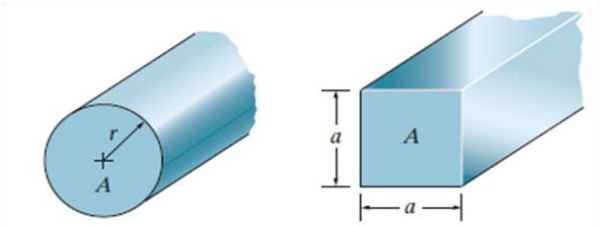
5-95. Compare the values of the maximum elastic shear stress and the angle of twist developed in 304 stainless steel shafts having circular and square cross sections. Each shaft has the same cross-sectional area of 5600 mm^2, length of 900 mm, and is subjected to a torque of 500 N.m.

Solution:



Maximum Shear Stress:

For circular shaft

$$A = \pi c^2 = 5600; \quad c = 42.22\ mm$$

$$(\tau_c)_{\max} = \frac{Tc}{J} = \frac{Tc}{\frac{\pi}{2}c^4} = \frac{2T}{\pi c^3} = \frac{2 * 500 * 1000}{\pi(42.22)^3} = 4.23\ MPa. \quad \textbf{Ans.}$$

For rectangular shaft

$$A = a^2 = 5600; \quad a = 74.833\ mm$$

$$(\tau_r)_{\max} = \frac{4.81T}{a^3} = \frac{4.81 * 500 * 1000}{(74.833)^3} = 5.74\ MPa. \quad \textbf{Ans.}$$

Angle of Twist:

For circular shaft

$$\phi_c = \frac{TL}{JG} = \frac{500 * 1000 * 900}{\frac{\pi}{2}(\frac{5600}{\pi})^2 * 75 * 10\text{^}3} = 0.0012\ Rad. \quad \textbf{Ans.}$$

=

For rectangular shaft

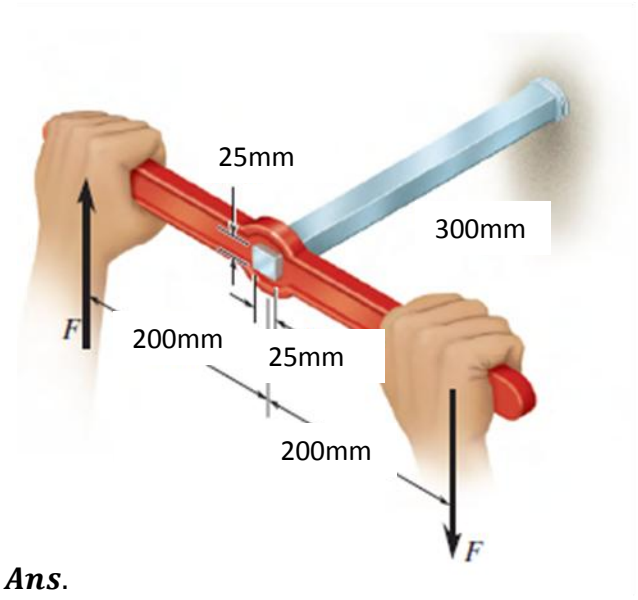
$$\phi_r = \frac{7.10\,TL}{a^4 G} = \frac{7.10 * 500 * 1000 * 900}{74.833^4 * 75 * 10\text{^}3} = 0.00136\ Rad. \quad \textbf{Ans.}$$

=

The rectangular shaft has a greater maximum shear stress and angle of twist.

5-106. The steel shaft is 300 mm. long and is screwed into the wall using a wrench. Determine the maximum shear stress in the shaft and the amount of displacement that each couple force undergoes if the couple forces have a magnitude of F = 150 N, Gst = 75 GPa.

Solution:

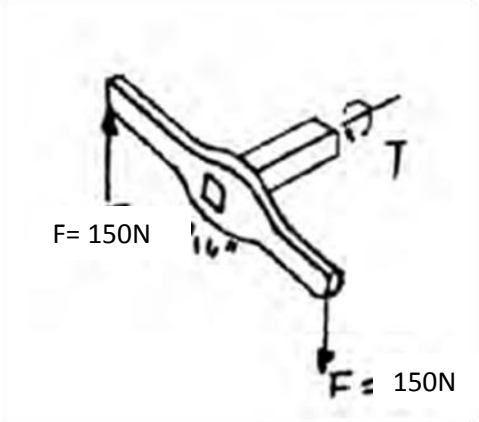


$$T - 150 * 400 = 0\ ; \quad T = 60000\ N.mm$$

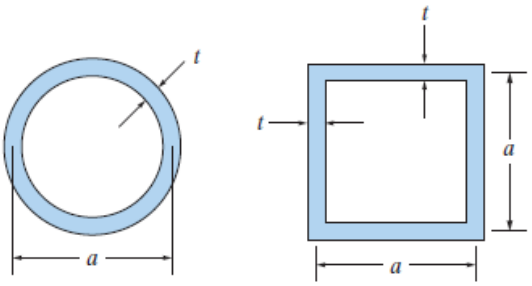
$$\tau_{max} = \frac{4.18T}{a^3} = \frac{4.18 * 60000}{25^3} = 16.1\ MPa. \quad \boldsymbol{Ans}.$$

$$\emptyset = \frac{7.1TL}{a^4 G} = \frac{7.1 * 60000 * 300}{25^4 * 75 * 10^3} = 0.00436\ Rad.$$

$$\boldsymbol{\delta_F} = 200 * 0.00436 = \mathbf{0.872\ mm} \quad \boldsymbol{Ans}.$$



5–111. A torque **T** is applied to two tubes having the cross sections shown. Compare the shear flow developed in each tube.



