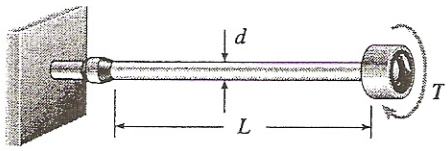
Solution 3.3-6 Socket wrench



$d = 8.0$ mm $\quad L = 200$ mm

$\tau_{allow} = 60$ MPa $\quad G = 78$ GPa

MAXIMUM PERMISSIBLE TORQUE

From Eq. (3-12): $\tau_{max} = \dfrac{16T}{\pi d^3}$

$$T_{max} = \frac{\pi d^3 \tau_{max}}{16}$$

$$T_{max} = \frac{\pi(8.0 \text{ mm})^3(60 \text{ MPa})}{16}$$

$$T_{max} = 6.03 \text{ N} \cdot \text{m} \quad \longleftarrow$$

ANGLE OF TWIST

From Eq. (3-15): $\phi = \dfrac{T_{max} L}{G I_P}$

From Eq. (3-12): $T_{max} = \dfrac{\pi d^3 \tau_{max}}{16}$

$$\phi = \left(\frac{\pi d^3 \tau_{max}}{16}\right)\left(\frac{L}{G I_P}\right) \quad I_P = \frac{\pi d^4}{32}$$

$$\phi = \frac{\pi d^3 \tau_{max} L(32)}{16 G(\pi d^4)} = \frac{2\tau_{max} L}{G d}$$

$$\phi = \frac{2(60 \text{ MPa})(200 \text{ mm})}{(78 \text{ GPa})(8.0 \text{ mm})} = 0.03846 \text{ rad}$$

$$\phi = (0.03846 \text{ rad})\left(\frac{180}{\pi} \text{deg/rad}\right) = 2.20° \quad \longleftarrow$$

Solution 3.5-1 Hollow aluminum shaft

$d_2 = 4.0$ in. $\quad d_1 = 2.0$ in. $\quad \theta = 0.54°/\text{ft}$

$G = 4.0 \times 10^6$ psi

MAXIMUM SHEAR STRESS

$\tau_{max} = G r \theta$ (from Eq. 3-7a)

$r = d_2/2 = 2.0$ in.

$$\theta = (0.54°/\text{ft})\left(\frac{1 \text{ ft}}{12 \text{ in.}}\right)\left(\frac{\pi \text{ rad}}{180 \text{ degree}}\right)$$

$$= 785.40 \times 10^{-6} \text{ rad/in.}$$

$$\tau_{max} = (4.0 \times 10^6 \text{ psi})(2.0 \text{ in.})(785.40 \times 10^{-6} \text{ rad/in.})$$

$$= 6283.2 \text{ psi}$$

(a) MAXIMUM TENSILE STRESS

σ_{max} occurs on a 45° plane and is equal to τ_{max}.

$\sigma_{max} = \tau_{max} = 6280$ psi $\quad \longleftarrow$

(b) APPLIED TORQUE

Use the torsion formula $\tau_{max} = \dfrac{Tr}{I_P}$

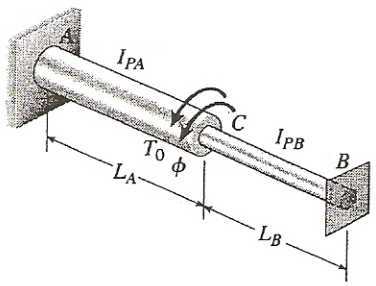
$$T = \frac{\tau_{max} I_P}{r} \quad I_P = \frac{\pi}{32}[(4.0 \text{ in.})^4 - (2.0 \text{ in.})^4]$$

$$= 23.562 \text{ in.}^4$$

$$T = \frac{(6283.2 \text{ psi})(23.562 \text{ in.}^4)}{2.0 \text{ in.}}$$

$$= 74{,}000 \text{ lb-in.} \quad \longleftarrow$$

Solution 3.9-7 Statically indeterminate bar



STRAIN ENERGY (FROM EQ. 3-51B)

