$= 64.06 + 114.06$

$\underline{\sigma_1 = 178.1 \text{ MN/m}^2}$

Alternative Method

$\sigma_2 = -50 = ½ (150 + \sigma_y) - ½ \sqrt{} [(150 - \sigma_y)^2 + 4 \times 75^2]$

$- 50 = 75 + \sigma_y/2 - ½ \sqrt{}(150-\sigma_y)^2 + 4 \times 75^2]$

$- 125 \times 2 = \sigma_y - \sqrt{}[150 - \sigma_y)^2 + 4 \times 75^2]$

$(\sigma_y + 250)^2 = [(150 - \sigma_y)^2 + 4 \times 75^2]$

$\sigma_y^2 + 500 \sigma_y + 62\,500 = 22500 - 300 \sigma_y + \sigma_y^2 + 22500$

$800\sigma_y = -17500$

$\sigma_y = -21.88 \text{ MN/m}^2$ (as before)

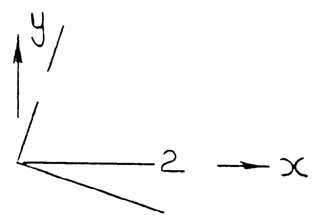
$\sigma_1 = ½ (150 - 21.88) + \sqrt{}[150 + 21.88^2 + 4 \times 75^2]$

$= 64 + ½ \times 228.1$

$\underline{\sigma_1 = 178.1 \text{ MN/m}^2}$

6.

$\epsilon_\theta = ½ (\epsilon_x + \epsilon_y) + ½ (\epsilon_x - \epsilon_y) \cos 2\theta + ½ \gamma_{xy} \sin 2\theta$



Let $\underline{\epsilon_2 = \epsilon_x = 300 \times 10^{-6}}$

$\epsilon_{-60} = ½ (300 \text{ E-6} + \epsilon_y) + ½ (300\text{E-6}-\epsilon_y) \cos (-120) + ½ \gamma_{xy} \sin (-120)$

$\therefore -500\text{E-6} = 150\text{E-6} + 0.5\epsilon_y - 0.25 (300\text{E-6}-\epsilon_y) - 0.433 \gamma_{xy}$

$- 500 \text{ E-6} - 150\text{E-6} + 75\text{E-6} = 0.75 \epsilon_y - 0.433\gamma_{xy}$

$- 575\text{E-6} = 0.75 \epsilon_y - 0.433 \gamma_{xy}$ 1

$\epsilon_{+60} = ½(300\text{E-6}+\epsilon_y) + ½ (300\text{E-6}-\epsilon_y) \cos (120) + ½ \gamma_{xy} \sin (120)$

$600\text{E-6} = 150\text{E-6} + 0.51 \epsilon_y - 75\text{E-6} + 0.25 \epsilon_y + 0.433\gamma_{xy}$

$525\text{E-6} = 0.75\epsilon_y + 0.433 \gamma_{xy}$ 2

Take 1 from 2

$1100E\text{-}6 = 0.866\ \gamma_{xy}$

$\underline{\gamma_{xy} = 1270E\text{-}6}$

$$G = \frac{E}{2\ (1 + \upsilon)} = \underline{8.20E10}$$

$\underline{\tau_{xy} = 8.20E10 \times 12.70E\text{-}6 = 104.18\ MN/m_2}$

$$J = \frac{\pi \times 0.03^4}{32} = \underline{7.952E\text{-}8m^4}$$

$$T = \frac{\tau}{r} * J = \frac{104.18E6 \times 7.952E\text{-}8}{0.015}$$

$\underline{T = 552.3N.m}$

$$M_{max} = \frac{w\ell^2}{8}; \quad A = 7.069E\text{-}4$$

$w = \rho Ag = \underline{54.5\ N/m}$

From 1

$$\epsilon_y = -\frac{575E\text{-}6 + 550E\text{-}6}{0.75}$$

$\underline{\epsilon_y = -33.3E\text{-}6}$

$$\theta = \tfrac{1}{2} \tan^{-1} \left(\frac{1270}{333} \right)$$

$\underline{\theta = 37.65°}$ anti-clockwise from the middle gauge

$$\sigma_x = \frac{E}{(1 - \nu^2)} (\epsilon_x + \nu\ \epsilon_y) = \frac{2.1E11}{0.922} (300E\text{-}6\text{-}9.32E\text{-}6)$$

$\underline{\sigma_x = 66.2\ MN/m^2}$

$\underline{M_{max} = \sigma_x I/\bar{y} = 175.5 \text{ N.m}}$

$$\ell = \sqrt{\frac{8M_{max}}{w}} = \sqrt{\frac{8 \times 175.5}{54.5}}$$

$\underline{\ell = 5.08 \text{ m}}$

$$\theta = \tfrac{1}{2} \tan^{-1} \left[\frac{2\tau_{xy}}{\sigma_x - \sigma_y} \right]$$

$$= \tfrac{1}{2} \tan^{-1} \left[\frac{\gamma_{xy}}{\epsilon_x - \epsilon_y} \right]$$

