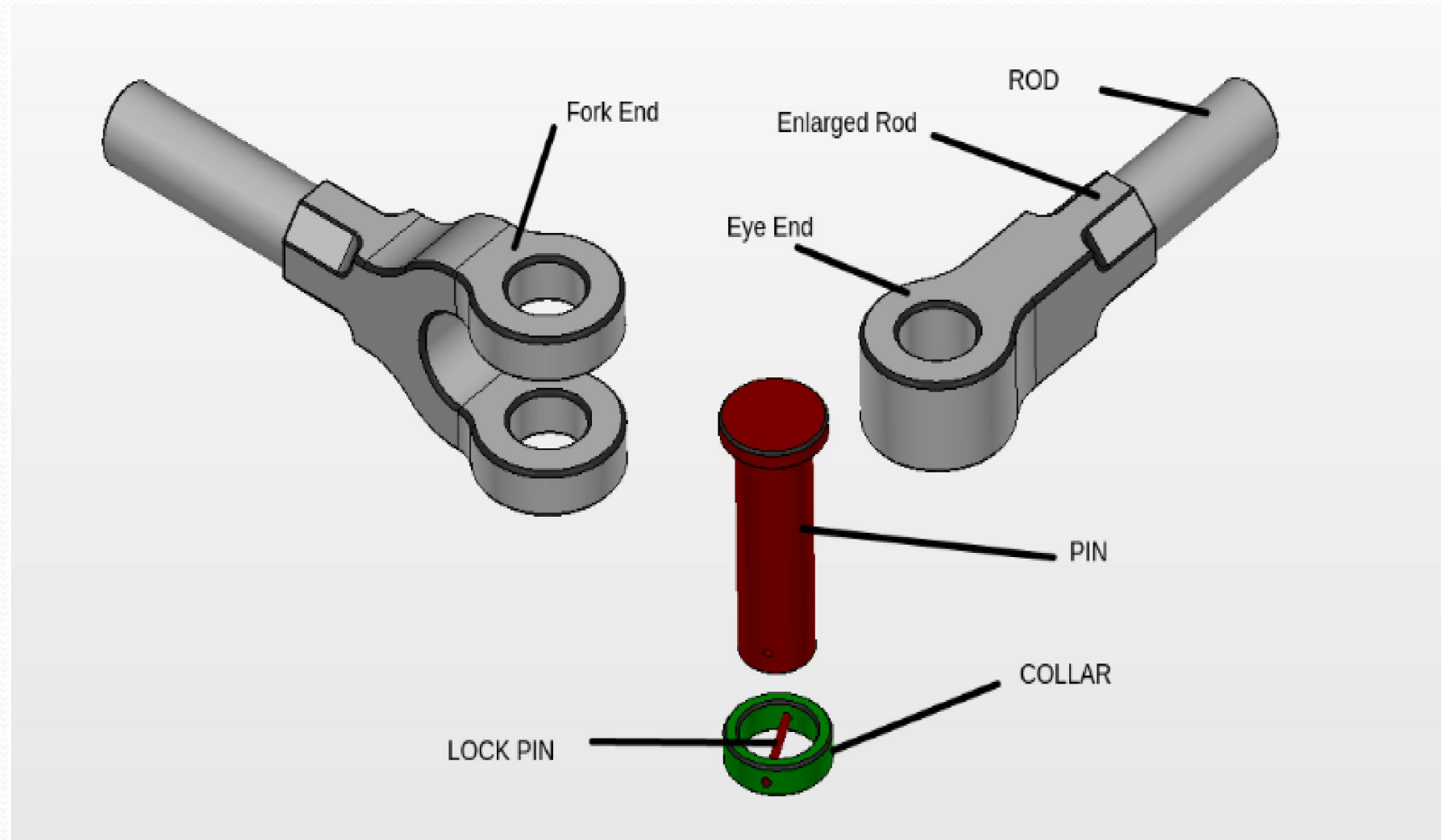
Knuckle joints

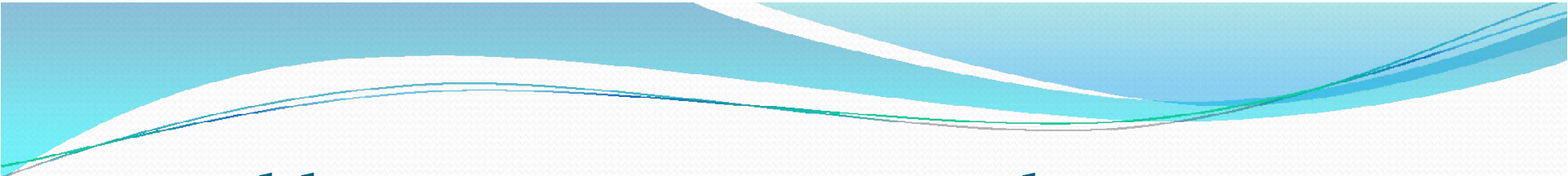
A **knuckle joint** is used to connect two rods which are under a tensile load, when there is a requirement of small amount of flexibility, or angular moment is necessary. There is always axial or linear line of action of load



e.g. Chain, truss member, pump etc.

Knuckle Joint Design Procedure:



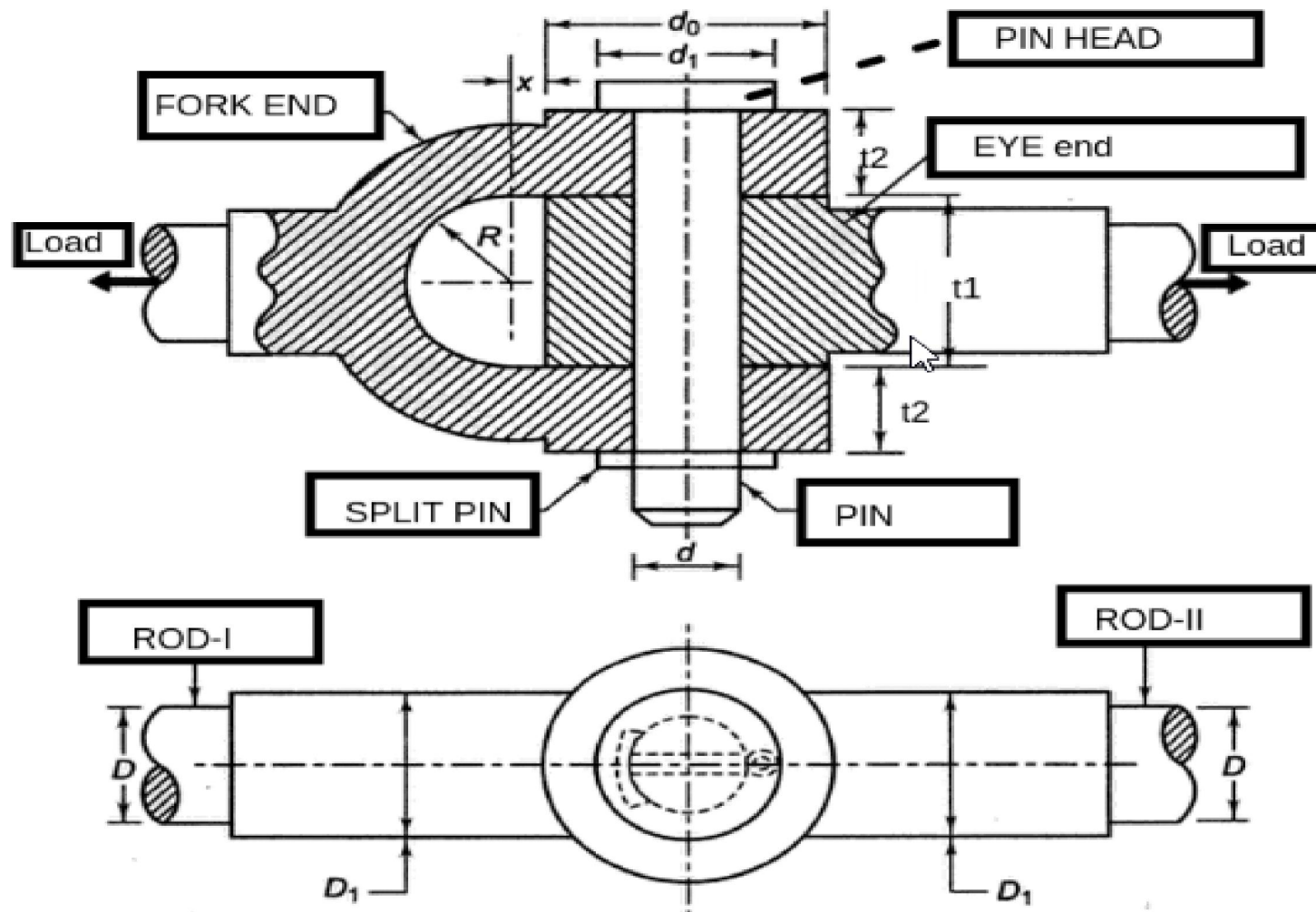


Knuckle Joint Design Procedure:

As seen in the assembly the Knuckle joint has main four parts:-

- Rods
- Single eye
- Double eye or Forked end
- Pin
- Collar
- Split pin or taper pin

Notations used in Knuckle Joint:



Notations used in Knuckle Joint:

P = Tension in rod (Load on the joint)

D = Diameter of rod

D_1 = Enlarged diameter of rod

d = Diameter of pin

d_1 = Diameter of pin head

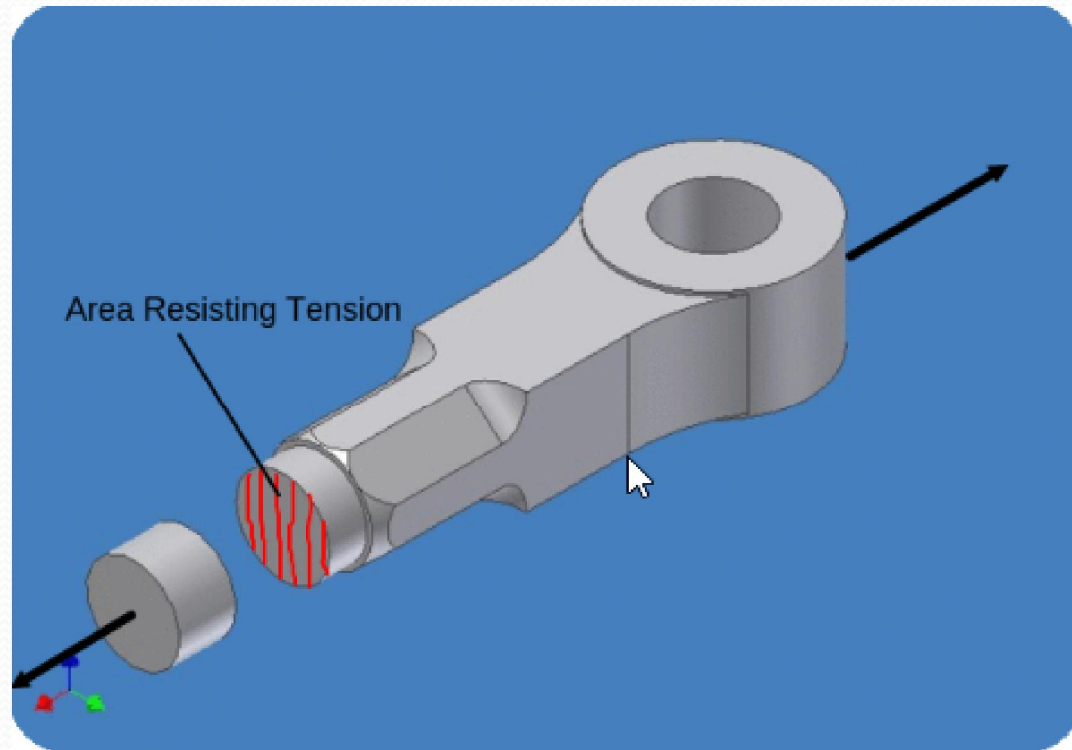
d_o = Outer diameter of eye or fork

t_1 = thickness of eye end

t_2 = thickness of forked end (double eye)

