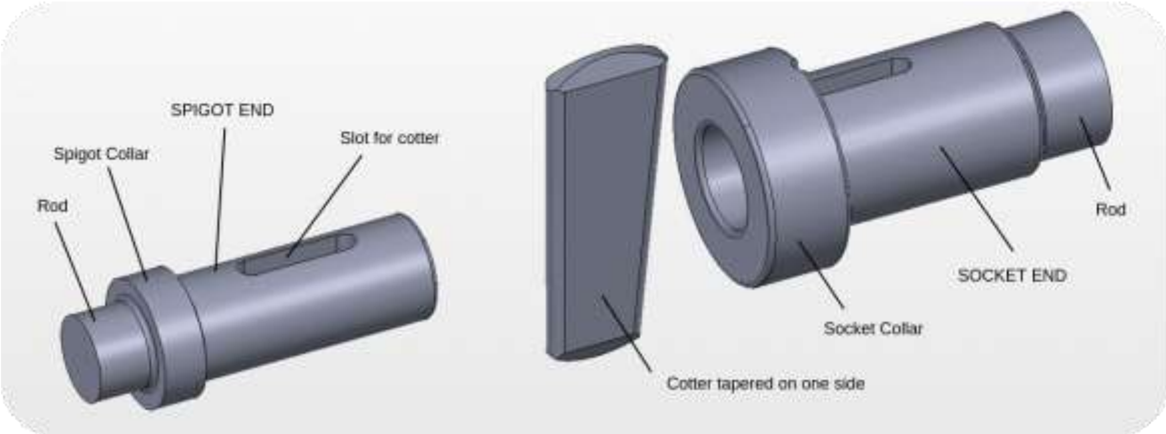
A) DESIGN PROCEDURE OF COTTER JOINT

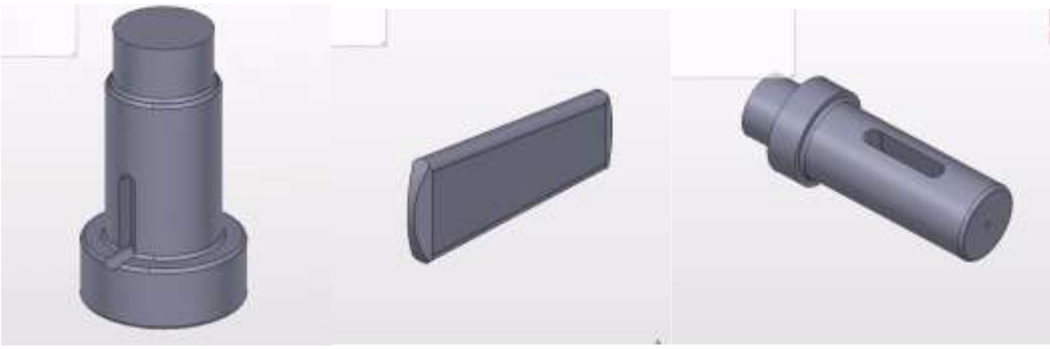
Cotter Joint Introduction

Before going into detailed steps to design and find dimensions of cotter joint, it is necessary to understand clearly the various components, their functions and assembly of cotter joint. Here is the exploded view of cotter joint.



Exploded View of Cotter joint assembly

Let us see the animation of each component so as to get clear idea of its details and dimensions.



