6-18*

(a) $\tau_{max} = \dfrac{Tc}{J} = \dfrac{(45{,}000)(0.075)}{\pi(0.075)^4/2} = 67.9(10^6)\ \text{N/m}^2 = 67.9\ \text{MPa}$ .... **Ans.**

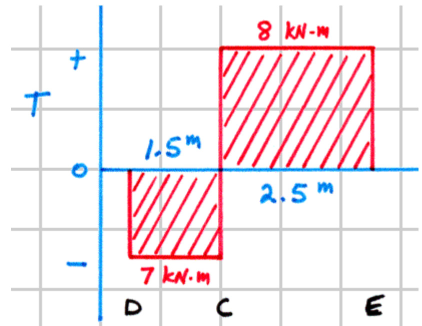
(b) $T_C = (150/450)(45) = 15\ \text{kN}\cdot\text{m}$ $T_D = 15 - 8 = 7\ \text{kN}\cdot\text{m}$

$\tau_{max} = \tau_{CE} = \dfrac{(8000)(0.040)}{\pi(0.040)^4/2} = 79.6(10^6)\ \text{N/m}^2$

$\tau_{max} = 79.6\ \text{MPa}$ .... **Ans.**

(c) $\theta = \dfrac{TL}{JG} = \dfrac{(8000)(2.5) + (-7000)(1.5)}{\left[\pi(0.040)^4/2\right](80\times10^9)}$

$\theta = 0.0295\ \text{rad}$ .... **Ans.**



6-22

With the left end of the shaft at $x = L$
and the right end of the shaft at $x = 2L$

$$\rho = rx/L$$

$$J = \frac{\pi}{2}\left(\rho^4 - R^4\right) = \frac{\pi}{2L^4}\left(r^4x^4 - R^4L^4\right)$$

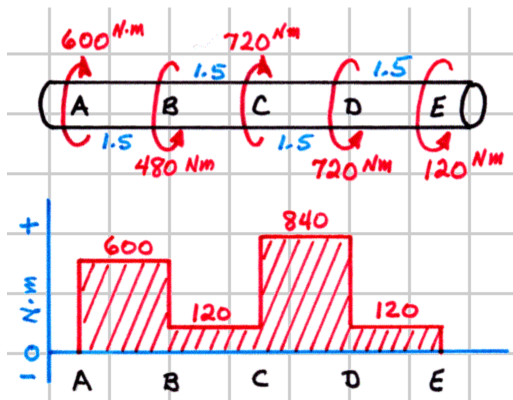
$$d\theta = \frac{T\,dx}{JG} = \frac{2TL^4}{\pi G}\left(\frac{dx}{r^4x^4 - R^4L^4}\right)$$

$$\theta = \int d\theta = \frac{2TL^4}{\pi G}\int_L^{2L}\left(\frac{dx}{r^4x^4 - R^4L^4}\right)$$

$$\theta = \frac{TL}{2\pi GR^3 r}\left[\ln\left(\frac{2r-R}{r-R}\right)\left(\frac{r+R}{2r+R}\right) - 2\tan^{-1}\left(\frac{2r}{R}\right) + 2\tan^{-1}\left(\frac{r}{R}\right)\right]$$ .... **Ans.**

6-36

$$J = \pi d^4/32 = \pi(20)^4/2 = 0.251327(10^6)\ \text{mm}^4$$



(a) $$\tau_{AB} = \frac{Tc}{J} = \frac{(600)(0.020)}{(0.251327\times10^{-6})} = 47.7(10^6)\ \text{N/m}^2$$

$\tau_{AB} = 47.7$ MPa ....**Ans.**

$$\tau_{BC} = \frac{(120)(0.020)}{(0.251327\times10^{-6})} = 9.55(10^6)\ \text{N/m}^2$$

$\tau_{BC} = 9.55$ MPa .... **Ans.**

$$\tau_{CD} = \frac{(840)(0.020)}{(0.251327\times10^{-6})} = 66.8(10^6)\ \text{N/m}^2 = 66.8\ \text{MPa}$$ .... **Ans.**

$$\tau_{DE} = \frac{(120)(0.020)}{(0.251327\times10^{-6})} = 9.55(10^6)\ \text{N/m}^2 = 9.55\ \text{MPa}$$ .... **Ans.**

(b) $\sigma_{\max T} = \sigma_{\max C} = \tau_{\max T} = 66.8$ MPa (T&C) .... **Ans.**

(c) $$\theta = \frac{TL}{JG} = \frac{(600+120+840+120)(1.5)}{(0.251327\times10^{-6})(76\times10^9)} = 0.1319\ \text{rad}$$ .... **Ans.**

6-47

(a) Motor shaft: $Power = T\omega = \dfrac{2\pi NT}{60} = \dfrac{2\pi(360)T_1}{60} = (100\times 550)\ \text{lb}\cdot\text{ft/s}$

$T_1 = 1458.92031\ \text{lb}\cdot\text{ft} = 17{,}507.0\ \text{lb}\cdot\text{in.}$