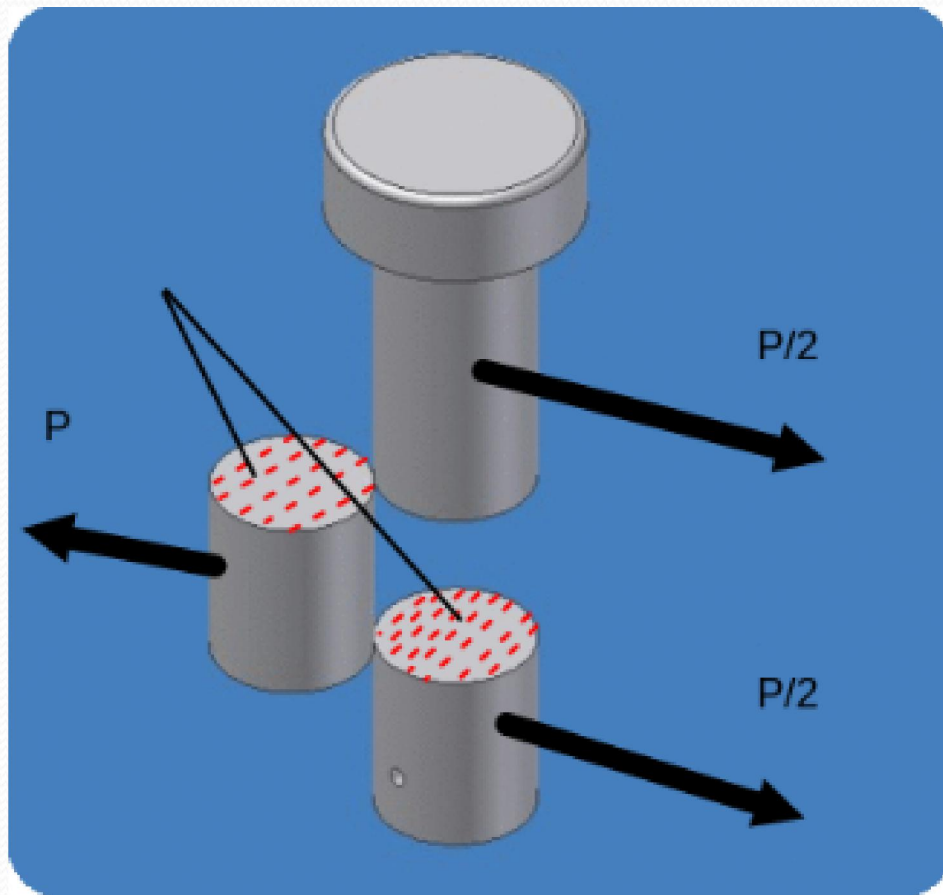
x = distance of the Centre of fork radius R from the eye

Tensile failure of rod:



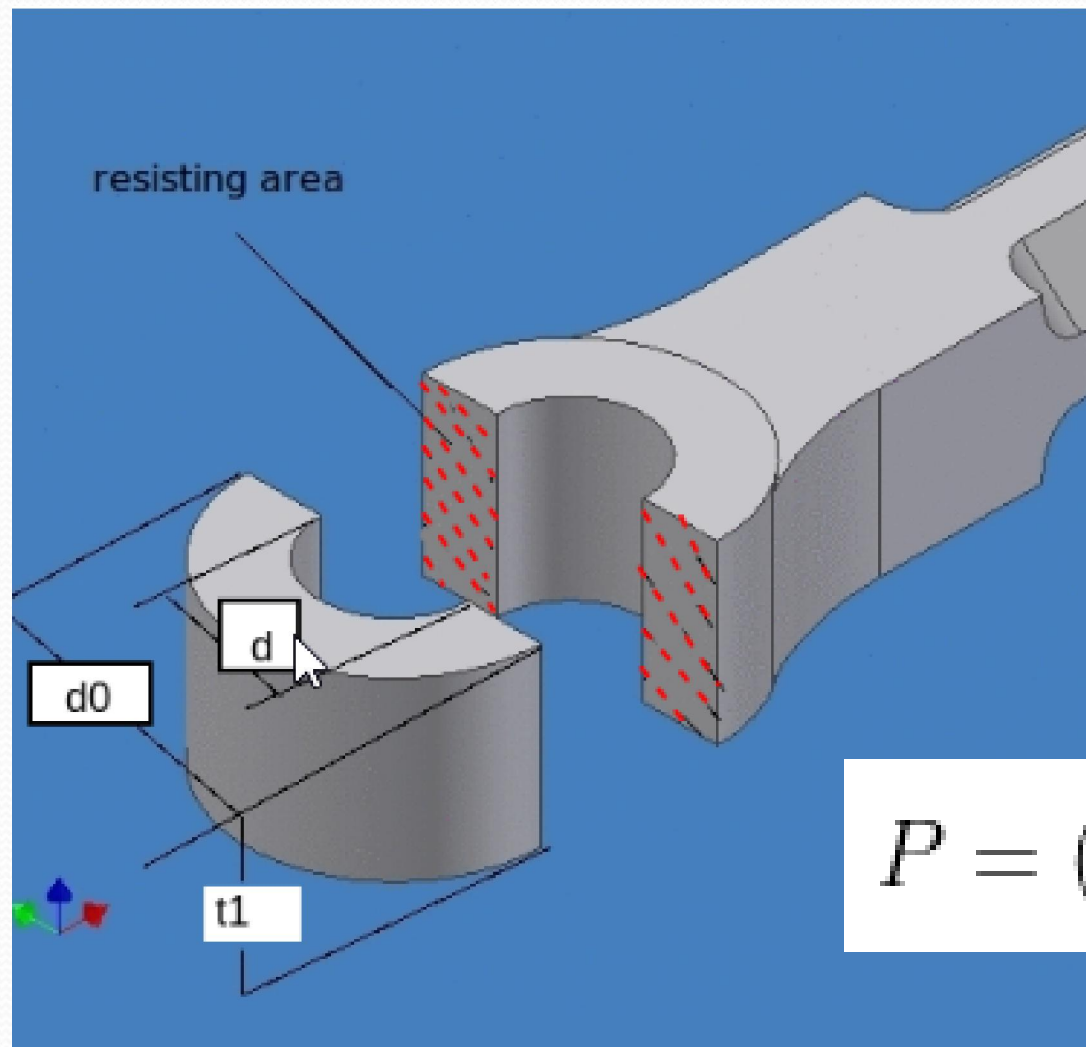
$$P = \frac{\pi}{4} \times D^2 \times \sigma_t$$

Double shear Failure of pin:



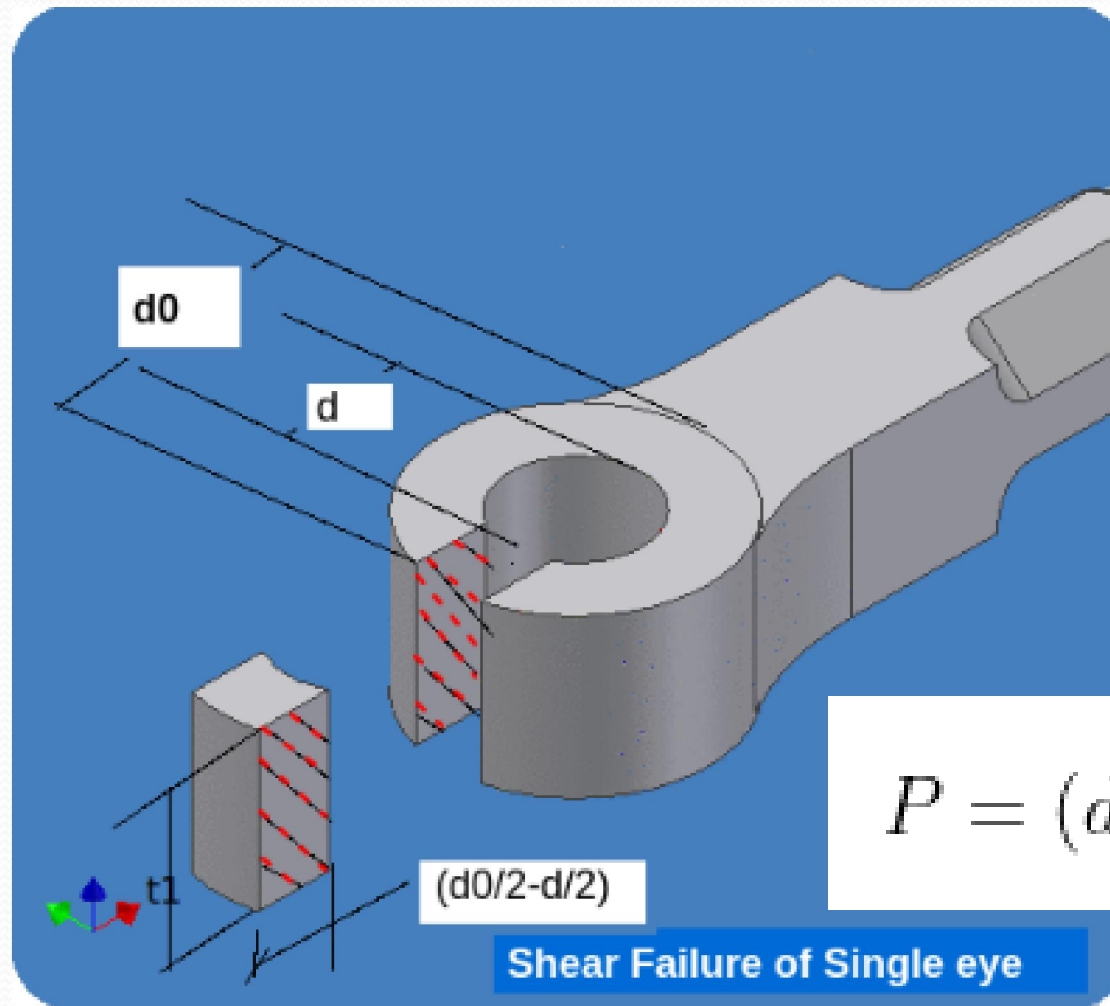
$$P = 2 \times \frac{\pi}{4} \times d^2 \times \sigma_s$$