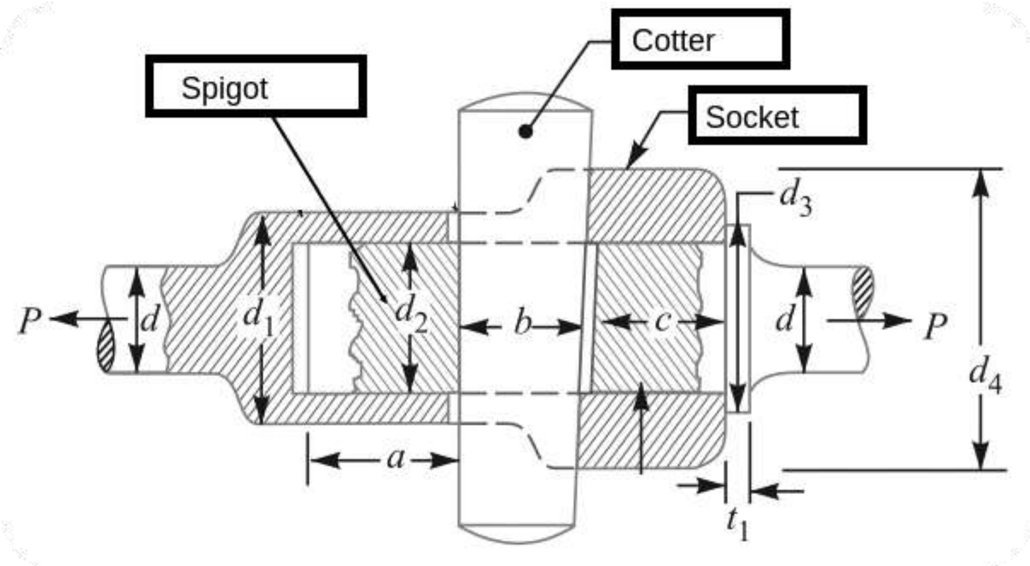
Spigot is the male part of the joint , it has a rectangular slot for passing the cotter through it. Spigot has a collar which rests against the socket end.

Socket is the female part of the joint, it also has a rectangular slot for passing the cotter through it. It has a circular hole in which spigot fits.

Cotter is a wedge shaped piece of metal which actually connects two parts which are non rotating. Cotter is fitted in the slot and remains in its position by wedge action.
Taper is provided to, i) With taper it is easy to remove the cotter and dismantle the joint ii) It ensures tightness of the joint in operation and prevents loosening of the parts.

Cotter is driven in or out using the hammer. Value of taper on cotter is 1 in 48 to 1 in 24 .

DESIGN PROCEDURE OF COTTER JOINT

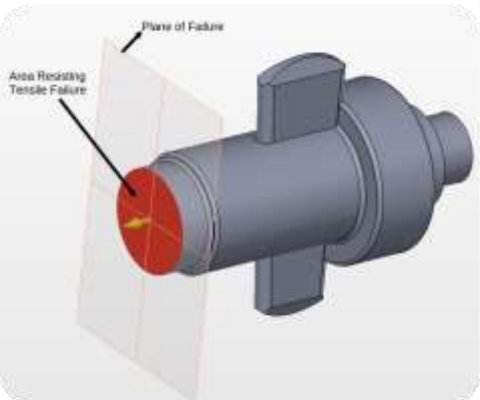


Notations used in design are as follows,

P= Load on the joint or pull acting on rods, d= Diameter of the rod, d1= outer diameter of socket,d2= Diameter of spigot or inside diameter of socket, d3= Outside diameter of spigot collar,d4= Diameter of socket collar, t1= 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

Step 1 : Design of rod('d')

Tensile failure of rod



Since the area resisting is circular using the basic equation of design

Load = Stress * Area

$$P = (Area \quad Resisting \quad Tension) \times (Allowable \quad Stress)$$

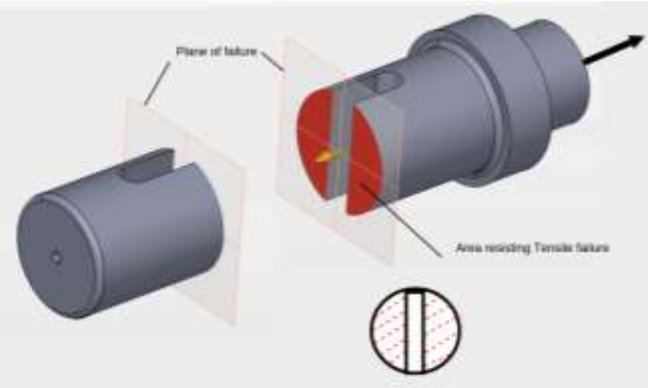
$$P = \frac{\pi}{4} \times d^2 \times \sigma_t$$

...From this equation diameter d of the rod is determined.

Step 2 : Design of Spigot { ‘d_2’,’d3’,t1’,’a’}

Tensile failure of Spigot

The spigot end may fail under tension into two parts as shown in figure below, Since the plane of failure is perpendicular to the direction of force it is tensile failure,



the area resisting the failure is shown by red in the diagram, since it is circular minus a rectangle the equation will be,

$P=[\frac{\pi}{4}(d_2)^2-d_2\times t]\sigma_t$ …………From this equation the diameter of spigot end d_2 can be found. If you observe clearly it will form a quadradic equation .

