Design of machine elements

module 1:- Fundamental to mechanical engineering & design & static stresses.

module 2:- Design for Impact & Dynamic loading conditions.

Module 3:- Design for shafts; Joints, keys, coupling (16 Marks Problem)

Module 4:- Riveted & weld Joints.

module 5:- Threaded Fastners & power screws

Module :- 1

Fundamentals of Mechanical Engineering Design :

Design :- Design can be defined as decision making process. If we have a Problem we need to design a solution.

(or)

Design is a process plan to satisfied a particular need by creating something with physical reality.

Ex:- Chair Design of a Chair.

Machine :- A machine is a combination of several machine elements arranged to work together as a whole to accomplish specific purpose.

Machine elements :- It is an elementary part of a machine (or) Each part of machine which has motion with respect to some Part is called a machine element.

Ex :- Bearing, fasteners, springs, couplings etc

Imp

machine design :- machine design is defined as the use of scientific principles, technical knowledge & imagination in the description of a machine (or) a mechanical system to perform specific function with maximum economy & efficiency.

Design Procedure

The complete design procedure is outline in following figure.

Idendification of need
↓
Definition of Problem
↓
synthesis
↓
Analysis & optimization
↓
Evalution
↓
Presentation.

The process begins with an idendification of need & the decision to do something about it. after many iterations the process ends with the presentation of the plans for satisfying the need.

1) Idendification of need: Generally starts design process. Recognition of need & phrasing the need often constitute a highly creative act. recognition is usually triggered by a particular circumferance (or) random circumferances that arises almost simultaneously

Definition of problem must include all the specifications for the object to be designed. The specification are the input & output quantities, the characteristics & the dimensions of space the object must accupyd.

3) synthesis can be called the inventions of the concept (or) concept design various. schemes must be proposed, investigated analysis must be perform to acess wheather the system performance is satisfactory (or) better. system schemes the donot survive analysis are revised, improved (or) discarded those with potential are optimised to determine the best performance. Both analysis & optimization require that we construct (or) device abstruct model of the system that will admit some form of mathematical analysis (hope that simulation can relate real physics as well)

5) Evalution is a significant phase of total design process. —— evalution is the final proof of successfull design & usually involves testing of prototype in the Labouratory, here we will discover that the design really satisfie the need, it is reliable, will it complete successfully with similar product, is it economical for manufacture , it is easil

maintain & adjusted.

6) communicating the design to others is the final, vital presentation steps in the design process.

Design consideration

The important design considerations are

1) strength. 4) Reliability 7) safety 10) Thermal properties
2) stiffness. 5) cost 8) size & shape 11) Hardness.
3) wear 6) weight 9) utility 12) Ease of manufacturing

Engineering materials:- The knowledge of materials & there properties is of ~~grate~~ greate significance for a design engineer. The engineer machine element should be made of such a element which has properties suitable for the conditions of operations.

The engineering materials are mainly classification as

1) metals & their alloys such as Iron, steel, copper, Aluminum.

2) non-metals such as rubber, glass & plastic etc.

The metals may be further classified

i) Ferrous metals:- The metals which have iron ~~consis~~ has their main constituents
ex:- steel, cast iron, wrought iron.

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non-ferrous :- metals which have other than iron as their main ~~constit~~ constituent.
Ex:- Brass, tin, Al, cupper, Brass, ~~a~~ zinc etc.

Selection of material

The selection of proper material for engineer purpose. is one of the most ~~a~~ difficult problem for design engineer.
The best material is the one which serve the desired objective at the minimum cost ~~etc~~. The following factors are consider while selecting the materal.
1) Availability of material.
2) cost.
3) suitable of material for the working condition in service

The important properties which determines the utility of the material are physical, chemica & mechanical property.

mechanical property

1) Strength :- Ability of the material to resist externally applied force without breaking (or) yielding.
2) ~~Elastic~~ Elasticity :- Ability of the material to regain the original size & shapes after deformation when external forces are remove.

3) plasticity :- Ability of the material to retain the deformation produced under the load on a permanent basis.

4) stiffness (Rigidity) :- It is the ability of the material to resist deformation under the action of an external load. The modulus of elasticity is measure of stiffness.

5) Resilience :- Ability of the material to observe the energy when deform elastically & to ~~recol~~ release ~~the~~ this energy when external load is removed. ex:- spring.

6) maleability :- Ability of the material to a greater extent before the sign of crack when it subiected to compressive force

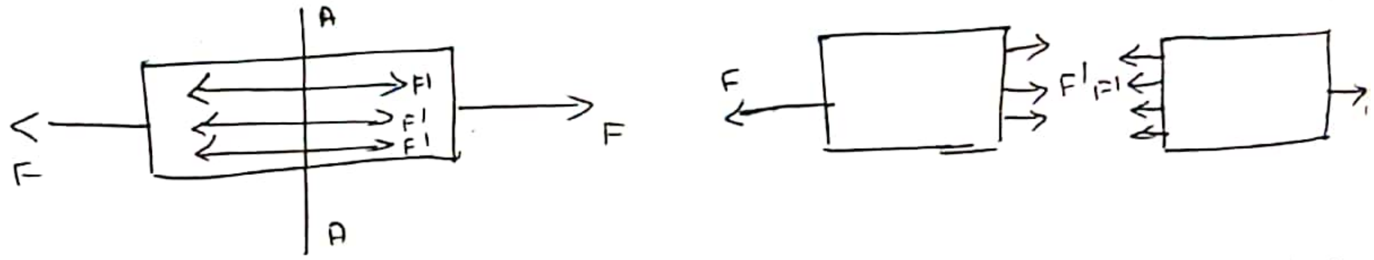
7) Ductility :- Ability of the material to a greater extent before the sign of crack when it subjected to tensile force.

8) Brittleness :- property of material which show negligable plastic deformation before fracture takes place. Brittleness is opposite of ductility

9) Hardness :- Hardness is defined as the resistance of the material to peneteration (or) permanent deformation.

10) Toughness :- Ability of the material to absorb energy before fracture takes place

Stress:- The Intensity of internally distributed force that tends to resist change in shape of a body is known as stress. It denoted by 'σ'



$$\sigma = \frac{\text{Resisting Force}}{\text{Area}} = \frac{F'}{A} = \frac{F}{A}$$

Types of stress

1) normal stress
2) shear stress
3) Bending stress
4) Bearing stress

1) normal stress:- The Internal forces & the corresponding stress acting in the direction perpendicular to the surface is known as normal (or) direct Stress.

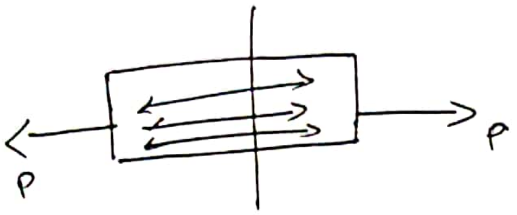
normal stress is of two types

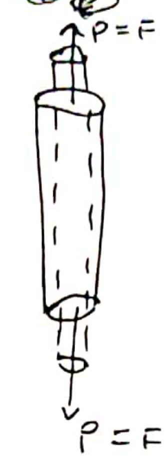
1) Tensile stress.
2) Compressive stress.

1) Tensile stress:- Two equal & opposite loads acting away from each other with tends to pull apart the particles of materials causing extension in the direction of application of

load ~~when~~ then the load is called Tensile load & corresponding stress is tensile stress.

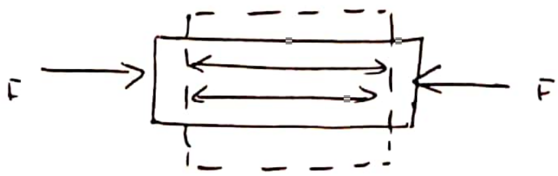
It denotes by 'σ_t'

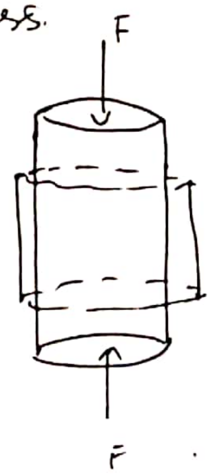




$$\sigma_t = \frac{P}{A} = \frac{F}{A}$$

2) compressive stress:- Two equal & opposite loads acting towards each other which pushe the particles of the materials nearer causing ~~starting~~ shortening in the direction of load then the load is called compressive load & the corresponding stress is compressive stress.

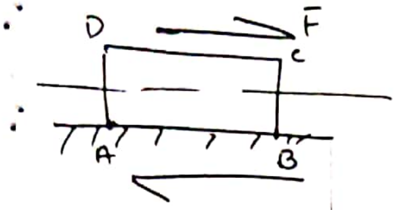


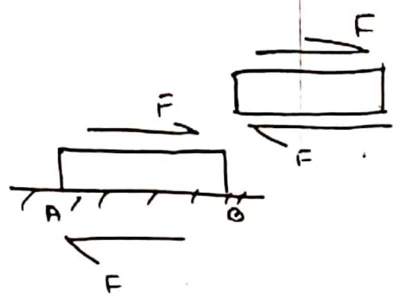


$$\sigma_c = F/A$$

2) Shear stress:- Two equal & opposite forces acting tangentially on a plane is known as shear force. Thus the stress induced in a body occurs the resisting section ie known as Shear Stress

It denotes by (τ)





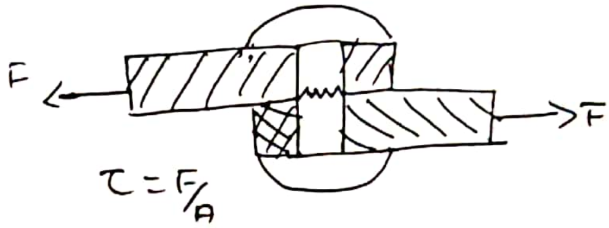
$$\tau = \frac{\text{Resistance Force}}{\text{shear area}}$$

$$\tau = \frac{F}{A}$$

Types of shear stress

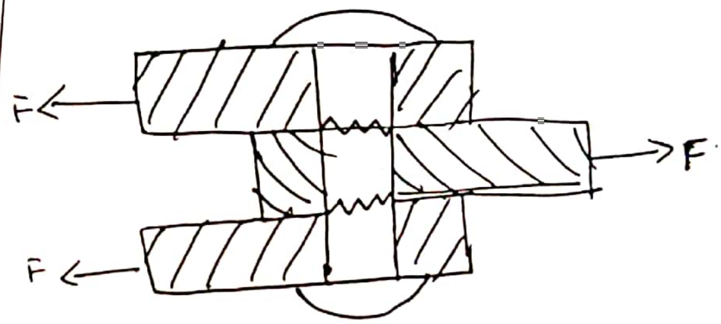
1) single shear stress.
2) Double shear stress

1) single shear stress



$$\tau = F/A$$

2) Double shear stress

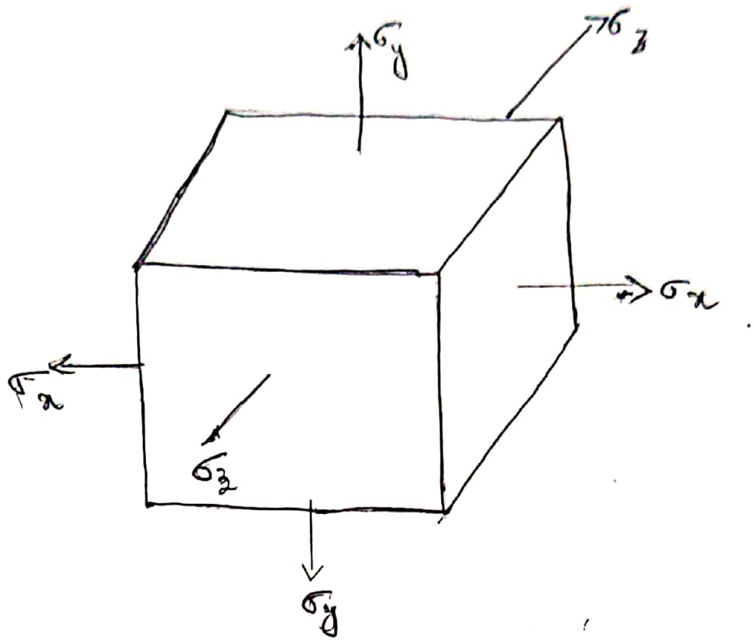


$$\tau = \frac{F}{2A}$$

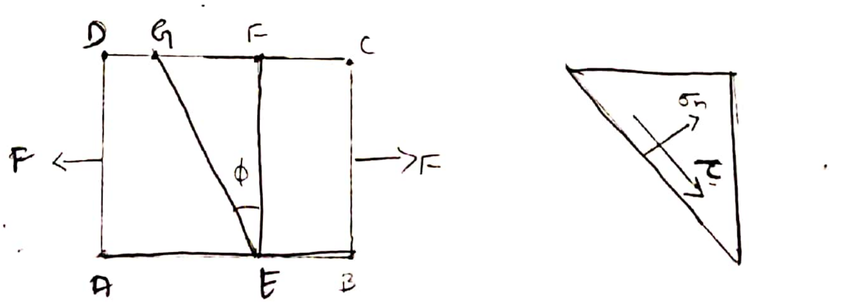
Principal planes & Principal stresses

Principal planes are ~~those~~ the plane on which only the normal stress will act with zero shear stress. The stress across the principal plane is known as principal stresses.

At any point in a strain material there are three such plane mutually ~~[illegible]~~ orthogon to each other out of these planes, the one carrying the maximum normal stresses is called major Principal plane & the normal stress acting on the plane is called major Principal stress the plane carrying the minimum normal stress is called minor principle plane & the normal stresses acting on the plane is called minor principal stress.



Principal stresses on uniaxial stress member



Normal stress $\sigma_n = \sigma_x \cos^2 \phi \rightarrow$ [Eq 1.6(a), Pg 4]

(shear)
Tangential stress $\tau = \frac{\sigma_x}{2} \sin 2\phi \rightarrow$ [Eq 1.6 (b), Pg 4]

when $\phi = 0$,

maximum principal stress, $\sigma_1 = \sigma_x \cos^2(0)$

$\therefore \sigma_1 = \sigma_x$

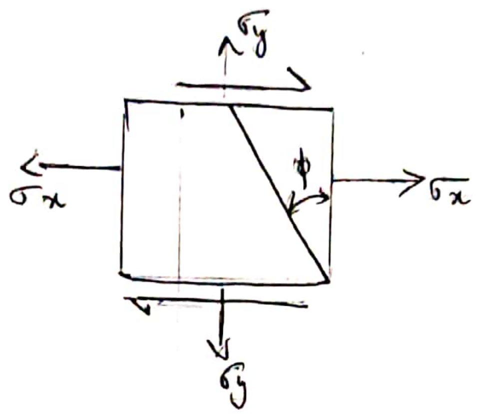
$\phi = 90°$,

minimum principal stress. $\sigma_2 = \sigma_x \cos^2(90)$

Maximum shear stress $\tau_{max} = \frac{\sigma_x}{2} \sin(\pm 90)$

$$\boxed{\tau_{max} = \frac{\sigma_x}{2}} \rightarrow [\text{eq } 1.6(c), \text{Pg } 4]$$

Plane stress system



normal stress $= \sigma_n = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\phi \rightarrow [\text{eq}^n\ 1.8(a), \text{pg } 5]$

shear stress $= \tau_n = \left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\phi - \tau_{xy}\cos 2\phi \rightarrow [\text{eq}^n\ 1.8(b), \text{pg } 5]$

max. principal stress $= \sigma_1 = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow$

$[\text{eq}^n\ 1.8(c), \text{Pg } 5]$

min. principal stress =

$$\sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow [\text{eq}^n\ 1.8(d), \text{Pg } 5]$$

~~Direction of Principal stress~~

$$\cancel{\tan 2\phi_1 = \left(\frac{2\tau_{xy}}{\sigma_x - \sigma_y}\right) \rightarrow [\text{eq}^n\ 1.8(e), \text{Pg } 5]}$$

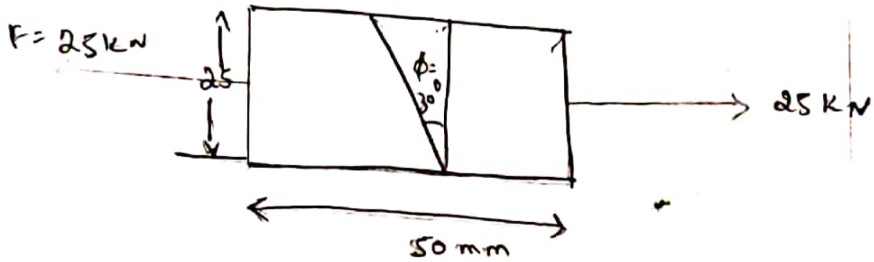
max. shear stress

$$\tau_{max} = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \frac{\sigma_1 - \sigma_2}{2}$$

$\rightarrow [\text{eq}^n\ 1.8(f)\ \text{Pg } 5]$

1) A rectangular bar of section 50 x 25 mm is subjected to a tensile load of 25 kN. Determine the values of normal stress & shear stress on a plane 30° with the vertical also calculate the magnitude & direction of maximum shear stress.

Solⁿ :-



Determine

normal stress = σ_n = ?

shear stress = τ = ?

$\phi = 30^\circ$

magnitude & direction of maximum shear stress (τ_{max}) = ?

Normal stress

$$\sigma_n = \sigma_x \cos^2\phi \rightarrow [\text{eq}^n\ 1.6(a),\ pg(4)]$$

where, $\sigma_x = \frac{P}{A} = \frac{25\times10^3}{50\times25} = \underline{20\ N/mm^2}$

$$\sigma_n = 20 \times \cos^2(30)$$

$$\boxed{\sigma_n = 15\ N/mm^2}$$

Shear stress

$$\tau = \frac{\sigma_x}{2}\sin 2\phi \rightarrow [\text{eq}^n\ 1.6(b)\ pg(4)]$$

$$\tau = \frac{20}{2}\sin 2\times30$$

$$\tau = 8.6602\ N/mm^2$$

max shear stress (τ_{max}) = $\frac{\sigma_x}{2}$ → [eqn 1.6(e), Pg 4]

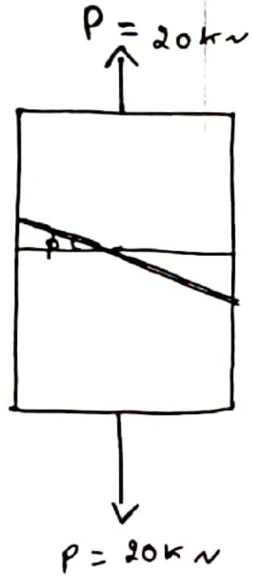
$= \frac{20}{2}$

$\boxed{\tau_{max} = 10 \ N/mm^2}$

∴ max. shear stress occurs at angle of 45°

2. A circular bolt of diameter 25mm is subjected to an axial force of 20kN as shown in figure. Find the stress on plane making 30° to plane of axial stress & also on the plane which has maximum shear ~~&~~ normal ~~shear~~ stress.