Tensile failure of eye end:



$$P = (d_0 - d)t_1 \times \sigma_t$$

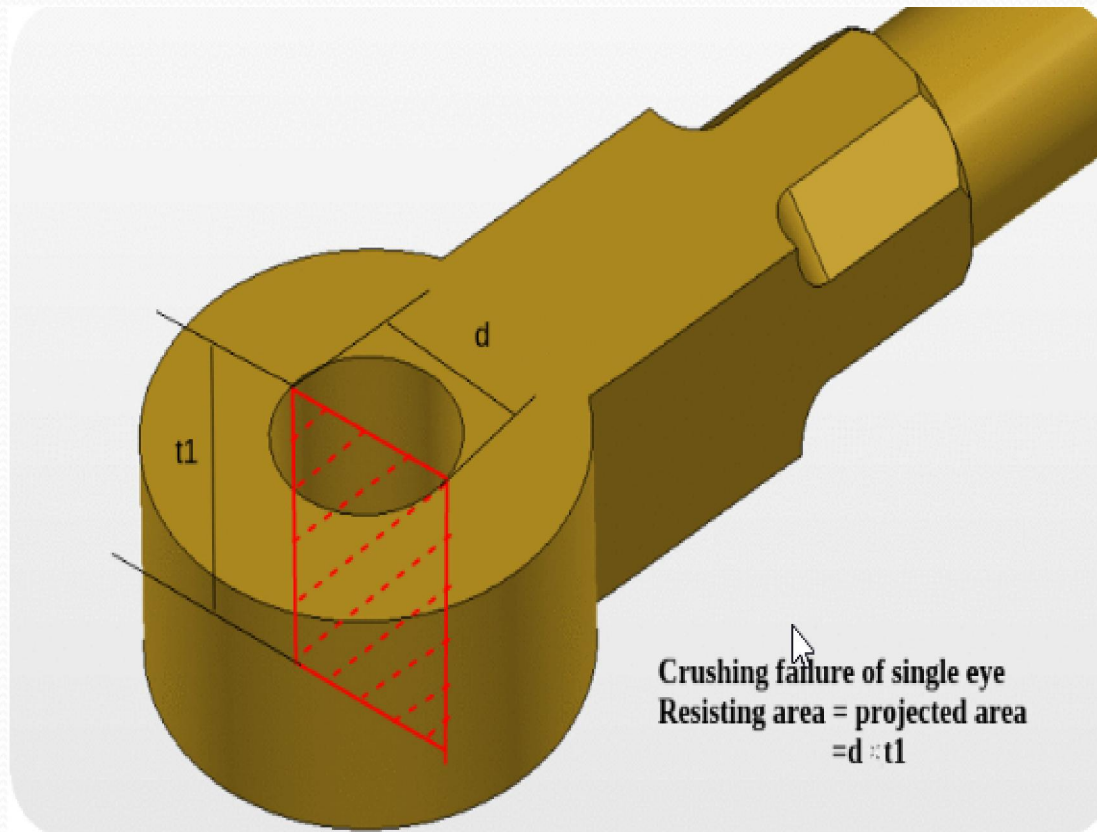
Shear failure of eye end:



$$P = 2 \times \left(\frac{d_0}{2} - \frac{d}{2} \right) t_1 \times \sigma_s$$

$$P = (d_0 - d) \times t_1 \times \sigma_s..$$

Crushing Failure of eye end:



$$P = d \times t_1 \times \sigma_c$$

Dimensions calculated by relations:

P = Tension in rod (Load on the joint)

D = Diameter of rod

D_1 = Enlarged diameter of rod (1.1 D)

d = Diameter of pin

d_1 = Diameter of pin head (1.5 d)

d_o = Outer diameter of eye or fork (2 d)

t_1 = thickness of eye end (1.25 D)

t_2 = thickness of forked end (double eye) (.75 D)

Dimension of various components:

If d is the diameter of rod
then

diameter of pin $d_1 = d$

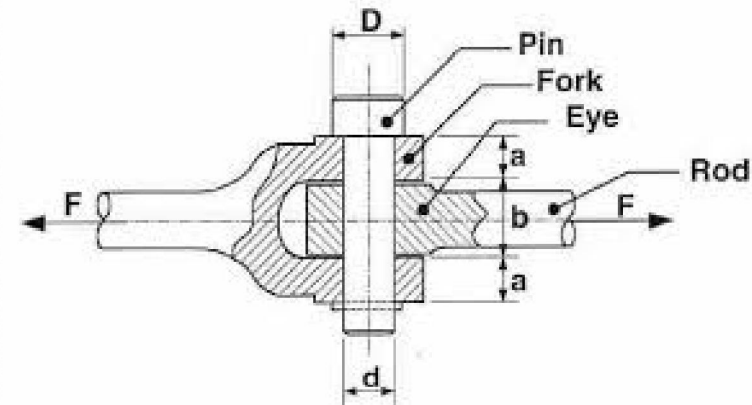
Outer diameter of eye $d_2 = 2d$

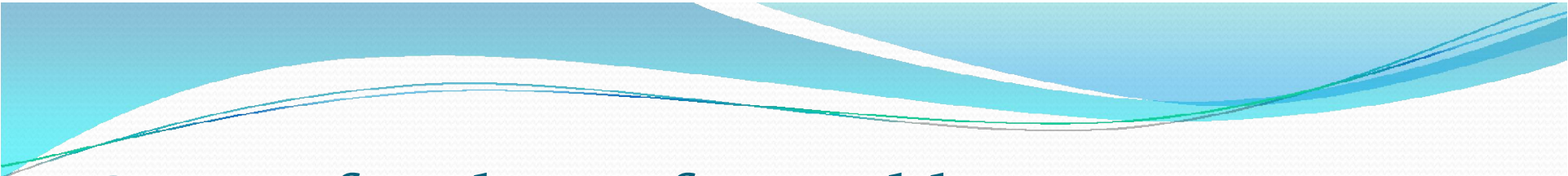
Diameter of knuckle pin head and collar $d_3 = 1.5d$

Thickness of single eye or rod end $t = 1.25d$

Thickness of fork $t_1 = 0.75d$

Thickness of pin head $t_2 = 0.5d$





Cases of Failure of Knuckle Joint :

P = Tensile load acting on the rod

d = Diameter of the rod

d = Diameter of the pin

d_1 = Outer diameter of eye

d_1 = Outer diameter of fork end

t = Thickness of single eye

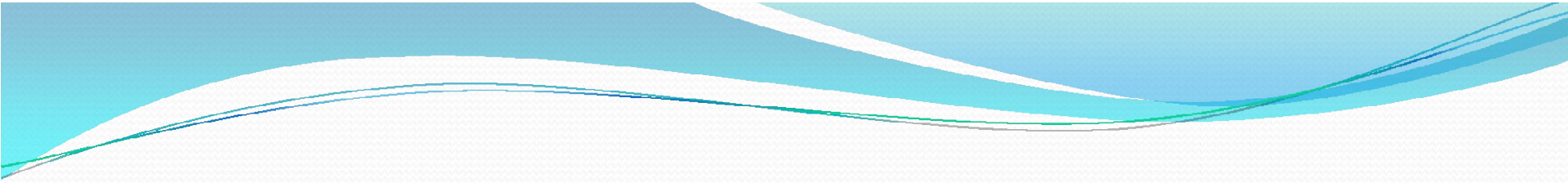
t_1 = Thickness of fork

σ^t , τ and σ^c = stresses in tension, shear and crushing



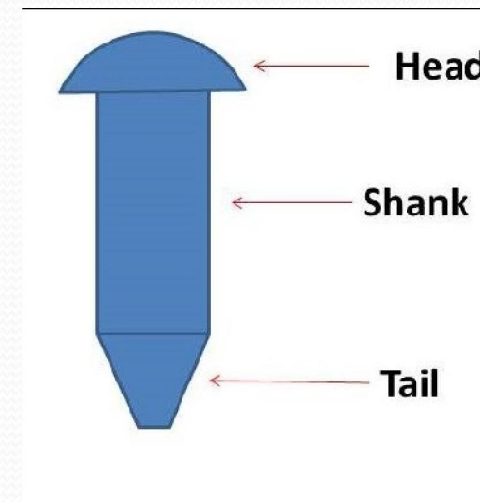
Cases of Failure of Knuckle Joint :

- 1. Failure of the solid rod in tension
- 2. Failure of the single eye or rod end in tension
- 3. Failure of the single eye or rod end in shearing
- 4. Failure of the single eye or rod end in crushing
- 5. Failure of the forked end in tension
- 6. Failure of the forked end in shear
- 7. Failure of the forked end in crushing
- 8. Failure of the knuckle pin in shear



Rivet joint

A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail.

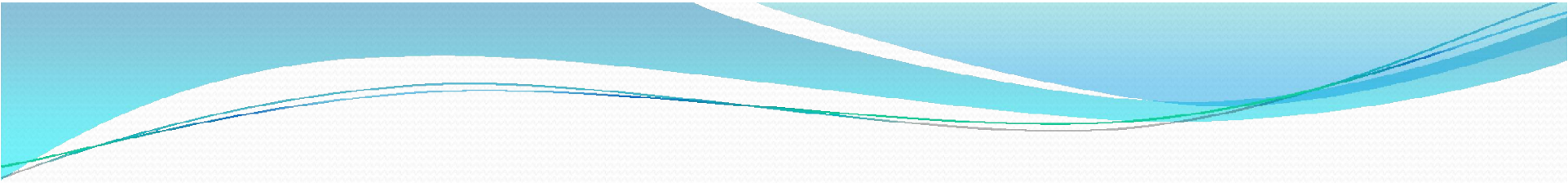


The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals.



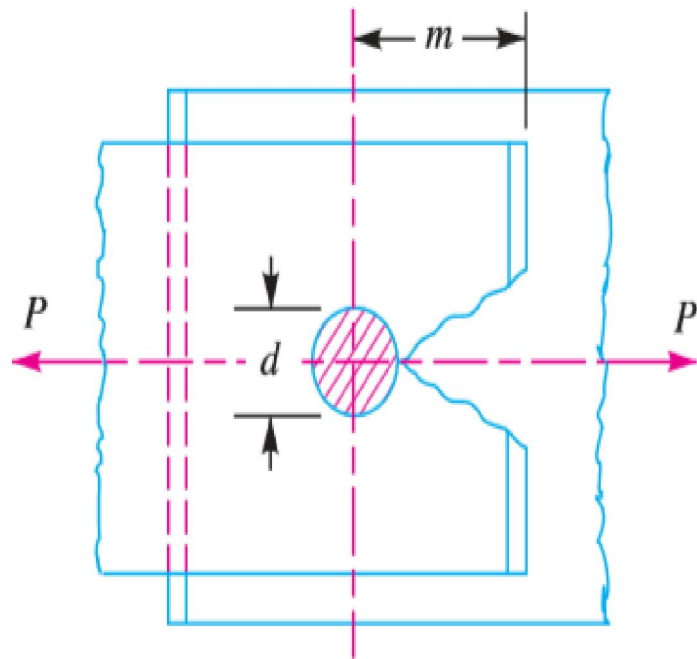
Important Terms Used in Riveted Joints

1. **Pitch:** It is the distance from the centre of one rivet to the centre of the next rivet denoted by p .
2. **Back pitch:** It is the perpendicular distance between the centre lines of the successive rows.
3. **Diagonal pitch:** It is the distance between the centres of the rivets in adjacent rows of zig-zag riveted
4. **Margin or marginal pitch:** It is the distance between the centre of rivet hole to the nearest edge of the plate, denoted by m

