

## Principal Stress and Strain:-

### Tension:-

#### ① Zero rank tension:-

It can be defined by its magnitude.  
Ex:- mass.

#### ② 1st rank tension:-

It is one which can be defined by its magnitude and direction.

Ex:- Force

#### ③ 2nd rank tension:-

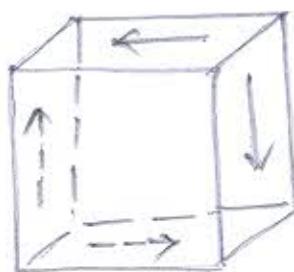
It is one which can be defined by its magnitude, dir<sup>n</sup> and plane of application.

Ex:- Stress, strain etc.

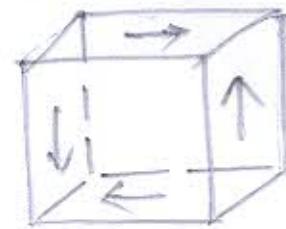
### Principal Stress:-

It is the maximum or minimum normal stress acting on any plane. There may be three principal planes in three dimensional stress system on mutually perpendicular direction which always carry zero shear stress.

Sign convention of shear stress :-



[-ve shear stress]



[+ve shear stress]

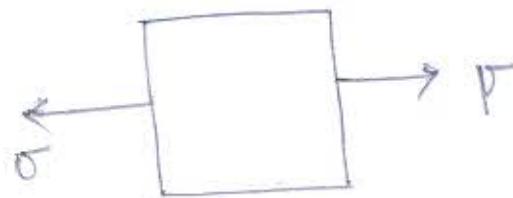
Analytical method :-

① Member subjected to axial load :-

$$P_n = \sigma \cos^2 \theta$$

$$P_t = \frac{\sigma}{2} \sin 2\theta$$

$$P_R = \sqrt{P_n^2 + P_t^2}$$



② Member subjected to three principal stresses :-

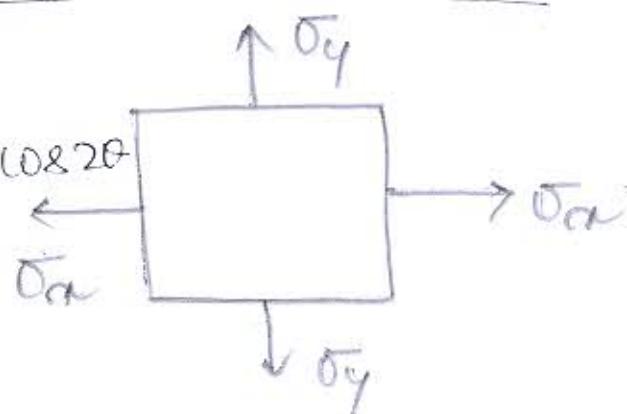
$$P_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$$

$$P_t = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$$

$$\tau_{max} = \frac{\sigma_x - \sigma_y}{2}$$

$$P_R = \sqrt{P_n^2 + P_t^2}$$

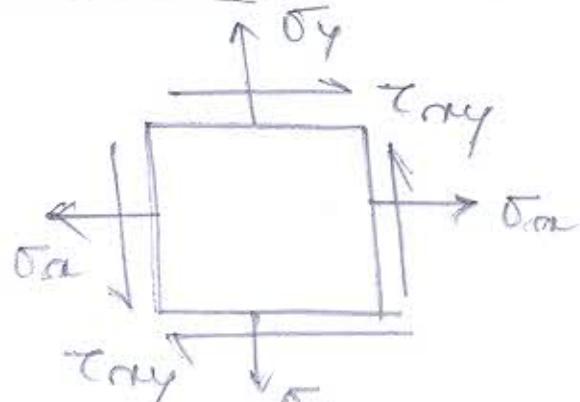
$$\tan \phi = \frac{P_t}{P_n} \rightarrow \text{Plane of obliquity.}$$



(45)

③ For biaxial Stress with shear:-

$$\sigma_1, \sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm$$



$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

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

$$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

$\theta_p = \theta_{p1}$  = major principal Plane

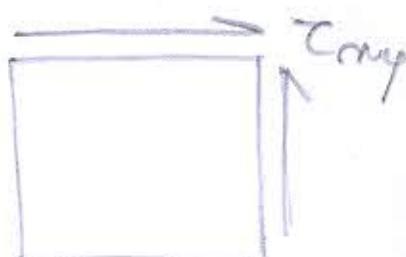
$\theta_{p2} = 90^\circ \pm \theta_p$  - minor principal Plane

④ Pure Shear:-

$$\sigma_x = \tau_{xy} \sin 2\theta$$

$$\sigma_y = -\tau_{xy} \sin 2\theta$$

$$\tau'_{xy} = \tau_{xy} \cos 2\theta$$



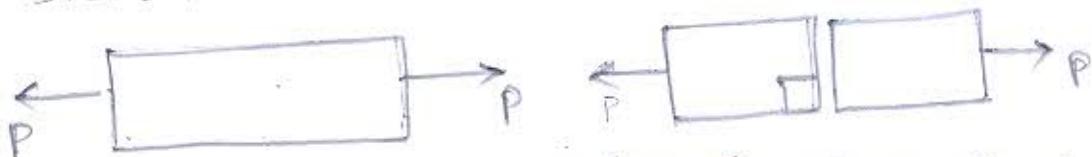
Note :-

- (i) Generally brittle materials are strong in compression but weak in tension, whereas its shear strength is in between its comp. strength and its tensile strength.
- (ii) Generally ductile materials are equally strong in compression and tension, but weak in shear.