Solⁿ



d = 25mm

P = 20×10^3 N

$\phi = 30^\circ$

normal ~~shear~~ stress σ_n = ?

shear stress = ?

max shear stress = ?

$$\sigma_n = \sigma_y \cos^2\phi \ [\text{eqn } (1.6(a)), \text{ Pg } 4]$$

WKT

$$\sigma_y = \frac{P}{A}$$

$$A = \frac{\pi d^2}{4}$$

$$A = \frac{\pi \times (25)^2}{4}$$

$$A = 490.8739 \ mm^2$$

$$\sigma_y = \frac{20 \times 10^3}{490.8739}$$

$$\sigma_y = 40.7437 \ N/mm^2$$

$\sigma_n = \sigma_y \cos^2\phi$

$= 40.7437 \times \cos^2(30)$

$\therefore \boxed{\sigma_n = 30.5577\ N/mm^2}$

Shear stress

$\tau = \frac{\sigma_y}{2} \sin 2\phi \rightarrow$ [eqn 1.6(b), pg 4]

$\tau = \frac{40.7437}{2} \sin(2\times30)$

$\boxed{\tau = 17.6425\ N/mm^2}$

max. shear stress

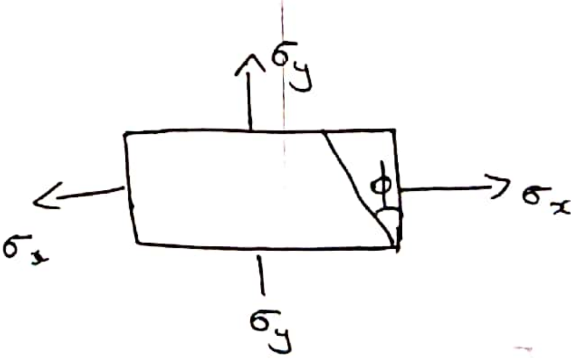
$\tau_{max} = \frac{\sigma_y}{2} \rightarrow$ (eqn 1.6(c), pg 4)

$\tau_{max} = \frac{40.7437}{2}$

$\therefore \boxed{\tau_{max} = 20.3719\ N/mm^2}$

max. shear stress occurs at angle of $\underline{\underline{45^\circ}}$.

3. A machine member is subjected to the following stresses $\sigma_x = 90$ MPa, $\sigma_y = 30$ MPa. determine i) normal & shear stresses along a plane inclined at 30°.
ii) principal stress.
iii) max. shear stress.



soln $\sigma_x = 90\times10^6\ N/m^2$

~~$= 90\times10^6 \times 10^{-6}$~~

~~$\sigma_x = 90\ N/mm^2$~~

$\sigma_x = 90\times10^6\times10^{-6}\ N/mm^2$

$\therefore \boxed{\sigma_x = 90\ N/mm^2}$

$\sigma_y = 30\times10^6\ N/m^2$

$\therefore \boxed{\sigma_y = 30\ N/mm^2}$

i) $\sigma_n = ?$ iii) σ_1 & $\sigma_2 = ?$

ii) $\tau = ?$ iv) $\tau_{max} = ?$

i) Normal stress

$$\sigma_n = \left(\frac{\sigma_x+\sigma_y}{2}\right) + \left(\frac{\sigma_x-\sigma_y}{2}\right)\cos 2\phi \rightsquigarrow [eq^n\ 1.7(a)\ Pg\ 4$$

$$= \left[\frac{90+30}{2}\right] + \left[\frac{90-30}{2}\right]\cos(2\times 30)$$

$$= 60 + 30\cos(60)$$

$$\boxed{\sigma_n = 75\ N/mm^2}$$

$1m = 1000mm$

$1m = 10^3 mm$

$1m^2 = 10^6 mm^2$

ii) Shear stress

$$\tau = \left(\frac{\sigma_x-\sigma_y}{2}\right)\sin 2\phi \rightsquigarrow [eq^n\ 1.7(b)\ Pg\ 4)$$

$$= \left(\frac{90-30}{2}\right)\sin(2\times 30)$$

$$\boxed{\tau = 25.9808\ N/mm^2}$$

iii) $\left\{\boxed{\sigma_1 = \sigma_x \text{ \& } \sigma_2 = \sigma_y \rightsquigarrow [eq^n\ 1.7(c),\ Pg\ 4]}\right\}$

Not written

note Principal stresses

$\sigma_1 = \sigma_{max}$ [max. of σ_x (or) σ_y]

$\sigma_2 = \sigma_{min}$ [min. of σ_x (or) σ_y]

✓ maximum Principal stress

$\therefore \sigma_1 = 90\ N/mm^2$

✓ minimum principal stress

$\therefore \sigma_2 = 30\ N/mm^2$

iv) max. shear stress (Eq 1.7(e), Pg 4)

$$\tau_{max} = \left(\frac{\sigma_x-\sigma_y}{2}\right) = \frac{90-30}{2} = 30\ N/mm^2$$

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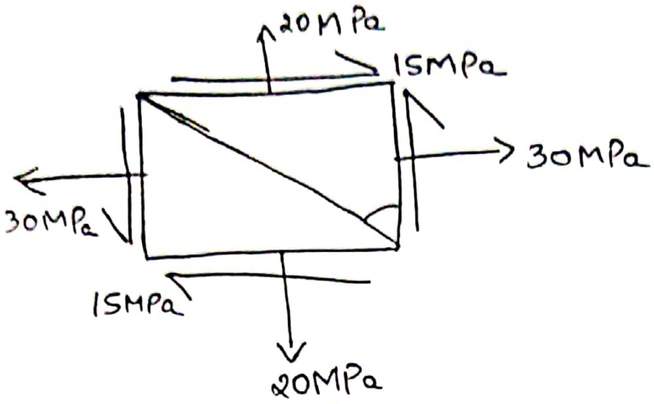
A point in a structural member is subjected to plane stress as shown in figure. Determine the principal stress & there direction.



Solⁿ :- $\sigma_x = 30\,MPa = 30\times10^6\times10^{-6}\,N/mm^2$

$\therefore \sigma_x = 30\,N/mm^2$

$\sigma_y = 20\,MPa = 20\times10^6\times10^{-6}\,N/mm^2$

$\therefore \sigma_y = 20\,N/mm^2$

$\tau_{xy} = 15\,MPa = 15\times10^6\times10^{-6}\,N/mm^2$

$\therefore \tau_{xy} = 15\,N/mm^2$

$\phi = 45^\circ$ [is not given]

i) normal stress

$$\sigma_n = \left(\frac{\sigma_x+\sigma_y}{2}\right) + \left(\frac{\sigma_x-\sigma_y}{2}\right)\cos 2\phi + \tau_{xy}\sin 2\phi$$ [eqⁿ 1.8(a), Pg 5]

$$\sigma_n = \left(\frac{30+20}{2}\right) + \left(\frac{30-20}{2}\right)\cos(2\times45) + 15\sin(2\times45)$$

$$\sigma_n = 25 + 0 + 15$$

$$\boxed{\sigma_n = 40\,N/mm^2}$$

ii) shear stress

$$\tau_n = \left(\frac{\sigma_x-\sigma_y}{2}\right)\sin 2\phi - \tau_{xy}\cos 2\phi$$ (eqⁿ 1.8(b), Pg 5)

$$= \left(\frac{30-20}{2}\right)\sin(90) - 15\cos(90)$$

$$\therefore \boxed{\tau_n = 5\,N/mm^2}$$

Maximum Principal Stress

$$\therefore \sigma_1 = \left(\frac{\sigma_x+\sigma_y}{2}\right) + \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightsquigarrow [eq^n 1.8 (c), Pg 5]$$

$$\sigma_1 = \left(\frac{30+20}{2}\right) + \sqrt{\left(\frac{30-20}{2}\right)^2 + 15^2}$$

$$= 25 + \sqrt{5^2+15^2}$$

$$\boxed{\sigma_1 = 40.8114\ N/mm^2}$$

iv) ~~σ~~. min. principal stress

$$\sigma_2 = \left(\frac{\sigma_x+\sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow [eq^n 1.8(d), Pg 5]$$

$$\sigma_2 = \left(\frac{30+20}{2}\right) - \sqrt{\left(\frac{30-20}{2}\right)^2 + 15^2}$$

$$= 25 - \sqrt{5^2+15^2}$$

$$\boxed{\sigma_2 = 9.1886\ N/mm^2}$$

v) max. shear stress

$$\tau_{max} = \pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightsquigarrow [eq^n 1.8(f) Pg (5)]$$

$$= \pm\sqrt{\left(\frac{30-20}{2}\right)^2 + 15^2}$$

$$= \pm\sqrt{5^2+15^2}$$

$$\tau_{max} = \underline{\pm 15.8114\ N/mm^2}$$

vi) Direction of principal stress.

$$\tan 2\phi_1 = \left(\frac{2\tau_{xy}}{\sigma_x-\sigma_y}\right) \rightsquigarrow [eq^n 1.8(e) \; Pg (5)]$$

$$\tan 2\phi_1 = \left(\frac{2\times 15}{30-20}\right)$$

$2\phi_1 = \tan^{-1}\left(\frac{30}{10}\right)$

$\therefore \boxed{\phi_1 = 35.7825^\circ}$

$\phi_2 = \phi_1 + 90^\circ$

$\boxed{\phi_2 = 125.7825^\circ}$

vii) Direction of (max.) shear stress

$$\tan(2\phi_s) = \frac{\sigma_x - \sigma_y}{2\tau_{xy}} \rightarrow [\text{eqn } 1.8(g), \text{ pg } 5]$$

$$\tan(2\phi_s) = \frac{30-20}{2\times 15}$$

$$\therefore \boxed{\phi_s = 9.2175^\circ}$$

extra

Direction of max. shear stress $\phi_{s_{max}} = \phi_1 + 45^\circ$

$\phi_{s_{max}} = 35.7825 + 45$

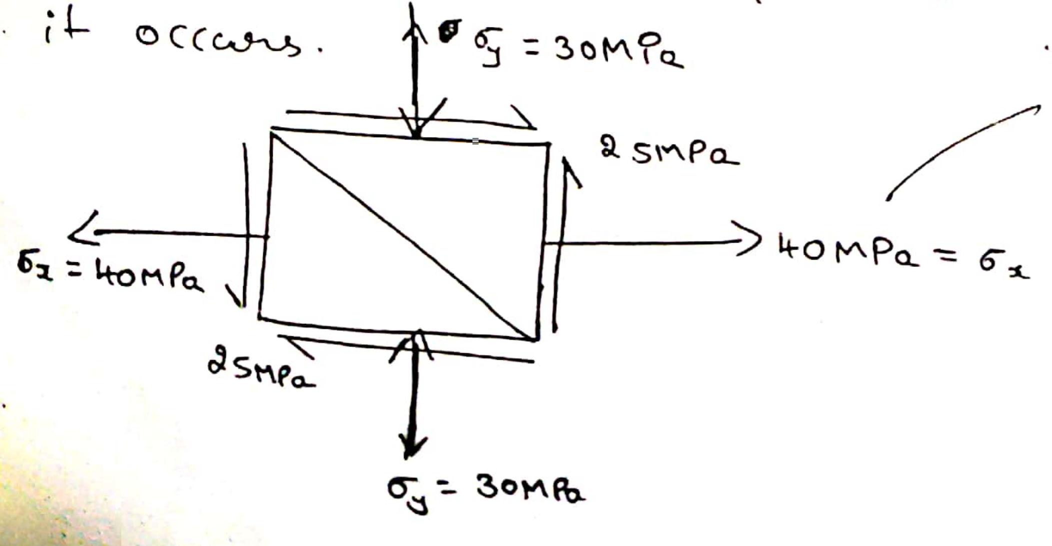
$\therefore \boxed{\phi_{s_{max}} = 80.7825^\circ}$

Direction of min. shear stress, $\phi_{s_{min}} = \phi_1 + 135^\circ$

$= 35.7825 + 135^\circ$

$\therefore \boxed{\phi_{s_{min}} = 170.7825^\circ}$

5. A point in a structural member subjected to plane stress is shown in figure. Determine normal stress, shear stress, principal stress & their direction, maximum shear stress & their direction on which it occurs.



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$\sigma_x = 40 MPa = 40 N/mm^2$

$\sigma_y = -30 MPa = -30 N/mm^2$

$\tau_{xy} = 25 MPa = 25 N/mm^2$

$\phi = 45^0$

i) normal stress

$$\sigma_n = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\phi + \tau_{xy}\sin 2\phi \rightarrow [eq^n\ 1.8(a),\ Pg\ 5]$$

$$\sigma_n = \left(\frac{40 - 30}{2}\right) + \left(\frac{40 + 30}{2}\right)\cos(90) + 25\sin(90)$$

$$\sigma_n = 5 + 0 + 25$$

$$\therefore \boxed{\sigma_n = 30\ N/mm^2}$$

ii) shear stress

$$\tau_n = \left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\phi - \tau_{xy}\cos 2\phi \rightarrow (eq^n 1.8(b)\ Pg\ 5)$$

$$\tau_n = \left(\frac{40+30}{2}\right)\sin(90) - 25\cos(90)$$

$$\boxed{\tau_n = 35\ N/mm^2}$$

iii) max. principal stress.

$$\sigma_1 = \left(\frac{\sigma_x + \sigma_y}{2}\right) + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow (eq^n\ 1.8(c),\ Pg\ 5)$$

$$= \left(\frac{40 - 30}{2}\right) + \sqrt{\left(\frac{40+30}{2}\right)^2 + 25^2}$$

$$= 5 + \sqrt{35^2 + 25^2}$$

$$\boxed{\sigma_1 = 48.0116\ N/mm^2}$$

iv) ~~max.~~ min. principal stress.

$$\sigma_2 = \left(\frac{\sigma_x + \sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow [eq^n\ 1.8(d), Pg\ 5]$$

$$\sigma_2 = \left(\frac{40-30}{2}\right) - \sqrt{\left(\frac{40+30}{2}\right)^2 + 25^2}$$

$$= 5 - \sqrt{35^2+25^2}$$

$$\boxed{\sigma_2 = -38.0116\ N/mm^2}$$

v) Direction of principal stress.

$$\tan 2\phi_1 = \left(\frac{2\tau_{xy}}{\sigma_x - \sigma_y}\right) \rightarrow [eq^n\ 1.8(e)\ Pg\ 5]$$

$$\tan 2\phi_1 = \left(\frac{2 \times 25}{40+30}\right)$$

$$\boxed{\phi_1 = 17.7688^\circ}$$

$$\phi_2 = \phi_1 + 90$$

$$\boxed{\phi_2 = 107.7688^\circ}$$

vi) max. shear stress

$$\tau_{max} = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \rightarrow [eq^n\ 1.8(f), Pg\ 5)$$

$$= \pm\sqrt{\left(\frac{40+30}{2}\right)^2 + 25^2}$$

$$= \pm\sqrt{35^2+25^2}$$

$$\boxed{\tau_{max} = \pm 43.0116\ N/mm^2}$$

vii) Direction of ~~max~~ shear stress → [eq^n 1.8 (g) Pg 5]

$$\tan(2\phi_s) = \left(\frac{\sigma_x - \sigma_y}{2\tau_{xy}}\right) = \left(\frac{40+30}{2\times 25}\right)$$

$$\boxed{\phi = 27.2312^\circ}$$

Direction of Max shear stress

$$\phi_{s_{max}} = \phi_1 + 45^\circ$$

$$= 17.7688 + 45^\circ$$

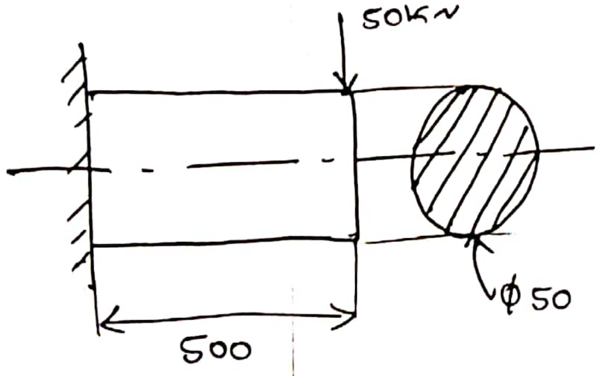
$$\boxed{\phi_{s_{max}} = 62.7688^\circ}$$

Note :-

1) simple stress :- stress produced by shear, tension & compression is called simple stress.

2) compound stress :- stress produced by torsion & Bending are termed as compound stress.