Emperical Relations

{Other three dimensions of Spigot are decided on the basis of emperical relations and then checked whether the stress induced is withing safe limits or not}

$d_3 = 1.5 \times d$

$t_1 = 0.45 \times d$

$a = 0.75 \times d$

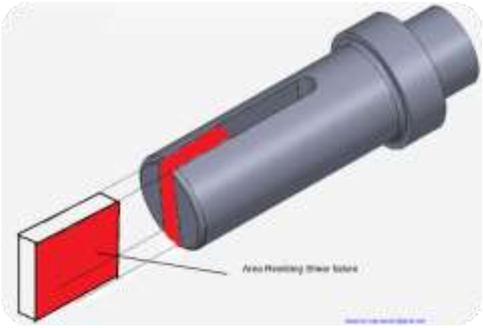
Crushing failure of Spigot (Check crushing stress induced)

$P = t \times d_2 \times \sigma_c$ **……...Find σ_c Using this equation and check if it is within safe limits or not .**

Shear failure of Spigot (Check Shear stress induced)

$P = 2 \times a \times d_2 \times \tau$ **……...Find τ Using this equation and check if it is within safe limits or not .**

Diagram showing the Shear failure of Spigot end

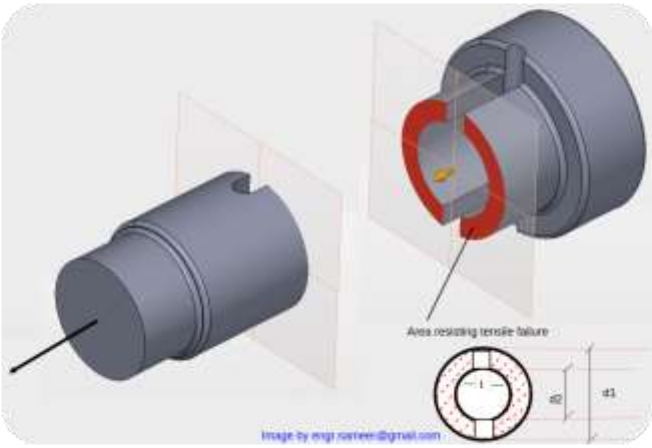


Step 3 : Design of Socket { ‘d1’,’d4’,’c’}

Following dimensions of socket are to be found and stresses induces must be checked for safe limit.

Tensile failure of Socket

The socket may also fail under tension into two parts as shown in figure below, since the plane of failure is perpendicualr to direction of force it is the tensile failure.



Area resisting is a hollow square minus a rectangular strip having length (d1-d2) and thickness t, so the strength equation becomes,

$P = \left\{\frac{\pi}{4}[(d_1)^2 - (d_2)^2] - (d_1 - d_2)t\right\}\sigma_t$ ………..From this equation diameter d_1 can be determined, again there is quadradic equation formation. Refer to numerical problems section to view the detailed solution.

Emperical Relations

{Other three dimensions of Socket are decided on the basis of emperical relations and then checked whether the stress induced is withing safe limits or not}

$$d_4 = 2.4 \times d$$

$$c = 0.75 \times d$$

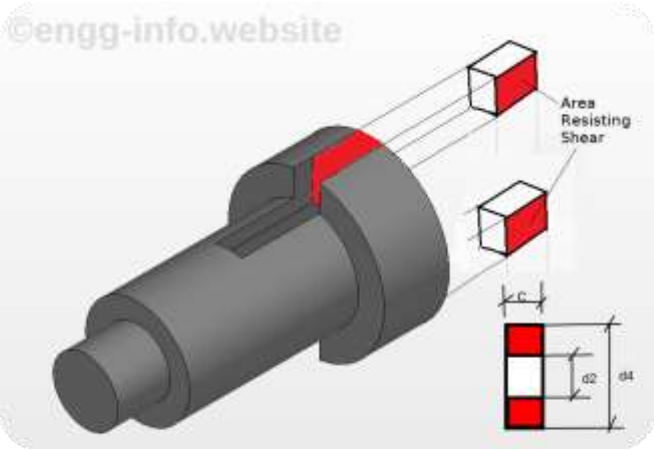
Crushing failure of Socket(Check crushing stress induced)