Failure in material :-

Case-1 :-

Brittle material under tension



Since brittle material is weak in tension therefore failure will be in principal tension and failure plane is at  $90^\circ$  from longitudinal axis.

Case-2 :-

Brittle material under compression



Since the brittle material is strong in compression therefore it will fail in shear. The angle of failure plane is at  $45^\circ$  from longitudinal axis.

Case-3:-

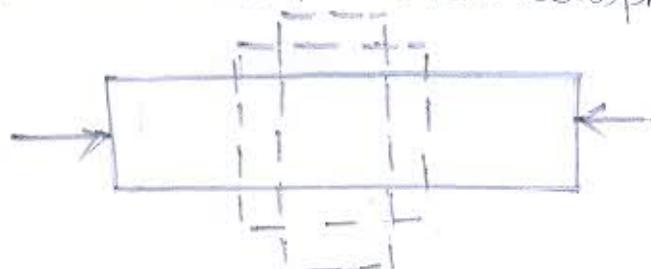
Ductile material under tension



Since ductile material weak in shear, therefore failure is due to shear. Failure plane is at  $45^\circ$  from longitudinal axis. Such type of failure is known as shear-cone failure.

Case-4:-

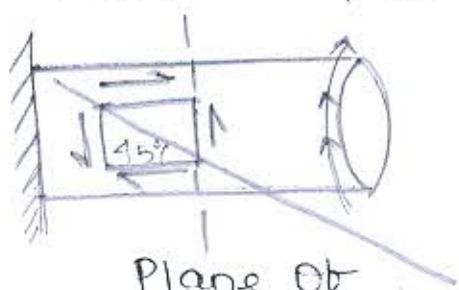
Ductile material under compression.



The failure of ductile material is compression failure and also known as compression yielding (crushing).

Case-5:-

Failure in pure shear:-



Plane of ductile failure

Plane of brittle  
failure  
(Helical failure).

Problems :-

Q:- The principal tensile stresses at a point across two perpendicular planes are  $80 \text{ N/mm}^2$  and  $40 \text{ N/mm}^2$ . Find the normal and tangential stresses and resultant stress and its obliquity on a plane at  $20^\circ$  with major principal plane. Find also the intensity of stress which acting alone can produce the same maximum strain. Take Poisson's ratio =  $\frac{1}{4}$ .

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Given data:-

$$\sigma_x = 80 \text{ N/mm}^2$$

$$\sigma_y = 40 \text{ N/mm}^2$$

$$\theta = 20^\circ$$

$$\mu = \frac{1}{4}$$

$$P_r = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$$

$$= \frac{80+40}{2} + \frac{80-40}{2} \cos 40^\circ$$

$$= 60 + 20 \cos 40^\circ$$

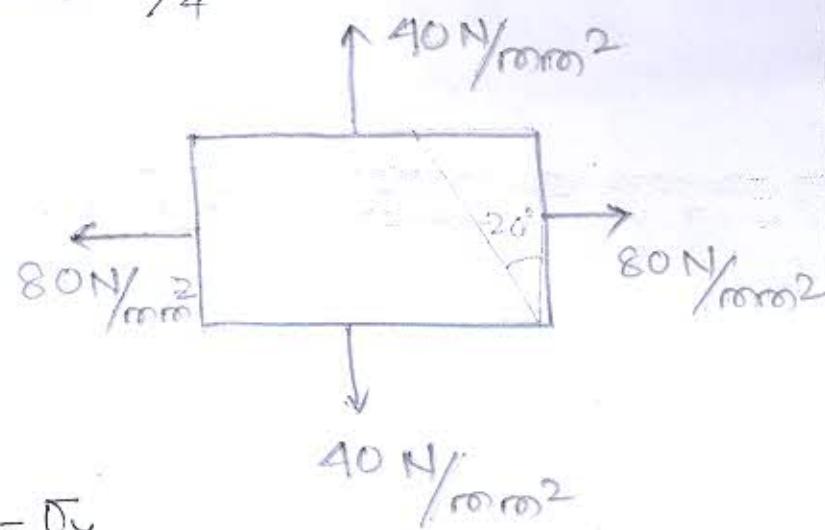
$$= 75.32 \text{ N/mm}^2 \text{ (Tensile).}$$

$$P_t = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$$

$$= \frac{80-40}{2} \sin 40^\circ$$

$$= 20 \sin 40^\circ$$

$$= 12.86 \text{ N/mm}^2$$



$$\begin{aligned}\text{Resultant Stress} &= \sqrt{P_n^2 + P_t^2} \\ &= \sqrt{75.32^2 + 12.86^2} \\ &= 76.41 \text{ N/mm}^2\end{aligned}$$

$$\begin{aligned}\text{Obliquity } \phi &= \tan^{-1} \frac{P_t}{P_n} \\ &= \tan^{-1} \frac{12.86}{75.32} \\ &= 9^\circ 41'\end{aligned}$$

$$\begin{aligned}\text{Maximum strain } \epsilon_{\alpha} &= \frac{\sigma_{\alpha}}{E} - \frac{\nu}{E} \sigma_y \\ &= \frac{1}{E} (80 - \frac{1}{4} \times 40) \\ &= \frac{30}{E}\end{aligned}$$

