5th June'19

Preffered Number ~~are~~ or sizes are established for the purpose of standardization.

Preferred no.s are series of numbers which are used for deciding the no. of sizes of any product. These are specially recomended values and these specifies the proportions of items, powers, capacities, speeds and all other parameters used in proportion and expressed numerically.

The preffered no.s are classified into 4 basic series R5, R10, R20, R40.

It has been established by experience that a certain range can be covered efficiently with a minimum no. of sizes by the use of geometrical progression [ϕ] with constant ratio.

Geometrical progression can be given as

$$\phi = \left(\frac{max}{min}\right)^{1/(n-1)}$$

Q) A gear box is to be designed with 6 speeds ranging from 250 - 2000 rpm. Determine the speeds obtained from the above range.

Ans - max = 2000 rpm
min = 250 rpm

$$\phi = \left(\frac{2000}{250}\right)^{\frac{1}{6-1}} = 8^{\frac{1}{5}} = 1.5157$$

$N_1 = 250$
$N_2 = 250 \times 1.5157 = 378.93$
$N_3 = 378.93 \times 1.5157 = 574.34$
$N_4 = 574.34 \times 1.5157 = 870.53$
$N_5 = 1319.46$
$N_6 = 2000$

28) A pump has to be designed from 1 HP to 10 HP. Determine the numbers by using R5 basic series.

Ans - $\phi = 1.6$

$P_1 = 1$ HP

$P_2 = 1.6$ HP

$P_3 = 2.56$ HP

$P_4 = 4.096$ HP

$P_5 = 6.5536$ HP

$P_6 = 10$ HP

83) A manufacturer is interested in starting a new business with 5 different models of tractors ranging from 7.5 to 75 kW capacities. Specify the power capacites of models. There is an expansion plan to further increase the no. of models 5 to 9 to fulfil the requirements of farmers. Specify the power capacities of additional models.

Ans - $\phi = \left(\frac{75}{7.5}\right)^{\frac{1}{5-1}} = 10^{1/4}$

$= 1.778$

$P_1 = 7.5$ kW

$P_2 = 13.33$ kW

$P_3 = 23.7$ kW

$P_4 = 42.2$ kW

$P_5 = 75$ kW

$n = 9$

$\phi = \left(\frac{75}{7.5}\right)^{\frac{1}{9-1}} = 10^{1/8} = 1.33$

$P_1 = 7.5$ kW

$P_2 = 10$ kW

$P_3 = 13.33$ kW

$P_4 = 17.78$ kW

$P_5 = 23.72$ kW

$P_6 = 31.62$ kW

$P_7 = 42.17$ kW

$P_8 = 56.24$ kW

$P_9 = 75$ kW

Additional Models: P_2, P_4, P_6, P_8

* Types of Designs *

1) Adaptive design
2) Developmental design
3) New design

1) This is based on existing design. eg: Standard products for a new application eg: In bicycles, I.e engines etc there is hardly anything left for the designer to do except making a minor modification.

2) It starts with an existing design but finally modified design is obtained. This type of design requires considerable scientific training and design ability to modify the existing design.

3) New design: Entirely a new one but based on existing scientific principles.
This design needs lots of research, technical ability & creative thinking

* The design based on the methods used classified as

1) Rational design:
Depends upon mathematical formulae based on principles of mechanics.
eg: Determining stress & strain of components & thereby deciding their dimensions.

2) Emperical design:
Based on past experience and existing practise

3) Industrial design:
These are based on industrial consideration and norms like market survey, external look, production facility, use of existing standard products and with a cost aspect.

8th July '19

Design and Manufacturing
→ Limits
→ Fits
→ Tolerances
→ Preferred numbers

- Allowance → 0 → snug fit (difference b/n 2 mating parts)
- Limits
eg. $50^{+0.5}_{-0.5}$