$\underline{\theta = 37.65°}$ anti-clockwise from the middle gauge

$$\sigma_y = \frac{E}{(1 - \upsilon^2)} (\epsilon_y + \upsilon \epsilon_x)$$

$= 2.278E11 \ (-33.3E\text{-}6 + 84E\text{-}6)$

$\underline{\sigma_y = 11.55 \text{ MN/m}^2}$

$$\sigma_1 = \tfrac{1}{2} (66.2 + 11.5) + \tfrac{1}{2} \sqrt{(66.2 - 11.55)^2 + 4 \times 104.2^2}$$

$= 38.8 + 107.7$

$\underline{\sigma_1 = 146.5 \text{ MN/m}^2}$

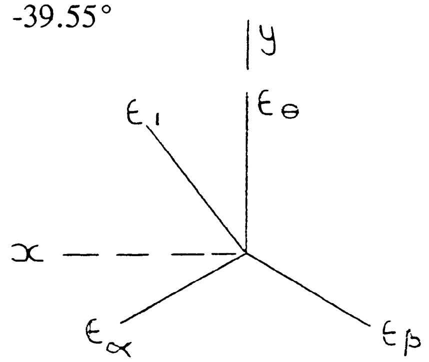
$\underline{\sigma_2 = -68.9 \text{ MN/m}^2}$

7. $$\tan 2\theta = \frac{\sqrt{3} \ (\epsilon_\alpha - \epsilon_\beta)}{(2\epsilon_\theta - \epsilon_\beta - \epsilon_\alpha)}$$

$$= \frac{\sqrt{3} \ (-300 - 600)}{(600 - 600 + 300)} = -5.1962$$

$2\theta = -79.1°$

$\theta = -39.55°$



$$\epsilon_1 = ⅓ (\epsilon_\theta + \epsilon_\alpha + \epsilon_\beta) + \frac{\sqrt{2}}{3} \sqrt{[(\epsilon_\theta - \epsilon_\alpha)^2 + (\epsilon_\alpha - \epsilon_\beta)^2 + (\epsilon_\theta - \epsilon_\beta)^2]}$$

$$= 10^{-6} [200 + 0.4714 \sqrt{1260000}\ ]$$

$$\epsilon_1 = 729.1 \times 10^{-6}$$

$$\epsilon_2 = 10^{-6} (200 - 529.1) = -329.1 \times 10^{-6}$$

$$\epsilon_\phi = ½ (\epsilon_1 + \epsilon_2) + ½ (\epsilon_1 - \epsilon_2) \cos 2\phi$$

$$\phi = 90 - 39.55 = 50.45°$$

$$\therefore \epsilon_x = \epsilon_\phi = 10^{-6} (200 - 529.1 \times 0.1891)$$

$$\epsilon_x = 100 \times 10^{-6}$$

$\underline{\epsilon_y = E_\theta = 300 \times 10^{-6}}$

Check ϵ_y

$\underline{\epsilon_y = 10^{-6} (200 + 529.1 \times 0.1891)}$

$$\epsilon_y = 300 \times 10^{-6}$$

$$\sigma_x = \frac{E (\epsilon_x + \upsilon \epsilon_y)}{(1 - \upsilon^2)}$$

$$= \frac{1 \times 10^{11}}{0.8976} \times 10^{-6} (100 + 0.32 \times 300)$$

$\sigma_x = 1.111 \times 10^5 \times 196 = 21.78$ MPa

$$A = \frac{\pi \times 0.03^2}{4} = 7.0686 \times 10^{-4} \text{ m}^2$$

$\therefore$ Axial load $= 21.78 \times 10^3 \times 7.0686 \times 10^{-4}$ kN

<u>Axial load = 15.4 kN</u>

$$\frac{\gamma_\phi}{2} = \frac{(\epsilon_1 - \epsilon_2)}{2} \sin 2\phi$$

$\therefore \quad \gamma_{xy} = 1058.2 \times 10^{-6} \sin 100.9°$

$\gamma_{xy} = 1039.1 \times 10^{-6}$

$J = \pi \times 0.03^4/32 = 7.952 \times 10^{-8}$ m^4

$$\tau_{xy} = \frac{1 \times 10^{11}}{2.64} \times 1039.1 \times 10^{-6} = 39.24 \text{ MPa}$$

$\therefore \quad T = \tau_{xy} \times J/r = 208$ N.m

CHAPTER 8

1. Cylinder

$$\sigma_H = \frac{pr}{\eta_L t}$$

$$t = \frac{\pi}{\eta_L \sigma_H} = \frac{1E6 \times 2}{0.75 \times 100\ E6} = 0.027\ m = \underline{2.67\ cm}$$

Dome

$$t = \frac{pr}{2 \times \eta_c\ \sigma} = \frac{1E6 \times 2}{2 \times 0.5 \times 100\ E6} = 0.02\ m = \underline{2\ cm}$$