$\tau = \dfrac{Tc}{J} = \dfrac{(17.5070)(d_1/2)}{\pi d_1^4/32} = 12\ \text{ksi}$ $d_1 = 1.951\ \text{in.}$ .... **Ans.**

(b) Power shaft: $N_{power} = (96/16)N_{motor} = 6(360) = 2160\ \text{rpm}$

$Power = T\omega = \dfrac{2\pi NT}{60} = \dfrac{2\pi(2160)T}{60} = (100\times 550)\ \text{lb}\cdot\text{ft/s}$

$T_2 = 243.15339\ \text{lb}\cdot\text{ft} = 2917.84\ \text{lb}\cdot\text{in.}\ (= T_1/6)$

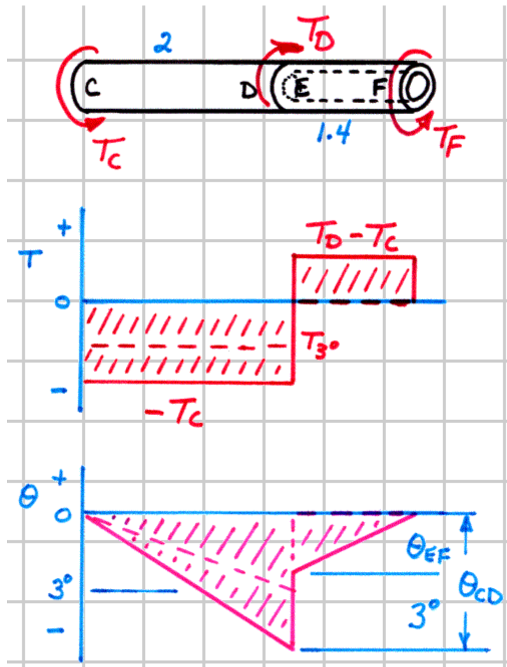
$\tau = \dfrac{(2.91784)(d_2/2)}{\pi d_2^4/32} = 12\ \text{ksi}$ $d_2 = 1.074\ \text{in.}$ .... **Ans.**

6-74

$$J_s = \frac{\pi d^4}{32} = \frac{\pi(120)^4}{32} = 20.35752(10^6) \text{ mm}^4 \qquad \theta = TL/JG$$

$$J_a = \frac{\pi(120^4 - 60^4)}{32} = 19.08518(10^6) \text{ mm}^4$$

$$J_b = \frac{\pi(60)^4}{32} = 1.272345(10^6) \text{ mm}^4$$



Equilibrium: $T_s = -T_C$ (a)

$T_D - T_C = T_a + T_b$ (b)

Deformations: $\theta_{total} = \theta_{CD} + \theta_{slip} + \theta_{EF} = 0$ (c)

$\theta_{EF,a} = \theta_{EF,b}$ (d)

$$\theta_{CD} = \frac{(-T_C)(2)}{(20.35752\times10^{-6})(80\times10^9)} = -1.22805(10^{-6})(T_C) \text{ rad}$$

$$\theta_{EF,a} = \frac{(T_a)(1.40)}{(19.08518\times10^{-6})(28\times10^9)} = 2.61983(10^{-6})(T_a) \text{ rad}$$

6-74 (cont.)

$$\theta_{EF,b} = \frac{(T_b)(1.40)}{(1.272345\times 10^{-6})(45\times 10^{9})} = 24.45179(10^{-6})(T_b)\ \text{rad}$$

If $\theta_{CD} \le 3° = 0.0523599\ \text{rad}$, then $T_C = T_D \qquad T_a = T_b = \theta_{EF} = 0$

If $\theta_{CD} \ge 3° = 0.0523599\ \text{rad}$, then

$$2.61983(10^{-6})(T_a) = 24.45179(10^{-6})(T_b) \qquad \text{(d)}$$

$$T_a = 9.33335 T_b$$

$$-1.22805(10^{-6})T_C + \frac{3\pi}{180} + 2.61983(10^{-6})(T_a) = 0 \qquad \text{(c)}$$

$$T_C = [42{,}636.60 + 2.13333 T_a]\ \text{N} = [42{,}636.60 + 19.91107 T_b]\ \text{N}$$

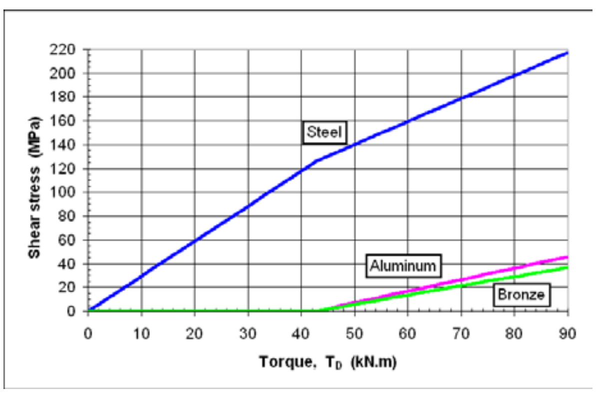
$$T_D = (42{,}636.60 + 19.91107 T_b) + (9.33335 T_b) + T_b \qquad \text{(b)}$$