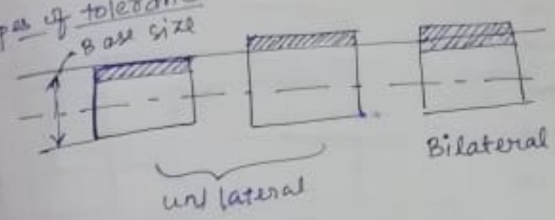
50.05 mm → upper limit
49.95 mm → lower limit

upper deviation = 50.05 − 50 = 0.05
Lower deviation = 49.95 − 50 = −0.05

$50^{-0.5}$ → no upper limit i.e 0 upper deviation

tolerance: difference of UL & LL

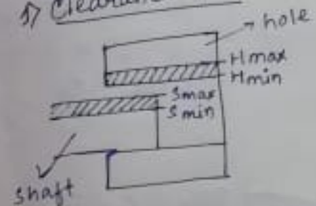
- Types of tolerance



- Fit System

1) Clearance Fit

Allowance → +ve

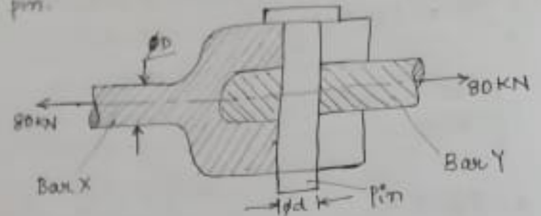


Hmin > Smax & Smin

In this type of fit, shaft of largest possible diameter can also be fitted easily even in the hole of smallest possible diameter.

19-July-'19

Q) A pull of 80KN is transmitted from a bar X to a bar ~~Y~~ through a pin as shown. The permissible stress in the bar is 1000 N/mm² & the permissible shear stress in pin is 80 N/mm². Determine the diameter of bar and pin.



Ans -
$\sigma = 100\ N/mm$
$\tau = 80\ N/mm$
$P = 80KN$
$D = ?$
$d = ?$

Consider the bar

$$\sigma = \frac{P}{A} = \frac{80}{\frac{\pi}{4}D^2}$$

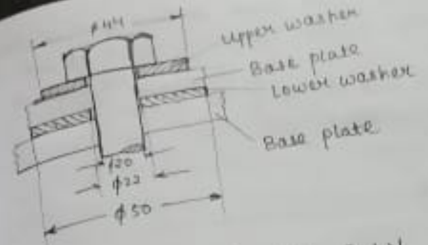
$$\Rightarrow D = \frac{80 \times 4 \times 10^3}{\pi \times 100} = 31.9\ mm$$

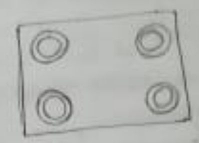
Consider the Pin:

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

$$\Rightarrow d^2 = \frac{80 \times 10^3 \times 4}{80 \times 2 \times \pi} = 25.23\ mm$$

Q) A rectangular base plate is fixed at each of the 4 corners by a 20mm dia bolt and nut as shown in figure. The plate rests on washer 22 mm internal dia & 50 mm ext. dia. Cu washers which are placed b/n the nut and the plate are 22 mm di and 44mm ext dia. If the base plate carries a load of 120 KN including self weight ~~strain~~ distributed equally in 4 corners. Calculate the stress on the lower washers before the nuts are tightened. What could be the stress in the upper and the lower washers, when the nuts are tightened so as to produce a 5KN on each bolt.





Ans -
$P_T = 120 kN$; $P = \frac{120}{4} = 30kN$
$P_1 = 5KN$
$A_L = \frac{\pi}{4}(50^2 - 22^2) = 1583.36\ mm^2$
$A_u = \frac{\pi}{4}(44^2 - 22^2) = 1140.398\ mm^2$

Case 1:

$P = 30KN$

$$\sigma_{L_1} = \frac{30 \times 10^3}{A_L} = \frac{30 \times 10^3}{1583.36} = 18.95\ N/mm^2$$

Case 2: Bolts tightened

On upper washer:

$P = 5KN$

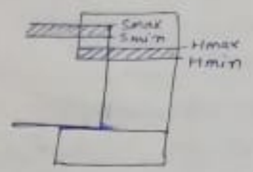
$$\sigma_u = \frac{5 \times 10^3}{A_u} = \frac{5 \times 10^3}{1140.398} = 4.38\ N/mm^2$$

On lower washer:

$P = (5+30) KN$
$= 35 KN$

$$\sigma_L = \frac{35 \times 10^3}{1583.36} = 22.1\ N/mm^2$$

2> Interferance.