6. Determine the max. stress induced in a machine element as shown in figure under loading conditions



WKT Bending moment equation

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

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

where For circular (object) cross section [Pg 12]

$$y = d/2$$

$$y = 50/2 = \underline{25\,mm}$$

$$I = \frac{\pi D^4}{64} = \frac{\pi \times (50)^4}{64}$$

$$I = 306.7961 \times 10^3\ mm^4$$

$$M = 50 \times 10^3 \times 500$$

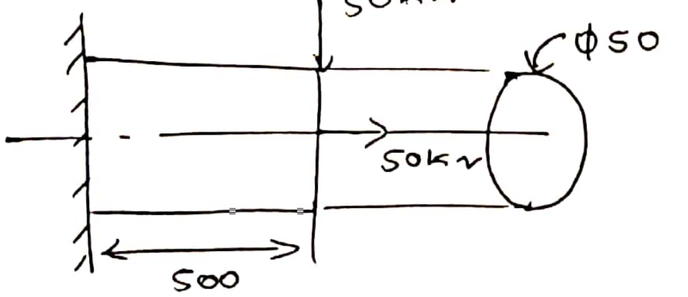
$$M = 25000 \times 10^3\ N\text{-}m$$

$$\boxed{M = 25 \times 10^6\ N\text{-}m}$$

$$\sigma_b = \frac{25 \times 10^6 \times 25}{306.7961 \times 10^3}$$

$$\therefore \sigma_b = 2037.1837\ N/mm^2$$

17) Determine the max. stress induced in a machine element as shown in figure. under loading condition



max. stress $= \sigma = \sigma_b + \sigma_d$

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

this eqn obtain only For circular cross-sections it is available in page 2

$$\sigma_b = \frac{M \times y}{I} \text{ (or) } = \frac{32M}{\pi d^3}$$ → [eqn 1.1 (b) Pg (2)]

$$\sigma_b = \frac{32M}{\pi d^3} = \frac{32 \times 50 \times 10^3 \times 500}{\pi \times (50^3)}$$

$$\boxed{\sigma_b = 2037.1833\ N/mm^2}$$

$$\sigma_d = \frac{P}{A} = \frac{50 \times 10^3}{1963.4954}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi \times 50^2}{4}$$

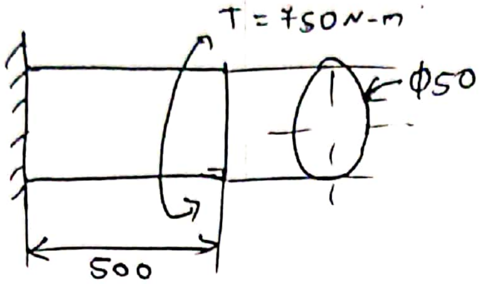
$$A = 1963.4954\ mm^2$$

$$\boxed{\sigma_d = 25.4648\ N/mm^2}$$

Max Stress

$$\sigma = \sigma_b + \sigma_d$$
$$= 2037.1837 + 25.4648$$
$$\therefore \sigma = 2062.6481 \ N/mm^2$$

8) Determine the max. stress induced in machine element as shown in figure.



$T = 750 \times 10^3 \ N\text{-}mm$

wkT for Torsion

$$\frac{T}{J} = \frac{\tau}{r}$$

$$\tau = \frac{T \times r}{J}$$

$$\tau = \frac{T \times d/2}{\pi d^4/32} = \frac{T \times 16}{\pi d^3}$$

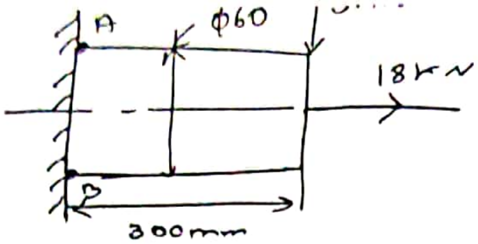
This eqⁿ (obtain) come only for circular & it is available in page 2

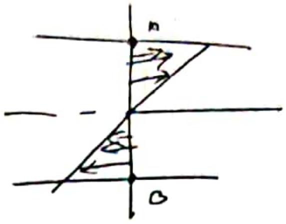
$$\tau = \frac{16 \times 750 \times 10^3}{\pi \times (50)^3}$$

$$\therefore \boxed{\tau = 30.5577 \ N/mm^2}$$

4) A machine member of D = 60mm in a form of cantilever & 300mm long carries an axial load of 18000N & transverse load of 3kN at its free end. determine the nature & magnitude of the stresses at critical points.

[In case of question they ask find max shear stress we multiply 0.5 to max. stress.] ex:- $\sigma_a \times 0.5$





A → (direct) tensile stress.
B → compressive stress.

note
at A tensile stress is acting
at B compressive stress is acting.

$\underline{\text{Sol}^n}$ $l = 300mm$; $d = 60mm$

For axial load

Direct stress (tensile stress) $= \sigma_d = \frac{P}{A} = \frac{18 \times 10^3 \times 4}{\pi \times (60^2)} = \underline{6.3662 \text{ N/mm}^2}$

For bending load

only for circular object

Bending stress, $\sigma_b = \frac{32M}{\pi d^3}$ → [eqn 1.1(b), Pg 2]

WKT $M = F \times \text{Distance}$

$M = 3 \times 10^3 \times 300$

$M = \underline{900 \times 10^3} \text{ N-mm}$

$\sigma_b = \frac{32 \times 900 \times 10^3}{\pi \times (60^3)}$

$\sigma_b = \underline{42.4413 \text{ N/mm}^2}$

At Critical point A (tensile stress)

$\sigma_A = \sigma_d + \sigma_b$

$\sigma_A = 6.3662 + 42.4413$

$\sigma_A = \underline{48.8075 \text{ N/mm}^2}$

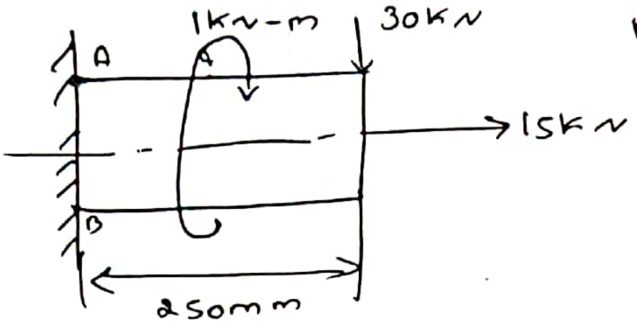
At Critical point B (compressive stress)

$\sigma_B = \sigma_d - \sigma_b$

$= 6.3662 - 42.4413$

$\sigma_B = \underline{-36.0751} \text{ N/mm}^2$

7) A circular rod of dimension 50mm is subjected to load conditions as shown in figure. Calculate the nature & magnitude of stress at the critical points.



$d = 50mm$

$P = 15kN$

$F = 30kN$

$T = 1kN-m$

$T = 1 \times 10^6 N-mm$

soln:- The critical points A & B

The shaft is subjected for axial, bending, torsional load.

For axial load

Direct stress due to axial load.

$$\sigma_d = \frac{P}{A} = \frac{15 \times 10^3 \times 4}{\pi \times (50^2)} = 7.6394 \, N/mm^2$$

For Bending load

Bending stress due to bending load.

(For circular objects)

$$\sigma_b = \frac{32M}{\pi d^3} \rightarrow [eq^n \ 1.1(b), Pg 2]$$

WKT $M = F \times \perp^{r} distance.$

$= 30 \times 10^3 \times 250$

$M = 7.5 \times 10^6 N-mm$

$$\sigma_b = \frac{32 \times 7.5 \times 10^6}{\pi \times (50^3)}$$

$\sigma_b = 611.1550 \, N/mm^2$

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For torsional load

Torsional shear stress due to torsional load.
(For circular)

$$\tau = \frac{16T}{\pi d^3} \rightsquigarrow [\text{eq}^n\ 1.1(d),\ \text{pg } 2]$$

$$\tau = \frac{16 \times 1 \times 10^6}{\pi \times (50^3)}$$

$$\tau = 40.7437\ N/mm^2$$

Critical point at A

max. stress

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [\text{eq}^n\ 1.5(a),\ \text{pg } 3]$$

where

$$\sigma = \sigma_d + \sigma_b \qquad \tau = 40.7437\ N/mm^2$$

$$\sigma = 7.6394 + 611.1550$$

$$\sigma = 618.7944\ N/mm^2$$

$$\sigma_{max} = \frac{618.7944}{2} + \sqrt{\left(\frac{618.7944}{2}\right)^2 + (40.7437)^2}$$

$$\boxed{(\sigma_{max})_A = 621.4656\ N/mm^2}$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \longrightarrow [\text{Eq } 1.5(b)\ \text{pg } 3]$$

$$= \sqrt{\left(\frac{618.7944}{2}\right)^2 + (40.7437)^2}$$

$$\therefore \boxed{(\tau_{max})_A = 312.0684\ N/mm^2}$$

Critical point at B

$\therefore \sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow$ [Eqn 1.5(a) Pg 3]

$\tau = 40.7437 N/mm^2$

$\sigma = \sigma_d - \sigma_b$

$\sigma = 7.6394 - 611.1550$

$\sigma = \underline{-603.5156} N/mm^2$

$$\sigma_{max} = \frac{-603.5156}{2} + \sqrt{\left(\frac{-603.5156}{2}\right)^2 + (40.7437)^2}$$

$$\boxed{(\sigma_{max})_B = 2.7382} N/mm^2$$

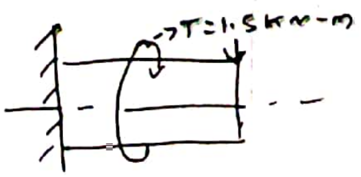
$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow$ [eqn 1.5(b), Pg 3]

$$= \sqrt{\left(\frac{-603.5156}{2}\right)^2 + (40.7437)^2}$$

$$(\tau_{max})_B = \underline{304.4960} N/mm^2$$

11) A machine member is subjected to a twisting moment of 1.5 kN-m, & a bending moment of 3 kN-m. Find suitable diameter of the shaft if the normal & shear stress are 120 MPa & 75 MPa respectively.

Note :- Torsional load → shear stress.
Bending load → bending stress.
axial load → direct (or) tensile (or) compressive (or) normal stress.



$T = 1.5 \times 10^6 N-mm$ $M = 3 \times 10^6 N-mm$

$\sigma_{max} = 120 \times 10^6 \times 10^{-6} N/mm^2$

$= \underline{120} N/mm^2$

$\tau_{max} = 75 N/mm^2$

i) Torsional shear stress due to twisting moment

(For circular object)

$$\tau = \frac{16T}{\pi d^3} \rightsquigarrow [eq^n\ 1.1(d),\ pg\ 2]$$

$$\tau = \frac{16 \times 1.5 \times 10^6}{\pi \times d^3}$$

$$\tau = \frac{7.6394 \times 10^6}{d^3}\ N/mm^2$$

ii) ~~Due to Bending~~ stress due to bending moment

$$\sigma_b = \frac{32M}{\pi d^3} \rightsquigarrow [eq^n\ 1.1(b),\ Pg(2)]$$

$$= \frac{32 \times 3 \times 10^6}{\pi \times d^3}$$

$$\sigma_b = \frac{30.5577 \times 10^6}{d^3}\ N/mm^2$$

WKT max. stress for combined loading.

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [eq^n\ 1.5(a),\ Pg\ 3]$$

where $\sigma = \sigma_d + \sigma_b$ $\therefore \boxed{\sigma_d = 0}$

$$\boxed{\sigma = \sigma_b}$$

$$\sigma = \frac{30.5577 \times 10^6}{d^3}$$

$$\sigma_{max} = \frac{30.5577 \times 10^6}{2 \times d^3} + \sqrt{\left(\frac{30.5577 \times 10^6}{2 \times d^3}\right)^2 + \left(\frac{7.6394 \times 10^6}{d^3}\right)^2}$$

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$$= \frac{15.27885 \times 10^6}{d^3} + \frac{1}{d^3}\sqrt{\left(\frac{30.5577 \times 10^6}{2}\right)^2 + (7.6394 \times 10^6)^2}$$

$$120 = \frac{1}{d^3}\left[15.2788 \times 10^6 + 17.0822 \times 10^6\right]$$

$$d^3 = \frac{32.3610 \times 10^6}{120}$$

$$\therefore d = \underline{64.60\ mm}$$

dia of shaft $= \underline{d = 64.60\ mm}$

wrt T

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightarrow [\text{eq}^n\ 65(b),\ Pg\ 3]$$

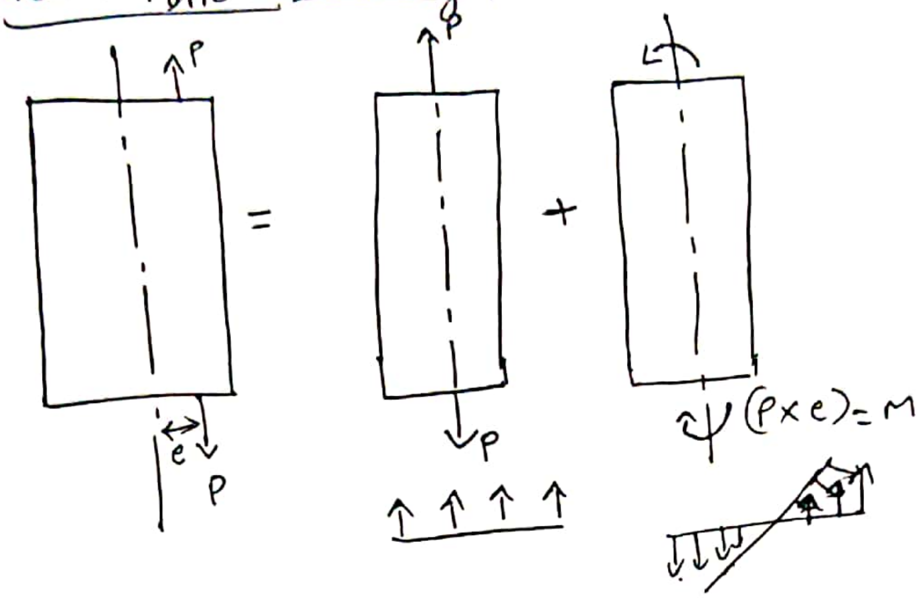
$$= \sqrt{\left(\frac{30.5577 \times 10^6}{2d^3}\right)^2 + \left(\frac{7.6394 \times 10^6}{d^3}\right)^2}$$

$$75 = \frac{1}{d^3}\sqrt{\left(\frac{30.5577 \times 10^6}{2}\right)^2 + (7.6394 \times 10^6)^2}$$

$$d^3 = \frac{17.0822 \times 10^6}{75}$$

$$\therefore d = \underline{61.07\ mm}$$

Eccentric loading.



$$\sigma = \sigma_d + \sigma_b$$

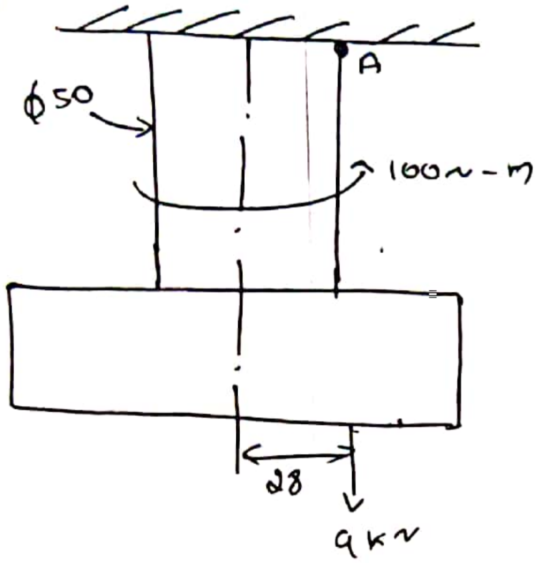
- An axial load whose line of action is parallel but doesn't coincide with centroidal axis of a machine component is known as eccentric load.
- Eccentric load is replaced by a parallel force acting through the centroidal axis - with couple (P×e). Resultant of these two forces is given by

$$\sigma = \sigma_d + \sigma_b$$

$$\sigma = \frac{P}{A} + \frac{M \times y}{I}$$

IMP

12) A 50mm dia of steel rod supports 9 kN load, & in addition it is subjected to a torsion moment of 100 N-m as shown in figure. Determine max tensile stress & maximum shear stress.



Dia = d = 50mm

eccentric distance = 28mm

load = 9kN

Torque = T = 100N-m

T = 100×10³ N-mm

The given load is an eccentric load there fore due to this load the steel rod is subjected to direct stress & bending stress.

∴ Combined stress at point A (they only)

$$\sigma = \sigma_d + \sigma_b$$

$$\sigma = \left(\frac{P}{A}\right) + \frac{M \times y}{I}$$

$$= \frac{P}{\frac{\pi d^2}{4}} + \left(\frac{M \times d/2}{\frac{\pi d^4}{64}}\right)$$

$$\sigma = \frac{9000 \times 4}{\pi \times (50)^2} + \frac{(9\times10^3\times28)(50/2)}{\left(\frac{\pi\times(50)^4}{64}\right)}$$

$$\sigma = \frac{9000\times4}{\pi\times(50)^2} + \left[\frac{9\times10^3\times28\times50\times64}{2\times\pi\times(50)^4}\right]$$

$$\sigma = 4.5837 + 20.5348$$

$$\boxed{\sigma = 25.1185\ N/mm^2}$$

WKT (for circular)

$$\tau = \frac{16T}{\pi d^3} \rightsquigarrow [\text{eq}^n\ f.1(d),\ \text{pg } 2]$$

$$\tau = \frac{16\times100\times10^3}{\pi\times(50)^3} = 4.0744\ N/mm^2$$

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To calculate max. tensile stress at point A

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [eq^n\ 1.5(a)\ pg\ 3]$$

$$= \frac{25.1185}{2} + \sqrt{\left(\frac{25.1185}{2}\right)^2 + (4.0744)^2}$$

$$= 12.5593 + 13.2036$$

$$\therefore \sigma_{max} = 25.7629\ N/mm^2$$

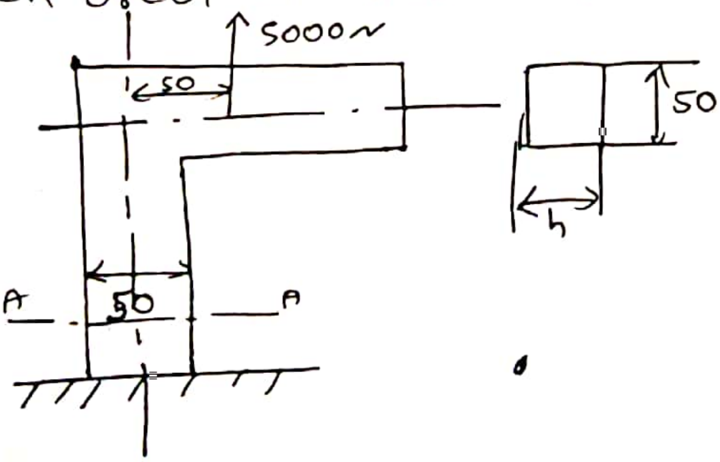
To Find max. shear stress

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [eq^n\ 1.5(b)\ pg\ 3]$$

$$= \sqrt{\left(\frac{25.1185}{2}\right)^2 + (4.0744)^2}$$

$$\therefore \tau_{max} = 13.2036\ N/mm^2$$

13) Determine the required thickness of a steel bracket at section A-A when loaded as shown in figure. In order to limit the tensile stress 100 N/mm²



The loading is eccentric load due to this it is subjected to direct stress & Bending stress.