$P = (d4 - d_2) \times t \times \sigma_c$ **……..Find σ_c Using this equation and check if it is within safe limits or not .**

Shear failure of Socket (Check Shear stress induced)

$P = 2(d4 - d_2) \times c \times \tau$ **……..Find τ Using this equation and check if it is within safe limits or not .**

Shear Failure of socket end is shown below



Step 4 : Design of Cotter { ‘t’, ‘b’ and ‘l’ of cotter}

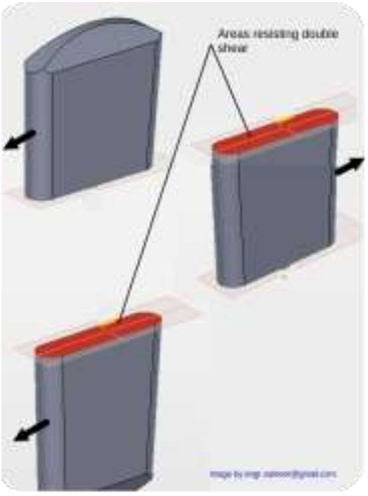
Empirical relation

The cotter thickness is determined using an empirical relation, and is proportional to the diameter of rod,

$$t = 0.31 \times d$$

Calculate the width of b of the cotter by sharing and bending consideration

Double shear of Cotter



$$P = Area \quad resisting \quad doubleshear \times allowable \quad shear \quad stress$$

$P = 2 \times b \times t \times \sigma_t$ {Note that 2 is because of double shear failure}

Bending failure of cotter

$$b = \sqrt{\frac{3P}{t \times \sigma_b}\left[\frac{d_2}{4} + \frac{d_4 - d_2}{6}\right]}$$

Q.1) State applications of Cotter Joint.

Ans : Following are the some of the applications of cotter joint. Mainly it is used to connect two rods which are not rotating and which carry tensile as well as compressive load.

1) It is used in bicycle for connecting pedal to sprocket wheel.

2) It is also used for connecting piston rod and the cross-head of steam engine.

3) It is used for connecting piston rod with the tail or pump rod

4) It is used in Foundation bolts.

Q.2) What is a Cotter? Why taper is provided on cotter? How much taper is provided?

Ans: Cotter is a flat wedge shaped part which is used to connect two rods which transmit the force/motion but without rotation. Cotter is fitted in the tapered slot and remains in its position by wedge action.

Because of taper,

i) It is easy to remove the cotter & dismantle the joint

ii) It ensures tightness of the joint in operation & prevents loosening of the parts.

Value of taper on cotter is 1 in 48 to 1 in 24.

Q.3) Why in a cotter joint the cotter is kept weakest?

Ans : In the whole assembly the cotter is the part with least material and easy to replace, hence for this economical and practical reason cotter is kept weakest, so that it can be replaced on failure. It generally fails in shearing or bending.

Q.4) State the advantages of cotter joint.

Ans :

1) Easy assembling and dismantling: It is assembled by hammering in the cotter and dismanteled by removing cotter.

2) Strong grip froce: Due to wedge action there is very strong tightening force which prevents loosening mf parts.

3) Simple to design and manufacture.

OBJECTIVE QUESTION AND ANSWERS ON COTTER JOINT

1) Assertion (A): A cotter joint is used to rigidly connect two coaxial rods carrying tensile load.

Reason (R): Taper in the cotter is provided to facilitate its removal when it fails due to shear.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

Answer : (b) Both A and R are true but R is NOT the correct explanation of A

The purpose of providing taper is to have wedging action and also ease of assembling and dismantling, the taper has nothing to do with tensile load carrying capacity of joint. Hence option (b) is correct answer.

2) The spigot of a cotter joint has a diameter D and carries a slot for cotter. The permissible crushing stress is x times the permissible tensile stress for the material of spigot where $x > 1$. The joint carries an axial load P. Which one of the following equations will give the diameter of the spigot?

