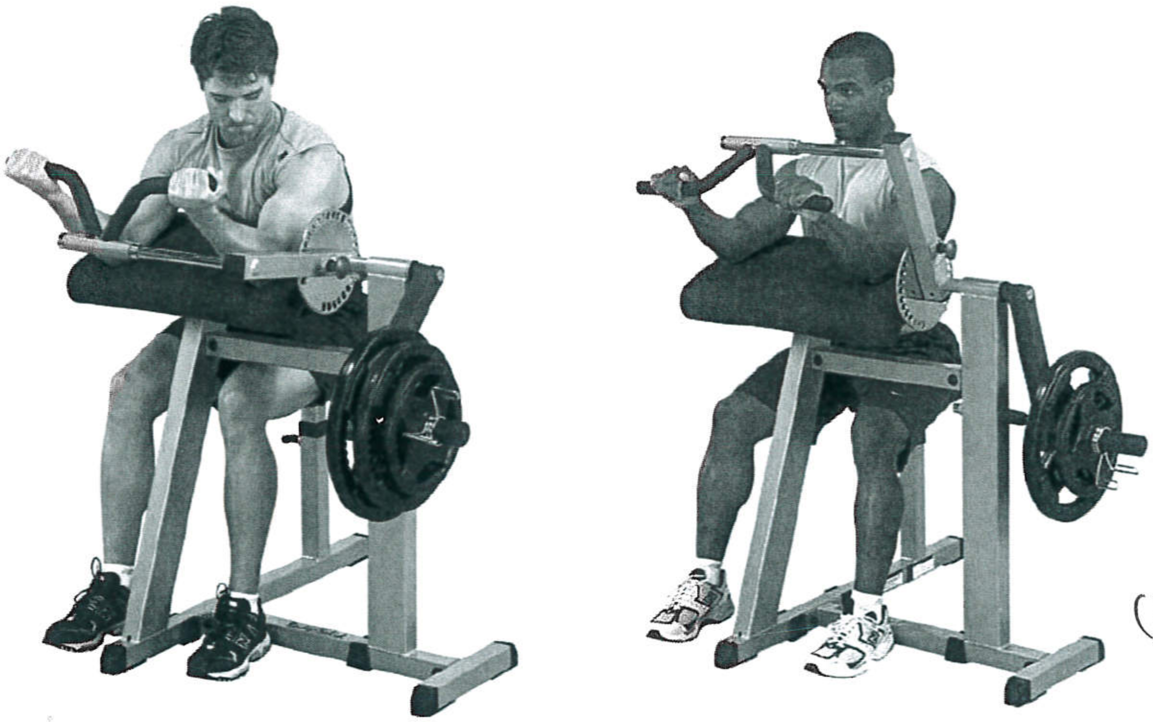
Deliverable (2)

Describe problem

· The body building equipment shown in (Figure 1) (body- Solid bricep/tricep).



(Figure 1)

The weight lifted by machine is equal to 100kg. The main metallic arm ABCDEF as shown in Figure (2) is made From (ASTM-A36) steel has different sections with Following data:

Section AB: Length = 500mm and circular hollow section having outer diameter = 50mm and wall thickness = 5mm

Sections BC & DE Length 500mm and rectangular hollow sections as 60X40X2.9mm.

A 12 mm diameter Pin is used at Point P.

Pin CD has outer diameter d = 50mm and inner diameter = 40mm.