Given $\sigma_{max} = 100\ N/mm^2$

At crossection A - A

$$\sigma_{max} = \sigma_d + \sigma_b$$

$$100 = \frac{P}{A} + \left(\frac{M \times y}{I}\right)$$

$$100 = \frac{5000}{50 \times h} + \left(\frac{M \times 50/2}{h\,b^3/12}\right)$$

$b = h$

$h = b$

$y = \frac{h}{2} = b/2 = 5$

$I = \frac{bh^3}{12} = \frac{hb^3}{12}$

$$100 = \frac{5000}{50 \times h} + \left(\frac{5000 \times 50 \times 50/2}{h \times (50)^3/12}\right)$$

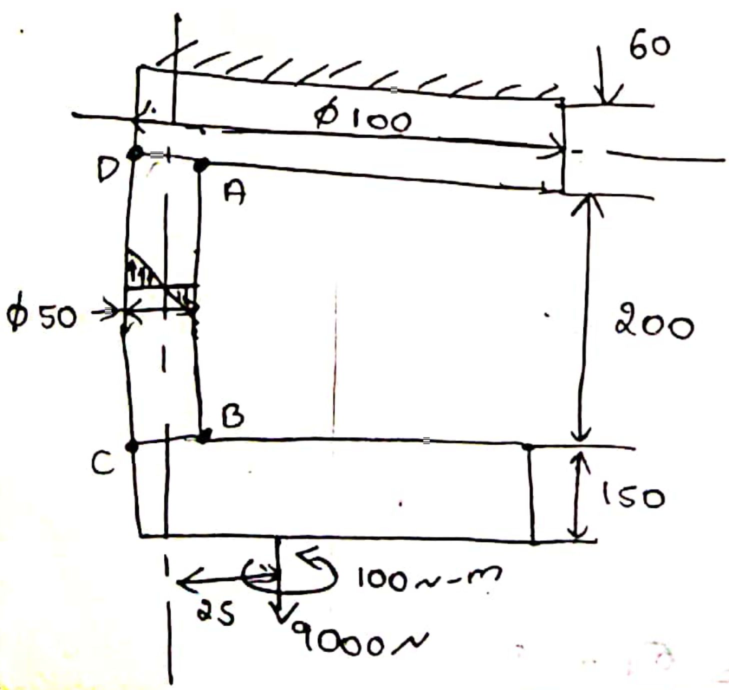
$$100 = \frac{1}{h}\left[100 + \frac{6.25 \times 10^6 \times 12}{50^3}\right]$$

$$100 = \frac{700}{h}$$

$$h = \frac{700}{100}$$

Thickness $\therefore h = 7\,mm$

14) A steel member is loaded as shown in figure Find the magnitude of maximum normal stress & minimum normal stress.



A - A

Due to eccentric load is subjected to ~~[illegible]~~ direct bending stress.

i) direct stress $= \sigma_d = \frac{P}{A} = \frac{P}{\pi d^2/4} = \frac{P \times 4}{\pi d^2}$

$$= \frac{9000 \times 4}{\pi \times (50)^2}$$

$$\boxed{\sigma_d = 4.5837 \ N/mm^2}$$

ii) bending stress $= \sigma_d = \frac{M \times y}{I}$ (or) $\sigma_d = \frac{32M}{\pi d^3}$ ⇝ [eqn 1.1(b), Pg 2]

(For circular)

$$\sigma_d = \frac{32M}{\pi d^3} = \frac{32 \times 9000 \times 25}{\pi \times (50)^3}$$

$$\boxed{\sigma_b = 18.3346 \ N/mm^2}$$

Due to twisting moment $T = 100 \ N\text{-}m$

$T = 100 \times 10^3 \ N\text{-}mm$

(For circular)

shear stress $= \tau = \frac{16T}{\pi d^3}$ ⇝ [eqn 1.1(d), Pg 2]

$$\tau = \frac{16 \times 100 \times 10^3}{\pi \times (50)^3}$$

$$\boxed{\tau = 4.0744 \ N/mm^2}$$

At portion A (or) B [tensile stress acting]

$$\sigma = \sigma_d + \sigma_b$$

$$= 4.5837 + 18.3346$$

$$\sigma = 22.9183 \ N/mm^2$$

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$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [eq^n\ 1.5(a), Pg\ 3]$$

$$= \frac{22.9183}{2} + \sqrt{\left(\frac{22.9183}{2}\right)^2 + (4.0744)^2}$$

$$\sigma_{max} = 11.4592 + 12.1620$$

$$\boxed{\sigma_{max} = 23.6212\ N/mm^2}$$

$$\sigma_{min} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{min} = \frac{22.9183}{2} - \sqrt{\left(\frac{22.9183}{2}\right)^2 + (4.0744)^2}$$

$$\sigma_{min} = 11.4592 - 12.1620$$

$$\boxed{\sigma_{min} = -0.7028\ N/mm^2}$$

extra

$$\boxed{\tau_{max} = 12.1620\ N/mm^2}$$

at portion C (or) D [compressive stress acting]

$$\sigma = \sigma_d - \sigma_b$$

$$= 4.5837 - 18.3346$$

$$\boxed{\sigma = -13.7509\ N/mm^2}$$

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightsquigarrow [eq^n\ 1.5(a)\ Pg\ 3]$$

$$= \frac{-13.7509}{2} + \sqrt{\left(\frac{-13.7509}{2}\right)^2 + (4.0744)^2}$$

$$= -6.8755 + 7.9920$$

$$\therefore \sigma_{max} = 1.1165\ N/mm^2$$

$$\sigma_{min} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \frac{-13.7509}{2} - \sqrt{\left(-\frac{13.7509}{2}\right)^2 + (4.0744)^2}$$

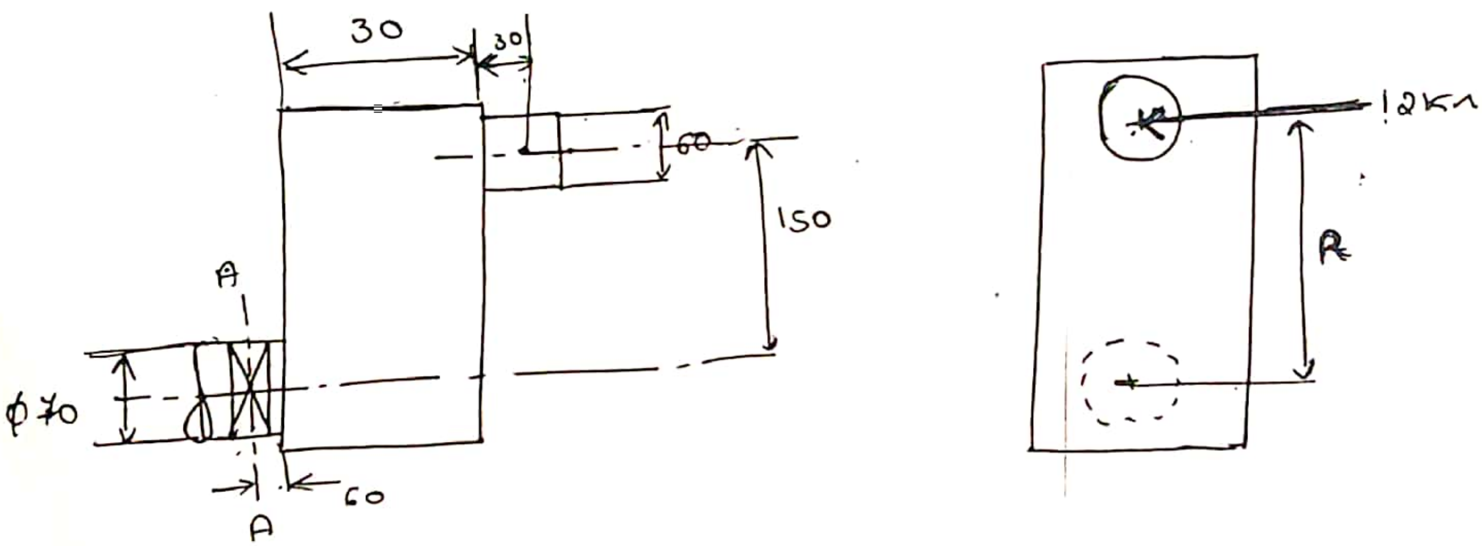
$$= -6.8755 - 7.9920$$

extra

$\boxed{\therefore \tau_{max} = 7.9920\ N/mm^2}$

$\therefore \sigma_{min} = -14.8675\ N/mm^2$

15) Determine normal & shear stress ~~A...~~ induced a section A-A when a load 12kN is applied at the cent of crank pin.



The given data acting on the crank pin has two effects at section A-A

i) Bending stress due to cantilever subjected to bending moment.

Bending moment $= F \times l$ where L = Distance from section A-A to the load.

$l = 60 + 30 + 30 = 120\ mm$

Bending stress, $\sigma_b = \frac{32M}{\pi d^3} = \frac{32 \times (12 \times 10^3 \times 120)}{\pi \times (70)^3}$

$\sigma_b = 42.7630\ N/mm^2$

(ii) shear stress due to twisting moment.

$T = F \times R$

$T = 12 \times 10^3 \times 150$

$T = 1.8 \times 10^6$ N-mm

Shear stress (for circular)

$$\tau = \frac{16T}{\pi d^3} = \frac{16 \times 1.8 \times 10^6}{\pi \times (70)^3}$$

$$\therefore \boxed{\tau = 26.7269 \, N/mm^2}$$

max stress $(\sigma_{max}) = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$ → [eqn 1.5(a) pg 3]

where $\sigma = \cancel{\sigma_d}^{\,0} + \sigma_b$

$\sigma = \sigma_b = 42.7630 \, N/mm^2$

$$\sigma_{max} = \frac{42.763}{2} + \sqrt{\left(\frac{42.763}{2}\right)^2 + (26.7269)^2}$$

$= 21.3815 + 34.2271$

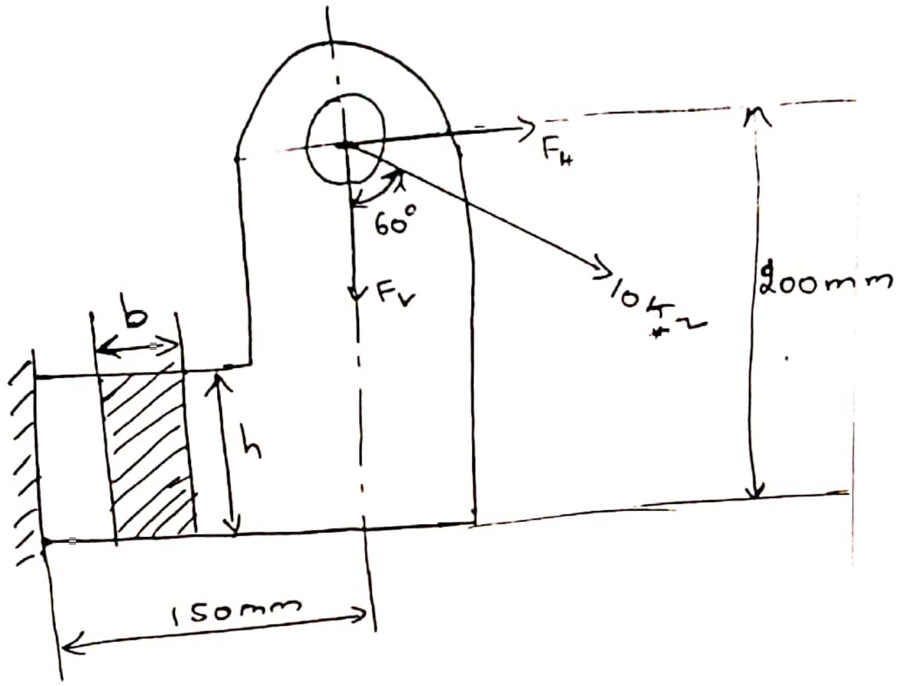
$\sigma_{max} = 55.6086 \, N/mm^2$

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \sqrt{\left(\frac{42.763}{2}\right)^2 + (26.7269)^2}$$

$\therefore \tau_{max} = 34.2271 \, N/mm^2$

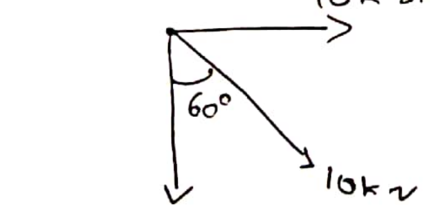
1) A mild steel Bracket shown in figure in subject to a pull of 10kN the Bracket has rectangular cross-section whose depth is twice the width. if the allowable stress for the material is. $80 N/mm^2$. Determine the cross-section of the Bracket.



Sol^n $\sigma_{max} = 80 N/mm^2$ $h \& b = ?$

$\boxed{h = 2b}$

Resolving force



$F_V = 10k \cos 60$

i) consider vertical component (F_V) due to vertical force Bending moment develop.

Bending moment, $M = F_V \times l$

$M = 10 \times 10^3 \cos 60 \times 150$

$= 750 \times 10^3$ N-mm

Bending stress

$$\cancel{\sigma_b = \frac{32M}{\pi d^3} = \frac{32 \times 750 \times 10^3}{\pi \times (}}$$

$$\sigma_b = \frac{M \times y}{I} = \frac{750 \times 10^3 \times h/\cancel{2}\,1}{bh^3/\cancel{12}\,6}$$

$$\sigma_b = \frac{750 \times 10^3 \times h \times 6}{bh^3}$$

$$\sigma_b = \frac{750 \times 10^3 \times 2\cancel{b} \times 6}{\cancel{b}(2b)^3}$$

$$\sigma_b = \frac{750 \times 10^3 \times \cancel{2}\,1 \times \cancel{6}\,3}{\cancel{8}\,\cancel{4}\,2\, b^3}$$

$$\sigma_b = \frac{2250 \times 10^3}{2b^3}$$

$$\sigma_b = \frac{1125 \times 10^3}{b^3} \rightarrow (1)$$

$$\sigma_1 = \cancel{\sigma_d}^{\,0} + \sigma_b$$

$$\sigma_1 = \sigma_b$$

ii) consider Horizontal component (F_H)

Due to horizontal forces two types of stresses are developed direct stress & Bending stress

Direct stress, $\sigma_d = \frac{F_H}{A}$

$$= \frac{10 \times 10^3 \sin 60}{b \times h}$$

$$= \frac{(10 \times 10^3 \sin 60)}{(b \times 2b)}$$

$$\sigma_d = \frac{4.33\times10^3}{b^2}$$

Bending stress.

moment $M = (F_H \times l)$

$$= (10\times10^3 \sin 60)\times 200$$

$$M = 1.73\times10^6 \text{ N-mm}$$

Bending stress $= \frac{M\times y}{I}$

$$= \frac{1.73\times10^6 \times h}{\cancel{2}_1 \times bh^3} \times \cancel{12}\,6$$

$$= \frac{10.38\times10^6\times h}{b\,h^3}$$

$$= \frac{10.38\times10^6 \times 2\cancel{b}}{\cancel{b}\times(2b)^3}$$

$$= \frac{10.38\times10^6 \times \cancel{2}\,1}{\cancel{8}_4\, b^3}$$

$$\sigma_b = \frac{2.595\times10^6}{b^3}$$

$$\sigma = \sigma_d + \sigma_b$$

$$\sigma_2 = \frac{4.33\times10^3}{b^2} + \frac{2.595\times10^6}{b^3} \rightsquigarrow (2)$$

The max. stress $\sigma_{max} = \sigma_1 + \sigma_2$

$$80 = \frac{1125\times10^3}{b^3} + \frac{4.33\times10^3}{b^2} + \frac{2.595\times10^6}{b^3}.$$

$$80 = \frac{1}{b^3}\left[3.72\times10^6\right] + \frac{1}{b^2}\left[4.33\times10^3\right]$$ ×lly by b/b

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$$80 = \frac{1}{b^3}\left[3.72\times10^6 + 4.33\times10^3\, b\right]$$

$$\cancel{b^3 = \frac{3.72\times10^6}{80} + \frac{4.33\times10^6\, b}{80}}$$

$$\cancel{b^3 = 46.5\times10^3 + 54.125\times10^3\, b}$$

$$\cancel{b^3 - 54.125\times10^3\, b - 46.5\times10^3 = 0}$$

$$80b^3 = 3.72\times10^6 + 4.33\times10^3\, b$$

$$80b^3 - 4.33\times10^3\, b - 3.72\times10^6 = 0$$

On solving,

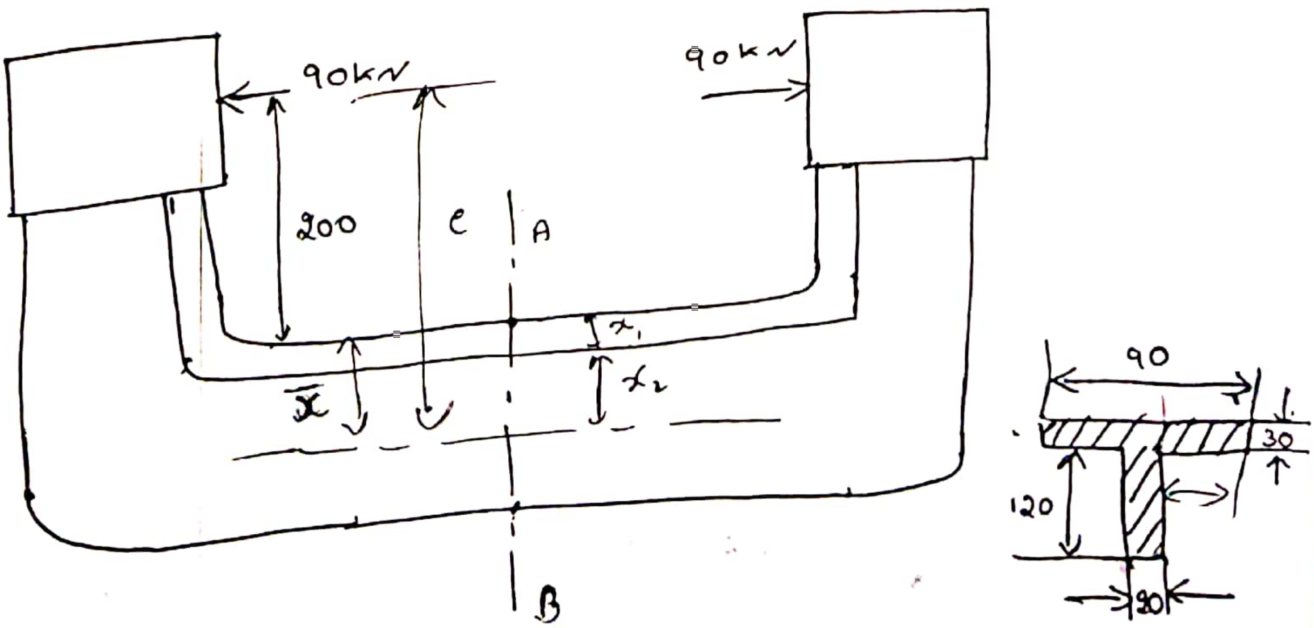
$$\boxed{b = 36.46\,mm}$$

$$h = 2b$$

$$\therefore \boxed{h = 72.92\,mm}$$

v.IMP

17) Determine the stress at A, B for a clamp loaded as shown in figure



An eccentric load acts parallel & away from the centroidal axis because of the eccentric load there are two effects direct/tensile stress & bending stress due to the couple which is tensile at the portion A & compressive at the portion B.

