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FORMULA SHEET

for

GATE-AE AIRCRAFT STRUCTURES

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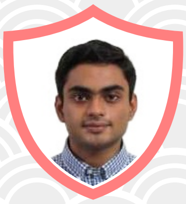

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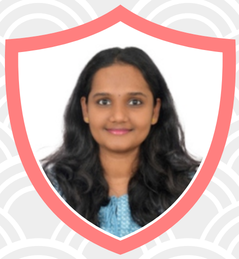

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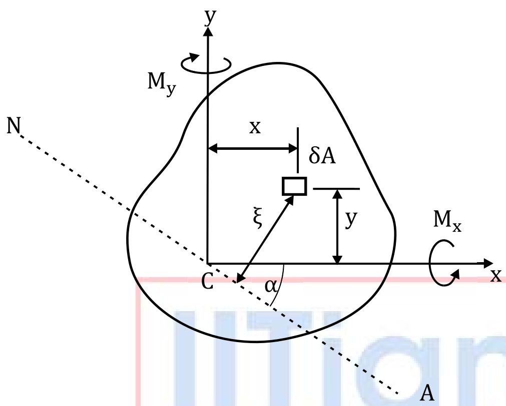
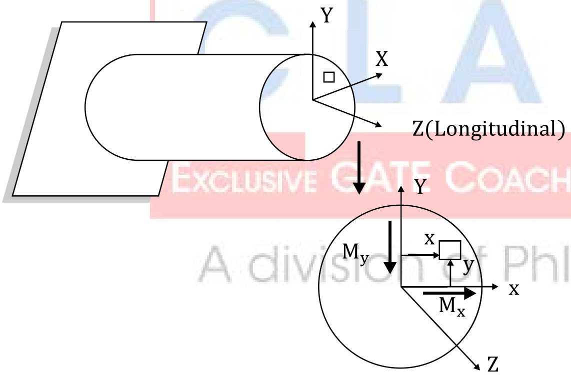
AIRCRAFT / THIN-WALLED STRUCTURES

UNSYMMETRICAL BENDING

For an unsymmetrical cross section under complex bending



Sign Convention



To produce to same effect or same kind of stress (compressive or tension), moment need to follow each other.

Moments in Inclined Plane

- The moment in YZ plane is always about X- axis.
- The moment in XZ plane is always about Y- axis.

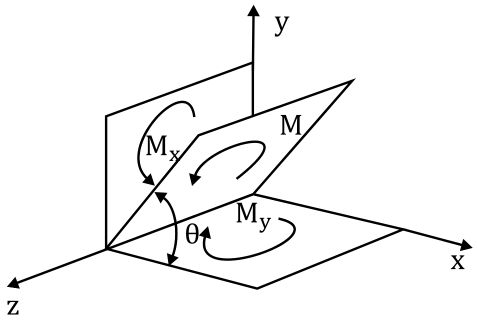


fig (a)

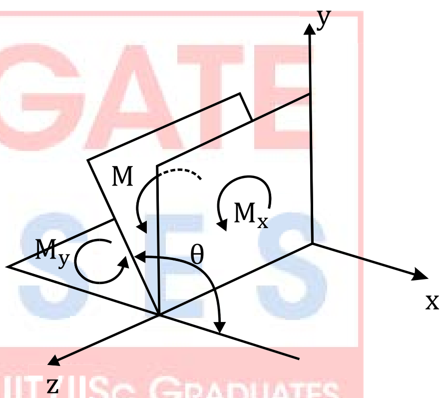


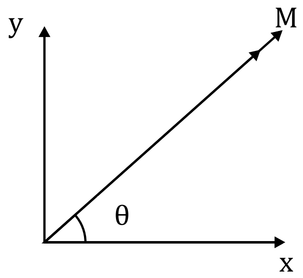
fig (b)

Resolution of bending moments sign depending on the size of θ. In both cases, for the sense of M shown

- $M_x = M\sin\theta$
- $M_y = M\cos\theta$

  This gives,
- For $\theta < \frac{\pi}{2}$, M_x and M_y positive (fig (a)) and for $\theta > \frac{\pi}{2}$, M_x positive and M_y negative (fig (b)).