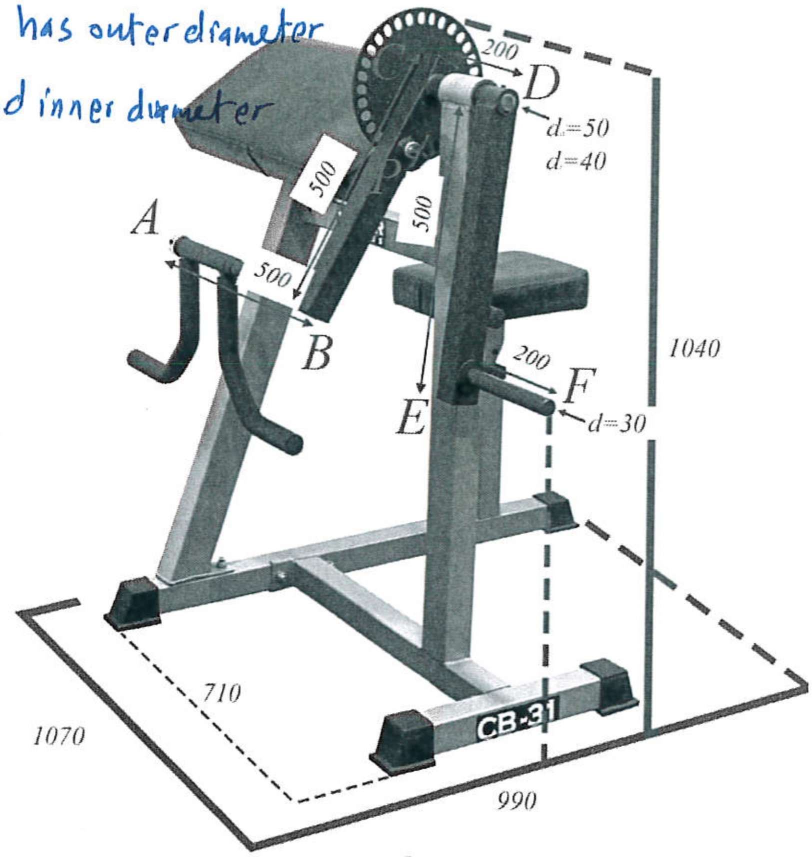
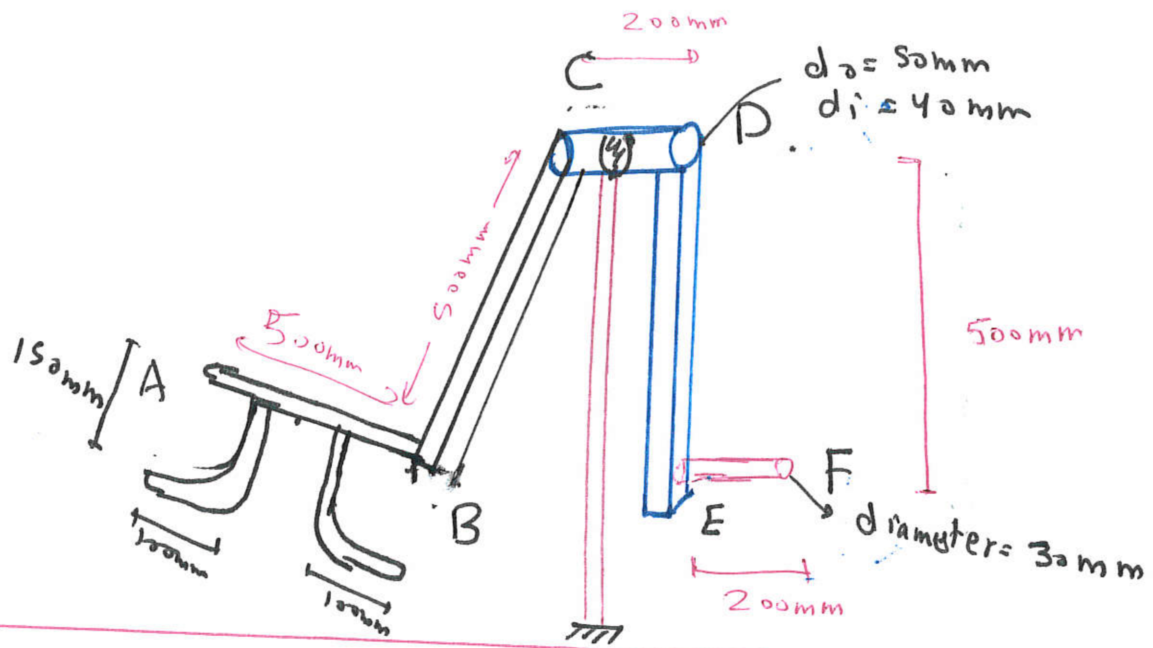