i) Direct stress

$$\cancel{\sigma_d = \frac{P}{A} = \frac{90\times10^3}{B\times H} = \frac{90\times10^3}{90\times150} = 6.667\ N/mm^2}$$

~~ii) Bending stress~~

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

~~where~~ $\cancel{M = 90\times10^3\times}$

$$\sigma_d = \frac{P}{A} = \frac{P}{A_1+A_2} = \frac{90\times10^3}{(90\times30)+(20\times120)}$$

$$\therefore \sigma_d = 17.6471\ N/mm^2$$

ii) Bending stress (σ_b)

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

where $M = F\times e$

$$\sigma_b = \frac{(F\times e)(y)}{I} = \frac{(F\times e)(c_1)}{I}$$

centroidal axis ($\bar{x}$)

$$\bar{x} = \frac{A_1x_1 + A_2x_2}{A_1+A_2}$$

$$= \frac{(90\times30)(30/2) + (120\times20)(30+120/2)}{(90\times30)+(120\times20)}$$

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$\bar{x} = 50.2941 \text{ mm}$

$\therefore e = 200 + \bar{x}$

$e = 200 + 50.2941 \text{ mm}$

$e = \underline{250.2941 \text{ mm}}$

Distance to Farthest point (c_1)

$c_1 = \bar{x} = y = \underline{50.2941 \text{ mm}}$

moment of Inertia (I)

$$I = \frac{Bc_1^3 - bh^3 + ac_2^3}{3}$$

$$= \frac{[(90 \times (50.2941)^3] - [70 \times (20.2941)^3 + [20 \times (99.7059)^3]}{3}$$

$I = \underline{10.22 \times 10^6 \text{ mm}^4}$

$$\sigma_b = \frac{(90 \times 10^3 \times 250.294)(50.2941)}{10.22 \times 10^6}$$

$\therefore \sigma_b = \underline{110.7524 \text{ N/mm}^2}$

$B = 90 \text{ mm}$

$c_1 = \bar{x} = 50.2941 \text{ mm}$

$h = c_1 - d$

$= 50.2941 - 30$

$h = 20.2941 \text{ mm}$

$a = 20 \text{ mm}$

$c_2 = 150 - \bar{x}$

$= 150 - 50.2941$

$c_2 = 99.7059 \text{ mm}$

$\frac{b}{2} = 35$

$b = 70 \text{ mm}$

max. stress at Point A

$\sigma_{max} = \sigma_d + \sigma_b$

$= 17.6471 + 110.7524$

$\therefore (\sigma_{max})_A = \underline{128.3995 \text{ N/mm}^2}$

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max. stress at point (B)

$$\sigma_{max} = \sigma_d + \sigma_b$$

$$\text{Bending stress} = \sigma_b = \frac{M \times y}{I} = \frac{M \times C_2}{I}$$

$$\sigma_b = \frac{M \times C_2}{I} = \frac{(90 \times 10^3 \times 250.294)(99.7059)}{(10.22 \times 10^6)}$$

$$\sigma_b = 219.7672 \, N/mm^2$$

$$\sigma_{max} = 17.6471 - 219.7672$$

$$(\sigma_{max})_B = -202.1201 \, N/mm^2$$

Factor of safety (FOS) (n)

It is defined as the ratio maximum stress to the working stress.

mathematically,

$$FOS = \frac{\text{maximum stress}}{\text{working/Allowable stress}}$$

working/ Allowable / Designed stress :- while designing the machine part it is desirable to keep the stress lower than the maximum (or) ultimate stress at which failure of the material takes place. This stress is known as working stress (or) allowable stress.

~~For~~ ductile material

$$\text{Factor of safety (FOS)} = \frac{\text{Yield stress}}{\text{working/allowable stress}}$$

For brittle material

$$\text{Factor of safety (FOS)} = \frac{\text{ultimate stress}}{\text{working/allowable stress}}$$

4M

Selection of factor of safety

- The selection of a proper factor of safety to be used in designing any machine component depend upon a number of considerations such as the material, mode of manufacture, type of stress etc.
- Before selecting a proper factor of safety a design engineer should consider the following points.

i) variation in material property.

ii) Type of loading & stress.

iii) Degree of accuracy in force analysis.

iv) Quality of manufacture.

v) Service conditions.

vi) overall concern for human safety

vii) specific requirements for life & reliability...

Stress concentration:-

Stress concentration is defined as the localization of high stress due to the irregularities present in the component & abrupt ~~the~~ change of cross-section.

Stress concentration is measured by stress concentration factor. It is denoted by 'K_t'.

Stress concentration factor is defined as the ratio of actual maximum stress at discontinuity to the nominal stress.

i.e $K_t = \frac{\sigma_{max}}{\sigma_{nom}}$ ... $\sigma_{nom} = \frac{P}{A}$

(or)

$K_{ts} = \frac{\tau_{max}}{\tau_{nom}}$

The subscript t denotes theoretical stress concentration factor.

The ~~maximum~~ magnitude of stress concentration factor depends upon the geometry of component.

Determination of stress concentration factor

- Theoretical stress concentration factor is determine by two methods.

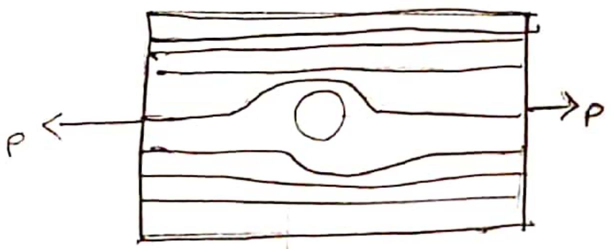
1) Experimental techniques.
   i) Photo elasticity.
   ii) Brittle coating methods.
   iii) Electrical strain gauge methods.

d) Numerical technique

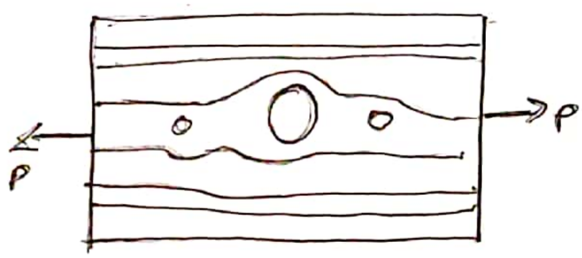
i) Finite element methods.

methods of reducing stress concentration

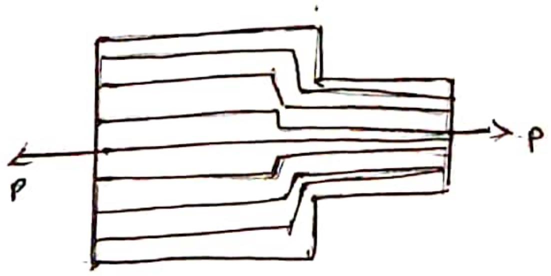
It is not possible to completly eliminate the effect of stress concentration there are methods to reduce the stress concentrations. This achieved by providing a specific geometry shape of the component.



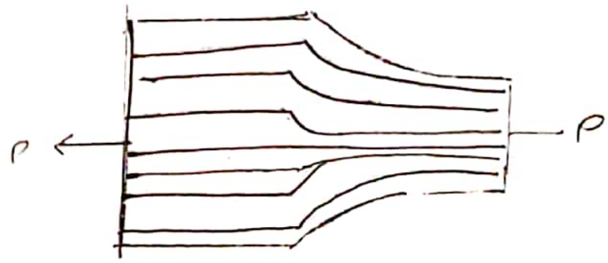
Bad design



Preferred design



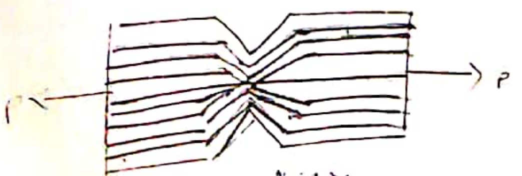
Bad design



Preferred design

Bad design

preferred design



Bad design

Preferred design

1) A rod steel rod is subjected to a tensile load of 90kN taking the yield stress for the steel has 328.6 MPa & factor of safety 1.8. Determine the suitable diameter of the rod.

Soln :- $P = 90kN$

$\sigma_y = 328.6 \, MPa = 328.6 \times 10^6 \times 10^{-6} N/mm^2$

$\therefore \sigma_y = 328.6 \, N/mm^2$

$n = 1.8$

WKT

allowable stress

$$\sigma_{all} = \frac{P}{A}$$

WKT $n = \dfrac{\sigma_y}{\sigma_{all}}$

$$1.8 = \frac{328.6}{\sigma_{all}}$$

$$\sigma_{all} = \frac{328.6}{1.8}$$

$$\sigma_{all} = 182.5556 \, N/mm^2$$

$$\sigma_{all} = \frac{P}{A}$$

$$182.5556 = \frac{90 \times 10^3 \times 4}{\pi \times d^2}$$

$$d^2 = \frac{90 \times 10^3 \times 4}{\pi \times 182.5556}$$

$$d = 25.0541 mm$$

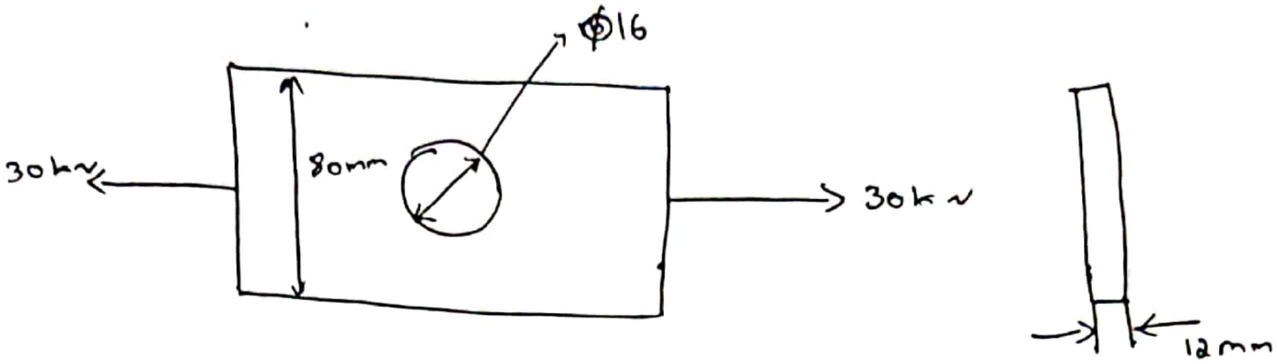
$\therefore$ diameter of rod $= d = 25.0541 mm$.

2) Determine the maximum stress induced in the following cases taking stress concentration into account.

i) A rectangular plate of 80mm wide with a hole of diameter 16mm in the centre is loaded in axial tension of 30kN. Thickness of plate 12mm.

ii) A stepped shaft step down from 60mm diameter to 40mm with a fillet radius of 8mm subjected to a twisting movement of 120N-m.

1) Rectangular plate with circular hole subjected to axial force:-



WKT stress concentration factor

$$k_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

where $\sigma_{nom} = \frac{P}{A}$

From fig 2.12, pg-36

$$A = (B-a)t$$

$$A = (80-16)12$$

$$A = \underline{\underline{768 \, mm^2}}$$

$$\sigma_{nom} = \frac{30 \times 10^3}{768}$$

$$\sigma_{nom} = \underline{\underline{39.0625}} \, N/mm^2$$

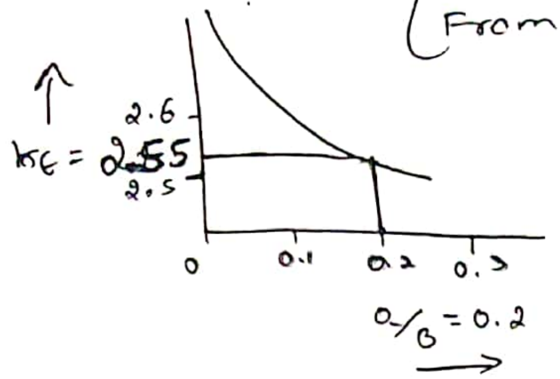
WKT $k_t = \frac{\sigma_{max}}{\sigma_{nom}}$

max. stress, $\sigma_{max} = k_t \times \sigma_{nom}$

To find k_t value [From fig 2.12 pg 36]

$$\frac{a}{B} = \frac{16}{80} = 0.2$$

[From fig 2.12 pg 36]

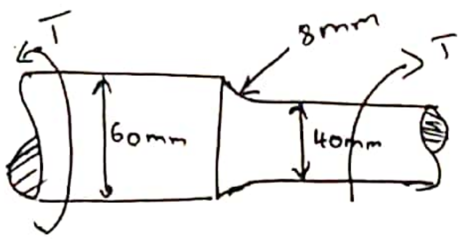


$k_t = 2.55$

max stress, $\sigma_{max} = 2.55 \times 39.0625$

$$\sigma_{max} = \underline{\underline{99.6094}}\ N/mm^2$$

ii) A stepped shaft step down from 60mm to 40mm ~~sel~~ -~~ded~~ with a fillet radius of 8mm subjected to a twisting movement of 120N-m



$D = 60mm$

$d = 40mm$

$r = 8mm$

$T = 120N-m$

$T = 120 \times 10^3\ N-mm$

WKT

$$k_{ts} = \frac{\tau_{max}}{\tau_{nom}}$$

$$\tau_{max} = k_t \times \tau_{nom}$$

To find τ_{nom} (For circular)

$$\tau_{nom} = \frac{16T}{\pi d^3} \quad [eq^n\ 1.1(d)\ pg\ 2]$$

$$\tau_{nom} = \frac{16 \times 120 \times 10^3}{\pi \times (40)^3}$$

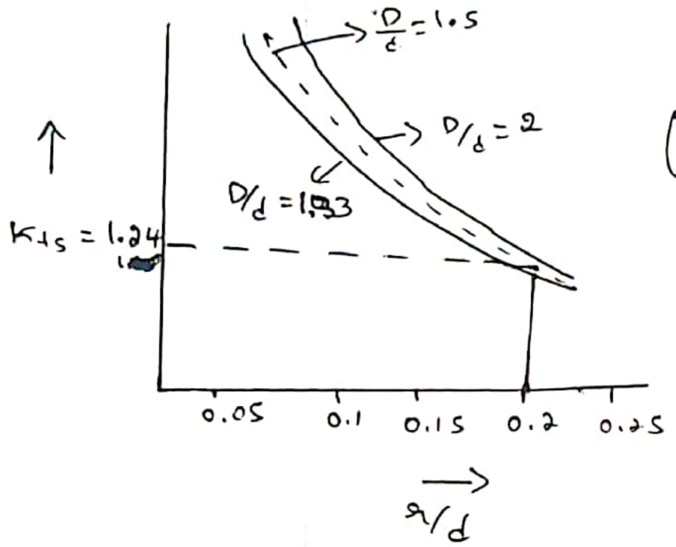
$$\tau_{nom} = \underline{\underline{9.5493}}\ N/mm^2$$

To find K_{ts}

From fig 2.27 Pg 44

$$\frac{r}{d} = \frac{8}{40} = \underline{0.20}$$

$$\frac{D}{d} = \frac{60}{40} = \underline{1.5}$$



[Fig 2.27 Pg 44]

$K_{ts} = \underline{1.24}$

max stress $\tau_{max} = K_{ts} \times \tau_{nom}$

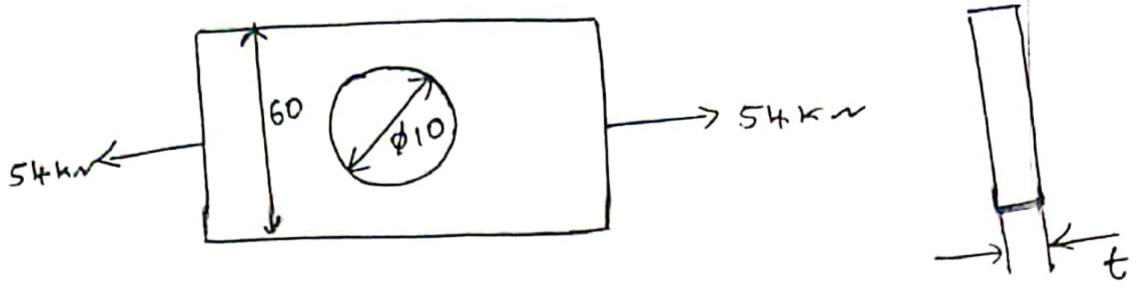
$$\tau_{max} = 1.24 \times 9.5493$$

$$\therefore \tau_{max} = \underline{11.8411 \ N/mm^2}$$

3) A plate of rectangular cross-section 60mm wide carries a tensile load of 54kN for some region a circular hole of 10mm diameter is to be drill exactly at the centre of the plate. Determine suitable thickness of the plate if it is made of C-40 steel. ($\sigma_y = 328.6$ MPa)

FOS(n) (1.5 - 3.5)

Sol



C-40 steel, $\sigma_y = 328.6 MPa$

$B = 60 mm$
$P = 54 kN$
$a = 10$
$t = ?$

$\sigma_y = 328.6 N/mm^2$

WKT $\quad K_t = \frac{\sigma_{max}}{\sigma_{nom}}$

where

$\sigma_{nom} = \frac{P}{A}$

$\sigma_{nom} = \frac{P}{(B-a)t}$

To find σ_{max}

WKT

$FOS(n) = \frac{\sigma_y}{\sigma_{all}(\sigma_{max})}$

$\sigma_{all/max} = \frac{\sigma_y}{FOS(n)}$

assume, $FOS(n) = 2$

[we can assume the n value from 1.5 - 3.5]