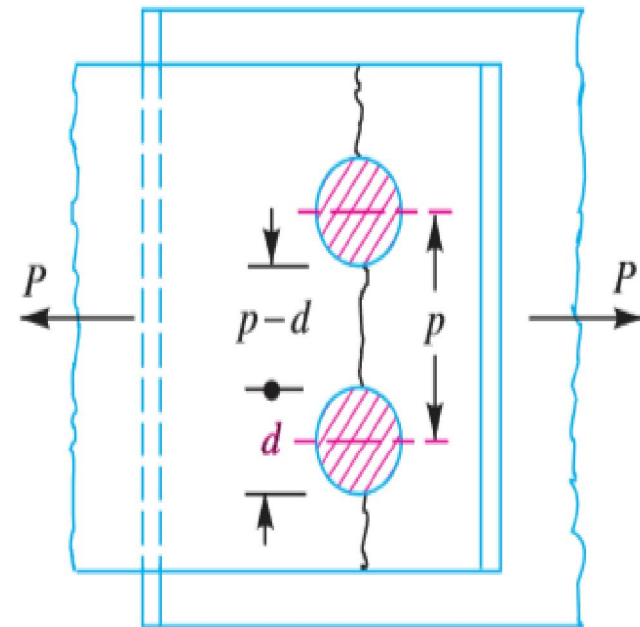


Failures of a Riveted Joint

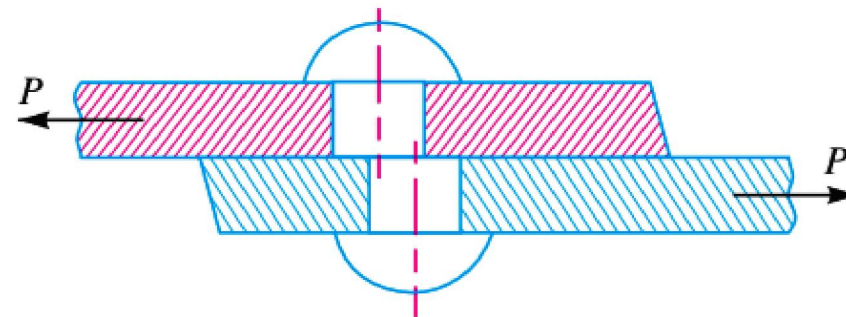
1. Tearing of the plate at an edge
2. Tearing of the plate across a row of rivets
3. Shearing of the rivets



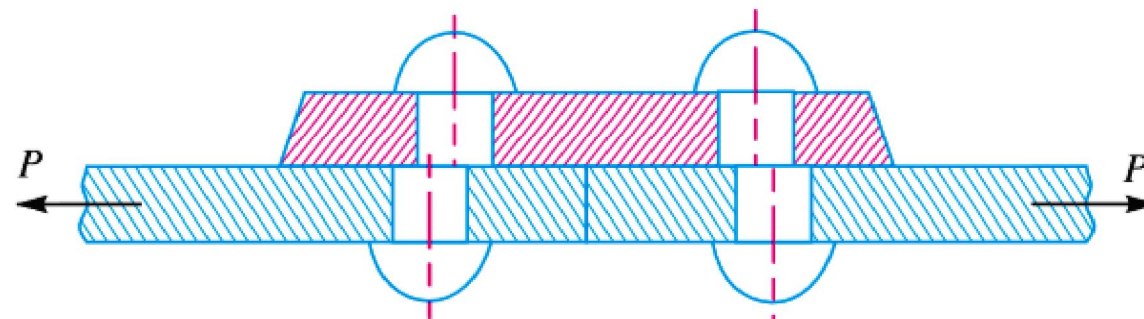
Tearing of the plate at an edge



Tearing of the plate across a row of rivets

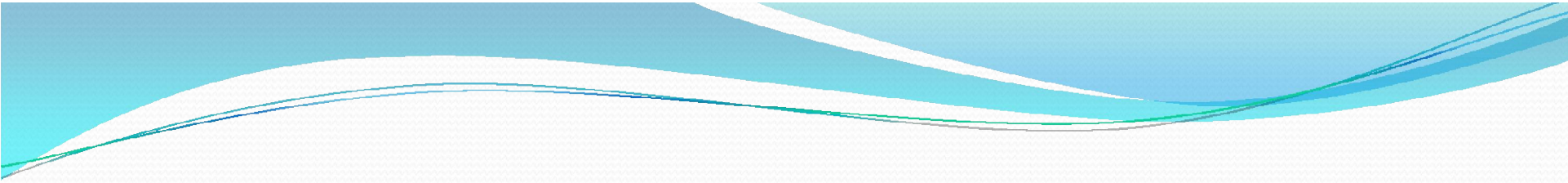


(a) Shearing off a rivet in a lap joint.

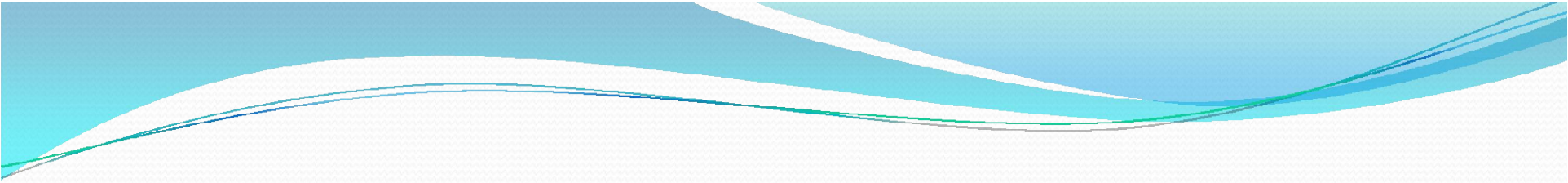


(b) Shearing off a rivet in a single cover butt joint.

Shearing of rivets

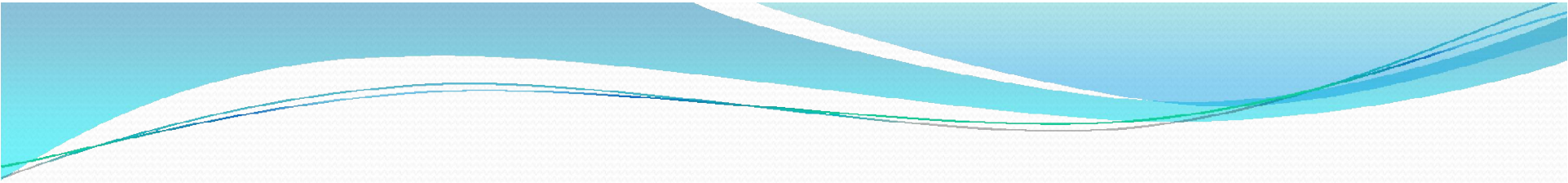


Design of CAM



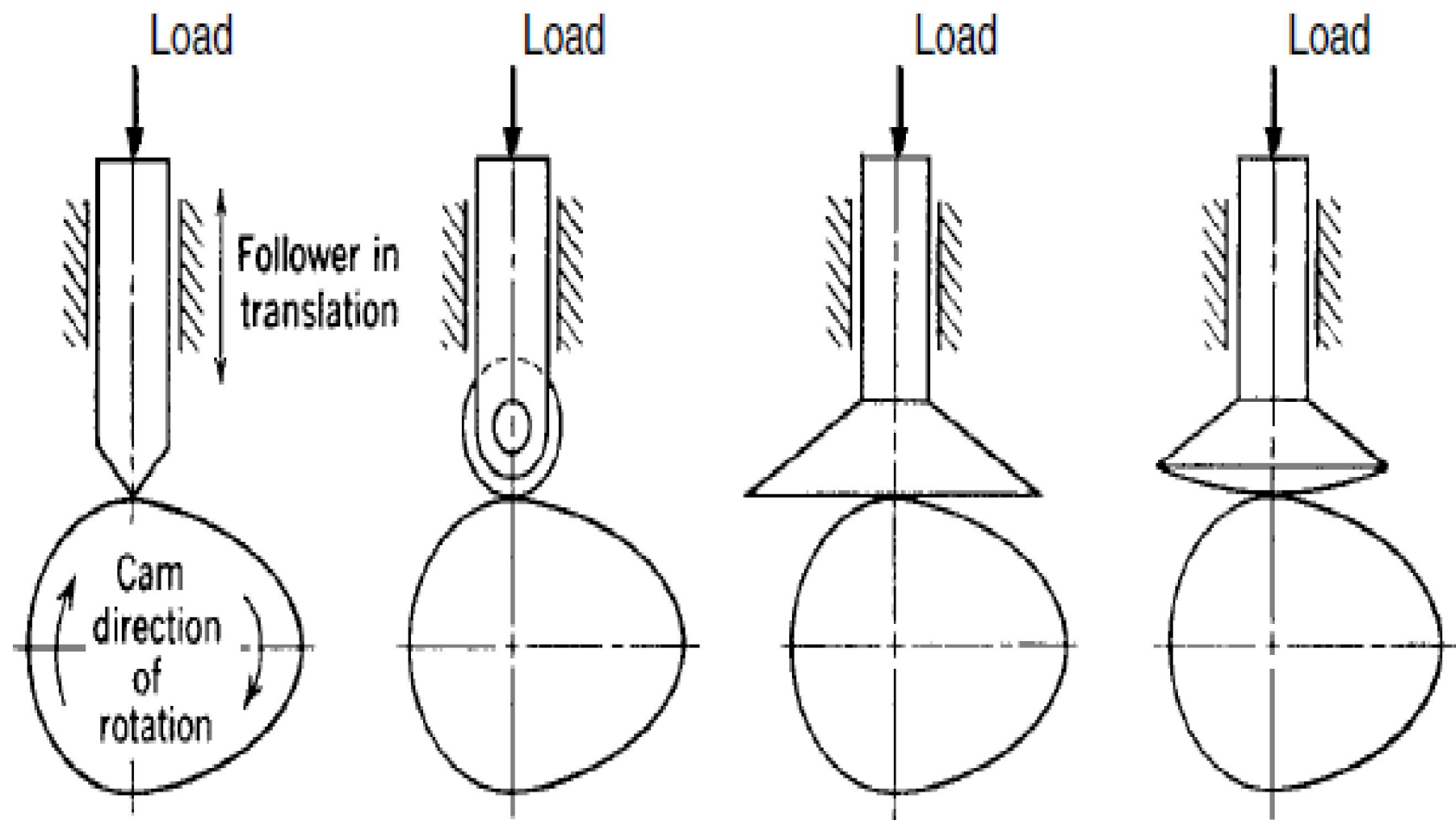
INTRODUCTION :

A cam is an element of the cam-follower mechanical system that compels the movement of the follower by direct contact. The motion of the follower is the result of a program. Just as a computer is programmed, so is a cam. Thus, the system can be thought of as a *mechanical information device*.



FOLLOWER TYPES :

Cam follower systems are classified by referring to the follower or the cam or both. The follower movement is *translation, oscillation, or indexing*. The follower surface is *knife-edge, flat, curved, or roller*. The *follower restraint to the cam* is *positive-driven by the use of rollers in the cam groove or multiple conjugate cams, is spring-loaded, or occurs by gravity*.