Q:- The principal stresses at a point in a bar are  $200 \text{ N/mm}^2$  (tensile) and  $100 \text{ N/mm}^2$  (comp). Determine the resultant stress in magnitude and direction on a plane inclined at  $60^\circ$  to the axis of the major principal stress. Also determine the maximum intensity of shear stress in the material at the point.

Soln:-  $\sigma_{\alpha} = 200 \text{ N/mm}^2$  (tensile)

$\sigma_y = 100 \text{ N/mm}^2$  (comp)

$$\theta = 90^\circ - 60^\circ = 30^\circ$$

$$\begin{aligned}
 P_o &= \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 20^\circ \\
 &= \frac{2\omega + (-1\omega)}{2} + \frac{2\omega - (-1\omega)}{2} \cos 60^\circ \\
 &= 50 + 150 \times \frac{1}{2} \\
 &= 125 \text{ N/mm}^2
 \end{aligned}$$

$$\begin{aligned}
 P_t &= \frac{\sigma_x - \sigma_y}{2} \sin 20^\circ \\
 &= \frac{2\omega - (-1\omega)}{2} \sin 60^\circ \\
 &= 129.9 \text{ N/mm}^2
 \end{aligned}$$

$$\begin{aligned}
 P_R &= \sqrt{P_o^2 + P_t^2} = \sqrt{125^2 + 129.9^2} \\
 &= 180.27 \text{ N/mm}^2
 \end{aligned}$$

$$\tan \phi = \frac{P_t}{P_o} = \frac{129.9}{125}$$

$$\phi = 46^\circ$$

$$\begin{aligned}
 \text{maximum shear stress} &= \frac{\sigma_x - \sigma_y}{2} \\
 &= \frac{2\omega - (-1\omega)}{2} \\
 &= \frac{3\omega}{2} \\
 &= 150 \text{ N/mm}^2
 \end{aligned}$$

Note:—

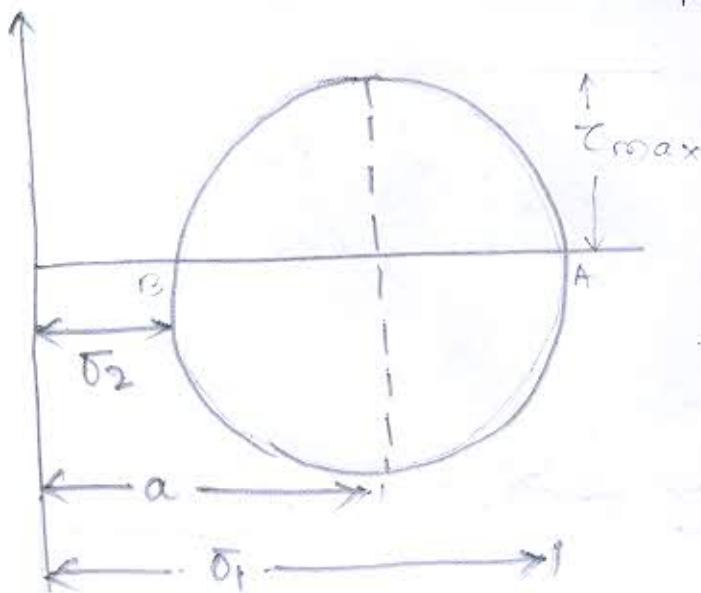
- (i) When two principal stresses are equal and like, the resultant stress on any plane is normal to the plane and equal in magnitude to either of the principal stresses.
- (ii) When the two principal stresses are equal and unlike, the resultant stress on any plane equals in magnitude of either of the principal stresses, but at an obliquity of  $2\theta$  where  $\theta$  is the angle between the plane and major principal plane.

Note:—

- (i) The two principal planes are normal to each other.
- (ii) The planes carrying the maximum shear stress are normal to each other.
- (iii) The planes carrying the maximum shear stress are at  $45^\circ$  with the principal planes.

## Mohr's circle:-

Mohr's circle is the locus of position of normal and shear stress magnitude acting on an element at various planes.