Answer : (b)

3) A cotter joint is used when no relative motion is permitted between the rods joined by the cotter. It is capable of transmitting

(a) Twisting moment

(b) The bending moment

(c) an axial tensile as well as compressive load

(d) only compressive axial load

Answer : (c)

4) 1. Cotter joint is used when the members are subjected to ...

a) Axial tensile forces only

b) Axial compressive forces only

c) Axial tensile or compressive forces

d) None of the mentioned

Answer : (c)

5) The piston rod of a steam engine is usually connected to the cross head by means of

a) Bolted joint

b) Knuckle joint

c) Turn buckle

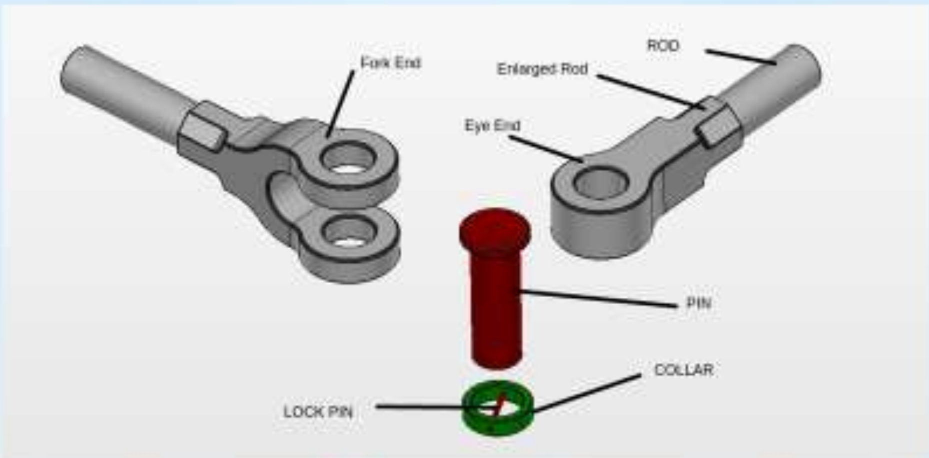
d) Cotter Joint

Answer : (4)

* Knuckle Joint Design Procedure

By

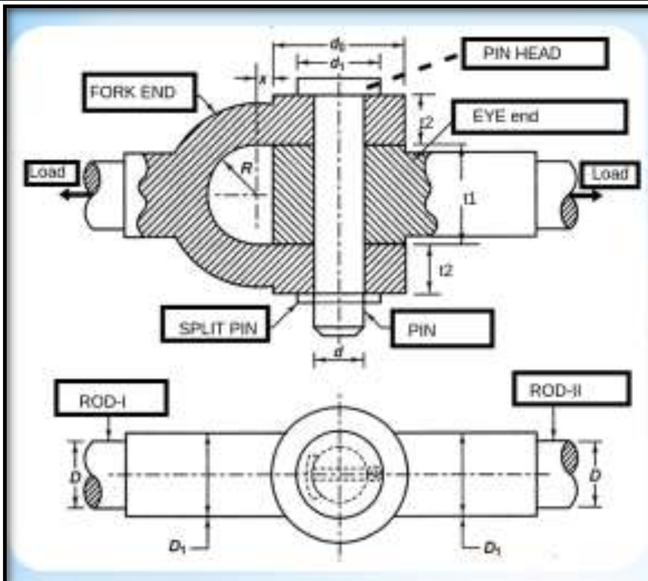
Dr. Sudipta Choudhury



*DETAILED PARTS

* Rods {Which are to be connected by joint }
* Single eye {Modified rod for assembly}
* Double eye or Forked end {Modified rod for assembly}
* Pin {Connects the two rods}
* Collar {to keep the pin in position}
* Split pin or taper pin {Not in diagram} {to prevent sliding away of pin}

*MAIN PARTS



Notations used in design :