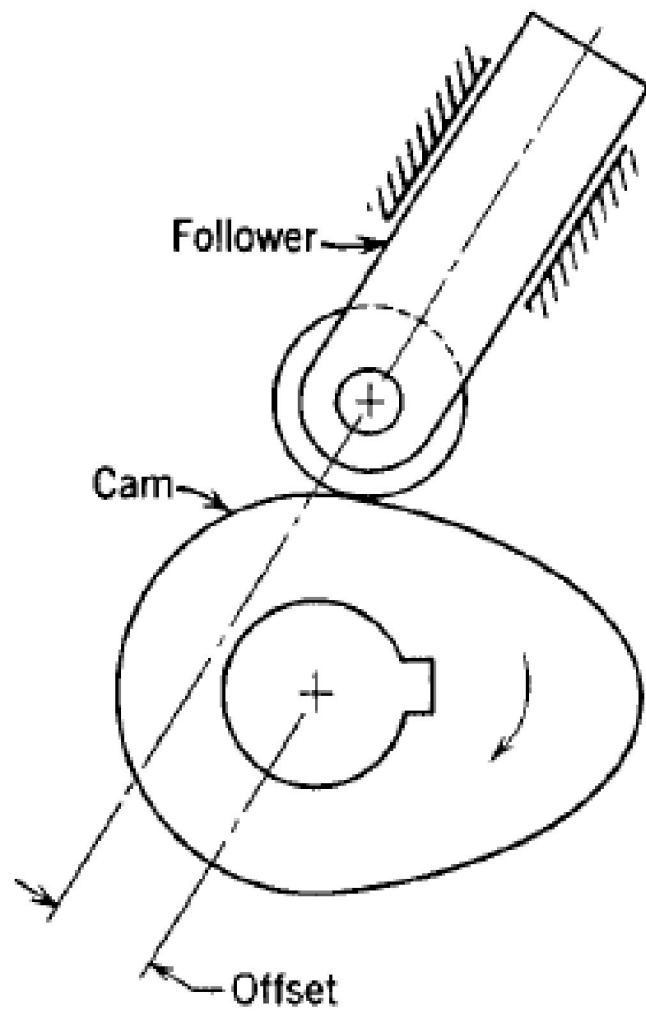


(a) Knife-edge follower.

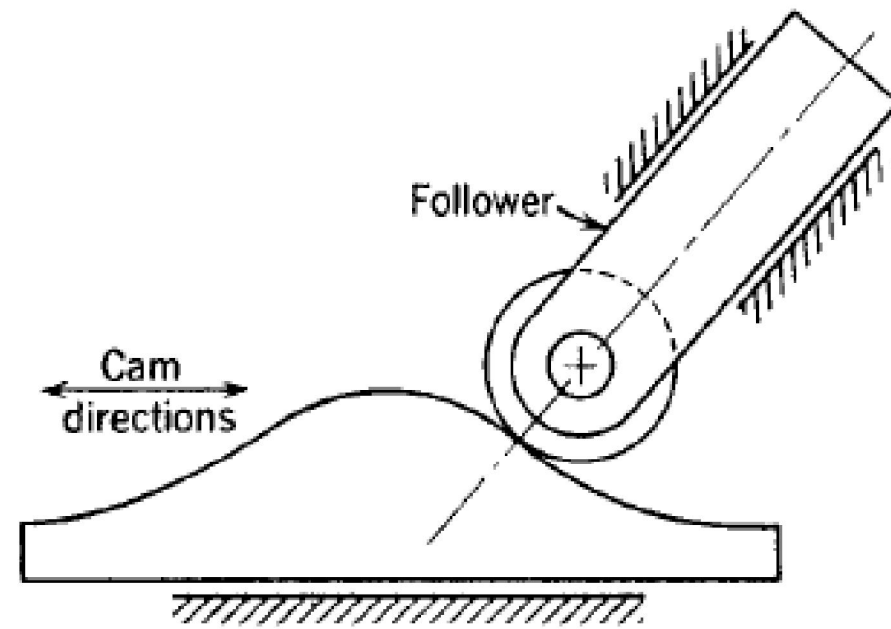
(b) Roller follower.

(c) Flat-faced follower.

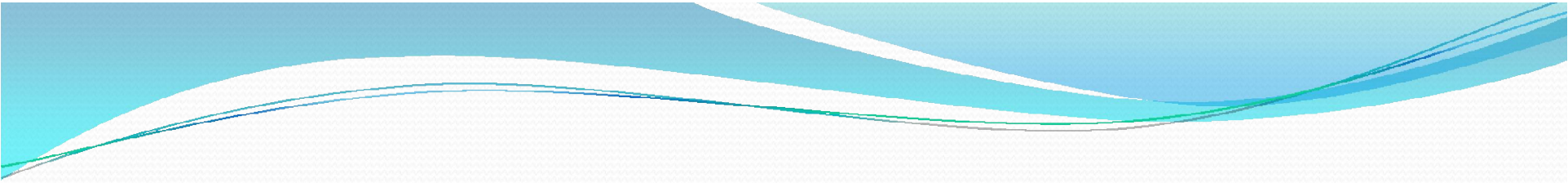
(d) Spherical-faced follower.



(a) Radial cam



(b) Translating cam

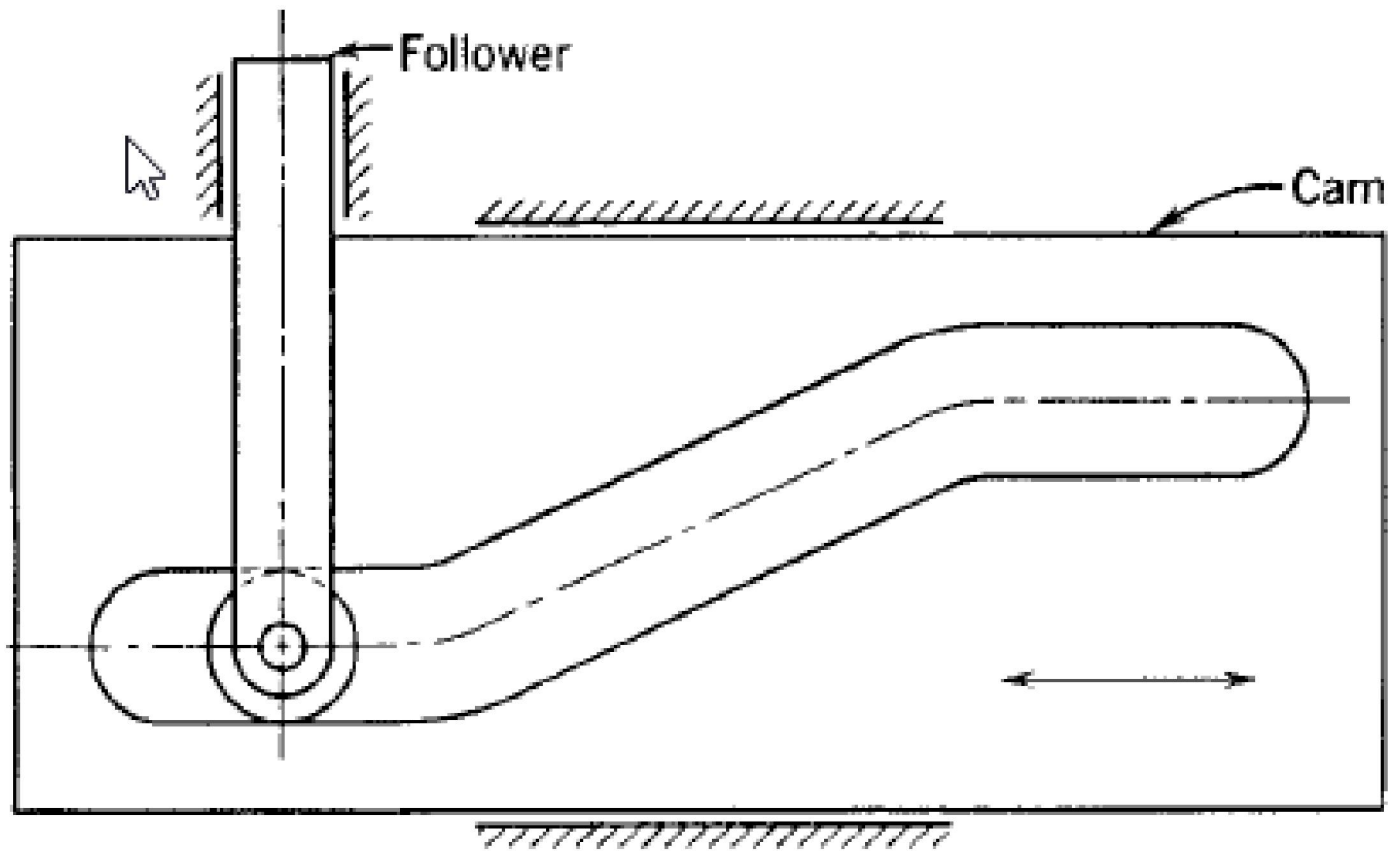


CAM CLASSIFICATIONS:

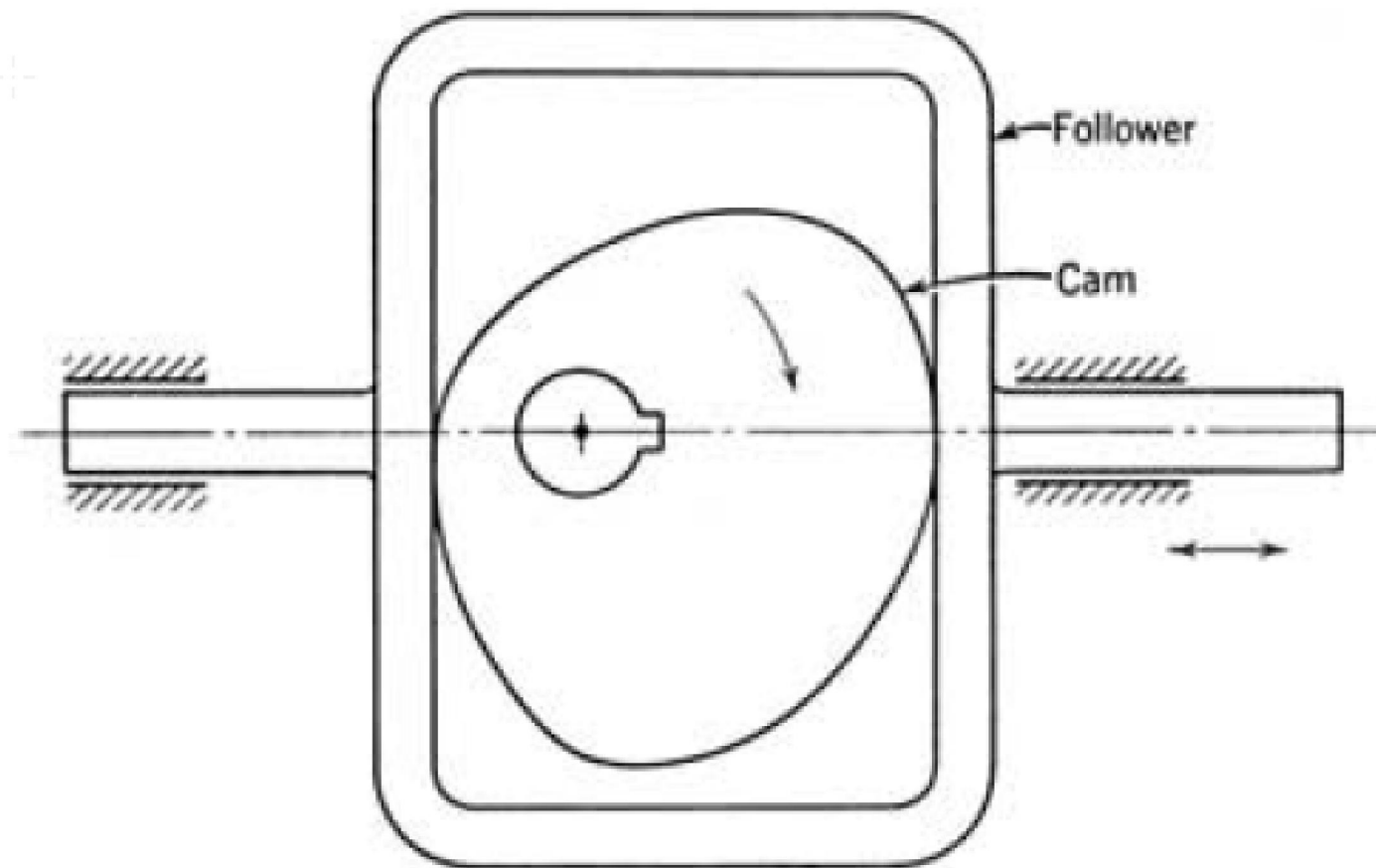
Cams are classified in three ways:

1. In terms of their shape, such as wedge, radial, cylindrical, globoidal, conical, spherical or three-dimensional;
2. In terms of the follower motion, such as dwell-rise-dwell (DRD), dwell-rise-return-dwell(DRRD), or rise-return-rise (RRR)
3. In terms of the follower constraint, which is accomplished by either positive drive or spring load.