2. Cylinder

$$\sigma_H = \frac{1E6 \times 2}{0.0267} = \underline{74.91\ MN/m^2 \quad \sigma_L = 37.455\ MPa}$$

$$\epsilon_H = \frac{1}{E}(\sigma_H - \upsilon\sigma_L) = 3.184E\text{-}4$$

$\underline{w = 6.367\ E\text{-}4m}$

$\underline{\delta V_1 = 2\pi RwL = 0.048m^3}$

$\sigma_L = 37.455\ MN/m^2$

$$\epsilon_L = \frac{1}{E}(\sigma_L - \upsilon\sigma_H) = 7.491E\text{-}5$$

$u = 4.495E\text{-}4$

$\underline{\delta V_2 = \pi R^2\ u = 0.0056\ m^3}$

Sphere

$\sigma = 37.455\ MN/m^2$

$$\epsilon = \frac{1}{E} (\sigma - \upsilon\sigma) = 1.311E\text{-}4$$

$w = 2.622\ E\text{-}4$

$\underline{\delta V_3 = 4\pi R^2 w = 0.0132\ m^3}$

Water

$$Vol = \pi R^2 L = \frac{4}{3} \pi R^3$$

$$= 75.4 + 33.5$$

$\underline{Vol = 108.91\ m^3}$

$$\delta V_4 = \frac{pV}{K} = 0.055$$

$\delta V = \delta V_1 + \delta V_2 + \delta V_3 + \delta V_4$

$\underline{\delta V = 0.122\ m^3}$

3. $p = \rho gh = 0.294$ MPa

$\sigma_H = pr/t = 1.15\ MN/m^2$

4. $$\frac{w}{r} = \epsilon_H = \frac{1}{E} (\sigma_H - \upsilon\ \sigma_L) \quad \text{Now } r = 0.625E\text{-}2$$

$$w = \frac{r}{E} (1.15 - 0.33 \times 1.15/2)$$

$w = 6E\text{-}8$

$\delta = 12E\text{-}8$

$\delta = 1.2E\text{-}7$

$= 0.12$ micrometres

5. $\sigma = \frac{pr}{t} = \frac{p \times 1.5E-2}{0.16E-2}$

$\therefore \frac{\sigma}{p} = 9.375$

<u>For spherical shell</u>

$\frac{\sigma}{p} = 0.7 \times 9.375 = 6.5625$

$\frac{\sigma}{p} = \frac{r}{2t}$

$6.5625 = \frac{0.5}{2t}$

$\underline{\therefore t = 0.0381 \text{ m} = 3.81 \text{ cm}}$

6. $\sigma = \frac{pr}{2t}$

$\therefore t = \frac{pr}{2\sigma} = \frac{0.7 \times 1}{2 \times 50} = 7E-3m = \underline{0.7 \text{ m}}$

load on bolts $= \pi r^2 p = 2.2E6MN$

$12 \times \sigma_b \times \frac{\pi d^2}{4} = 2.2E6$

$d^2 = \frac{2.2E6 \times 4}{12 \times 200E6 \times \pi}$

$d = 0.034 \text{ m} = \underline{3.4 \text{ cm}}$

7. $\sigma_H = \dfrac{pR}{t}$

$\sigma_L = pR/(2t)$

$\epsilon_H = \dfrac{w}{R} = \dfrac{1}{E}(\sigma_H - \upsilon\sigma_L)$

$= \dfrac{pR}{tE}(1 - \upsilon/2)$

$\therefore w = \dfrac{pR^2}{tE}(1 - 0.125)$

$\underline{w = 0.875\ pR^2/(tE)}$

$\dfrac{u}{L} = \dfrac{pR}{tE}(½ - \upsilon)$

$u = \dfrac{pRL}{tE}(½ - 0.25)$

$\underline{u = \dfrac{pRL}{tE} * 0.25}$

$\delta V_1 = \dfrac{2\pi rL * 0.875\ pR^2}{tE}$

$\underline{\delta V_1 = 5.498\ pR^3L/(tE)}$

$\delta V_2 = \pi R^2 u$

$= \dfrac{\pi R^2 * pRL * 0.25}{tE}$

$$\delta V_2 = \frac{0.785\ pR^3L}{tE}$$

$$\delta V_3 = \frac{pV}{K}$$

$$\delta V = \frac{6.283\ pR^3L}{tE} + \frac{pV}{K}$$

<u>2nd case</u>

$\sigma_H = pR/t \quad \sigma_L = 0 \qquad\qquad u = 0$

$$w = \frac{R}{E}(\sigma_H)$$

<u>$w = pr^2/(tE)$</u>

$\delta V_1 = 2\pi R * w * L = \underline{6.283\ pR^3}$

$\delta V_2 = 0$

$\delta V_3 = pV/K$

$$\delta V = \frac{6.283\ pR^3L}{tE} + \frac{pV}{k}$$