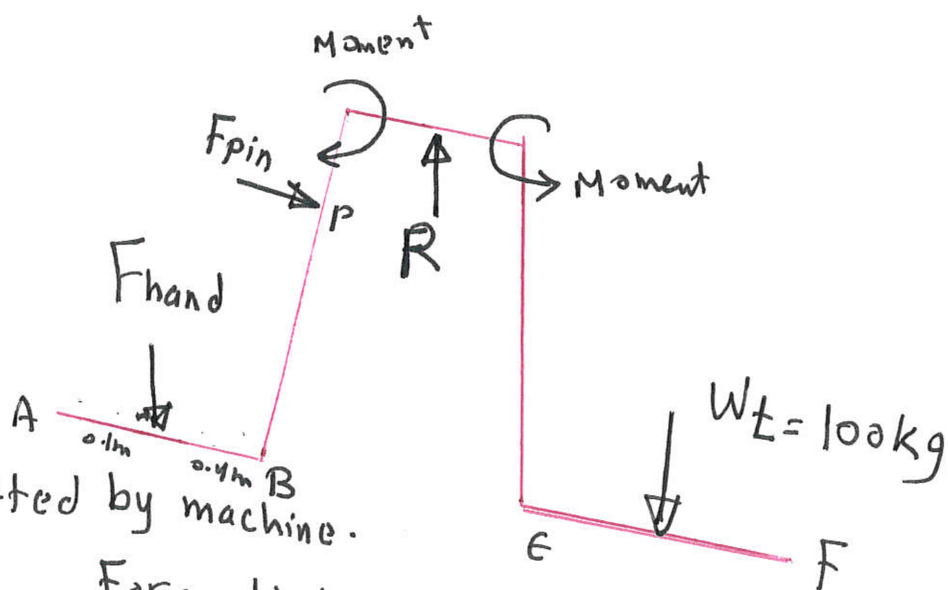
Figure 2: Machine Dimensions (All dimension are given in mm).

We Calculate maximum stresses (normal and shear stress) in metallic arm and Calculate Factor of safety according to selected material to insure that it is within the permissible range.

② Sketch arm ABCDEF



③ Create simplified line diagram of the arm indicating different Forces and moment:



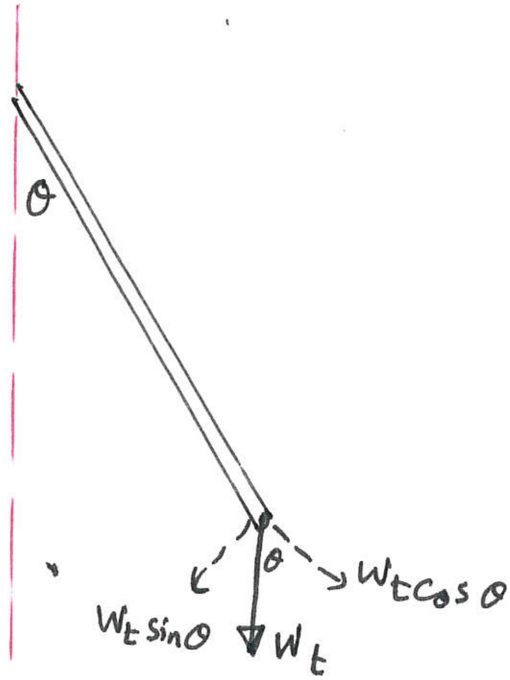
W_t → Weight Lifted by machine.

Fhand → Force that Can be applied at both handles.

R → Reaction of Vertical Rod.

4 Maximum Force Can apply at both handles:-

$W = 100 \times 9.81 = 981 \ N$



Maximum effort require is when $\theta = 90°$

$\theta = 90° \longrightarrow$ For maximum Load.

$$(F_{hand})_{max} = W_t \sin\theta = 981 \sin 90$$

$$(F_{hand})_{maximum} = 981 \ N$$

$$\frac{981}{2} = 490.5 \ N \text{ in each hand}$$

5 Determine material Used in the arm:

Selected material For arm is (ASTM A-36) steel. It is excellent welding properities and is suitable for Punching drilling and machining process.