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

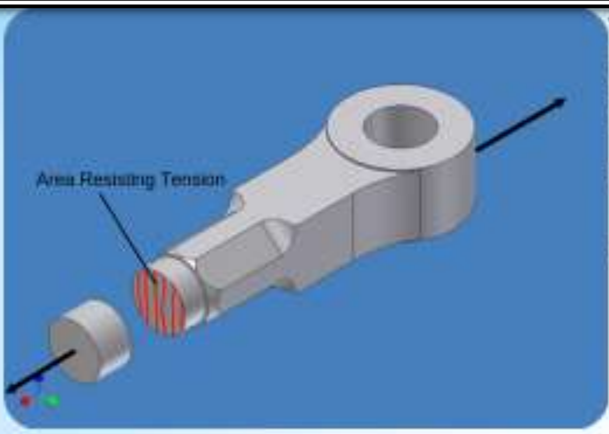
d_0 = Outer diameter of eye or fork

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

*ASSEMBLY DRAWING



Tensile failure of rod

Using basic strength equation

Load = Stress * Area

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

From This equation Diameter 'D' of rod can be found

Enlarged diameter of rod D_1 is determined by $D_1 = 1.1$ D

*Step 1 : Design of Rods (D, D_1)

Step 2 : Decide the thickness of eye end and forked end (t_1, t_2)

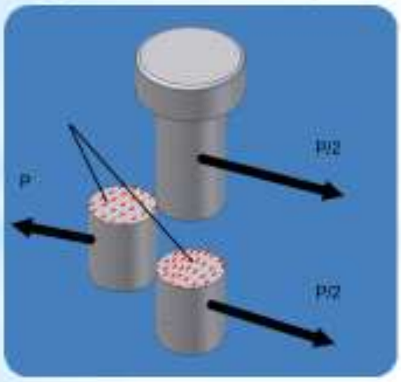
$t_1 = 1.25$ D and $t_2 = 0.75$ D

Step 3 : Decide the dimensions of pin (d, d_1)

Using basic strength equation

Load = Stress * Area

$P = 2x \frac{\pi}{4} D^2 X \sigma_s$ From This equation Diameter 'd' of pin can be found



Based on bending

$$d = \sqrt[3]{\frac{32}{\pi\sigma_b} x \frac{P}{2} x \left[\frac{t_1}{4} + \frac{t_2}{3}\right]}$$

the bigger of both is taken as the final size of pin

Pin head diameter

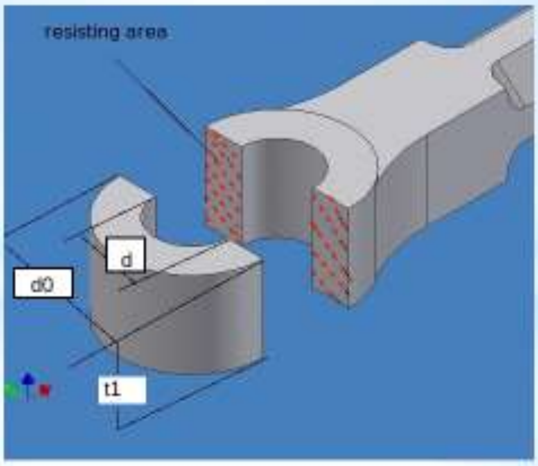
$d_1 = 1.5 \times d$

Step 4 : Check Stresses in Eye end

for outside diameter of eye and fork d_0=2d

Tensile failure of eye end

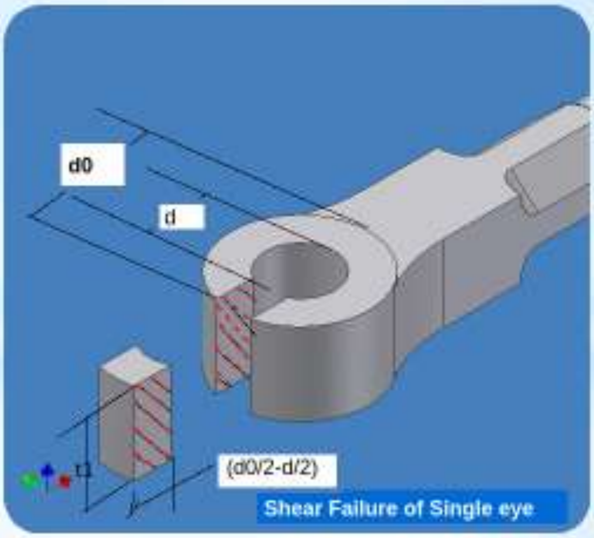
P =(d_0 - d)x t_1 x σ_{t}....... Using this equation find the value of σ_t and check if it is less than allowable value for design to be safe.