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

$$a = \frac{\sigma_1 + \sigma_2}{2} = \frac{\sigma_x + \sigma_y}{2}$$

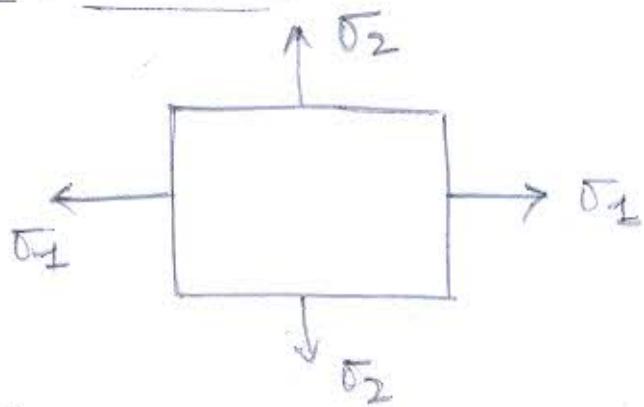
$$\text{Centre} = a, 0$$

## Properties of Mohr's circle:-

- (i) Mohr's circle is always symmetrical about normal stress axis and its centre lie on σ-axis.
- (ii) Mohr's circle cuts σ-axis at two points. The co-ordinate of which represents max<sup>th</sup> and min<sup>th</sup> principal stress.

- (iii) for the case of pure shear Mohr circle will be symmetrical about both the axis and its centre will coincide with the origin.
- (iv) If principal stress on two mutually perpendicular planes are equal in magnitude and of same sign either +ve or -ve, then mohr circle will become a point which will lie on σ-axis.
- ~~⇒ For a given mohr circle~~

Principal strain: —



$$\epsilon_1 = \frac{\sigma_1}{E} - \frac{\nu}{E} \sigma_2$$

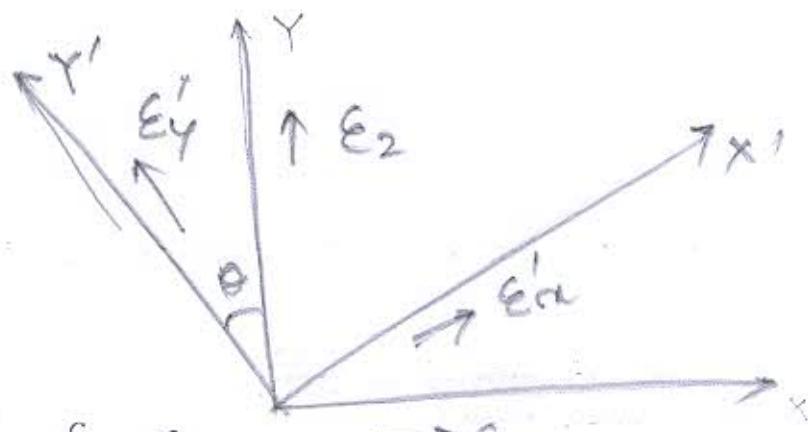
$$\epsilon_2 = \frac{\sigma_2}{E} - \frac{\nu}{E} \sigma_1$$

$$\sigma_1 = \frac{E}{1-\nu^2} [\epsilon_1 + \nu \epsilon_2]$$

$$\sigma_2 = \frac{E}{1-\nu^2} [\epsilon_2 + \nu \epsilon_1]$$

Case-1:-

Principal strain  $\epsilon_1$  and  $\epsilon_2$  are given on two mutually perpendicular plane and it is required to find normal strain and shear strain on any plane which is at an angle ' $\theta$ ' from vertical.



$$\epsilon'_n = \frac{\epsilon_1 + \epsilon_2}{2} + \frac{\epsilon_1 - \epsilon_2}{2} \cos 2\theta$$

$$\epsilon'_s = \frac{\epsilon_1 + \epsilon_2}{2} + \frac{\epsilon_1 - \epsilon_2}{2} \sin 2\theta$$

$$\frac{\Phi_{ray}}{2} = - \left( \frac{\epsilon_1 + \epsilon_2}{2} \right) \sin 2\theta$$

$$\frac{\Phi_{max}}{2} = \left| \frac{\epsilon_1 - \epsilon_2}{2} \right| \quad \theta = 45^\circ, 135^\circ$$

Case-2:-

Normal strain  $\epsilon_n$ ,  $\epsilon_s$  and shear strain  $\Phi_{ray}$  are given on two mutually perpendicular plane and it is required to find normal strain and shear strain on any plane which is at angle  $\theta$  from the given plane

$$\epsilon_a' = \frac{\epsilon_a + \epsilon_y}{2} + \frac{\epsilon_a - \epsilon_y}{2} w_{820} + \frac{\phi_{ay}}{2} \sin 2\theta$$

$$\epsilon_y' = \frac{\epsilon_a + \epsilon_y}{2} - \frac{\epsilon_a - \epsilon_y}{2} w_{820} - \frac{\phi_{ay}}{2} \sin 2\theta$$

Note:-

Summation of normal strain remains constant on any plane

$$\epsilon_a + \epsilon_y = \epsilon_a' + \epsilon_y' = \epsilon_1 + \epsilon_2 = \text{constant}$$

$$\frac{\phi'_{ay}}{2} = -\left(\frac{\epsilon_a - \epsilon_y}{2}\right) \sin 2\theta + \frac{\phi_{ay}}{2} w_{820}$$

For principal strain  $\phi'_{ay} = 0$ .

$$\tan 2\theta_p = \frac{\phi_{ay}}{\epsilon_a - \epsilon_y}$$

$$\theta_{p1} = \theta_p$$

$$\theta_{p2} = \theta_p + 90^\circ$$

Principal strain

$$\epsilon_1, \epsilon_2 = \frac{\epsilon_a + \epsilon_y}{2} \pm \sqrt{\left(\frac{\epsilon_a - \epsilon_y}{2}\right)^2 + \left(\frac{\phi_{ay}}{2}\right)^2}$$