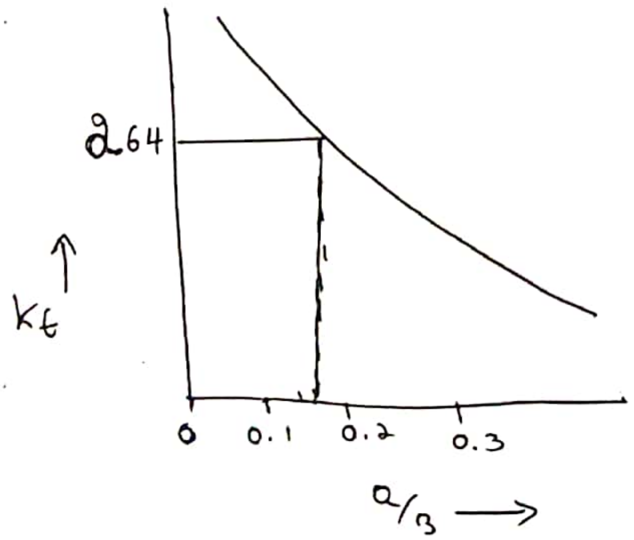
$\sigma_{max} = \frac{328.6}{2}$

$\therefore \sigma_{max} = 164.3 N/mm^2$

To find K_t

From the Fig 2.12 Pg 36

$a/B = \frac{10}{60} = 0.1667$



$K_t = 2.64$

wkT

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\sigma_{nom} = \frac{\sigma_{max}}{K_t}$$

$$= \frac{164.3}{2.64}$$

$$\sigma_{nom} = 62.2348 \, N/mm^2$$

$$\sigma_{nom} = \frac{P}{(B-a)t} = \frac{54\times10^3}{(60-10)t}$$

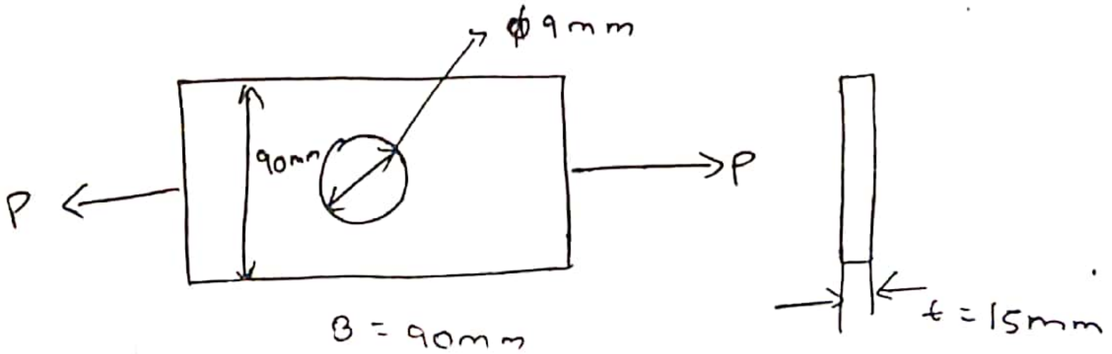
$$62.2348 = \frac{54\times10^3}{50t}$$

$$t = \frac{54\times10^3}{50\times62.2348}$$

$$t = 17.3536 \, mm$$

4) Determine the load carrying capacity of plate of rect-angular cross-section 90mm wide 15mm thick with the central hole of 9mm diameter limiting the stress to 90 MPa.

Solⁿ



$B = 90mm$

$a = 9mm$

$t = 15mm$

$P = ?$

$\sigma_{max} = 90 MPa$

$= 90 \, N/mm^2$

WKT $K_t = \frac{\sigma_{max}}{\sigma_{nom}}$

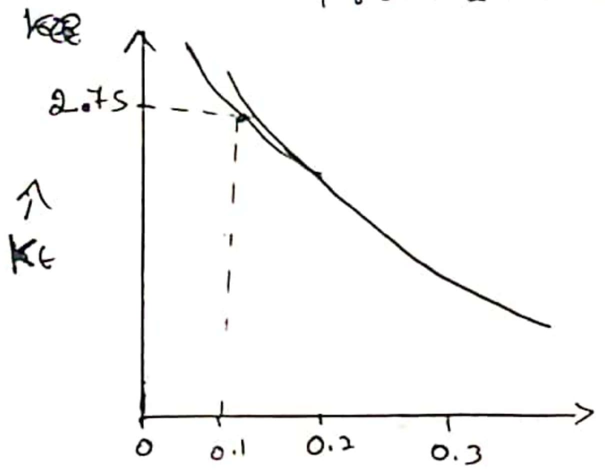
To find the value σ_{nom}

$$\sigma_{nom} = \frac{\sigma_{max}}{K_t}$$

To find the value K_t ⟶ From fig 2.12 pg 36

$$\frac{a}{B} = \frac{9}{90} = 0.1$$

From fig 2.12 pg 36



$K_t = 2.75$

$$\sigma_{nom} = \frac{\sigma_{max}}{K_t} = \frac{90}{2.75} = 32.7273 \ N/mm^2$$

WKT $\sigma_{nom} = \frac{P}{A}$

$$\sigma_{nom} = \frac{P}{(B-a)t}$$

$$P = \sigma_{nom} \times (B-a)t$$

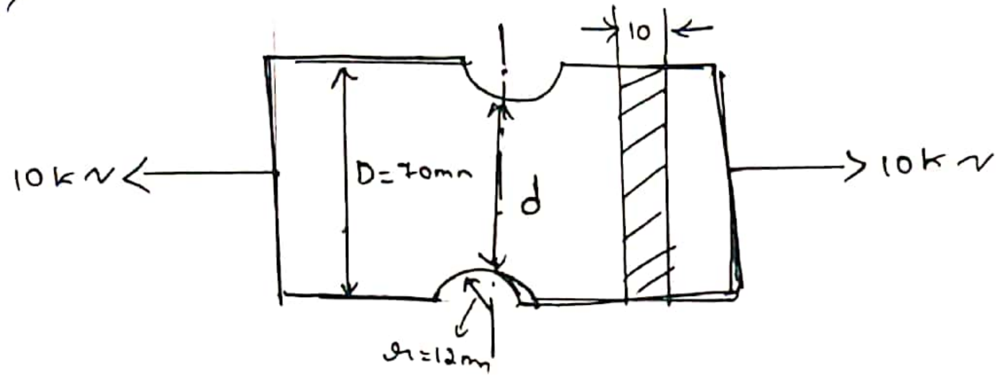
$$P = 32.7273 \times (90-9) \times 15$$

$$P = 39.7636 \times 10^3 \ N$$

$$\therefore P = 39.7636 \ kN$$

5) Find the maximum stress induced in the machine element as shown in figure.

i)



Soln:- $P = 10kN$

$D = 70mm$

$t = 10mm$

$r = 12mm$

$d = D - 2r$
$= 70 - 2 \times 12$
$= 70 - 24$
$d = 46mm$

WKT $K_t = \frac{\sigma_{max}}{\sigma_{nom}}$

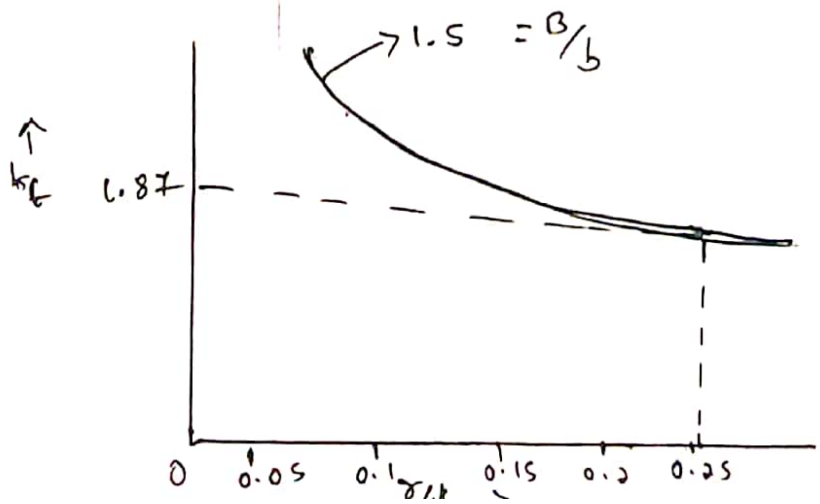
$\sigma_{max} = K_t \times \sigma_{nom}$

To find K_t

From fig 2.14, Pg 37

$\frac{r}{b} = \frac{12}{46} = 0.2609$

$\frac{B}{b} = \frac{70}{46} = 1.5217$



$K_t = 1.87$

To find σ_{nom}

$$\sigma_{nom} = \frac{P}{A} = \frac{P}{t \times b}$$

$$= \frac{10 \times 10^3}{10 \times 46}$$

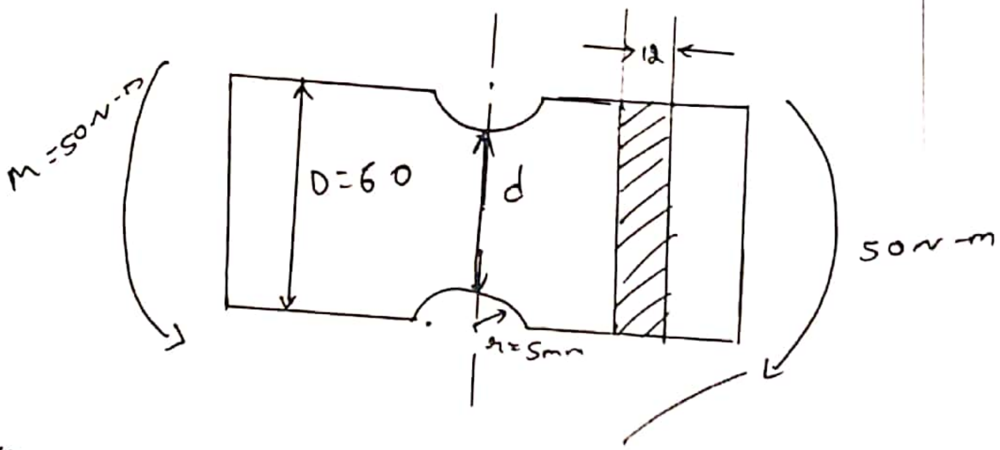
$$\sigma_{nom} = \underline{\underline{21.7391 \, N/mm^2}}$$

$$\sigma_{max} = K_t \times \sigma_{nom}$$

$$= 1.87 \times 21.7391$$

$$\sigma_{max} = \underline{\underline{40.6522 \, N/mm^2}}$$

ii)



Soln

Given

$D = 60\,mm$

$M = 50 N\text{-}m = 50 \times 10^3 \, N\text{-}mm$

$t = 12\,mm$

$d = D - 2r$

$= 60 - 2 \times 5$

$\boxed{d = 50\,mm}$

WKT

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

To find σ_{nom}

$$\frac{M}{I} = \frac{\sigma_{nom}}{y}$$

$$\sigma_{nom} = \frac{M \times y}{I}$$

$$= \frac{M \times 1}{t d^2 / 6}$$

$$= \frac{M \times \cancel{B} \times 6}{t d^2} = \frac{50 \times 10 \times 0}{12 \times (50^2)}$$

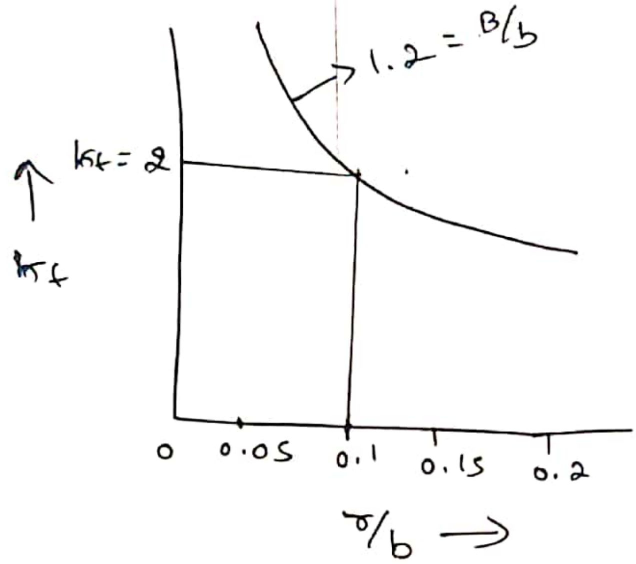
$$\sigma_{nom} = 10$$

To find k_t

From fig 2.15 pg 38

$$r/b = \frac{5}{50} = 0.1$$

$$\frac{B}{b} = \frac{60}{50} = 1.2$$



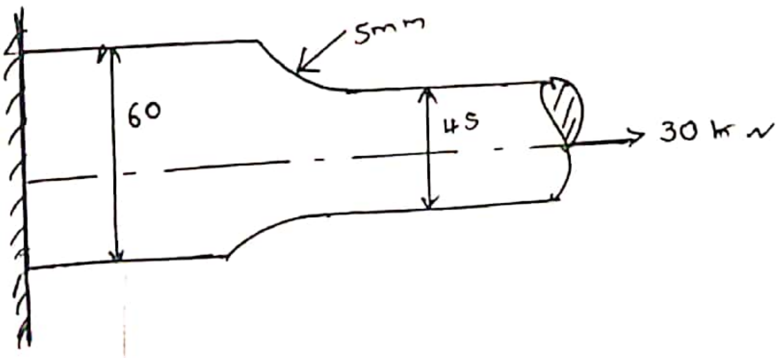
$$k_t = 2$$

$$\sigma_{max} = k_t \times \sigma_{nom}$$

$$= 2 \times 10$$

$$\therefore \sigma_{max} = 20\ N/mm^2$$

iii)



$D = 60\,mm$

$d = 45\,mm$

$P = 30\,kN$

$r = 5\,mm$

WKT

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

To find the value of σ_{nom}

$$\sigma_{nom} = \frac{P}{A} = \frac{P \times 4}{\pi d^2}$$

$$= \frac{30 \times 10^3 \times 4}{\pi \times (45^2)}$$

$$\sigma_{nom} = 18.8628\, N/mm^2$$

To find K_t

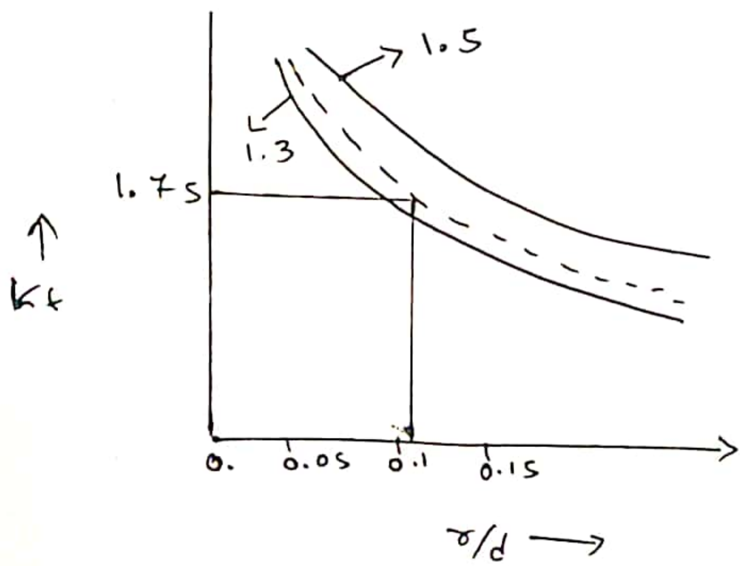
From Fig 2.23 pg 42

$$\frac{r}{d} = \frac{5}{45} = 0.1111$$

$$\frac{D}{d} = \frac{60}{45} = 1.333$$

$K_t = 1.75$

$K_t = 1.75$

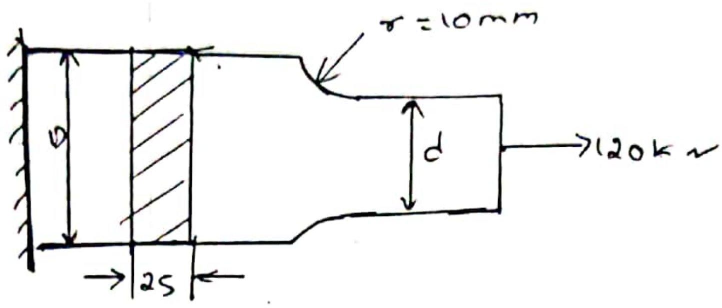


$$\sigma_{max} = K_t \times \sigma_{nom}$$

$$= 1.75 \times 18.862$$

$$\therefore \sigma_{max} = 33.0099\, N/m$$

Q) Determine the max stress of the fillet in geometric stress. concentration for the filleted bar is 1.8 have D/d ratio of 1.2 also determine the FOS (n) if $\sigma_y = 640$ MPa



Soln

$K_t = 1.8$ $\quad t = 25mm$

$\frac{D}{d} = 1.2$ $\quad r = 10mm$

$n = ?$

$\sigma_{max} = ?$

$\sigma_y = 640MPa = 640\ N/mm^2$

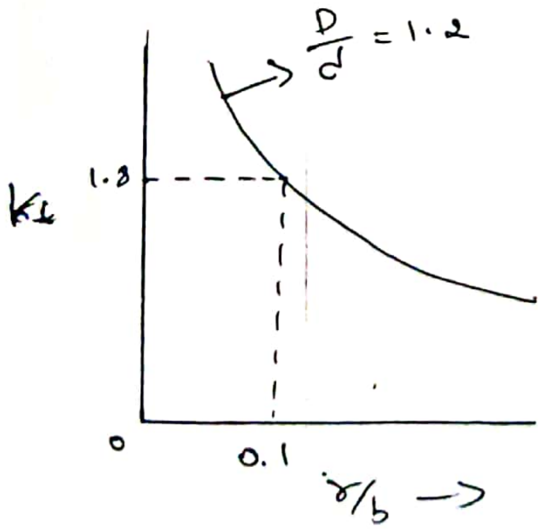
WKT

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\therefore \sigma_{nom} = \frac{P}{A}$$

$$= \frac{120\times10^3}{tb} \text{ (or) } \frac{120\times10^3}{td}$$

From fig 2.16, pg 38



$\frac{r}{b} = 0.1$

$\frac{r}{d} = 0.1$

$\frac{10}{d} = 0.1$

$d = \frac{10}{0.1}$

$d = 100mm$

wkt

$$\sigma_{nom} = \frac{120 \times 10^3}{td}$$

$$= \frac{120 \times 10^3}{25 \times 100}$$

$$\sigma_{nom} = 48 \; N/mm^2$$

~~Res:- max stress / working/allowable stress~~

$$= \cancel{86.4}$$

$$k_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\sigma_{max} = k_t \times \sigma_{nom}$$

$$= 1.8 \times 48$$

$$\therefore \sigma_{max} = 86.4 \; N/mm^2$$

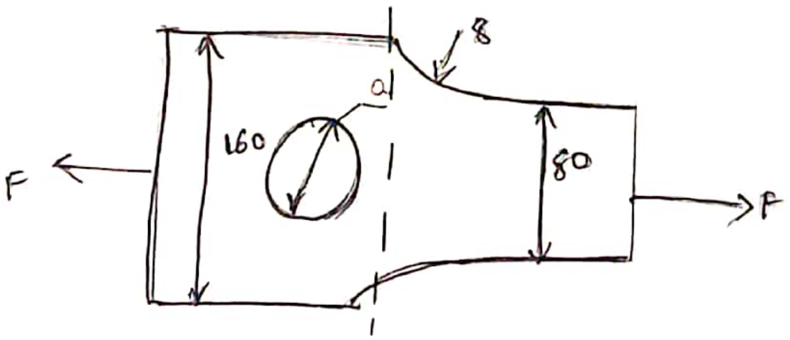
$$FOS = \frac{\sigma_y}{\sigma_{w/all} \,(or)\, \sigma_{max}}$$

$$= \frac{640}{86.4}$$

$$\cancel{\frac{640}{48}}$$

$$\boxed{FOS(n) = 7.40}$$

7) Find diameter of the hole for the following figure if the stress concentration factor at the hole is same as that at the fillet.