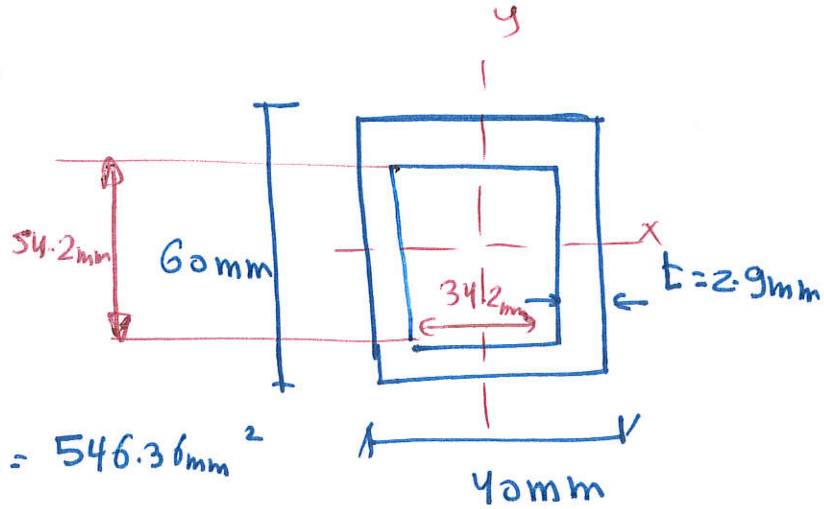
Properities of material

density	7860 kg/m^3
ultimate strength in tension	400 MPa
yield strength in tension	250 MPa
ultimate strength in compression	400 MPa
yield Shear stress	145 MPa
Modulus of elasticity	200 GPa
Modulus of rigidity	77.2 GPa
Coefficient of thermal expansion	11.7×10^{-6} °/C
Ductility Percentage elongation in 50mm	21%
Bulk Modulus	140 GPa
Poisson ratio	0.26
ultimate shear stress	150 MPa

stresses

Properities of Area

member BC, ED



Area

$$A = 40 \times 60 - 34.2 \times 54.2 = 546.36\,mm^2$$

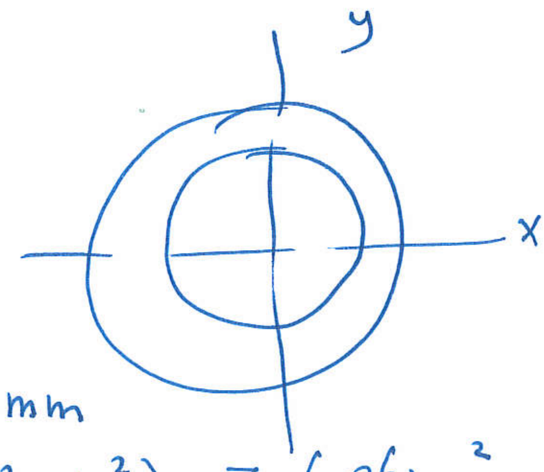
moment of inertia about x axis

$$I_x = \frac{40 \times 60^3}{12} - \frac{34.2 \times 54.2^3}{12} = 266.22 \times 10^3\ mm^4$$

moment of inertia about y

$$I_y = \frac{40^3 \times 60}{12} - \frac{34.2^3 \times 54.2}{12} = 139.33 \times 10^3\ mm^4$$

Member AB



$d_{outer} = 50mm$

$t = 5mm$

$d_i = d_o - 2t = 50 - 2 \times 5 = 40mm$

Area:

$$A = \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(50^2 - 40^2) = 706.86\,mm^2$$

moment of inertia $_{x,y}$

$$I_x = I_y = \frac{\pi}{4}(r_o^4 - r_i^4) = \frac{\pi}{4}(25^4 - 20^4) = 181.13 \times 10^3\ mm^4$$

Polar moment of inertia

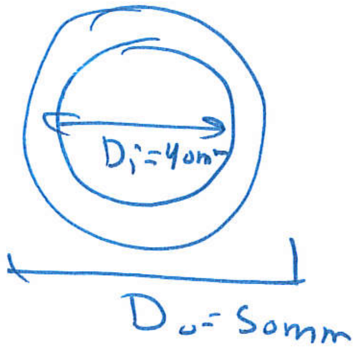
$$J = \frac{\pi}{2}(r_o^4 - r_i^4) = \frac{\pi}{2}(25^4 - 20^4) = 362.26 \times 10^3\ mm^4$$