Maximum shear strain

$$\frac{\phi_{max}}{2} = \frac{\epsilon_1 - \epsilon_2}{2} = \sqrt{\left(\frac{\epsilon_a - \epsilon_y}{2}\right)^2 + \left(\frac{\phi_{ay}}{2}\right)^2}$$

Case-3 :-

- Case of Pure Shear

$$\epsilon_x' = \frac{\Phi_{xy}}{2} \sin 2\theta$$

$$\epsilon_y' = -\frac{\Phi_{xy}}{2} \sin 2\theta$$

$$\frac{\Phi_{xy}}{2} = \frac{\Phi_{xy}}{2} \cos 2\theta$$

For principal strains

$$\theta_p = 45^\circ \quad \Phi_{xy}' = 0$$

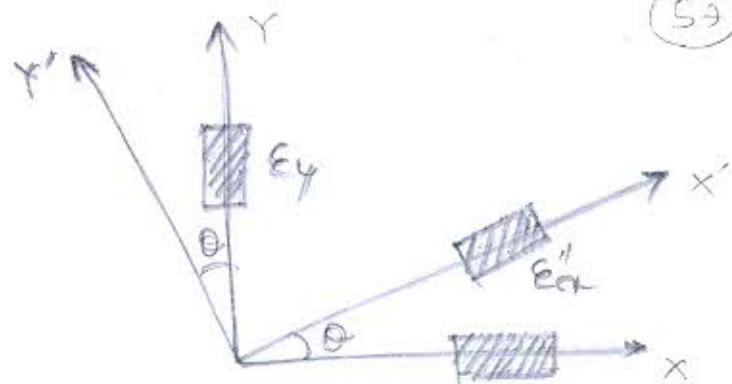
$$\epsilon_1 = \frac{\Phi_{xy}}{2} \quad \epsilon_2 = -\frac{\Phi_{xy}}{2}$$

Strain Rosette :-

- It is the combination of 3 linear strain gauge which are used to measure linear strain in 3 different direction.
- The measurement of normal stress, shear stress, and shear strain is not practical because there is no such device which can measure normal stress, shear stress and shear strain directly.

Therefore strain rosette are used to measure above things by using the following formulas.

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$$\epsilon_a' = \frac{\epsilon_{ax} + \epsilon_{ay}}{2} + \frac{\epsilon_{ax} - \epsilon_{ay}}{2} \cos 2\theta + \frac{\Phi_{ay}}{2} \sin 2\theta$$

$$\epsilon_1, \epsilon_2 = \frac{\epsilon_{ax} + \epsilon_{ay}}{2} \pm \sqrt{\left(\frac{\epsilon_{ax} - \epsilon_{ay}}{2}\right)^2 + \left(\frac{\Phi_{ay}}{2}\right)^2} \quad (2)$$

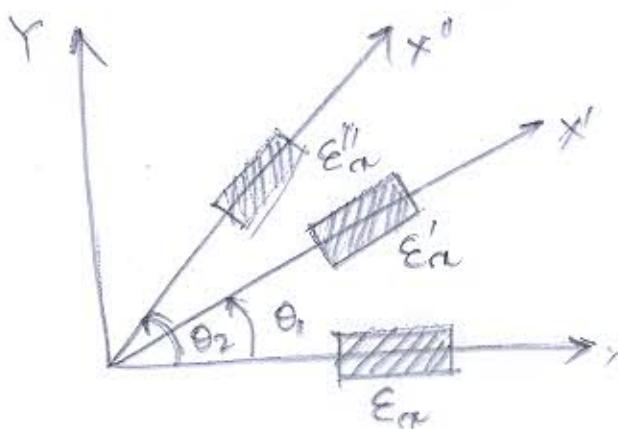
From eq (1) Shear strain  $\Phi_{ay}$  can be calculated

From eq (2) Principal strains  $\epsilon_1$  and  $\epsilon_2$  can be calculated.

$$\sigma_1 = \frac{E}{1-\nu^2} (\epsilon_1 + \nu \epsilon_2)$$

$$\sigma_2 = \frac{E}{1-\nu^2} (\epsilon_2 + \nu \epsilon_1)$$

From the above eq  $\sigma_1$  and  $\sigma_2$  can be calculated



$$\epsilon_a' = \frac{\epsilon_{ax} + \epsilon_{ay}}{2} + \frac{\epsilon_{ax} - \epsilon_{ay}}{2} \cos 2\theta_1 + \frac{\Phi_{ay}}{2} \sin 2\theta_1$$

$$\epsilon_a'' = \frac{\epsilon_{ax} + \epsilon_{ay}}{2} + \frac{\epsilon_{ax} - \epsilon_{ay}}{2} \cos 2\theta_2 + \frac{\Phi_{ay}}{2} \sin 2\theta_2$$