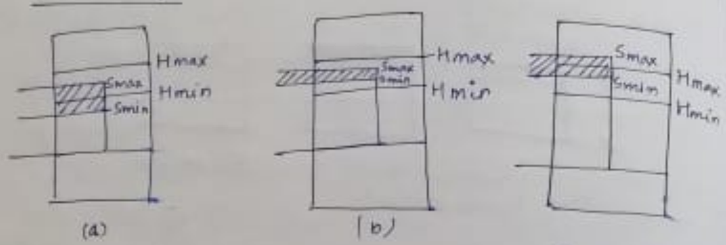


allowance → -ve

Hmin > Smax & Smin

In this case, no matter whatever may be the tollerance level of the shaft & the hole, there is always an overlapping of the mating parts is known as interferance / tight fit.

3> Transition fit:



* Hole Basis System: Hole fixed
* Shaft Basis System: Shaft fixed

In this case there will be a clearance b/n min. dimension of shaft & min. dim of the hole

- Upper deviation:

Difference of dim. b/n the max. possible size of component to the basic size of the component.

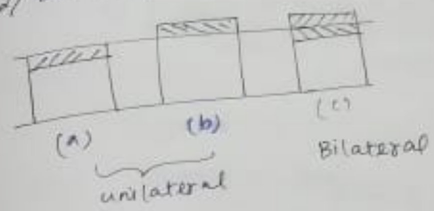
Similarly, difference b/n min. possible size of the component to the basic size is called lower deviation

- Tolerance:

Difference b/n max. dim. to the min. dim. i.e, difference b/n upper limit and lower limit.

Types of tolerance:

1> Unilateral
2> Bilateral



Problems:

1> The recommended class of fit for a hydrodynamic bearing is 40H6/e7. Determine the sizes and tolerances of hole and shaft and mention the type of fit.

40 → Basic size
H → Hole
e → Shaft

H6: 40.016 → Hole max dia
(8) column 40.000 → Hole min dia

$+16 \times 10^{-3}$

tolerance of hole = 0.016

e7:
(8) column 30-50

39.95 mm → Shaft max dia
39.925 mm → Shaft min dia

tolerance of shaft = 0.025

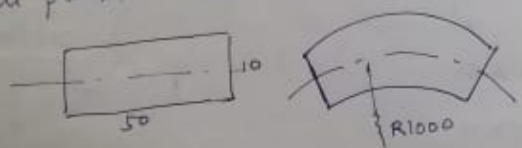
+ve fit.
clearance fit

8> A coil chain of a train is required to carry a max load of 50 KN. Find the diameter of the link as shown in fig if permissible tensile stress in the link material is not to exceed 75 MPa.
Find dia of link.

$\sigma = \frac{P}{A} \Rightarrow A = \frac{P}{\sigma} = \frac{50}{75}$

$\Rightarrow d^2 = \sqrt{\frac{50 \times 10^3}{75 \times \frac{\pi}{4}}} = 29.13$ mm

8) A steel plate of section 50 X 10 mm is bent into an arc of 1000 mm radius. Determine the bending stress induced & the bending moment required to bend the plate. Assume E = ~~2.5 X~~ 2.1 X 10^5 MPa



Ans - $\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$

$M = \frac{E \times I}{R} = \frac{2.1 \times 10^5 \times \frac{50 \times 10^3}{12}}{1000}$

$= \cancel{887}\ 875000$ Nm

$\sigma_b = \frac{M}{Z} = \frac{875000}{\frac{50 \times 10^2}{6}} = 1050$ MPa

8> A hydraulic press exerts a total load of 3.5 MN. This load is carried by 2 steel rods supporting the head of the press. Then the safe stress is 85 MPa. E = 210 KN/mm^2. Determine the diameter of the rod, extension of each rod in length 2.5 m.

