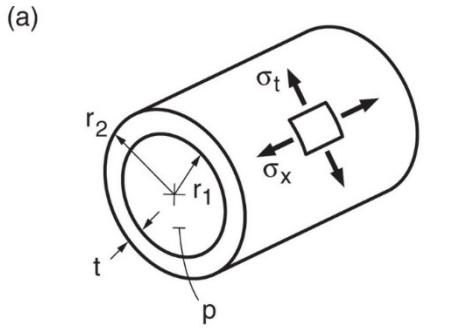
A thin-walled tube is installed in a machine with threaded collar connections at both ends. Drawn from AISI 4142 steel tempered at 450 °C, the tube has an inside radius, r_1 = 80 mm and a wall thickness, t = 6 mm. The tube is subjected to an internal pressure of 20 MPa. Due to misalignment at installation, the connection induces a bending moment of 20 kN-m on the thin-walled tube. The tube can be considered closed.

AISI 4142 Steel Tempered to 450 °C: E = 207 GPa, S_y = 1378 MPa, S_{ut} = 1413 MPa

1. (85) What is the factor of safety against yielding of the installed tube?
2. (15) Is the tube in danger of yielding if the connection **also** induces a torque of 60 kN-m on the tube at installation?

Equations/Figures:

Thin-Wall Pressure Vessel Theory- Internal Pressure:

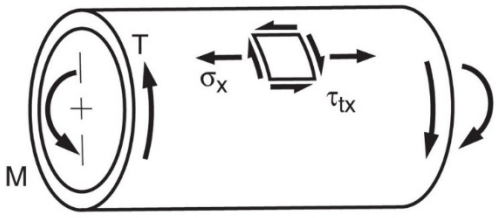


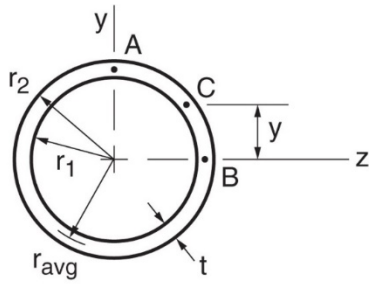
$$\sigma_t = \frac{pr_1}{t}, \qquad \sigma_x = \frac{pr_1}{2t}$$

$(\sigma_x = 0$, open ends)

$\sigma_r = -p$ (inside)

$\sigma_r = 0$ (outside)





$$\tau_{tx} = \frac{T}{2\pi r_{\text{avg}}^2 t}, \qquad \sigma_x = \frac{My}{\pi r_{\text{avg}}^3 t}, \qquad \sigma_{xA} = \frac{M}{\pi r_{\text{avg}}^2 t}, \qquad \sigma_{xB} = 0$$

2-D State of Stress:

$$\sigma' = \left(\sigma_A^2 - \sigma_A\sigma_B + \sigma_B^2\right)^{1/2}$$

$$\sigma' = \left(\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2\right)^{1/2}$$

3-D State of Stress:

$$\sigma' = \frac{1}{\sqrt{2}}\left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6\left(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2\right)\right]^{1/2}$$

$$\sigma' = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}\right]^{1/2}$$