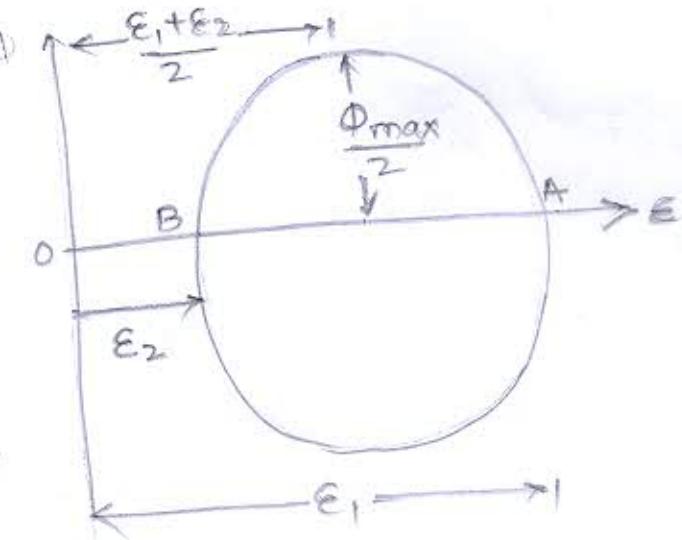
\* Mohr's Strain Circle:

Radius of Mohr's

$$\text{circle} = \frac{\epsilon_1 - \epsilon_2}{2}$$

$$= \frac{\Phi_{\max}}{2}$$

$$= \sqrt{\left(\frac{\epsilon_1 - \epsilon_2}{2}\right)^2 + \left(\frac{\Phi_{\max}}{2}\right)^2}$$



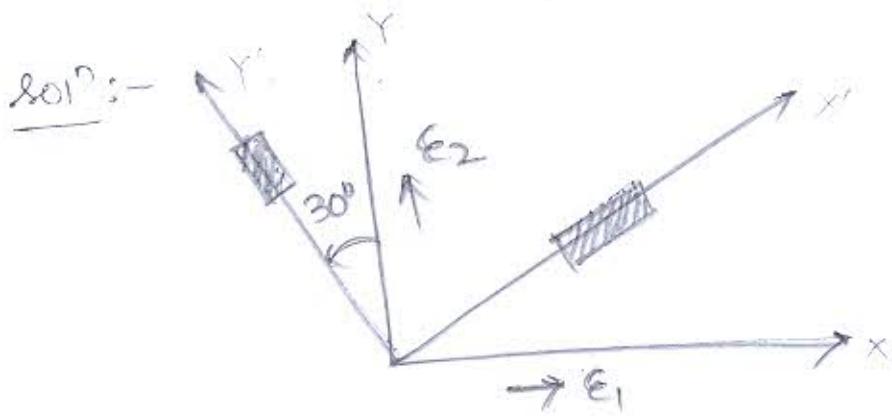
$$\text{Centre} = \left( \frac{\epsilon_1 + \epsilon_2}{2}, 0 \right)$$

$$= \left( \frac{\epsilon_1 + \epsilon_2}{2}, 0 \right)$$

Q:- In a stressed member 2 strain gauges are fixed such that they are inclined at  $30^\circ$  to the node direction of principal stress. The strains measured by these two strain gauge are  $915 \times 10^{-6}$  and  $-32 \times 10^{-6}$  respectively.

Given that  $E = 2 \times 10^5 \text{ MPa}$   $\nu = 0.3$

Determine magnitude of principal stress.



$$\epsilon_a' = 445 \times 10^{-6}$$

$$\epsilon_y' = -32 \times 10^{-6}$$

$$\epsilon_a' = \frac{\epsilon_1 + \epsilon_2}{2} + \frac{\epsilon_1 - \epsilon_2}{2} \cos 2\theta$$

$$\epsilon_y' = \frac{\epsilon_1 + \epsilon_2}{2} - \frac{\epsilon_1 - \epsilon_2}{2} \cos 2\theta$$

$$\Rightarrow 445 \times 10^{-6} = \frac{\epsilon_1 + \epsilon_2}{2} + \frac{\epsilon_1 - \epsilon_2}{2} \cos 2\theta$$

$$-32 \times 10^{-6} = \frac{\epsilon_1 + \epsilon_2}{2} - \frac{\epsilon_1 - \epsilon_2}{2} \cos 2\theta$$