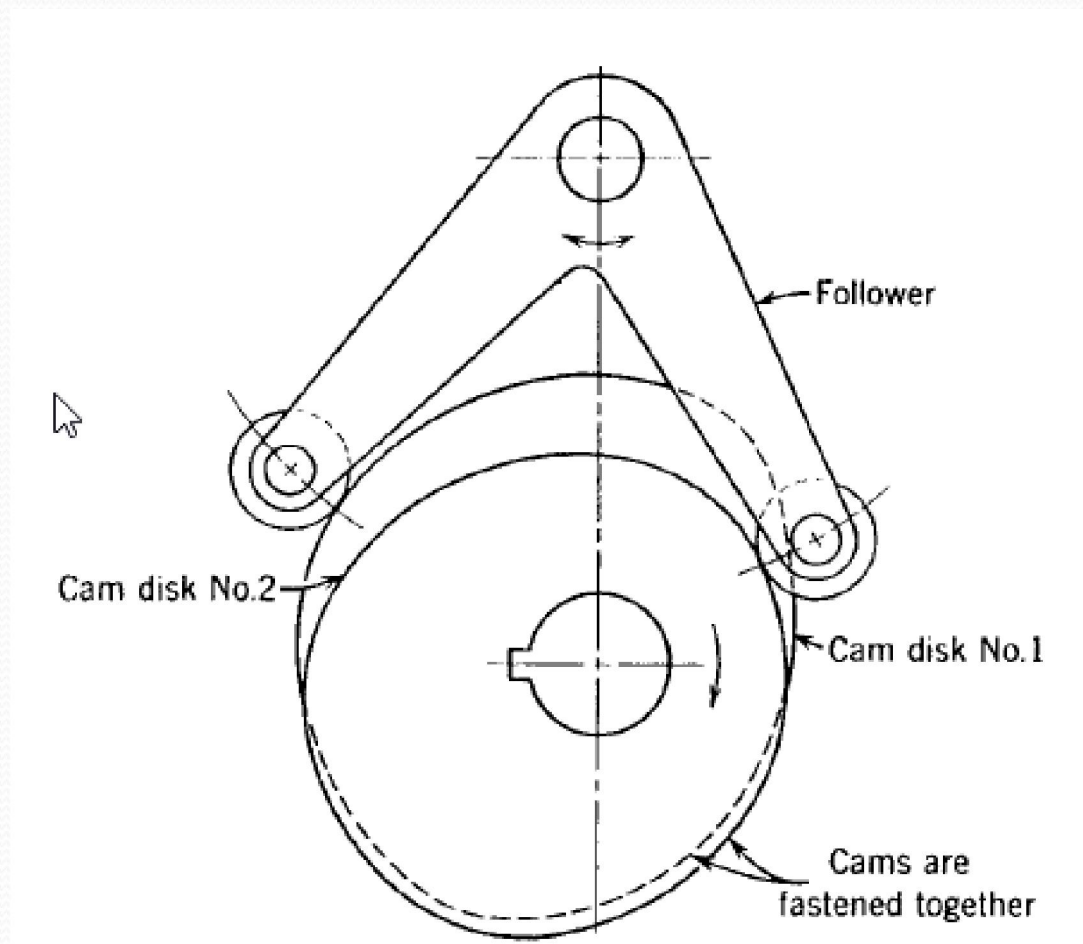
Translating cam



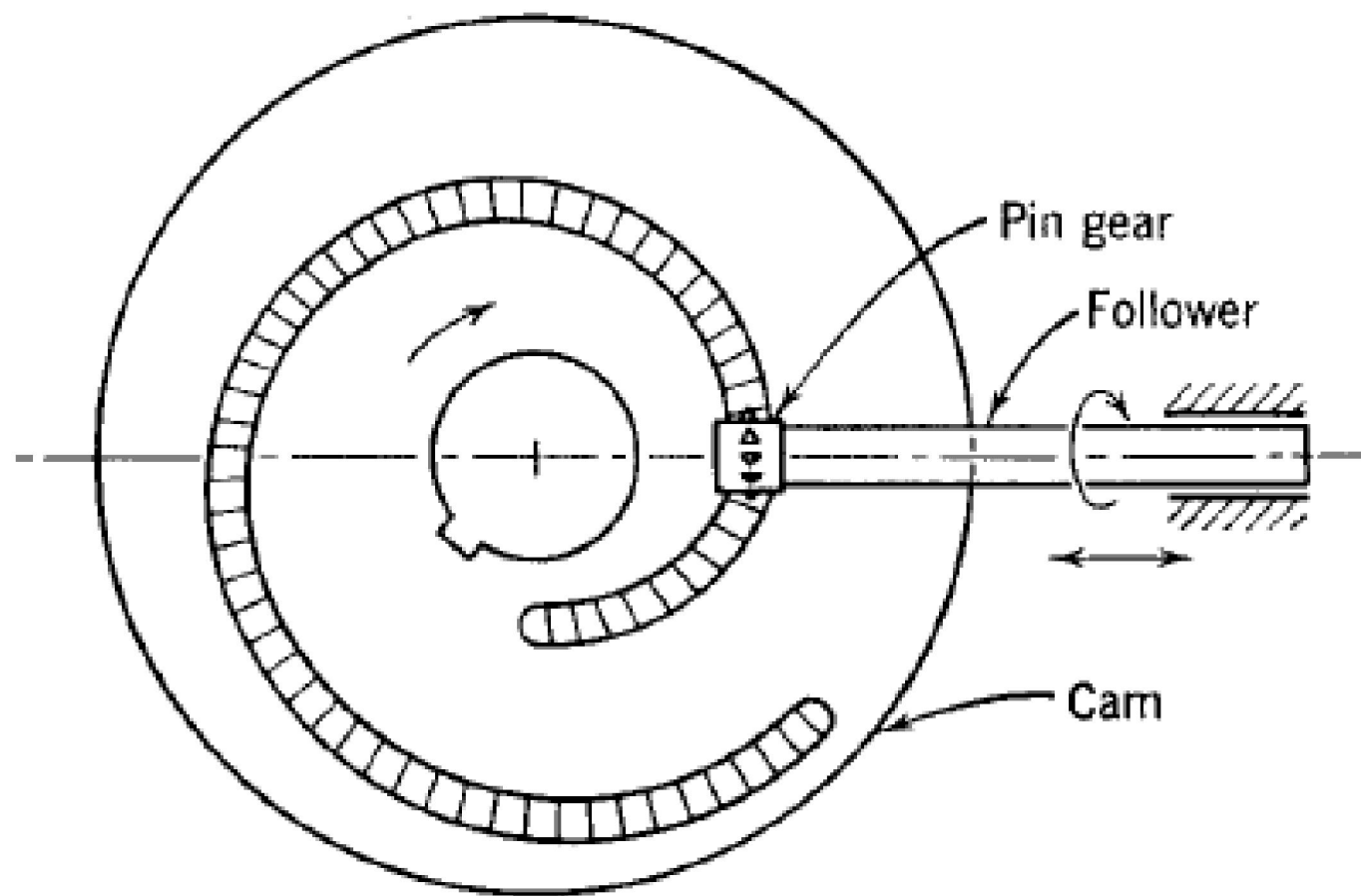
Yoke cam



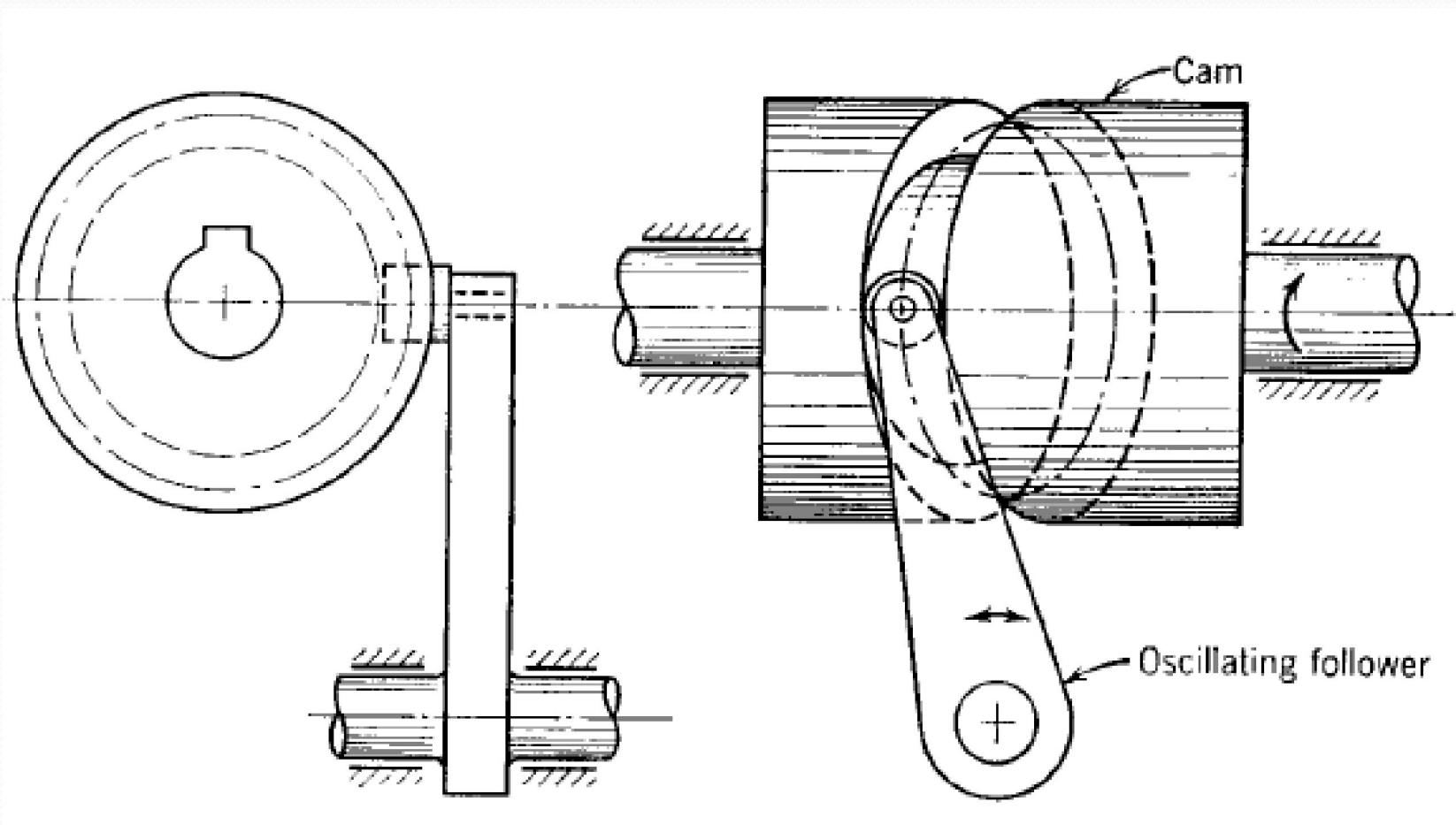
Conjugate cam



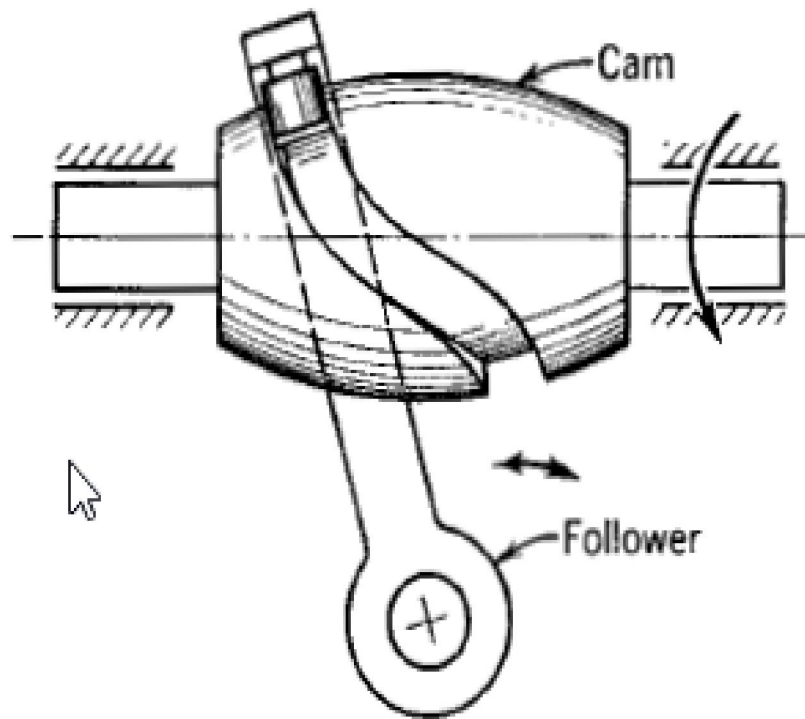
Spiral cam



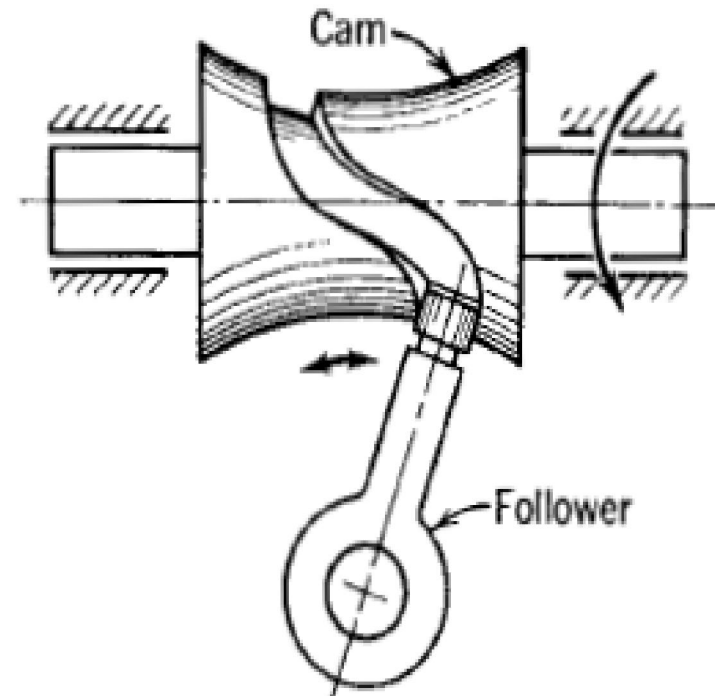
Cylindrical cam



Convex and concave cam

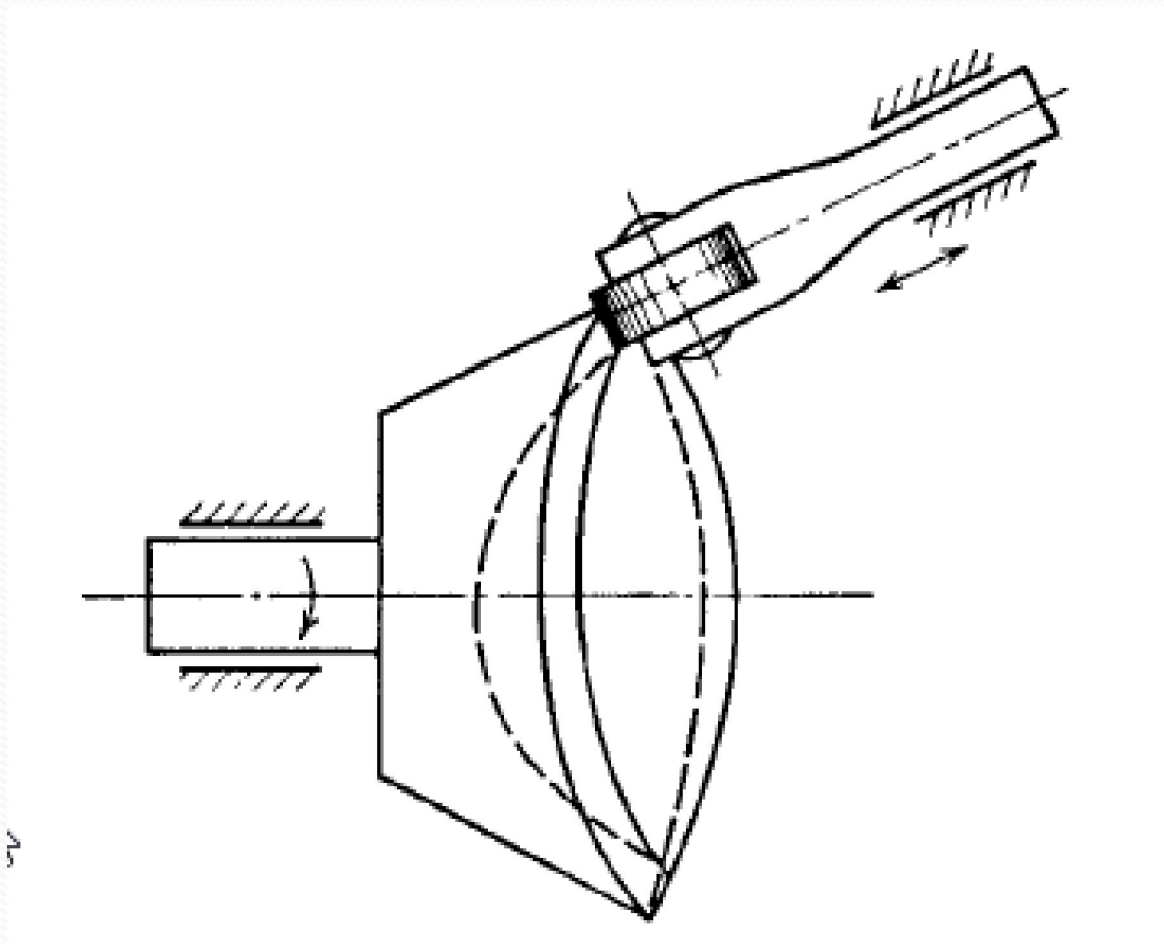


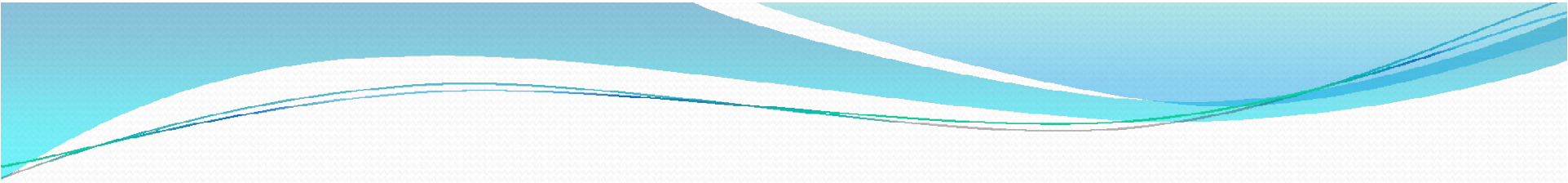
(a) Convex cam.



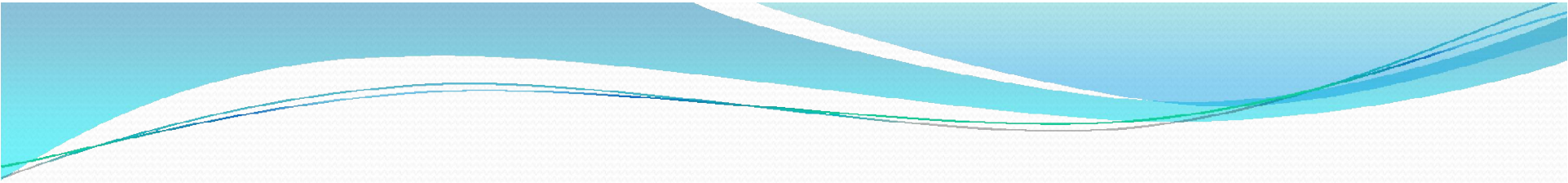
(b) Concave cam.