Pin CD

$d_{outer} = 50mm \quad d_{inner} = 40mm$

Area

$$A = \frac{\pi}{4}\left(50^2 - 40^2\right) = 706.86 mm^2$$

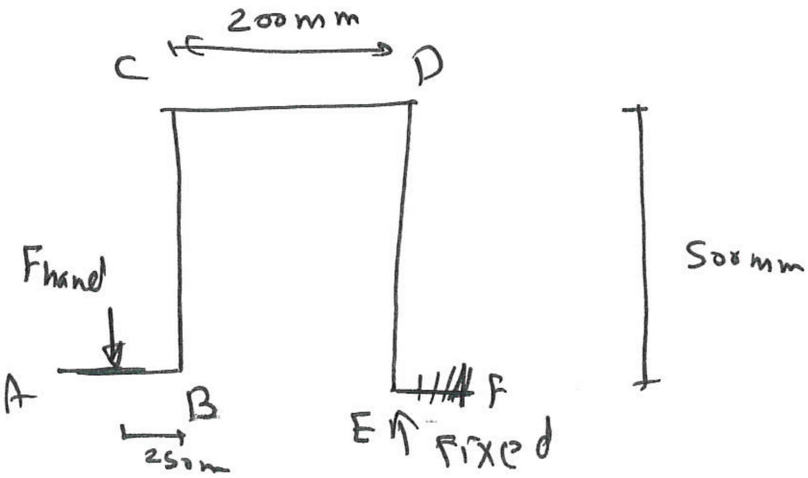


Moment of inertia about x & y axis

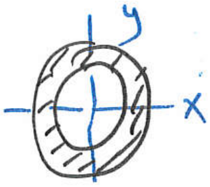
$$I_x = I_y = \frac{\pi}{4}\left(25^4 - 20^4\right) = 181.13 \times 10^3 mm^4$$

Polar moment of inertia

$$J = \frac{\pi}{2}\left(r_o^4 - r_i^4\right) = \frac{\pi}{2}\left(25^4 - 20^4\right) = 362.26 \times 10^3 mm^4$$

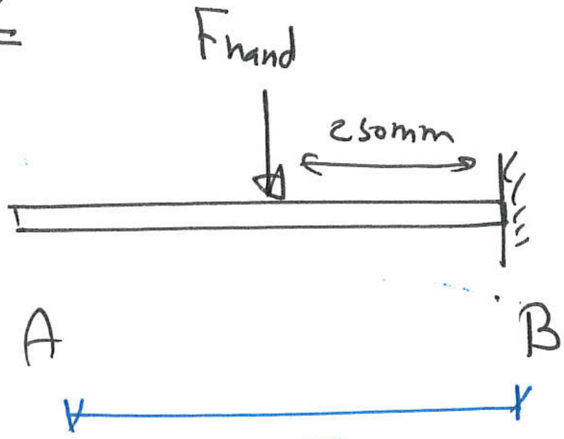


Member AB



$d_o = 50mm$

$t = 5mm$



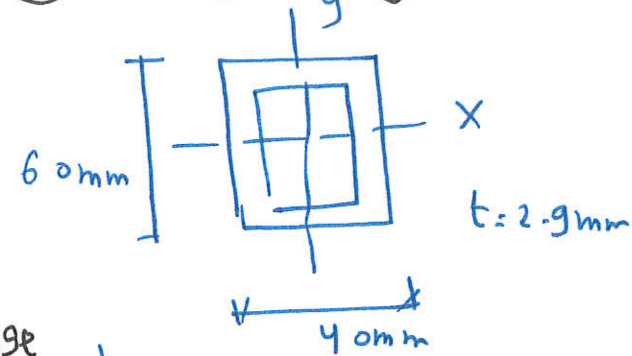
average shear stress due to transverse shear

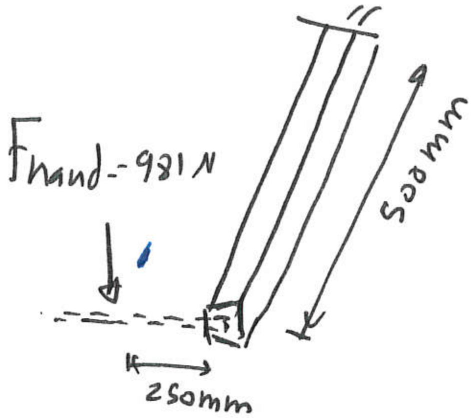
$$\tau = \frac{P}{A} = \frac{981}{706.86} = 1.388 \text{ MPa}$$

Max normal stress due to bending

$$\sigma = \frac{M}{I} c = \frac{(981 \times 250)}{181.13 \times 10^3} * 25 = 33.85 \text{ MPa}$$