$$U = \sum_{i=1}^{n} \frac{G I_{Pi} \phi_i^2}{2L_i} = \frac{G I_{PA} \phi^2}{2L_A} + \frac{G I_{PB} \phi^2}{2L_B}$$

$$= \frac{G\phi^2}{2}\left(\frac{I_{PA}}{L_A} + \frac{I_{PB}}{L_B}\right)$$

WORK DONE BY THE TORQUE T_0

$$W = \frac{T_0 \phi}{2}$$

EQUATE U AND W AND SOLVE FOR ϕ

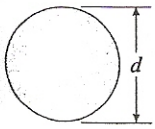
$$\frac{G\phi^2}{2}\left(\frac{I_{PA}}{L_A} + \frac{I_{PB}}{L_B}\right) = \frac{T_0 \phi}{2}$$

$$\phi = \frac{T_0 L_A L_B}{G(L_B I_{PA} + L_A I_{PB})} \quad \longleftarrow$$

(This result agrees with Eq. (3-48) of Example 3-9, Section 3.8.)

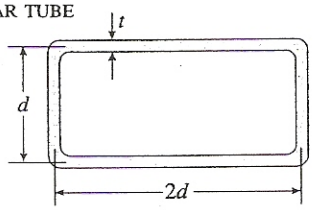
Solution 3.10-2 Bar and tube

SOLID BAR



$$\tau_{max} = \frac{16T}{\pi d^3} \qquad \text{(Eq. 3-12)}$$

RECTANGULAR TUBE



$$A_m = (d)(2d) = 2d^2 \qquad \text{(Eq. 3-64)}$$

$$\tau_{max} = \frac{T}{2tA_m} = \frac{T}{4td^2} \qquad \text{(Eq. 3-61)}$$

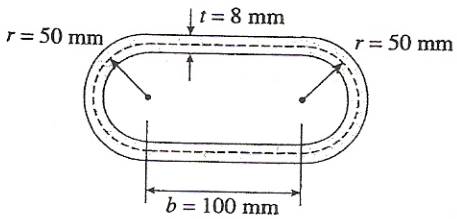
EQUATE THE MAXIMUM SHEAR STRESSES AND SOLVE FOR t

$$\frac{16T}{\pi d^3} = \frac{T}{4td^2}$$

$$t_{min} = \frac{\pi d}{64} \longleftarrow$$

If $t > t_{min}$, the shear stress in the tube is less than the shear stress in the bar.

Solution 3.10-6 Steel tube



$G = 76$ GPa

$L = 1.5$ m

$T = 10$ kN · m

$A_m = \pi r^2 + 2br$

$$A_m = \pi(50 \text{ mm})^2 + 2(100 \text{ mm})(50 \text{ mm})$$
$$= 17{,}850 \text{ mm}^2$$

$$L_m = 2b + 2\pi r$$
$$= 2(100 \text{ mm}) + 2\pi(50 \text{ mm})$$
$$= 514.2 \text{ mm}$$

$$J = \frac{4tA_m^2}{L_m} = \frac{4(8 \text{ mm})(17{,}850 \text{ mm}^2)^2}{514.2 \text{ mm}}$$
$$= 19.83 \times 10^6 \text{ mm}^4$$

SHEAR STRESS

$$\tau = \frac{T}{2tA_m} = \frac{10 \text{ kN} \cdot \text{m}}{2(8 \text{ mm})(17{,}850 \text{ mm}^2)}$$
$$= 35.0 \text{ MPa} \longleftarrow$$

ANGLE OF TWIST

$$\phi = \frac{TL}{GJ} = \frac{(10 \text{ kN} \cdot \text{m})(1.5 \text{ m})}{(76 \text{ GPa})(19.83 \times 10^6 \text{ mm}^4)}$$
$$= 0.00995 \text{ rad}$$
$$= 0.570° \longleftarrow$$