Conical cam



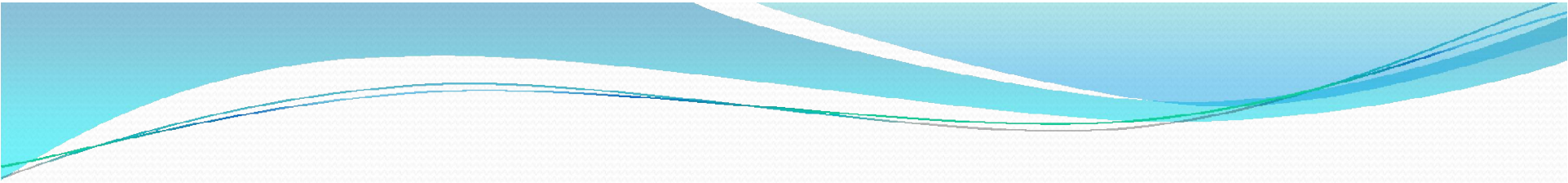


Design of Leaf Springs



Leaf Springs

In order to have an idea of working principle of a leaf spring, let us think of the diving board in a swimming pool. The diving board is a cantilever with a load, the diver, at its free end. The diver initiates a to and fro swing of the board at the free end and utilizes the spring action of the board for jumping. The diving board basically is a leaf spring.

