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Stress Analysis
ACUA 5015

Joseph Sudo

1902709

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1) $\epsilon_x = 2.9 \times 10^{-6}$ $\epsilon_y = -1.0 \times 10^{-6}$ $\nu = 0.28$ $E = 170 \text{ GPa}$

$$\sigma_x = \frac{E}{1-\nu^2} (\epsilon_x + \nu \epsilon_y) \quad \sigma_x = \frac{170 \times 10^9}{1-0.28^2} (2.9 \times 10^{-6} + 0.28 \times -1.0 \times 10^{-6})$$

$\sigma_x = 683.29 \text{ kPa}$ (Tensile)

$$\sigma_y = \frac{E}{1-\nu^2} (\epsilon_y + \nu \epsilon_x) \quad \sigma_y = \frac{170 \times 10^9}{1-0.28^2} (-1.0 \times 10^{-6} + 0.28 \times 2.9 \times 10^{-6})$$

$\sigma_y = -36.68 \text{ kPa}$ (Compression)

ii) $\sigma_x = 8.0 \times 10^6 \text{ Pa}$ $\sigma_y = -6.9 \times 10^6 \text{ Pa}$ $\nu = 0.28$ $E = 170 \text{ GPa}$

$$\epsilon_x = \frac{1}{E} (\sigma_x - \nu \sigma_y) \quad \epsilon_x = \frac{1}{170 \times 10^9} (8.0 \times 10^6 - 0.28 \times -6.9 \times 10^6)$$

~~$\epsilon_x = 5.51 \times 10^{-5}$~~ $\epsilon_x = 5.51 \times 10^{-4}$

$$\epsilon_y = \frac{1}{E} (\sigma_y - \nu \sigma_x) \quad \epsilon_y = \frac{1}{170 \times 10^9} (-6.9 \times 10^6 - 0.28 \times 8.0 \times 10^6)$$

~~$\epsilon_y = -6.2 \times 10^{-5}$~~ $\epsilon_y = -6.2 \times 10^{-4}$

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2) $\sigma_x = 107 \text{ MPa}$ $\sigma_y = 200 \text{ MPa}$ $\tau_{xy} = 125 \text{ MPa}$

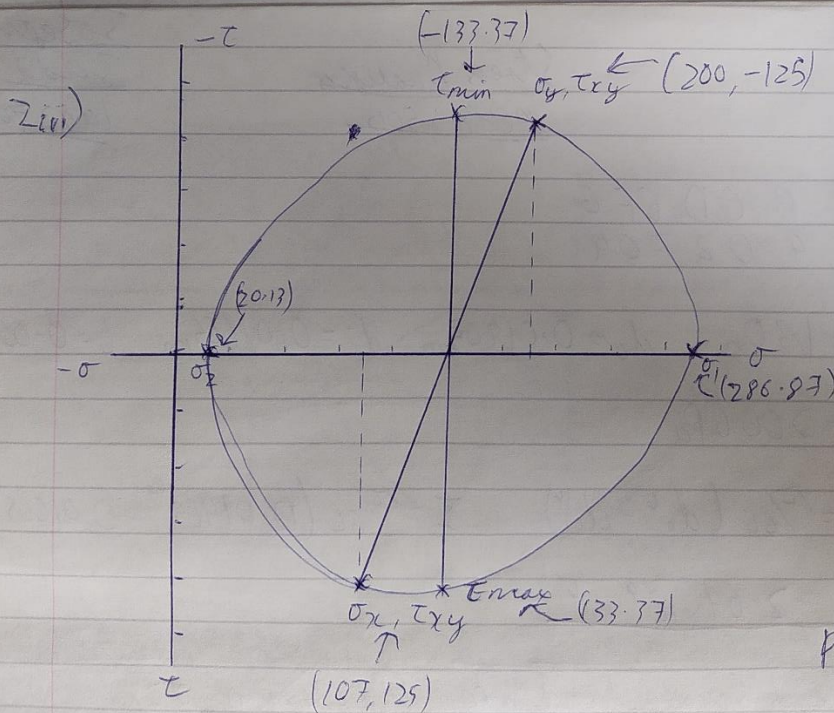
$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{1,2} = \frac{107 \times 10^6 + 200 \times 10^6}{2} \pm \sqrt{\left(\frac{107 \times 10^6 - 200 \times 10^6}{2}\right)^2 + (125 \times 10^6)^2}$$

$\sigma_1 = 286.87 \text{ MPa}$ $\sigma_2 = 20.13 \text{ MPa}$

ii) $\tau_{\max, \min} = \pm \left(\frac{\sigma_1 - \sigma_2}{2}\right)$ $\tau_{\max, \min} = \pm \left(\frac{286.87 \times 10^6 - 20.13 \times 10^6}{2}\right)$

$\tau_{\max} = 133.37 \times 10^6 \text{ MPa}$ $\tau_{\min} = -133.37 \times 10^6 \text{ MPa}$