Circular tube:

$$q_{ct} = \frac{T}{2A_m} = \frac{T}{2\pi\,(a/2)^2} = \frac{2T}{\pi\,a^2}$$

Square tube:

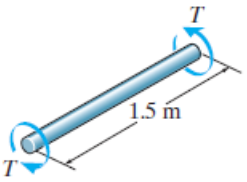
$$q_{st} = \frac{T}{2A_m} = \frac{T}{2a^2}$$

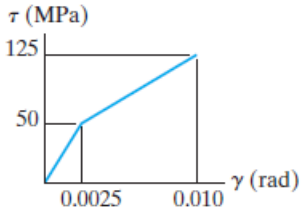
$$\frac{q_{st}}{q_{ct}} = \frac{T/(2a^2)}{2T/(\pi\,a^2)} = \frac{\pi}{4}$$

Thus;

$$q_{st} = \frac{\pi}{4}\,q_{ct}$$ **Ans.**

•5–137. The shear stress–strain diagram for a solid 50-mm-diameter shaft can be approximated as shown in the figure. Determine the torque T required to cause a maximum shear stress in the shaft of 125 MPa. If the shaft is 1.5 m long, what is the corresponding angle of twist?





Strain Diagram:

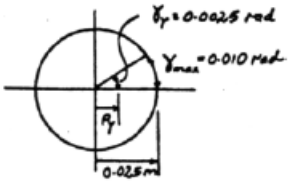
$$\frac{\rho_\gamma}{0.0025} = \frac{0.025}{0.01}; \qquad \rho_\gamma = 0.00625 \text{ m}$$

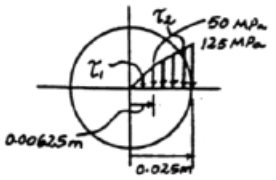
Stress Diagram:

$$\tau_1 = \frac{50(10^6)}{0.00625}\,\rho = 8(10^9)\,\rho$$

$$\frac{\tau_2 - 50(10^6)}{\rho - 0.00625} = \frac{125(10^6) - 50(10^6)}{0.025 - 0.00625}$$

$$\tau_2 = 4\left(10^9\right)\,\rho + 25\left(10^6\right)$$





The Ultimate Torque:

$$T = 2\pi \int_0^c \tau\,\rho^2 d\rho$$

$$= 2\pi \int_0^{0.00625\text{ m}} 8\left(10^9\right)\rho^3\,d\rho + 2\pi \int_{0.00625\text{ m}}^{0.025\text{ m}} \left[4\left(10^9\right)\rho + 25\left(10^6\right)\right]\rho^2 d\rho$$

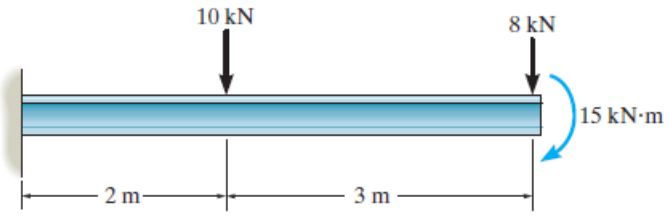
$$= 2\pi\left[2\left(10^9\right)\rho^4\right]\Big|_0^{0.00625\text{m}} + 2\pi\left[1\left(10^9\right)\rho^4 + \frac{25(10^6)\rho^3}{3}\right]\Bigg|_{0.00625\text{ m}}^{0.025\text{ m}}$$

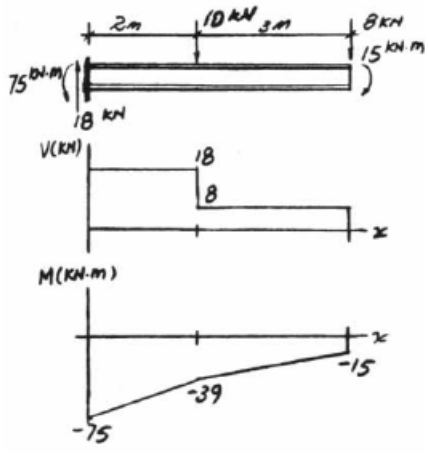
$$= 3269.30\text{ N}\cdot\text{m} = 3.27\text{ kN}\cdot\text{m} \qquad \textbf{Ans.}$$

Angle of Twist:

$$\phi = \frac{\gamma_{\max}}{c}L = \left(\frac{0.01}{0.025}\right)(1.5) = 0.60\text{ rad} = 34.4^\circ \qquad \textbf{Ans.}$$

6–5. Draw the shear and moment diagrams for the beam.





6–6. Draw the shear and moment diagrams for the overhang beam.