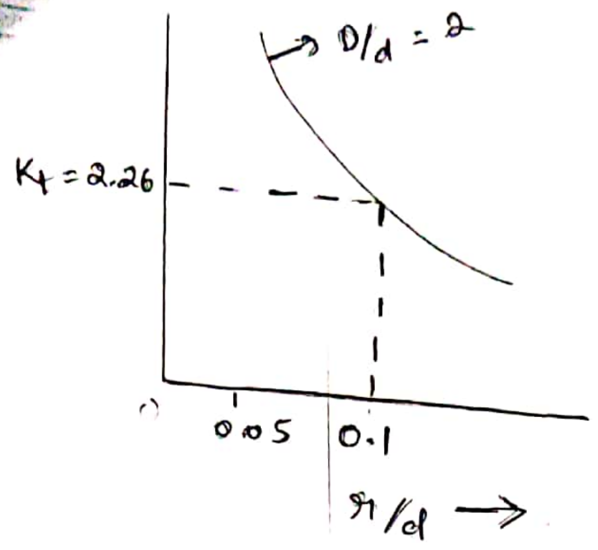


i) consider across fillet :-

D = 160 mm d = 80 mm, r = 8 mm

From the fig 2.16 Pg 38

$$\frac{D}{d} = \frac{160}{80} = 2, \quad \frac{r}{d} = \frac{8}{80} = 0.1$$

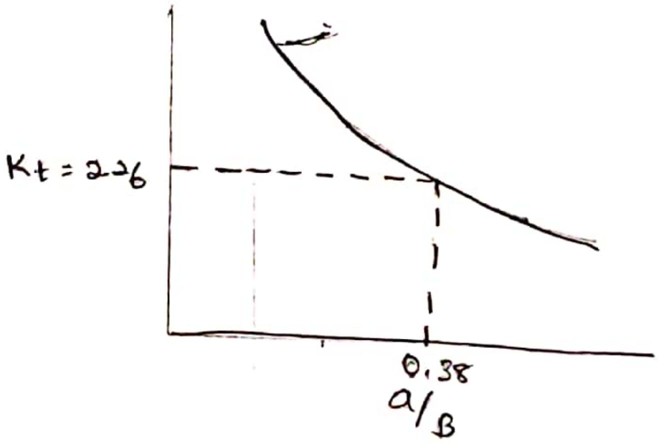


$K_t = 2.26$

ii) Consider a cross hole

K_t = From the fig 2.12, pg 36

$K_t = 2.26$ [Given]



$K_t = 2.26$, $\frac{a}{B} = 0.38$

$a/B = 0.38$

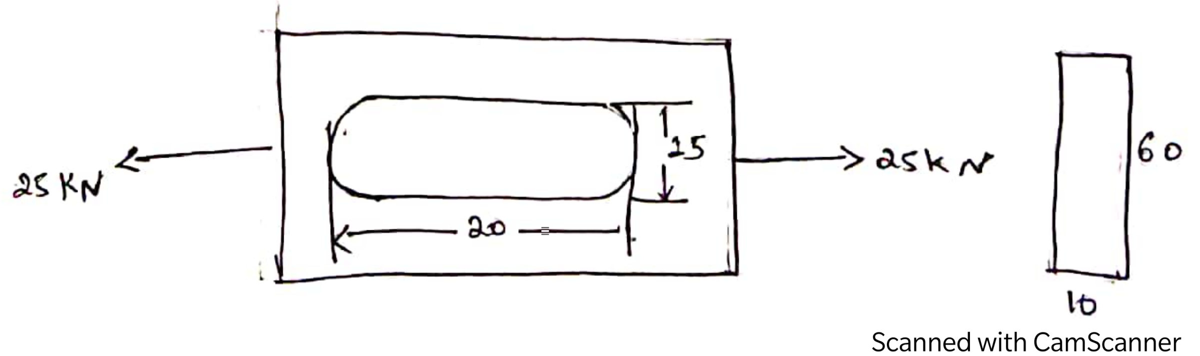
$\frac{a}{160} = 0.38$

$a = 0.38 \times 160$

$a = 60.8\ mm$

∴ The diameter of the hole = 60.8 mm

8) ~~A flat plate subjected~~ Find the max. stress induced in the machine element as shown in figure



WKT

$$k_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\sigma_{max} = k_t \times \sigma_{nom}$$

$$\sigma_{nom} = \frac{P}{A}$$

$$= \frac{P}{(w-a)t} = \frac{25 \times 10^3}{(60-15)10} = 55.55 \ N/mm^2$$

To find k_t

For elliptical hole

From Table 2.1 Pg 30

$$k_t = 1 + \frac{2c}{b}$$

From Fig (2.11 Pg 36)

$$c = \frac{15}{2} = 7.5$$

$$b = \frac{20}{2} = 10$$

$$k_t = 1 + \frac{2(7.5)}{10}$$

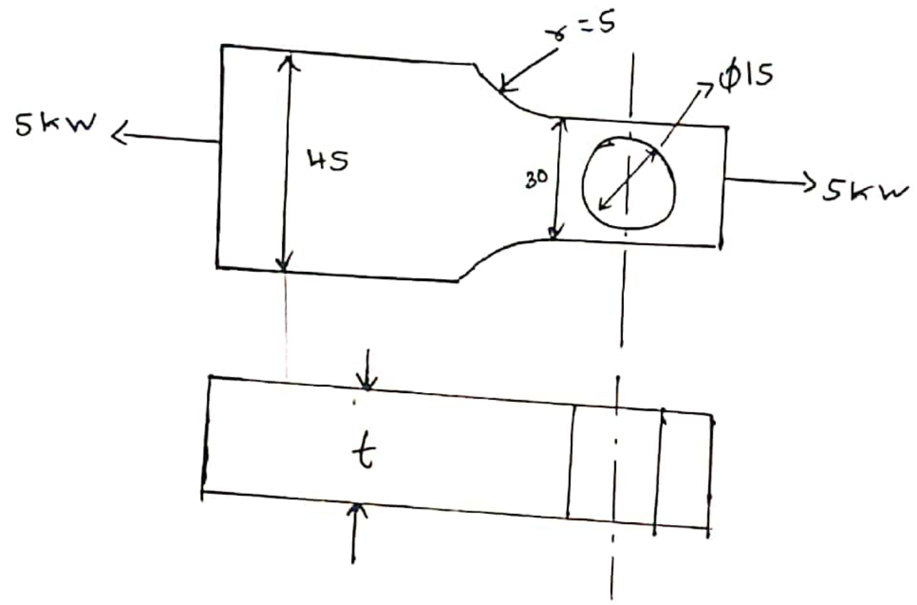
$$k_t = 2.5$$

$$\sigma_{max} = k_t \times \sigma_{nom}$$

$$= 2.5 \times 55.55$$

$$\therefore \sigma_{max} = 138.875 \ N/mm^2$$

A flat plate subjected to tensile force of 5KN is shown in the figure the plate material is gray cast iron having ultimate stress 200 MPa. Determine the thickness of ~~ato~~ the plate using factor of safety of 2.5.



Sol^n

$\sigma_u = 200\, MPa = 200\, N/mm^2$

$FOS = n = 2.5$

$t = ?$

WKT $n = \dfrac{\sigma_u}{\sigma_{all/max}}$

$\sigma_{max} = \dfrac{\sigma_u}{n}$

$\sigma_{max} = \dfrac{200}{2.5}$

$\therefore \underline{\sigma_{max} = 80\, N/mm^2}$

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ii) consider o-cross fillet

$B = 45$

$b = 30$

$r = 5$

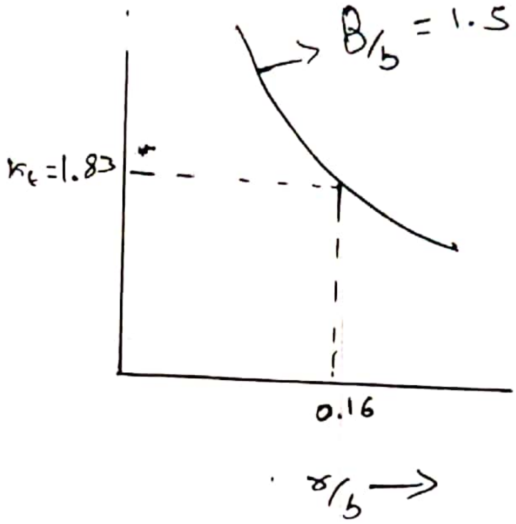
wkT $\quad K_t = \dfrac{\sigma_{max}}{\sigma_{nom}}$

To find Kt

From fig 2.16 Pg 38

$\dfrac{B}{b} = \dfrac{45}{30} = 1.5$

$\dfrac{r}{b} = \dfrac{5}{30} = 0.1667$



$K_t = 1.83$

$\sigma_{nom} = \dfrac{\sigma_{max}}{K_t}$

$= \dfrac{80}{1.83}$

$\sigma_{nom} = 43.71 \text{ N/mm}^2$

nominal stress, $\sigma_{nom} = \dfrac{P}{A}$

$43.71 = \dfrac{5 \times 10^3}{t \times b}$

$t = \dfrac{5 \times 10^3}{43.71 \times 30}$

$t = 3.8130 \text{ mm}$

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ii) Consider the plate with hole.

$B = 30$

$a = 15$

$F = 5 \times 10^3 N$

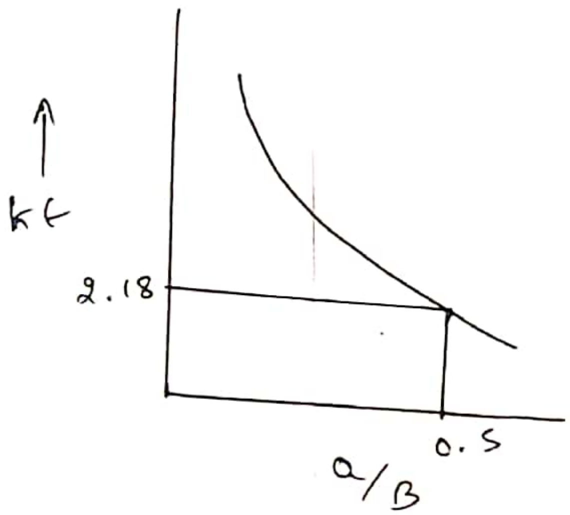
$t = ?$

WKT $\quad K_t = \dfrac{\sigma_{max}}{\sigma_{nom}}$

To find the K_t value

From fig 2.12 pg 36

$$\frac{a}{B} = \frac{15}{30} = 0.5$$



$\underline{\underline{K_t = 2.18}}$

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\sigma_{nom} = \frac{F}{A} = \frac{5 \times 10^3}{(B-a)t} = \frac{5 \times 10^3}{(30-15)t}$$

$$\sigma_{nom} = \frac{\sigma_{max}}{K_t}$$

$$\sigma_{nom} = \frac{80}{2.18} = \underline{\underline{36.6972}} \ N/mm^2$$

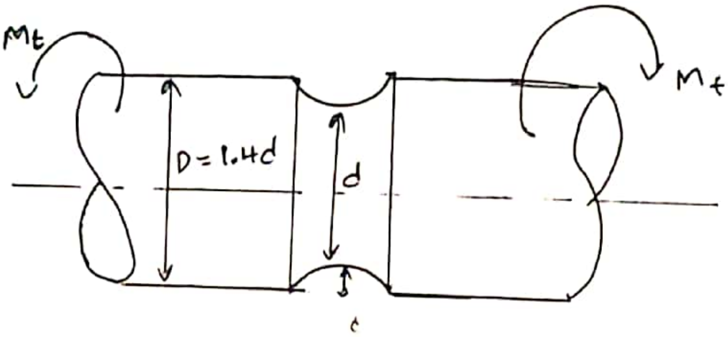
$$36.6972 = \frac{5\times10^3}{(30-15)t}$$

$$t = \frac{5\times10^3}{(30-15)\times 36.6972}$$

$$\therefore t = \underline{9.0833\,mm}$$

Therefore, ~~Th~~ The thickness value $\underline{t = 9.0833\,m}$ (larger value of thickness)

10) A grooved shaft as shown in figure. is to transmit 5kW at 120rpm. Determine the diameter of the shaft at the groove if it is made of C-15 steel (σ_y = 235. MPa). FOS = n = 2.



P = 5kW

N = 120rpm d = ? D = 1.4d

σ_y = 235.4 MPa = 235.4 N/mm²

FOS (n) = 2

WKT $$FOS = \frac{\sigma_y}{\sigma_{max}} = \frac{235.4}{\sigma_{max}} = 2$$

$$\sigma_{max} = \frac{235.4}{2}$$

$$\underline{\sigma_{max} = 117.7\ N/mm^2}$$

stress concentration factor

$$K_t = \frac{\tau_{max}}{\tau_{nom}}$$

WKT (For circular τ_{nom})

$$\tau_{nom} = \frac{16T}{\pi d^3}$$

$$P = \frac{2\pi N T}{60}$$

$$\frac{5\times10^3 \times 60}{2\times\pi\times120} = T$$

~~τ_{max}~~

$$T = 397.8874 \text{ N-m}$$

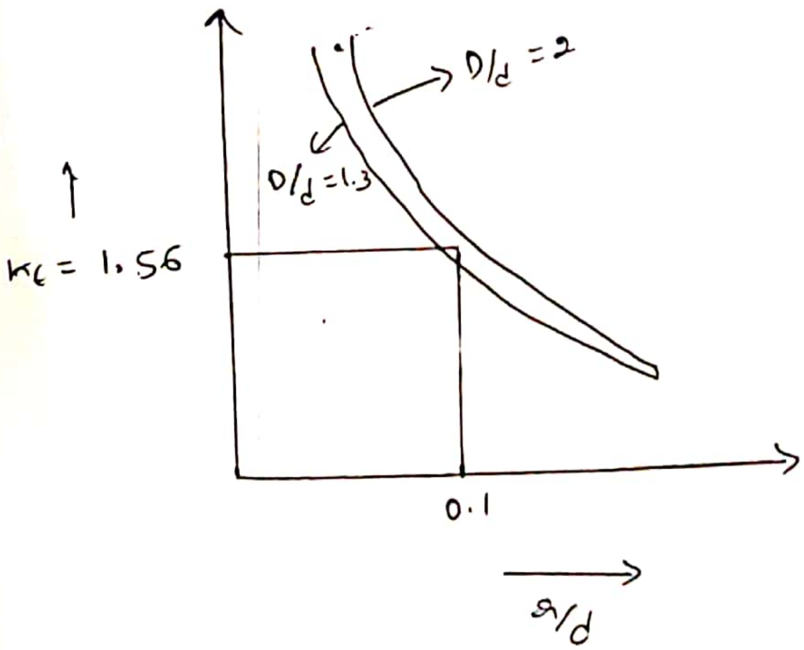
$$T = 397.8874\times10^3 \text{ N-mm}$$

To find the value of K_t

From fig 2.22 Pg 41

$$\frac{r}{d} = \frac{0.1\cancel{d}}{\cancel{d}} = 0.1$$

$$\frac{D}{d} = \frac{1.4\cancel{d}}{\cancel{d}} = 1.4$$



$$K_t = 1.56$$

To find τ_{max}

$$\tau_{max} = \frac{\sigma_{max}}{2} = \frac{117.7}{2}$$

$$\tau_{max} = 58.85 \text{ N/mm}^2$$

τ_{nom}

WKT $\quad K_t = \dfrac{\tau_{max}}{\tau_{nom}}$

$$\tau_{nom} = \frac{\tau_{max}}{K_t}$$

$$= \frac{58.85}{1.56}$$

$$\boxed{\tau_{nom} = 37.7244 \text{ N/mm}^2}$$

For circular object: τ_{nom}

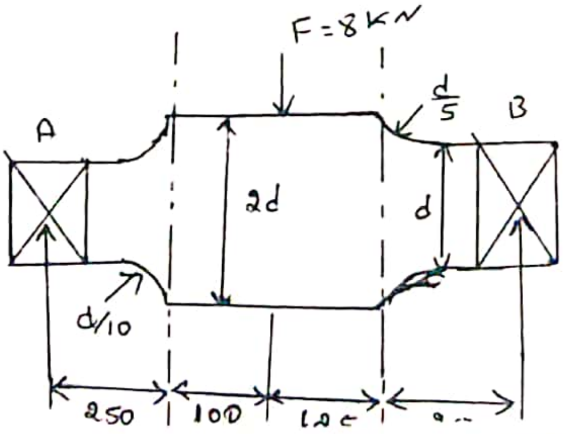
$$\tau_{nom} = \frac{16T}{\pi d^3}$$

$$d^3 = \frac{16T}{\pi \times \tau_{nom}}$$

$$= \frac{16 \times 397.8874 \times 10^3}{\pi \times 37.7244}$$

$$d = 37.7314 \text{ mm}$$

ii) A step shaft shown in figure is subjected to a transvers load. the shaft is made of steel with ultimate tensile strength 400 MPa. Determine the diameter 'd' of the shaft Based on the factor of safety 2.