$$\Rightarrow \epsilon_1 = 683.5 \times 10^{-6}$$

$$\epsilon_2 = -230 \times 10^{-6}$$

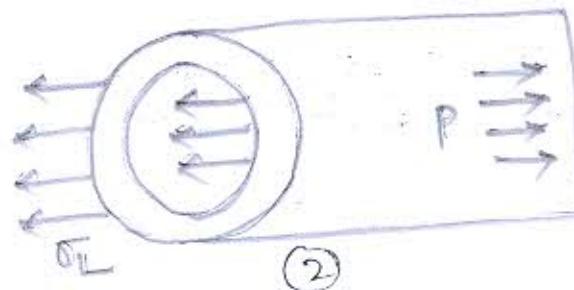
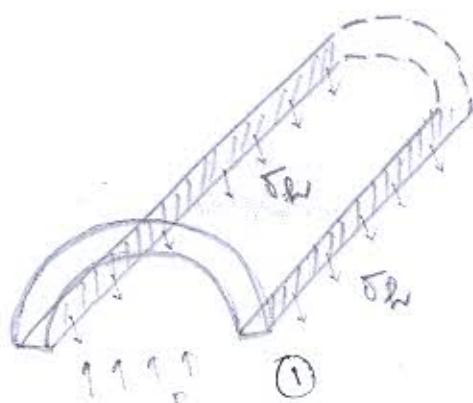
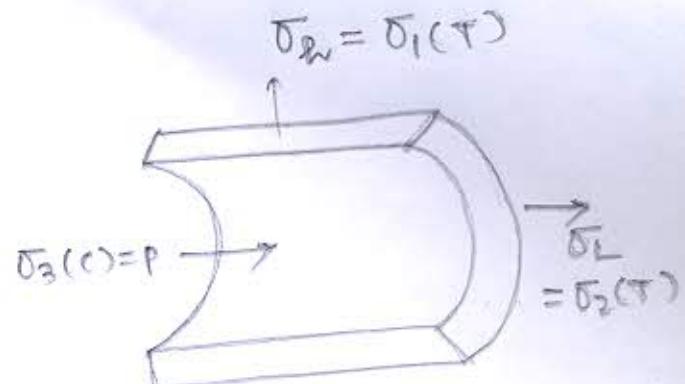
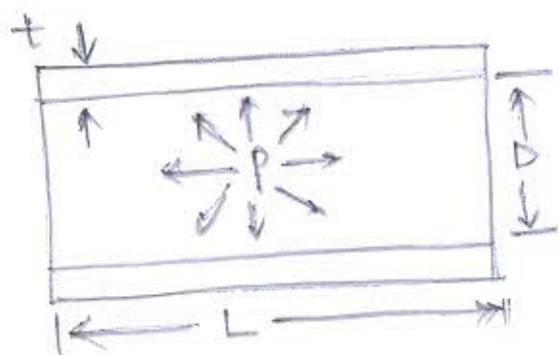
$$\sigma_1 = \frac{E}{1-\nu^2} (\epsilon_1 + \nu \epsilon_2) = 132.48 \text{ MPa}$$

$$\sigma_2 = \frac{E}{1-\nu^2} (\epsilon_2 + \nu \epsilon_1) = -14.38 \text{ MPa}$$

- : Thin cylinder:-

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If  $\frac{D}{t}$  ratio  $> 20$  then it is said to be thin otherwise thick.



At equilibrium for body ①

$$2\sigma_h \times t \times L = P \times D \times L$$

$$\boxed{\sigma_h = \frac{PD}{2t}} \leftarrow \text{Hoop stress or circumferential stress.}$$

For body - 2 At equilibrium

$$\sigma_L \cdot \pi D t = P \times \frac{\pi}{4} \times D^2$$

$$\boxed{\sigma_L = \frac{PD}{4t}} \leftarrow \text{longitudinal or axial stress.}$$

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Due to fluid pres<sup>ure</sup> (radial stress - radial pres<sup>ure</sup>)  
 two types of stress are developed in cylinder.

- (i) Circumferential stress / Hoop stress ( $\sigma_h$ )
- (ii) longitudinal stress / Axial stress ( $\sigma_L$ ) .

The nature of these two stresses are tensile.  
 Since the thickness of cylinder is small, therefore variation of stress along the thickness is negligible. Hence assumed to be uniform along thickness. Since there is no shear on the surface of the cylinder therefore all the stresses are principal stresses.

Maximum shear stress

$$\tau_{\max(1,2)} = \frac{\sigma_1 - \sigma_2}{2} = \frac{PD}{8t}$$

$$\tau_{\max(1,3)} = \frac{\sigma_1 - \sigma_3}{2} = \frac{PD}{4t} + p = \frac{PD}{4t} \rightarrow \text{absolute maximum}$$

$$\tau_{\max(3,2)} = \frac{\sigma_2 - \sigma_3}{2} = \frac{PD}{4t} + p \approx \frac{PD}{8t}$$

Hoop strain or circumferential strain

$$\begin{aligned}\epsilon_h &= \frac{\sigma_h}{E} - \nu \frac{\sigma_L}{E} \\ &= \frac{PD}{2tE} - \nu \frac{PD}{4tE}\end{aligned}$$

$$\boxed{\epsilon_h = \frac{PD}{4tE} (2 - \nu)}$$

Longitudinal or axial strains

$$\epsilon_L = \frac{\sigma_L}{E} - \nu \frac{\sigma_h}{E}$$

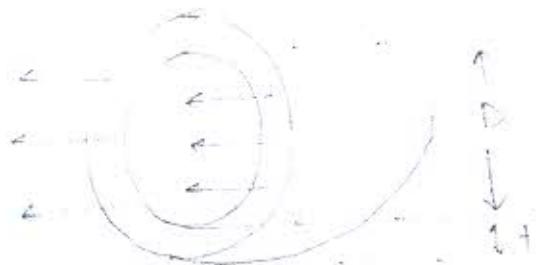
$$= \frac{PD}{4tE} - \nu \frac{PD}{2tE}$$