Moments About Inclined Axis



Resolving Bending Moment along x and y axis

- $M_x = M\cos\theta$
- $M_y = -M\sin\theta$
- For all values of θ

Direct stress due to Unsymmetrical Bending:

$$\sigma_z = \left(\frac{I_{xx}M_y - I_{xy}M_x}{I_{xx}I_{yy} - I_{xy}^2}\right)x + \left(\frac{I_{yy}M_x - I_{xy}M_y}{I_{xx}I_{yy} - I_{xy}^2}\right)y$$

$$\sigma_z = k_1 x + k_2 y$$

here

$$k_1 = \frac{(I_{xx}M_y - I_{xy}M_x)}{(I_{xx}I_{yy} - I_{xy}{}^2)}$$

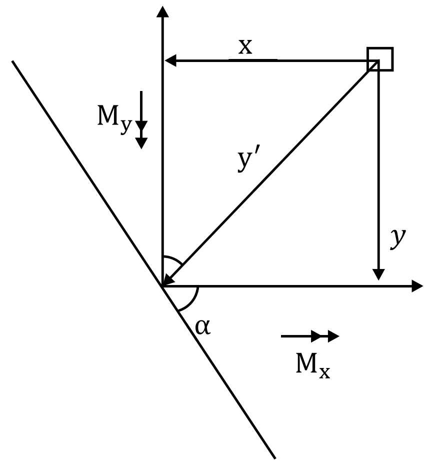
$$k_2 = \frac{(I_{yy}M_x - I_{xy}M_y)}{(I_{xx}I_{yy} - I_{xy}{}^2)}$$

For Symmetric C/S

$I_{xy} = 0$

$$\sigma_z = \frac{M_{xy}}{I_{yy}}x + \frac{M_x}{I_{xx}}y$$

Position of Neutral axis:



At neutral axis

$$\sigma_z = k_1 x + k_2 y = 0$$

$$\Rightarrow k_1 x_{NA} + k_2\, y_{NA} = 0$$

$$\Rightarrow \frac{-y_{NA}}{x_{NA}} = \tan\alpha = \frac{k_1}{k_2}$$

Where α is inclination of neutral axis

α is measure in x-axis in clockwise direction

THIN WALLED-SHEAR FLOW

For thin-walled Open Section

Change of shear flow along section

$$\frac{\partial q}{\partial s} = -t\left[\frac{I_{xx}\frac{\partial M_y}{\partial z} - I_{xy}\frac{\partial M_x}{\partial z}}{I_{xx}I_{yy} - I_{xy}{}^2}\right]x - t\left[\frac{I_{yy}\frac{\partial M_x}{\partial z} - I_{xy}\frac{\partial M_y}{\partial z}}{I_{xx}I_{yy} - I_{xy}{}^2}\right]y$$

$$V_x = \frac{\partial M_y}{\partial z} \text{ and } V_y = \frac{\partial M_x}{\partial z}$$

$$\frac{\partial q}{\partial s} = -t\frac{(I_{xx}V_x - I_{xy}V_y)}{(I_{xx}I_{yy} - I_{xy}{}^2)}x - t\frac{(I_{yy}V_y - I_{xy}V_x)}{(I_{xx}I_{yy} - I_{xy}{}^2)}y$$

$$q_{s2} - q_{s1} = \int_{s_1}^{s_2}\frac{\partial q}{\partial s}ds$$

Note: For thin-walled section at the free end (open end) shear flow is considered as zero (Boundary condition)