Ans - $\frac{P}{2} = \frac{3.5 \text{ MN}}{2} = 1.75$ MN

$\sigma = \frac{P}{A} \Rightarrow \sqrt{\frac{1.75}{85 \times \frac{\pi}{4}}} = d^2$

$\Rightarrow d = 0.1619$ m

E = 1.7

8> A shaft of 1 m length is transmitting a power of 100 KW at 200 rpm. Determine the diameter of the shaft. The angle of twist is not to exceed 0.5°. Take allowable stress limit for shaft is 60 MPa & also modulus of rigidity = 85 GPa

Ans - $\underbrace{\frac{T}{J} = \frac{\tau}{R}}_{\text{strength eqn}} = \frac{G\theta}{l}$ (rigidity eqn)

$\tau = \frac{T}{Z_P}$ → polar section modulus

N = 200 rpm

l = 1000 mm

$\theta = 0.5°$

$G = 85$ GPa

$Z_P = \frac{\pi d^3}{16}$

$P = \frac{2\pi N T}{60} \Rightarrow T = \frac{100 \times 60 \times 10^3}{2\pi \times 200}$

$= 4774.64$ Nm

$60 \times 10^6 = \frac{4774.64}{\frac{\pi}{16} \times d^3}$

$\Rightarrow d = \sqrt[3]{\frac{4774.64 \times 16}{\pi \times 60 \times 10^6}}$

$d = 0.02$ m

$R = \frac{60 \times 10^6 \times 1000}{85 \times 10^9 \times 0.5} = 1.4$

12-7-19

2) Recommended class of fit for a ~~a~~ hole and shaft is ~~50e~~ 50 H8/d8. Determine the sizes and tolerance of a hole and shaft and mention the type of fit

Ans: 50 → Basic size
H → hole
d → shaft

H8 → UD = 0.039
LD = 0.0

→ U.L = 50.039
L.L = 50   tolerance = 0.039

d8 → UD = -0.08
LD = -0.119

UL = 49.92
LL = 49.881

Tolerance = 0.039

Allowance = 50 − 49.92
= 0.08

+ve fit

3) 50 H8/j6

50 - Basic size
H → hole
j → shaft

H8 → UD = 0.039	j6 → UD = +0.011
LD = 0.0	LD = -0.005
UL = 50.039	UL = 50.011
LL = 50	LL = 49.995
Tolerance = 0.039	Tolerance = 0.016

Allowance = 50 − 50.011 = − 0.011
50 − 49.995 = + 0.005

∴ Hmin − Smax = −ve
Hmin − Smax = +ve

Transition fit

* Stresses in Machine Elements:

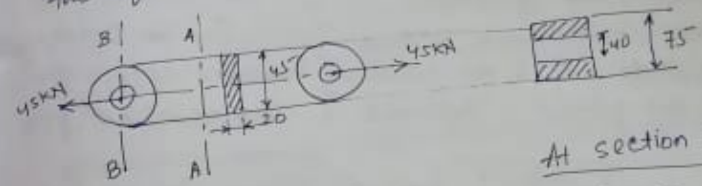
$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$\tau = \frac{T}{Z_P} \qquad Z_P = J/R \qquad \sigma_b = \frac{M}{Z}$$

$$Z = I/y$$

19th July '19

Q) A cast iron link as shown in figure, required to transmit a tensile load of 25 kN. Find the tensile stress induced in the link at the sections AA and BB. Also mention the safe working stress



At Section A-A

$P = 45 kN$

$$\sigma_A = \frac{P}{A} = \frac{45 \times 10^3}{45 \times 20} = 50 \text{ MPa}$$

At section B-B

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

$$= \frac{45 \times 10^3}{(75-40) \times 20}$$

$$= \frac{9}{7} \times 50 = 64.2 \text{ MPa}$$

Since the stress induced at section BB is maximum, implies that critical section is present at BB
∴ Safe working stress is 64.2 MPa.

★ Theories of Failure :

- Working stress : When designing a machine component it is desirable to keep the stress lower than the maximum or ultimate stress at which material fails. this stress is called working stress / design stress / safe stress / Allowable stress.

- Factor of safety : The ratio of maximum stress to the working stress i.e $\boxed{FOS = \frac{\text{max stress}}{\text{Working stress}}}$

In case of ductile materials,

$$\boxed{FOS = \frac{\text{yeild stress}}{\text{working stress}}}$$

For brittle materials,

$$\boxed{FOS = \frac{\text{ultimate stress}}{\text{working stress}}}$$

Selection of factor of safety :

Selection of proper FOS for designing any machine components depends on :

(1) Variations in material property.
(2) Type of loading and stress.
(3) Reliability of applied loads.
(4) Operating conditions
(5) Temperature effects.
(6) Extent of loss of property if failure occurs.
(7) Extent of loss of life.