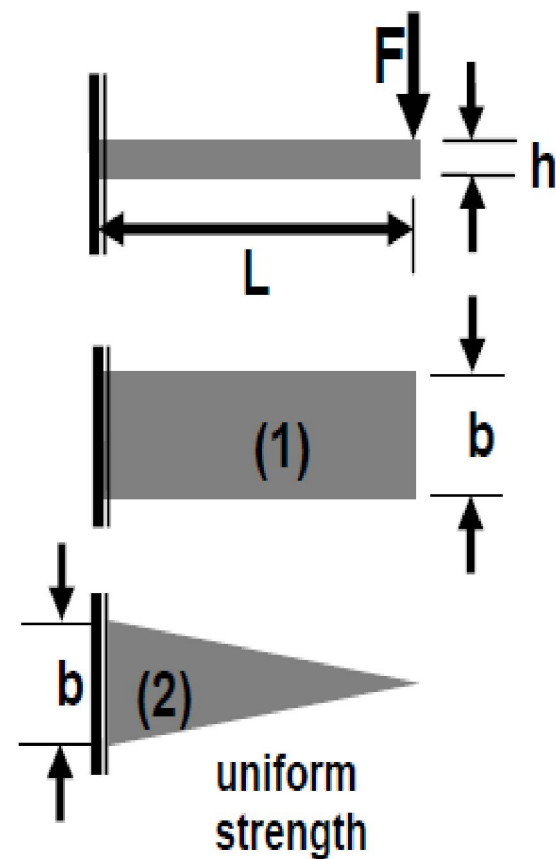


Leaf Springs

The leaf springs are widely used in suspension system of railway carriages and automobiles. But the form in which it is normally seen is laminated leaf spring. A simple cantilever type leaf spring is shown in the Figure.

Leaf Springs

In the cantilever beam type leaf spring, for the same leaf thickness, h , leaf of uniform width, b (case 1) and, leaf of width, which is uniformly reducing from b (case 2) is considered. From the basic equations of bending stress and deflection, the maximum stress, $\sigma_{\max}$ and tip deflection, $\delta_{\max}$ can be derived.



Leaf Springs

For case 1(uniform width)

$$\sigma_{\max} = \frac{6FL}{bh^2}$$

$$\delta_{\max} = \frac{4FL^3}{Ebh^3}$$

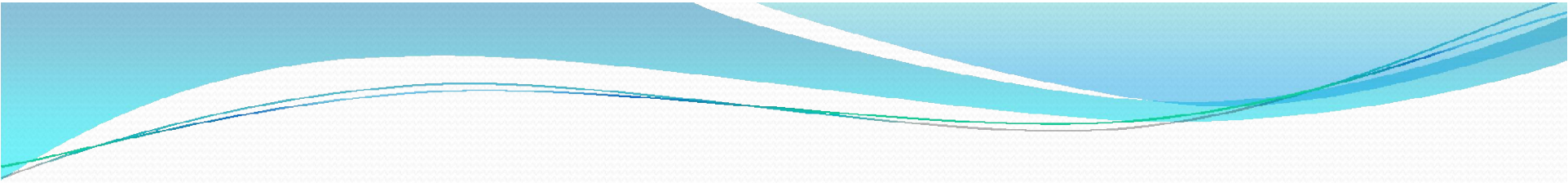
Leaf Springs

For case 2(non uniform width)

$$\sigma_{\max} = \frac{6FL}{bh^2}$$



$$\delta_{\max} = \frac{6FL^3}{Ebh^3}$$

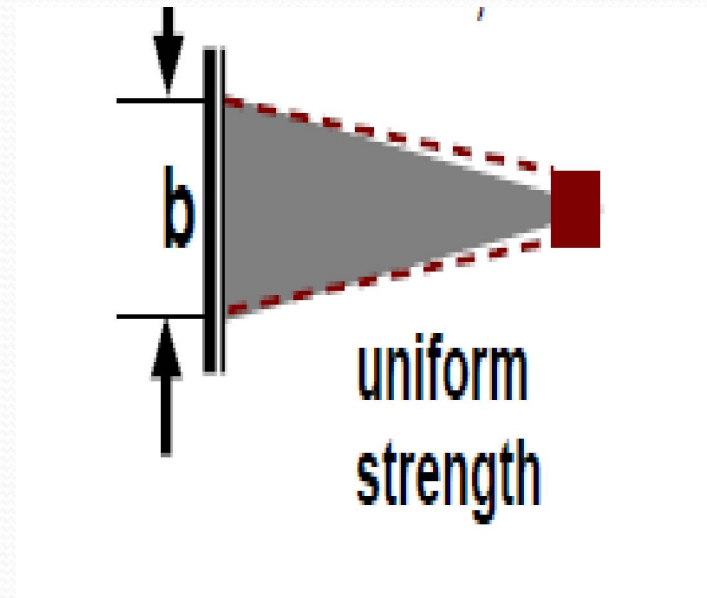


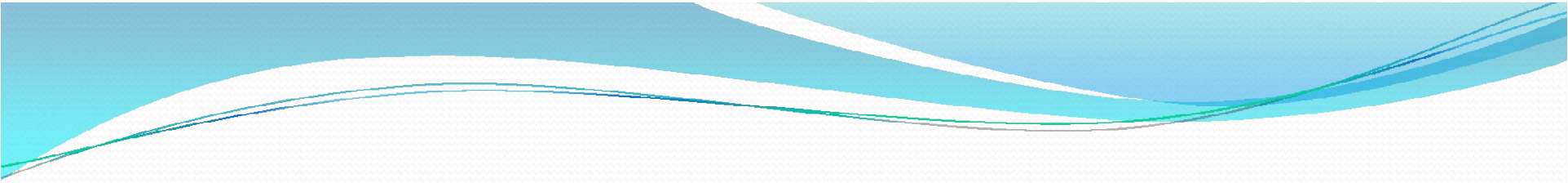
Leaf Springs

In the second case it is observed that instead of uniform width leaf, if a leaf of varying width (triangular one as shown in the figure) is used, the bending stress at any cross section is same and equal to $\max \sigma$. This is called as leaf of a uniform strength. Moreover, the tip deflection being more, comparatively, it has greater resilience than its uniform width counterpart.

Leaf Springs

However, one should keep in mind that in order to withstand the shear force the tip has to have some width. This is shown as a red zone in the figure. In one way non uniform width leaf is a better design than a uniform width leaf.

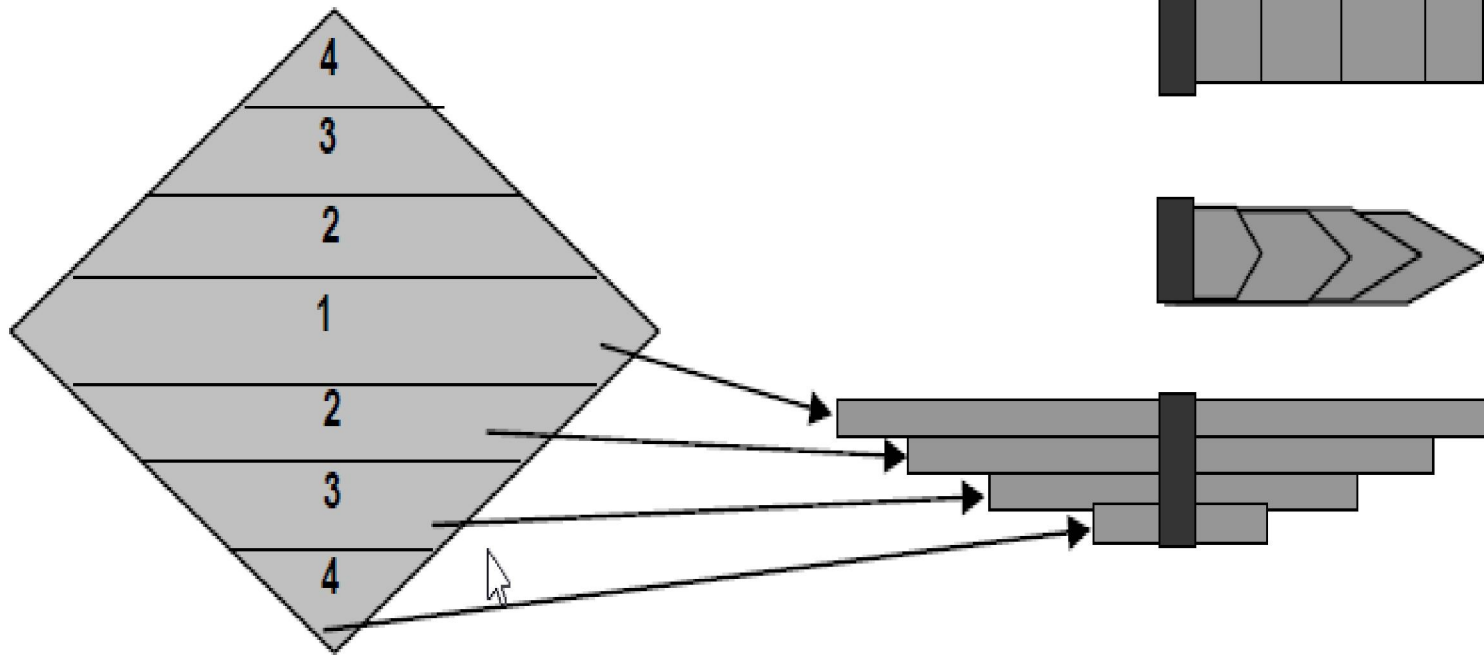




Laminated Springs

One of the difficulties of the uniform strength beam, is that the value of width b sometimes is too large to accommodate in a machine assembly. One practice is that instead of keeping this large width one can make several slices and put the pieces together as a laminate. This is the concept of laminated spring.

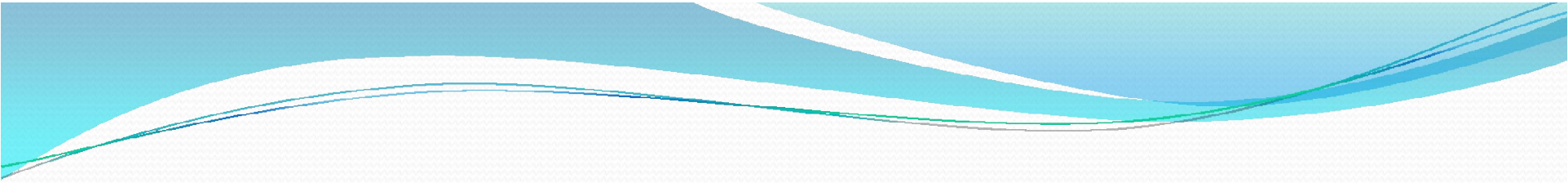
Laminated Springs



Laminated Springs

The Lozenge shaped plate is cut into several longitudinal strips, as indicated in the figure. The central strip, marked 1 is the master leaf which is placed at the top. Then two pieces, marked 2 are put together, side by side to form another leaf and placed below the top leaf. In the similar manner other pairs of strips, marked 3 and 4 respectively are placed in the decreasing order of strip length to form a laminated spring. Here width of each strip, is given as :

$$b_N = \frac{b}{N}$$



Thanks