For thin walled idealized (boom) section

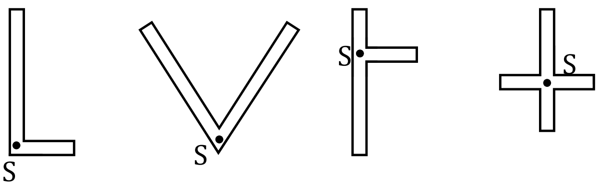
$$q_s = -\frac{(I_{xx}V_n - I_{xy}V_y)}{(I_{xx}I_{yy} - I_{xy}^2)}\sum Ax - \frac{(I_{xx}V_y - I_{xy}V_y)}{(I_{xx} - I_{yy} - I_{xy}^2)}\sum Ay$$

For Closed Section

$$q = q_s + q_{s,0}$$

Shear Centre

- Shear centre is a point, if transverse loading is applied through this point, and then there will be no twist of the section. It will be only undergoing bending.
- It is also the point of twist or centre of the twist or centre of flexure.
- Shear centre is cross section property and it is independence of loading.
- For any section, if there is a junction, the junction itself will be a shear centre.



- For doubly symmetric section, shear centre and centroid is same.
- For single symmetric section, shear centre lies on axis of symmetry.

THIN-WALLED TORSION

Solid shaft

$\tau \propto r$ (radial distance)

$\theta \propto l$ (Longitudnal length)

Torsional Formula

$$\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L} \qquad \tau_{\text{solid shaft}} = \frac{16T}{\pi d^3}$$

Thin-Walled single cell closed section:

$$q = \tau t$$

Bredth -Batho Theory:

$$T = 2Aq$$

$$\tau = \frac{q}{t} = \frac{T}{2At}$$

Angle of twist per unit length:

$$\frac{d\theta}{dx} = \frac{T}{4A^2G}\oint \frac{ds}{dt} = \frac{q}{2AG}\oint \frac{ds}{t}$$

$$T = GJ\frac{d\theta}{dx}$$

Torsional Constant:

$$J = \frac{4A^2}{\int \frac{ds}{t}}$$

Torsional Rigidity

$$GJ = \frac{4A^2}{\int \frac{ds}{Gt}} \rightarrow \text{torstonal Rigidity}$$

$$J = I_P \rightarrow \text{for circular crossection}$$
$$= 2\pi r^3 t$$

Thin-Walled single cell Open section:

Torsional formula

$$\frac{\tau}{t} = \frac{T}{J} = \frac{G\theta}{L}$$

Torsion constant $J = \sum \frac{bt^3}{3}$ or $\int \frac{t^3 ds}{3}$

Max shear stress

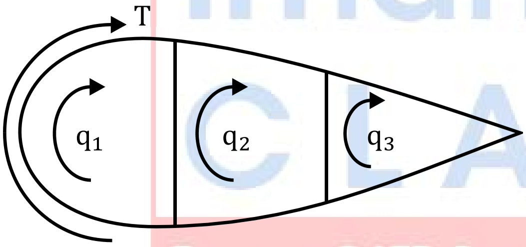
$$\tau_{max} = \frac{T}{J} t$$

Here t is thickness

Angle of twist per unit length

$$\frac{\theta}{L} = \frac{T}{GJ}$$

Thin-Walled multi cell closed section



Bredt Batho Equation

$T = 2A_1q_1 + 2A_2q_2 + 2A_3q_3$ .... (1)

Compatibility equation

$\theta'_1 = \theta'_2 = \theta'_3$ .... (2)

Note: - For multi shell there is less twist than single shell.

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- Topic Wise Assignments (e-form)
- Online Test Series
- Online Doubt Support
- Previous Year Solved Question Papers

OUR COURSES

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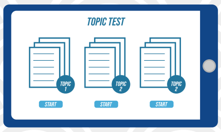
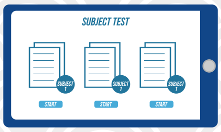
Course Features



Topic Wise Tests



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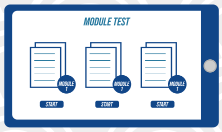
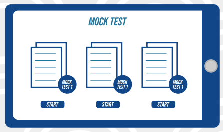


Module Wise Tests



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