- Failure criteria :

The point of failure is different for both ductile and brittle materials. For ductile materials, the point where the yeilding starts, is considered the point of failure & for brittle materials, it is the ultimate stress considered the point of failure.

While predicting the failure points, the uniaxial system are very easy to foredict but when biaxial & triaxial systems are considered, accurate predictions are difficult & hence some theories are used to predict the failure of components.

In machine design, the failure criteria may not be the mechanical fracture, but a part or component is said to have failed when it stops performing the function for which it was designed. A part may fail due to :

(1) Fracture
(2) Static / cyclic loads
(3) Excessive elastic deformation
(4) Yeilding
(5) Buckling

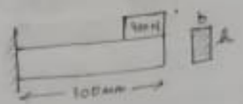
Mechanical failure may be due to :

(1) Yeilding - permanent deformation takes place.
eg: Ductile materials
(2) Fracture - Failure due to separation
eg: Brittle materials

In order to detect these failures in materials subjected to combined stresses, the following theories of failure have been formulated :

(1) Maximum normal stress theory or Rankine's Theory
(2) Maximum shear stress theory (or) Trepcar (or) Guests theory

Q) A beam of uniform rectangular cross-section is fixed at one end and carries an electric motor weighing 400N at a distance 300 mm from fixed end. Max bending stress in the beam is 40 MPa. Find the width and depth of the beam. Depth is twice that of width.



Ans - $W = 400N$

$\sigma_b = 40 MPa$

$\frac{M}{I} = \frac{\sigma}{y}$ $\qquad b = \frac{h}{2}$

$\Rightarrow \sigma_B = \frac{M}{Z}$

$Z = \frac{bh^2}{6} = \frac{\frac{h}{2} \times h^2}{6} = \frac{h^3}{12}$

$\Rightarrow 40 = \frac{400 \times 300 \times 12}{h^3}$

$\Rightarrow h = \sqrt[3]{36000}$

$= 33.02$ mm

$b = 16.5$ mm

Q) Piston rod of a steam engine is 50 mm in diameter and 600 mm long. The dia of piston is 400 mm and the max steam pressure is acting on piston is 0.9 N/mm². Find the compression of the piston rod, Young's modulus of piston rod is 210 KN/mm².

Ans - $\delta l = \frac{Pl}{AE} = \frac{0.9 \times 600 \times \frac{\pi}{4} \times 400^2}{\frac{\pi}{4} \times 50^2 \times 210 \times 10^3} = 1.3 \times 10^{-6}$ mm

0.16 mm

22nd July '19

Q) A 2-D ~~state~~ shear stress at a point is given by $\sigma_x = 60 MPa$, $\sigma_y = 20 MPa$.

(i) what is the permissible shear stress if max. principal stress is not exceed $\sigma_1 = 75 MPa$.

(ii) what is the magnitude of the other principal stress and maximum shear stress.

Ans - $\sigma_x = 60 MPa$

$\sigma_y = 20 MPa$

$e_{xy} = ?$

$\sigma_1 = 75 MPa$

$\sigma_2 = ?$

$e_{max} = ?$

$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + e_{xy}^2}$, $e_{xy} = 28.722$

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

$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$

(3) Maximum strain theory or Saint Venants theory
(4) maximum strain energy theory or Haigh's theory.
(5) Maximum distortion energy theory or Von-mixes or Henky's theory.

24th July'19

(1) Maximum Normal Stress theory (or) Rankine's Theory

This theory states that the failure of a member takes place when the max principal stress reaches it yeild or ultimate value.

If σ_1, σ_2 and σ_3 are principal stress in 3 mutually ⊥ dir

If $\sigma_1 > \sigma_2 > \sigma_3$

$\sigma_1 = \frac{\sigma_y}{FOS}$, $\sigma_1 = \frac{\sigma_u}{FOS}$

This theory does not take into the consideration of shear stress which acts whenever the normal stress acts on a member. This theory is based on the tension or compression and it ignores the failure due to shear stress.

Therefore, this theory is used for brittle material & not suitable for ductile material.