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$$3) EI \frac{d^2 y}{dx^2} = 1969.6[x] - \frac{450[x-0.5]^2}{2} + \frac{450[x-1.5]^2}{2} - \frac{2300[x-1.5]}{2} - \frac{800[x-1.5]^2}{2} + \frac{800[x-2.5]^2}{2} - \frac{1000[x-2.5]}{2}$$

$$ii) EI \frac{dy}{dx} = \frac{1969.6[x]^2}{2} - \frac{450[x-0.5]^3}{6} + \frac{450[x-1.5]^3}{6} - \frac{2300[x-1.5]^2}{2} - \frac{800[x-1.5]^3}{6} + \frac{800[x-2.5]^3}{6} - \frac{1000[x-2.5]^2}{2} + A$$

$$iii) EI y = \frac{1969.6[x]^3}{6} - \frac{450[x-0.5]^4}{24} + \frac{450[x-1.5]^4}{24} - \frac{2300[x-1.5]^3}{6} - \frac{800[x-1.5]^4}{24} + \frac{800[x-2.5]^4}{24} - \frac{1000[x-2.5]^3}{6} + Ax + B$$

iv)

$$x=0, y=0 \quad 0 = 0 - 0 + 0 - 0 - 0 + 0 - 0 + 0 + B \quad \underline{B=0}$$

$$x=3.1, y=0$$

$$0 = \frac{1969.6[3.1]^3}{6} - \frac{450[3.1-0.5]^4}{24} + \frac{450[3.1-1.5]^4}{24} - \frac{2300[3.1-1.5]^3}{6} - \frac{800[3.1-1.5]^4}{24} + \frac{800[3.1-2.5]^4}{24} - \frac{1000[3.1-2.5]^3}{6} + 3.1A$$

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3) iv) cont)

$$D = 9778.6 - 856.83 + 122.88 - 1570.13 - 218.45 + 6.32 - 36 + 3A$$

$$D = 7226.19 + 3A \quad A = \frac{-7226.19}{3} \quad A = -2408.06$$

$$A = -2408.06 \quad B = 0$$

v) $x = 1.55, y = ? \quad EI = 1.70 \text{ MPa}$

$$1.70 \times 10^6 y = \frac{1469.4 [1.55]^3}{6} - \frac{650 [1.55 - 0.5]^4}{24} + \frac{650 [1.55 - 1.5]^4}{24} - \frac{2300 [1.55 - 0.5]^3}{6} - \frac{800 [1.55 - 1.5]^4}{24} + \cancel{1.55 \times -2408.06}$$

$$1.70 \times 10^6 y = 1222.3 - 22.79 + 1.17 \times 10^{-4} - 0.048 - 2.08 \times 10^{-4} - 3732.44$$

$$1.70 \times 10^6 y = -2533.03 \quad y = \frac{-2533.03}{1.70 \times 10^6}$$

$$y = -1.49 \times 10^{-3} \text{ m} \quad (-1.49 \text{ mm})$$

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b) $D = 0.28m$ $L = 0.6m$ $\eta_L = 0.50$ $\eta_c = 0.69$ $P = 16.7 \text{ bar}$
 (1.67 MNm^{-2})

$\sigma_{max} = 150 \text{ MPa}$ $t = ?$

i) $\sigma_c = \frac{PD}{2t\eta_L}$ $2t\eta_L\sigma_c = PD$ $t = \frac{PD}{2\eta_L\sigma_c}$

$t = \frac{1.67 \times 10^6 \times 0.28}{2 \times 0.5 \times 150 \times 10^6}$ $t = 2.744 \times 10^{-3} \text{ m} (2.74 \text{ mm})$

ii) $\sigma_L = \frac{PD}{4t\eta_c}$ $4t\eta_c\sigma_L = PD$ $t = \frac{PD}{4\eta_c\sigma_L}$

$t = \frac{1.67 \times 10^6 \times 0.28}{4 \times 0.69 \times 150 \times 10^6}$ $t = 0.996 \times 10^{-3} \text{ m} (0.99 \text{ mm})$

iii) $t_{min} = 2.74 \text{ mm}$

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Zuda
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5) $L = 1.30\text{m}$ $d_o = 0.01905\text{m}$ $d_i = 0.01665\text{m}$ $t = 0.0012\text{m}$

$E = 200\text{GPa}$

i) $I = \frac{\pi}{64} (d_o^4 - d_i^4)$ $I = \frac{\pi}{64} (0.01905^4 - 0.01665^4)$

$I = 2.69 \times 10^{-9} \text{m}^4$

ii) 1 end fixed, 1 end free, therefore $n = 0.25$

iii) $F_{CR} = \frac{n \pi^2 E I}{L^2}$

$F_{CR} = \frac{0.25 \times \pi^2 \times 200 \times 10^9 \times 2.69 \times 10^{-9}}{1.3^2}$

$F_{CR} = 785.68\text{N}$

iv) $S.R. = L/k$ $k = \sqrt{\frac{E}{I/A}}$ $S.R. = \frac{L}{\sqrt{E/A}}$

$A = \frac{\pi}{4} (d_o^2 - d_i^2)$ $A = \frac{\pi}{4} (0.01905^2 - 0.01665^2)$

$A = 6.73 \times 10^{-5} \text{m}^2$

$S.R. = 1.3 / \sqrt{\frac{2.69 \times 10^{-9}}{6.73 \times 10^{-5}}}$

$S.R. = 205.62$

$S.R. > 120$, therefore a strut