*Shear failure of eye end

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

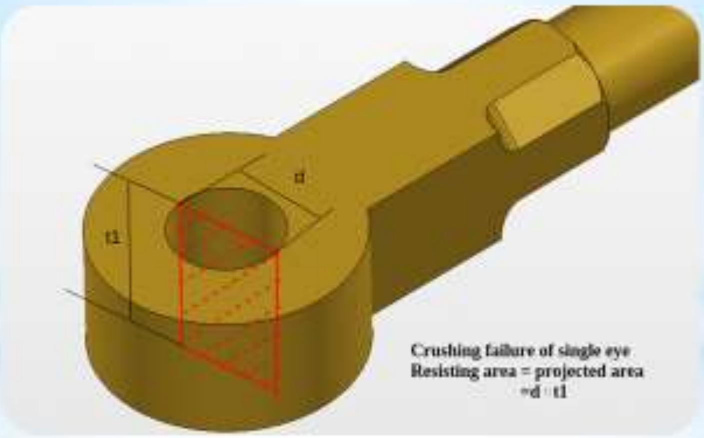
$P = (d_0 - d) \times t_1 \times \sigma_s$ ……. Using this equation find the value of σ_s and check if it is less than allowable value for design to be safe.



*Crushing Failure of eye end

$P = d \times t_1 \times \sigma_C$

Using this equation find the value of and check if it is less than allowable value for design to be safe.



Step 5 : Check Stresses fork end

* Tensile failure of fork end

$P = 2 \times (d_0 - d) \times t_2 \times \sigma_t$

Shear failure of fork end

$P = 2 \times (d_0 - d) \times t_2 \times \sigma_s$

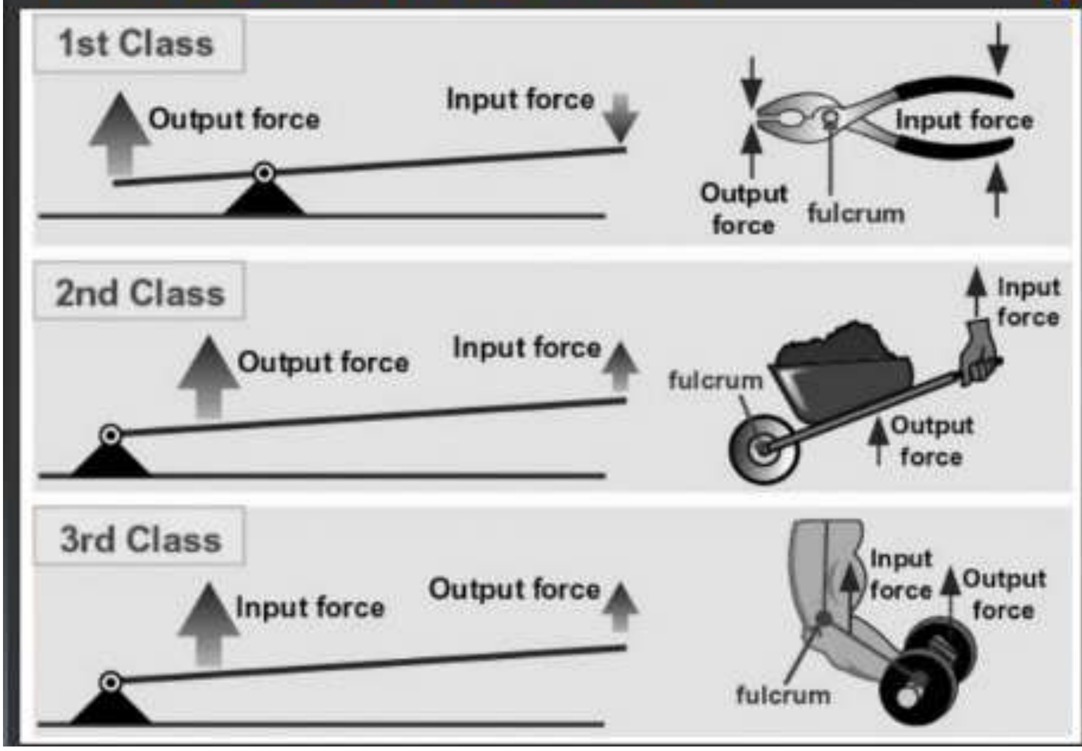
Crushing failure of fork end

$P = 2 \times d \times t_2 \times \sigma_s$

What is a mechanical Lever?

