

**Principal Stress & Maximal Shear Stress**

**2-Dimensional**

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

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

**3-Dimensional**

Determinants Equations (Stress Invariants)

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$

$$I_2 = \sigma_x\sigma_y + \sigma_y\sigma_z + \sigma_z\sigma_x - \tau_{xy}^2 - \tau_{yz}^2 - \tau_{zx}^2$$

$$I_3 = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{yz}\tau_{zx} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{zx}^2 - \sigma_z\tau_{xy}^2 + 3\sigma_x\tau_{xy}\tau_{yz}\tau_{zx}$$

Principal stress of 1, 2, 3, where

Plane, with normal  $(\sigma_{p1}, \tau_{p1})$       See text for principal direction

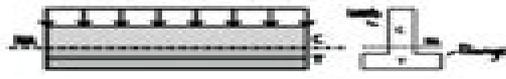
Plane, with normal  $(\sigma_{p2}, \tau_{p2})$

Plane, with normal  $(\sigma_{p3}, \tau_{p3})$

**Centroidal Bending**

$$\sigma_{max} = \sum \frac{M y}{I} + \frac{P}{A}$$

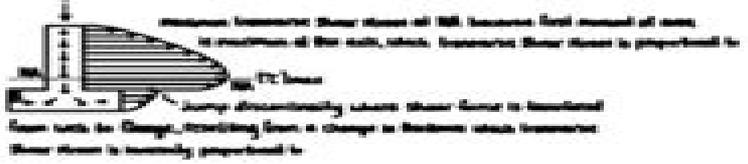
C is distance from NB to point of interest; it differs for circular shaft  
 I is NB with the MCT neutral axis  
 bending stress will be MCT (symptical) axis  
 P/A is axial (symptical) stress contribution  
 tensile bending → positive, compression bending → negative



**Transverse Shear**

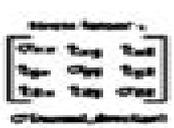
$$\tau = \frac{VQ}{It}$$

Q → Area, for rectangles along axis but I/Q are with respect to I/Q will be MCT axis opposite to V (another axis (symptical))



**Torsion**

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



**Plane Sectional Properties**

Centroid:  $\bar{y} = (\sum y_i A_i) / (\sum A_i)$

Second Moment of Area:

$$I_x = \sum (I_{x_i} + y_i^2 A_i) + \sum y_i^2 A_i$$

only use if when axis is not coincident

$$I_y = \sum (I_{y_i} + x_i^2 A_i) + \sum x_i^2 A_i$$

if I<sub>xy</sub>, have that in face perspective of xy-axis

if I<sub>xy</sub>, " " " " " "

Area Moment of Inertia:

$$J = \sum (I_{x_i}^2 + I_{y_i}^2) + \sum (x_i^2 y_i^2 A_i)$$

if bar is used as a shaft, hollow one:  $I_o = I_o - I_o'$

I<sub>x</sub> = I<sub>centroidal</sub> if bar is used as a beam

First Moment of Area:

moment of area above or below point of interest

$$Q = A\bar{y}$$

where A is the remaining cross sectional area above or below that point and  $\bar{y}$  is the distance between the centroid of that area to the centroid of the entire cross section

**2-Dimensional Plane Stress & Strain**

Stress:

(1) — one dimension compared to other two dimensions is very small  
 like a plate or a shell, stress with large constant

(2) — total has to be in the plane of the plate, etc., same way if strain etc.

Strain:

(1) — one dimension compared to other two dimensions is very large

(2) — symmetric loading condition

**Stress-Strain**

A: point of interest

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix} \rightarrow \begin{bmatrix} E_{11} & E_{12} & E_{13} \\ E_{21} & E_{22} & E_{23} \\ E_{31} & E_{32} & E_{33} \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix} \rightarrow \begin{bmatrix} E_{11} & E_{12} & E_{13} \\ E_{21} & E_{22} & E_{23} \\ E_{31} & E_{32} & E_{33} \end{bmatrix}$$

symmetry

**Stress-Strain Relationship**

$$E_{11} = E(\nu^2 k_{xx} - \nu^2 k_{yy} - \nu^2 k_{zz})$$

$$E_{22} = E(\nu^2 k_{yy} - \nu^2 k_{xx} - \nu^2 k_{zz})$$

$$E_{33} = E(\nu^2 k_{zz} - \nu^2 k_{xx} - \nu^2 k_{yy})$$

$$E_{12} = E(\nu k_{xy}) ; E_{21} = E(\nu k_{yx}) ; E_{13} = E(\nu k_{xz})$$

$$C = G(2G - \nu)$$

**Plane Stress Condition**

$$E_{11} = E(\nu^2 k_{xx} - \nu^2 k_{yy})$$

$$E_{22} = E(\nu^2 k_{yy} - \nu^2 k_{xx})$$

$$E_{33} = -\nu^2 E(k_{xx} + k_{yy})$$

$$E_{12} = E(\nu k_{xy})$$

# Course Notes Structural Mechanics Mechanical

**ML Morrison**



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