Member BC





average Shear stress due transverse loading

$$\tau = \frac{P}{A} = \frac{981}{546.36} = 1.8\ MPa$$

average Shear stress due to torsion

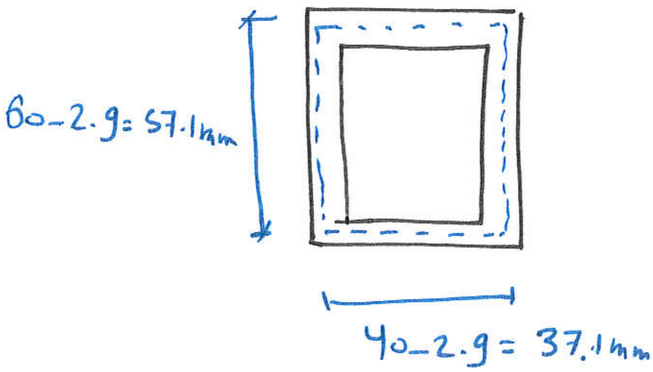
$$T = F_{hand} \times 250 = 981 \times 250 = 245.25 \times 10^3\ N.mm$$

$$\tau = \frac{T}{2tA_m}$$

Torsion shear stress due to hollow Rectangular shaft.

where A_m: Area of centerline shaft.

$t \rightarrow$ thickness shaft



$$A_m = 37.1 \times 57.1 = 2.118 \times 10^3\ mm^2$$

$$\tau = \frac{245.25 \times 10^3}{2 \times 2.9 \times 2.118 \times 10^3} = 19.96 \text{ MPa}$$

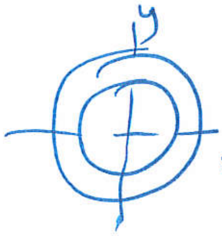
Maximum normal stress due to bending

$$M_x = 981 * 500 = 490500 \text{ N.mm}$$

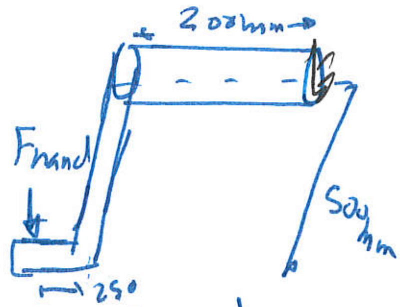
$$\sigma = \frac{M_x}{I_x} C = \frac{490500}{266.22 \times 10^3} * 30$$

$$= 55.3 \text{ MPa}$$

Pin CD



$d_o = 50mm$
$d_i = 40mm$



Shear stress due to transverse load

$$\tau = \frac{Force}{A} = \frac{981}{706.86} = 1.38 MPa$$

Shear stress due torsion load

$$T = 981 * 500 = 490500 \; N \cdot mm$$

$$\tau = \frac{T \cdot c}{J}$$

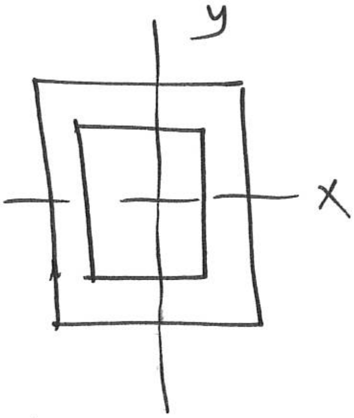
$$\tau = \frac{490500 * 25}{362.26 \times 10^3} = 33.85 MPa$$

maximum normal stress due to bending

$$M = 981(250 + 200) = 441450 \; N \cdot mm$$

$$\sigma = \frac{M \; c}{I} = \frac{441450 * 25}{181.13 \times 10^3} = 60.93 MPa$$

Member DE



average shear stress due to transverse load

$$\tau = \frac{P}{A} = \frac{981}{546.36} = 1.8 \text{ MPa}$$

average shear stress due to torsion load

$$T = 981 \times (200+250) = 441450 \text{ N·mm}$$

$$\tau = \frac{T}{2tA_m} = \frac{441450}{2 \times 2.9 \times 2.118 \times 10^3} = 35.94 \text{ MPa}$$

maximum normal stress due to bending

$$M = 981 \times 500 = 490500 \text{ N·mm}$$

$$\sigma = \frac{M}{I} c = \frac{490500 \times 30}{266.22 \times 10^3} = 55.3 \text{ MPa}$$

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Maximum normal stress

$\sigma_{max} = 60.93 \text{ MPa}$ at member CD, DE

Maximum shear stress

$\tau_{max} = 33.85 \text{ MPa}$ at pin CD

Factor of safety due to maximum normal stress

$$F.S = \frac{\sigma_{ult}}{\sigma_{all}} = \frac{400}{60.93} = 6.56$$

Factor of safety due to shear stress

$$F.S = \frac{\tau_{ult}}{\tau_{all}} = \frac{150}{33.85} = 4.43$$

Take smallest value of F.S **F.S = 4.43**

for overall factor of safety.