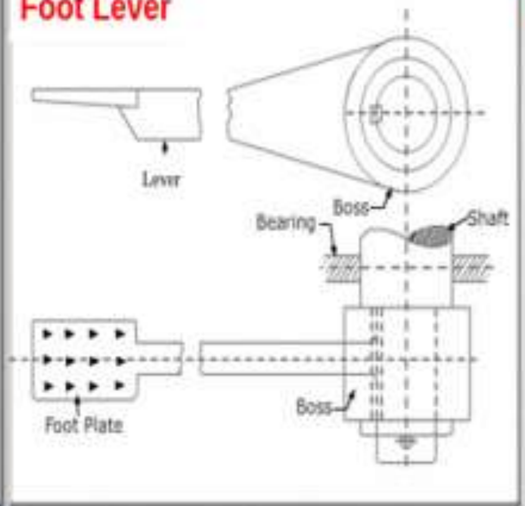
A lever is defined as a mechanical device in the form of a rigid link which is pivoted about a fulcrum to transfer or multiply the force

TYPES OF LEVER



DESIGN OF LEVER

Foot Lever



Hand Lever

DESIGN OF HAND LEVER

For a Hand and Foot Lever:

Let,

P = Force applied on the Handle

L = Effective Length of the Lever

d = Diameter of the Shaft

T = Twisting Moment

M = Bending Moment

d_2 = Diameter of the Boss

l_2 = Length of the Boss

d_1 = Diameter of the Shaft at the Centre of Bearing

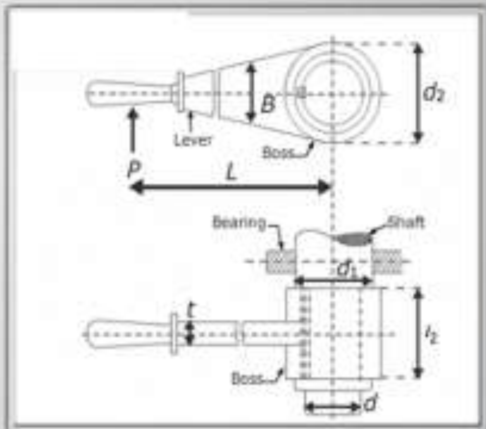
t = Thickness of the Lever

B = Width of Lever B

σt = Permissible Tensile Stress

τ = Permissible Shear Stress

HAND LEVER



Step 1: Design Of shaft and Boss(d,d_1,d_2,l_2)

1) Diameter of shaft d {subjected to torque only}

Torque Acting on Shaft

T= P X L

Diameter of Shaft obtained on basis of shear stress

T = $\frac{\pi}{16} x\ \sigma_S\ x\ d^3$ …….. Find diameter of shaft d using this equation

2) Diameter of shaft at centre of bearing d_1 {Subjected to torque and Bending moment}

Bending Moment acting on shaft, M = P . l

Equivalent torque acting on shaft, $T_e = \sqrt{T^2 + M^2}$

Diameter of Shaft at centre of bearing on the basis of shear strength

$$T_e = \frac{\pi}{16} X\ \sigma_S\ X\ d_1^3$$

Find diameter of shaft d_1 using this equation

3) Dimensions of Boss (Which holds the shaft)

d_2 = 1.6d l_2 = 1.5d

Step 2 : Design Of Key

Using a square Key

$t_k = w_k = \frac{d}{4}$

Shear Failure of key

- $\frac{torque}{radius} = area\ x\ stress$
- $\frac{T}{d_2} = w_k\ x\ l_k\ x\ \tau$ Find l_k using eqn. above

Step 3 : Design Of cross-section of lever (B,t)

Using bending equation ,

$$\frac{M}{I} = \frac{\sigma_b}{y}$$

Assume B = 3t

The lever is subjected to bending moment,

$$M = P \times \left(L - \frac{d}{2}\right)$$

Moment of inertia

$$I = \frac{tB^3}{12}$$

σ_b = Allowable stress for lever material

$$y = \frac{B}{2}$$