$$\boxed{\epsilon_L = \frac{PD}{4tE} (1 - 2\nu)}$$

Volumetric strain =  $\epsilon_v = \epsilon_L + 2\epsilon_h$

$$\boxed{\epsilon_v = \frac{PD}{4tE} (5 - 4\nu)}$$

Thin Sphere: —



$$\sigma_h \cdot \pi D t = P \times \frac{\pi}{4} \times D^2$$

$$\boxed{\sigma_h = \frac{PD}{4t} = \sigma_L}$$

$$\text{Hoop strain} = \epsilon_h = \epsilon_L = \frac{\sigma_h}{E} - \nu \frac{\sigma_L}{E}$$

$$= \frac{\sigma_h}{E} - \nu \frac{\sigma_h}{E}$$

$$= \frac{\sigma_h}{E} (1 - \nu)$$

$$\epsilon_h = \frac{PD}{4tE} (1-\nu)$$

Volumetric strain =  $3\epsilon_h = \epsilon_v$

$$\epsilon_v = \frac{3PD}{4tE} (1-\nu)$$

Q:- A seamless pipe 80mm diameter contains a fluid under pressure of  $2 \text{ N/mm}^2$ . If the permissible tensile stress be  $100 \text{ N/mm}^2$ . Find the maximum thickness of pipe.

Sol: Pressure =  $P = 2 \text{ N/mm}^2$

diameter =  $d = 80 \text{ mm}$

stress =  $\sigma = 100 \text{ N/mm}^2$

We know  $\sigma = \frac{Pd}{2t}$

$$t = \frac{P \times d}{2\sigma} = \frac{2 \times 80}{2 \times 100} = 8 \text{ mm}$$

Q:- A cylindrical air receiver has a compression is 2m in internal diameter and made of plates 12mm thick. If the hoop stress is not to exceed  $90 \text{ N/mm}^2$  and the axial stress is not to exceed  $60 \text{ N/mm}^2$ . Find the maximum safe air pressure.

Q1 Given data :

$$\text{diameter} = d = 2m = 2000 \text{ mm}$$

$$t = 15 \text{ mm}$$

$$\text{Hoop stress} = \sigma_h = 90 \text{ N/mm}^2$$

$$\sigma_h = \frac{Pd}{2t}$$

$$\Rightarrow 90 = \frac{P \times 2000}{2 \times 15}$$

$$P = 1.35 \text{ N/mm}^2$$

$$\text{Axial stress} = \sigma_L = 60 \text{ N/mm}^2$$

$$\sigma_L = \frac{Pd}{4t}$$

$$\Rightarrow 60 = \frac{P \times 2000}{4 \times 15}$$

$$\Rightarrow P = 1.8 \text{ N/mm}^2$$

Maximum safe air pressure is  $1.35 \text{ N/mm}^2$ .

(Ans)

Q:- A thin cylindrical tube with closed ends has an internal diameter of 50 mm and a wall thickness of 2.5 mm. The tube is axially loaded in tension with a load of 10 kN and is subjected to an axial torque of 50 Nm under an internal pressure of  $6 \text{ N/mm}^2$ . Determine the principal stress on the outer surface of the tube and the maximum shear stress.

Sol? Mean diameter of the tube =  $50 + 2.5 = 52.50 \text{ mm}$   
 Cross-sectional area of the tube material  
 $A = \pi \times 52.50 \times 2.50 = 131.25\pi = 412.33 \text{ mm}^2$

$$\text{Longitudinal stress} = \sigma_L = \frac{10000}{412.33} + \frac{6 \times \pi \times 50^2}{4} \cdot \frac{1}{412.33} \\ = 52.82 \text{ N/mm}^2$$

$$\text{Hoop stress} = \sigma_h = \frac{P D}{d t} = \frac{6 \times 50}{2 \times 2.5} = 60 \text{ N/mm}^2$$

$$\text{Shear stress} = \tau = \frac{T}{Z_p} = \frac{50 \times 10^3 \times 16 \times 55}{\pi (55^4 - 50^4)} \\ = 48.28 \text{ N/mm}^2$$

$$\text{Principal stress} = \frac{\sigma_L + \sigma_h}{2} \pm \sqrt{\left(\frac{\sigma_L - \sigma_h}{2}\right)^2 + \tau^2} \\ = \frac{52.80 + 60}{2} \pm \sqrt{\left(\frac{52.80 - 60}{2}\right)^2 + 48.28^2} \\ = 56.41 \pm 48.41$$

$$\sigma_1 = 104.82 \text{ N/mm}^2 \text{ (Tension)}$$

$$\sigma_2 = 8 \text{ N/mm}^2 \text{ (compression)}$$

$$\text{Max shear stress} = \frac{\sigma_1 - \sigma_2}{2} \\ = \frac{104.82 - 8}{2} \\ = 48.41 \text{ N/mm}^2$$

### Wire bound thin pipes :-

- Suppose a wire under tension is wound round a pipe at a close pitch, compressive stresses will be initially developed in the pipe section.
- If now a fluid under pressure be admitted into the pipe, the bursting force will be resisted by the pipe as well as the wires, increasing tensile stresses.