(2) Maximum Shear Stress Theory
(or)
Trescar's Theory

This theory states that, failure of a member takes place when the maximum shear stress reaches the yeild shear stress for a uniaxial load.

$\tau_{max} = \frac{\tau_y}{n}$

critically resolved shear stress $\tau_y = \frac{\sigma_y}{2}$

$\boxed{\tau_{max} = \frac{\sigma_y}{2n}} \Rightarrow \boxed{\tau_{max} = \frac{\sigma_1}{2}}$ → for uniaxial system where σ_1 is max

$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$ → for biaxial system

Similarly if σ_1, σ_2 & σ_3 are the principal stress,
if $\sigma_1 > \sigma_2 > \sigma_3$,

$$\boxed{\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}, \frac{\sigma_2 - \sigma_3}{2}, \frac{\sigma_3 - \sigma_1}{2}}$$

triaxial system

This theory is used for designing ductile materials such as Al, steel, Cu, Brass etc.

Since, both shear stress and normal stresses are considered. In triaxial system, all the three stresses are not considered in one equation, any one equation contains 2 of the 3 stresses, the effect of the 3rd stress is neglected & hence this theory is not suitable for tri-axial system.

(3) Maximum distortion Energy Theory or Von-mixex theory

This theory states that, the failure occurs when the distortion, strain energy (shear strain energy per unit volume) reaches the limiting distortion energy per unit volume as determined by a simple tensile stress.

The biaxial stress

$$\boxed{\frac{\sigma_y}{n} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}}$$

for triaxial system

$$\boxed{\frac{\sigma_y}{n} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1}}$$

where σ_1, σ_2 & σ_3 are mutually ⊥ to each other. All the ~~are~~ principal stresses are taken for account while determining the failure & it gives accurate values to the actual stress. This theory is called ductile material.

Q) The yield strength of a material, $\sigma_y = 150$ MPa. When the principal stress are diff for different from actual cases:

Case 1: $\sigma_1 = 100$ MPa, $\sigma_2 = 50$ MPa, $\sigma_3 = 0$

Case 2: ~~90~~ 0 MPa, $\sigma_2 = -50$ MPa, $\sigma_3 = -80$ MPa

~~Case 3: 20 MPa~~

determine the FOS for following theories of failure.

1) Rankine's theory
2) Tresca's Theory
3) Von-mises theory

Ans - case 1: $\sigma_1 = 100$ MPa
$\sigma_2 = 50$ MPa
$\sigma_3 = 0$ MPa

$$n = \frac{\sigma_y}{\sigma_1} = \frac{150}{100} = 1.5$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = 25 \text{ MPa}$$

$$\frac{\sigma_2 - \sigma_3}{2} = 25 \text{ MPa}$$

$$\frac{\sigma_3 - \sigma_1}{2} = -50 \text{ MPa}$$

$\tau_{max} = 50$ MPa

$$2n = \frac{\tau_y}{\tau_{max}} = 3$$

$n = 1.5$

$$\frac{\sigma_y}{n} = \sqrt{100^2 + 50^2 + 0 - 100\times 50 - 0 - 0}$$

$= 86.6$

$$\Rightarrow n = \frac{150}{86.6} = \boxed{1.732}$$

Case - II

$\sigma_1 = 0$
$\sigma_2 = -50$ MPa
$\sigma_3 = -80$ MPa

3) $$\frac{\sigma_y}{n} = \sqrt{0 + 50^2 + 80^2 - 80\times 50}$$

$= 70$

$$\Rightarrow \boxed{n = 2.1428}$$

1) $$n = \frac{\sigma_y}{\sigma_3} = \frac{150}{80} = 1.875,$$

σ_{max}: $\frac{\sigma_1 - \sigma_2}{2} = 25$
$\frac{\sigma_2 - \sigma_3}{2} = 15$
$\frac{\sigma_3 - \sigma_1}{2} = 40$

2) $\tau_{max} = 40$ MPa

$$2n = \frac{\tau_y}{\tau_{max}} = \frac{150}{40}$$

$$\Rightarrow n = \frac{150}{80} = 1.875$$

~~2~~.7.19

Q) A rod of ~~...~~, C45 steel

~~...~~ $T = 20$~~0~~$kN\,m$

$B = 150 kN\cdot m$

$n = 2$

$\phi = ?$

$\sigma_Y = 353$ MPa

(Table 1.8 pg 464)