Sol:

$\sigma_u = 400 MPa = 400 N/mm^2$

$n = 2$

WKT

$$FOS(n) = \frac{\sigma_u}{\sigma_{all/max}}$$

$$\sigma_{max} = \frac{400}{2}$$

$$\therefore \boxed{\sigma_{max} = 200 N/mm^2}$$

From Fig

$R_A + R_B = 8 kN$

Taking moment about Point A

$$-(R_B \times 500) + (8 \times 10^3 \times 350) = 0$$

$$R_B = \frac{8 \times 10^3 \times 350}{500}$$

$$\therefore \boxed{R_B = 5600 N}$$

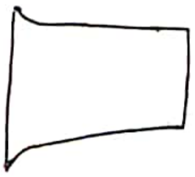
$$R_B = 5.6 kN$$

$$R_A = 8k - 5.6k$$

$$\therefore R_A = 2.4 kN$$

$$\therefore \boxed{R_A = 2400 N}$$

i) considering Right side of fillet:-



moment, $M_b = R_B \times 25$

$= 5600 \times 25$

$M_b = \underline{140 \times 10^3}$ N-mm

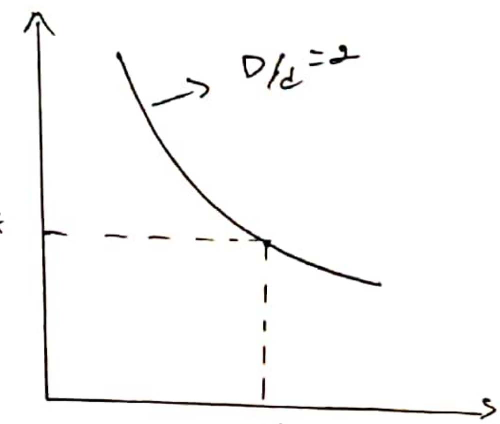
WKT $\quad K_t = \dfrac{\sigma_{max}}{\sigma_{nom}}$

To find Kt

From Fig 2.25 Pg 43

$\dfrac{r}{d} = \dfrac{d/5}{d} = \dfrac{1}{5} = \underline{0.2}$

$\dfrac{D}{d} = \dfrac{2d}{d} = 2$



$K_t = \underline{1.44}$

$\sigma_{nom} = \dfrac{32 M_b}{\pi d^3}$

$= \dfrac{32 \times 140 \times 10^3}{\pi \times 138.88 \, d^3}$

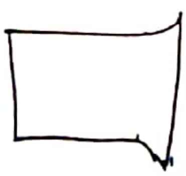
$\boxed{d = 21.735 \text{mm}}$

$d =$

$\sigma_{nom} = \dfrac{\sigma_{max}}{K_t}$

$\sigma_{nom} = \dfrac{200}{1.44} = \underline{138.88 \text{ N/mm}^2}$

ii) considering left side of fillet



moment, $M_A = R_A \times 250$

$= 2400 \times 250$

$M_A = \underline{600 \times 10^3}$ N-m

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$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

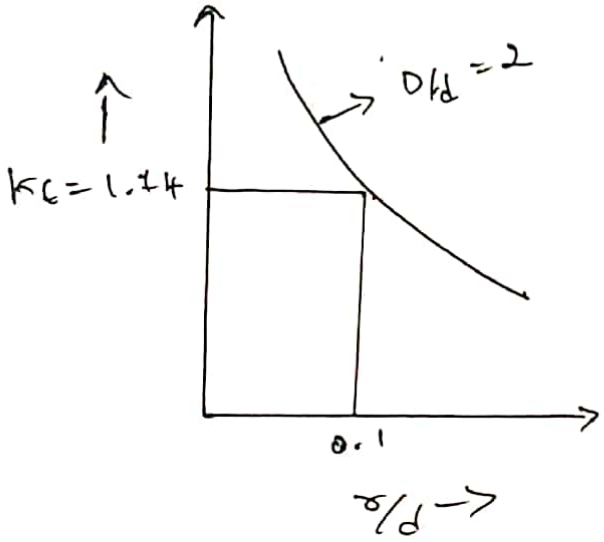
To find K_t

From fig 2.25 Pg 43

$$\frac{r}{d} = \frac{\cancel{d}/10}{\cancel{d}} = \frac{1}{10} = 0.1$$

$$\frac{D}{d} = \frac{2\cancel{d}}{\cancel{d}} = 2$$

$K_t = 1.74$



$$\sigma_{nom} = \frac{\sigma_{max}}{K_t} = \frac{200}{1.74}$$

$$\sigma_{nom} = 114.9425 \, N/mm^2$$

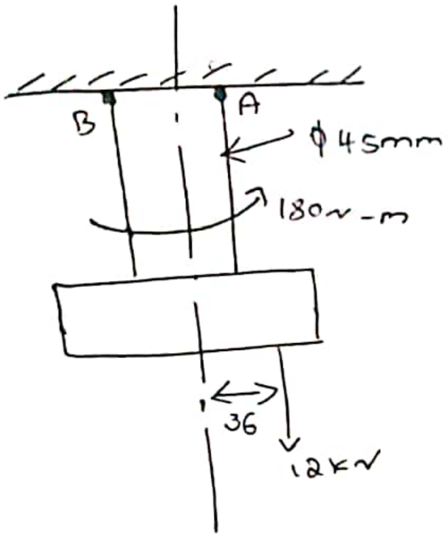
$$\sigma_{nom} = \frac{32 M_A}{\pi d^3}$$

$$d^3 = \frac{32 M_A}{\pi \times \sigma_{nom}} = \frac{32 \times 600 \times 10^3}{\pi \times 114.9425}$$

$$d = 37.603 \, mm$$

Eccentric load

1) A 45mm diameter steel rod carries a 12kN & twisting moment of 180N-m as shown in figure. Determine the maximum tensile & the maximum shear stress induced in it.



Sol^n

$P = 12kN$

$T = 180 N\text{-}m = 180 \times 10^3 N\text{-}mm$

$d = 45mm$

$e = 36mm$

$\sigma_{max} = ?$

$\tau_{max} = ?$

i) Shear stress due twisting moment (For circular)

$$\tau = \frac{16T}{\pi d^3} = \frac{16 \times 180 \times 10^3}{\pi \times (45^3)}$$

$$\therefore \tau = 10.0601 \, N/mm^2$$

ii) Due to eccentric loading two types of stresses are developed in the shaft

a) Direct stress

b) Bending stress

Direct stress, $\sigma_d = \frac{P}{A}$

$$= \frac{12 \times 10^3 \times 4}{\pi \times (45^2)}$$

$$\cancel{\sigma_d = 0.2676 \, N/mm^2}$$

$$\sigma_d = 7.5451 \, N/mm^2$$

Bending stress $\sigma_b = \frac{32M}{\pi d^3}$

$M = P \times e$
$M = 12 \times 10^3 \times 36$

$M = 432 \times 10^3 \ N\text{-}mm$

$$\sigma_b = \frac{32 \times 432 \times 10^3}{\pi \times (45^3)}$$

$$\sigma_b = 48.2887 \ N/mm^2$$

max. tensile stress is at point A

$$\sigma = \sigma_d + \sigma_b$$
$$= 7.5451 + 48.2887$$
$$\sigma = 55.8338 \ N/mm^2$$

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \rightarrow [\text{eq}^n \ 1.5(a) \ Pg \ 3]$$

$$= \frac{55.8338}{2} + \sqrt{\left(\frac{55.8338}{2}\right)^2 + (10.0601)^2}$$

$$= 27.9169 + 29.6742$$

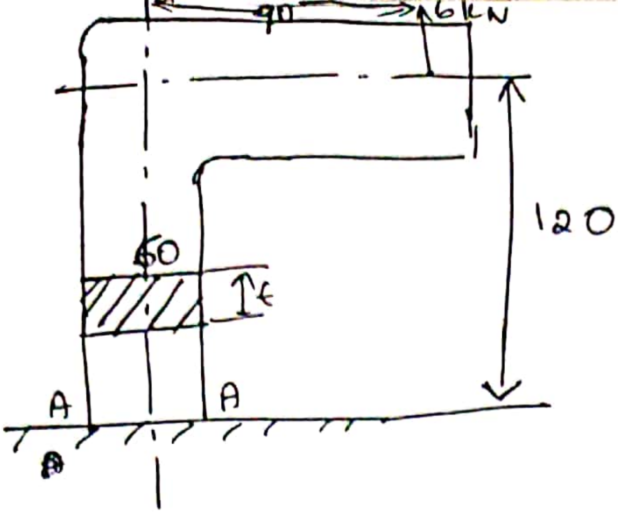
$$\sigma_{max} = 57.5911 \ N/mm^2$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$ [eq^n 1.5(b), Pg 3]

$$\tau_{max} = \sqrt{\left(\frac{55.8338}{2}\right)^2 + (10.0601)^2}$$

$$\therefore \tau_{max} = 29.6742 \ N/mm^2$$

2) Determine the thickness of the steel bracket loaded as shown in figure taking the allowable stress as 90 MPa.



at section

WKT $\sigma_{max} = \sigma_d + \sigma_b$

where $\sigma_d = \frac{P}{A}$

$\sigma_d = \frac{6\times10^3}{(60)t}$

$\therefore \sigma_d = \frac{100}{t}$

Solⁿ:-

$t = ?$

$\sigma = 90 MPa = 90 N/mm^2$

$P = 6 kN$

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

where

$M = 6\times10^3 \times 90$

$M = 540\times10^3 N\text{-}m$

$y = \frac{h}{2} = \frac{60}{2}$

$y = 30$

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

$I = \frac{t(60)^3}{12}$

$I = 18\times10^3 t$

$\sigma_b = \frac{540\times10^3\times30}{18\times10^3 t}$

$\therefore \sigma_b = \frac{900}{t}$

$\sigma_{max} = \sigma_d + \sigma_b$

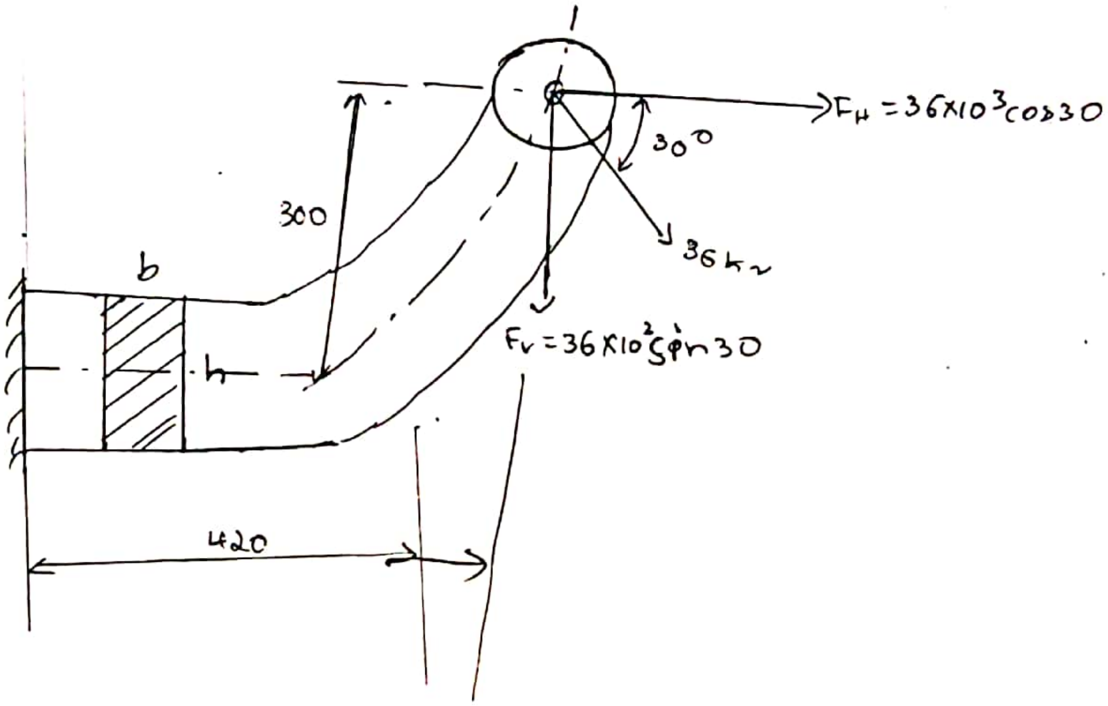
$90 = \frac{100}{t} + \frac{900}{t}$

$90 = \frac{1}{t}[1000]$

$t = \frac{1000}{90}$

$\therefore t = 11.1111 mm$

3) Figure shows the wall bracket subjected to a load of 36 kN. Find the width & depth of rectangular cross-section taking depth as thrice the width. Take $\sigma_y = 328.6 MPa$ & adopt a factor of safety of 2.5



sol^n

$\sigma_y = 328.6 \, MPa = 328.6 \, N/mm^2$

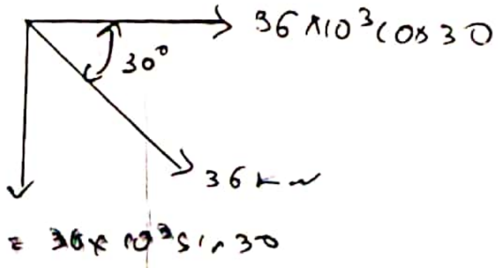
$b = ?$

$h = ?$

$n = 2.5$

$h = 3b$

Resolving the forces



i) consider vertical component (F_v)
Because of F_v the bracket subjected for bending stress.

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

$M = F_v \times \perp^{r} \text{ distance}$

$M = 36 \times 10^3 \sin 30 \times 420$

$M = 7.56 \times 10^6 \; N\text{-}mm$

$y = \frac{h}{2} = \frac{3b}{2}$

$$I = \frac{bh^3}{12} = \frac{b(3b)^3}{12} = \frac{27b^4}{12}$$

$$\sigma_b = \frac{7.56 \times 10^6 \times 3\cancel{b} \times 12}{2 \times 27 b^4}$$

$$\sigma_b = \frac{5.04 \times 10^6}{b^3} = \sigma_1$$

ii) consider ~~vertical ca~~ Horizontal component (F_H) Because of F_H the bracket subjected for eccentric load.

$\sigma = \sigma_d + \sigma_b$

$$\sigma_d = \frac{F_H}{A}$$

$$\sigma_d = \frac{36 \times 10^3 \cos 30}{b \times h} = \frac{36 \times 10^3 \cos 30}{b \times 3b}$$

$$\sigma_d = \frac{36 \times 10^3 \cos 30}{3b^2}$$

$$\sigma_d = \frac{10.3923 \times 10^3}{b^2}$$

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

where $M = F_H \times \perp^{r} \text{ distance}$

$M = 36 \times 10^3 \cos 30 \times 300$

$M = 9.3530 \times 10^6 \; N\text{-}mm$

$$y = \frac{h}{2} = \frac{3b}{2}$$

$$I = \frac{bh^3}{12} = \frac{27b\,b^3}{12} = \frac{27b^4}{12}$$

$$\sigma_d = \frac{M \times y}{I} = \frac{9.3530 \times 10^6 \times 3b \times 12}{2 \times 27 \times b^4}$$

$$\sigma_d = \frac{6.2353 \times 10^6}{b^3}$$

WKT

$$n = \frac{\sigma_y}{\sigma_{max}}$$

$$2.5 = \frac{328.6}{\sigma_{max/all}}$$

$$\sigma_{max/all} = \frac{328.6}{2.5} = 131.44\ N/mm^2$$

$$\sigma_{max/all} = 131.44\ N/mm^2$$

$$\cancel{\sigma_1 = \sigma_b + \sigma_d}$$

$$\cancel{131.44 = \frac{10.3923 \times 10^3}{b^2} + \frac{6.2353 \times 10^6}{b^3}}$$

$$\sigma_2 = \sigma_b + \sigma_d$$

$$\sigma_2 = \frac{10.3923 \times 10^3}{b^2} + \frac{6.2353 \times 10^6}{b^3}$$

$$\sigma_{max} = \sigma_1 + \sigma_2$$

$$131.44 = \frac{5.04 \times 10^6}{b^3} + \frac{10.3923 \times 10^3}{b^2} + \frac{6.2353 \times 10^6}{b^3}$$

$$131.44 = \frac{1}{b^3}\left[5.04\times10^{0} + 10.3423\times10^{3}b + 6.2353\times10^{6}\right]$$

$$131.44b^3 = 11.2753\times10^{6} + 10.3923\times10^{3}b$$

$$131.44b^3 - 10.3923\times10^{3}b - 11.2753\times10^{6} = 0$$

$$\underline{b = 44.7004\,mm}$$

$$h = 3b$$

$$h = 3\times44.7004$$

$$\underline{h = 134.1012\,mm}$$

Codes & standards

Standards :- A set of specification for parts material (or) process. The purpose of standard is to reduce the variety & limit the no of items to a ~~re~~reasonable level.

There are 3 types of standard.

1) Company standard :- ~~using~~ used in a particular company (or) group of sister concern.

2) National standards :- These are IS (bureau of Indian standard), SAI (USA), ~~[illegible]~~ BS (British Standards), DIN (Germany)

3) International standards :- These are prepared by International standard ~~ass~~ ~~ISO~~. organisation.

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Codes : A set of analysis for design, manufacture, testing on construction of product. The purpose of code is to achieve a specified degree of safety, efficiency & quality. various organisation & societies which are established.

Specification for standards & codes are listed

1) ASME :- American society of mechanical eng
2) ASM :- American society of metals
3) ASTM :- —— " —— for testing & materials
4) ISI :- Indian standard Institute.
5) NBS :- national Bureau of standard.
6) BSI :- British standard Institute.
7) AISI :- American Iron & steel Institute.

20/09/18

(standardization notes [illegible]).