I) Rankine theory

$$\sigma_1 = \frac{\sigma_y}{n}$$

$$\sigma_1 = \frac{353}{2}$$

$$= 176.5$$

(1-D)

$$\sigma_1 = \frac{\sigma_x + \cancel{\sigma_y}^{\,0}}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_b = \frac{M}{Z} = \frac{150\times10^6\times32}{\pi d^3}, \quad \tau = \frac{T}{Z_p} = \frac{200\times10^6\times16}{\pi d^3}$$

$$\sigma_x = \sigma_b$$

$$176.5 = \frac{150\times10^6\times32}{\pi\times d^3\times2} + \sqrt{\left(\frac{150\times10^6\times32}{\pi d^3\times2}\right)^2 + \left(\frac{200\times10^6\times16}{\pi d^3}\right)^2}$$

$$\frac{1}{\pi d^3}\left(\frac{150\times10^6\times32}{2} + \sqrt{\left(\frac{150\times10^6\times32}{\cancel{\pi d^3}\,2}\right)^2 + \left(200e6\times16\right)^2}\right.$$

$$\Rightarrow \pi d^3 = 36260623.23$$

$$d^3 = 11542114.85$$

$$d = 226 \text{ mm}$$

II) Trexcar

$\tau_{max} = \frac{\sigma_y}{2n}$

$= \frac{353}{2\times2} = 88.25\ MPa$

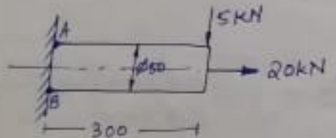
$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \cancel{\sigma_y}^{0}}{2}\right)^2 + \tau_{xy}^2}$

$88.25 = \sqrt{\left(\frac{200\times10^6\times16}{\pi d^3}\right)^2 + \left(\frac{50\times10^6\times32}{\pi d^3\times2}\right)^2}$

$d = 243.44\ mm$

Safe dia = 243.44

Q) A circular dia of 50 mm is subjected to loads as shown. Find nature & magnitude of stress at the critical points A and B.



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

$\sigma_b = \frac{M}{Z} = \frac{5\times10^3\times300\times32}{\pi d^3} = 122.2\ N/mm^2$

$\tau_{xy} = \frac{T}{Z_p} = 0$

Considering 'A'

$\sigma_1 = \frac{\sigma_x + \cancel{\sigma_y}^{0}}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$\sigma_x = \sigma_d + \sigma_b = 10.18 + 122.2 = 132.4\ MPa$

$\sigma_y = 0$, $\tau_{xy} = 0$

$\boxed{\sigma_1 = 132.4\ MPa}$

$\sigma_2 = 0$

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

$= 66.2$

Considering 'B'

$\sigma_x = \sigma_d - \sigma_b = 10.18 - 122.2 = -112.05\ MPa$

$\sigma_y = 0$

$\tau_{xy} = 0$

$\sigma_1 = ?$

$\sigma_2 = ?$

$\tau_{max} = ?$

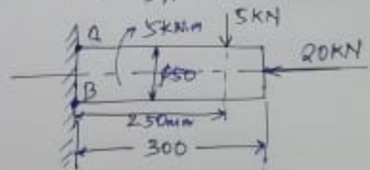
$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$= 0 - 224.1\ MPa$

$\sigma_2 = 0$

$\tau_{max} =$

Q) For the given cantilever beam, find the max. & min. shear & ~~bending~~ Normal stresses at critical pts.



$\sigma_d = \frac{P}{A} = \frac{20}{\frac{\pi}{4}(50)^2} = -10.18\ MPa$

$\sigma_b = \frac{M}{Z} = \frac{5\times10^3\times250\times32}{\pi\times50^3} = 101.86\ MPa$

$\tau_{xy} = \frac{T}{Z_p} = \frac{5\ \cancel{kNm}\times10^3\times16}{\pi d^3}$

$= 203.72\ MPa$

$\sigma_x = \sigma_d - \sigma_b$

$= -10.18 - 101.86$

$= -112.14\ MPa$

$\sigma_y = 0$

$\tau_{xy} = 203.72\ MPa$

$\sigma_1 =$