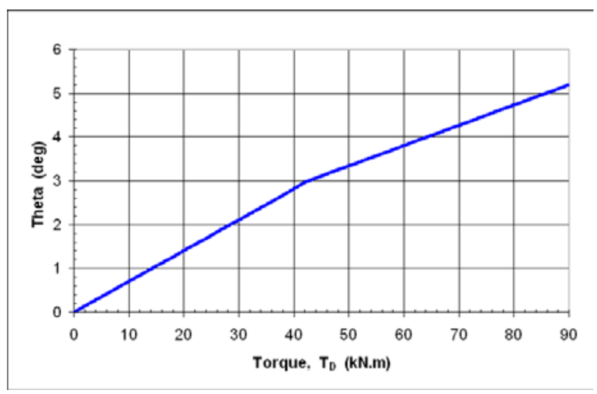
$$T_b = (0.0330639 T_D - 1409.734)\ \text{N} \qquad T_a = (0.308597 T_D - 13{,}157.54)\ \text{N}$$

$$T_s = -(0.658338 T_D + 14{,}567.29)\ \text{N}$$

$$\tau_a = \frac{(T_a)(0.060)}{(19.08518\times 10^{-6})} \qquad \tau_b = \frac{(T_b)(0.030)}{(1.272345\times 10^{-6})} \qquad \tau_s = \frac{(T_s)(0.030)}{(20.35752\times 10^{-6})}$$

$$\theta_D = \theta_{CD} = \frac{(T_s)(2)}{(20.35752\times 10^{-6})(80\times 10^{9})}$$





6-87*

$$\varepsilon_n = \varepsilon_x \cos^2\theta + \varepsilon_y \sin^2\theta + \gamma_{xy}\sin\theta\cos\theta$$

$$= (36)\cos^2(45°) + (150)\sin^2(45°) + \gamma_{xy}\sin(45°)\cos(45°) = 310$$

$$\gamma_{xy} = 434.00\ \mu\text{rad}$$

$$\sigma_a = \sigma_x = \frac{E}{1-\nu^2}\left[\varepsilon_a + \nu\varepsilon_b\right] = \frac{30,000}{1-(0.30)^2}\left[36 + (0.30)(150)\right](10^{-6}) = 2.67033\text{ ksi}$$

$$\sigma_b = \sigma_y = \frac{E}{1-\nu^2}\left[\varepsilon_b + \nu\varepsilon_a\right] = \frac{30,000}{1-(0.30)^2}\left[(150) + (0.30)(36)\right](10^{-6}) = 5.30110\text{ ksi}$$

$$p = \frac{2\sigma_a t}{r} = \frac{2(2.67033)(0.375)}{10} = 200\text{ psi}$$ .... **Ans.**

$$\tau_{xy} = \frac{E\gamma_{xy}}{2(1+\nu)} = \frac{(30,000)(434.00\times10^{-6})}{2(1+0.30)} = 5.00769\text{ ksi}$$

$$J = \pi d^4/32 = \pi\left(20.75^4 - 20^4\right)/32 = 2492.075\text{ in}^4$$

$$T = \frac{\tau_{xy}J}{c} = \frac{(5007.69)(2492.075)}{(10.375)}$$

$$T = 1.20285(10^6)\text{ lb}\cdot\text{in.} = 100.2\text{ kip}\cdot\text{ft}$$ .... **Ans.**

6-98*

$$\tau_{\max} = K_t \frac{Tc}{J} = K_t \frac{(3270)(d/2)}{\pi d^4/32} = 60\left(10^6\right) \text{ N/m}^2$$

$$d^3 = 277.56622\left(10^{-6}\right) K_t \qquad \text{(a)}$$

Guess $K_t \cong 2.0$ Then Eq. (*a*) $d = 0.08219$ m

$r/d = 5/82.19 = 0.061$ $D/d = 100/82.19 = 1.22$

and from Fig. 6-25*b* $K_t \cong 1.8$

2nd guess $K_t \cong 1.8$ Then Eq. (*a*) $d = 0.07935$ m

$r/d = 5/79.35 = 0.063$ $D/d = 100/79.35 = 1.26$

and from Fig. 6-25*b* $K_t \cong 1.8$

Therefore, the 2nd guess was correct, and $d = 79$ mm .... **Ans.**

6-148

$$J_{AB,s} = \pi d^4/32 = \pi(160)^4/32 = 64.33982(10^6)\text{ mm}^4$$

$$J_{BC,s} = \pi(160^4 - 100^4)/32 = 54.52234(10^6)\text{ mm}^4$$

$$J_{BC,b} = \pi(100)^4/32 = 9.81748(10^6)\text{ mm}^4$$

Equilibrium: $T_s + T_b = 75\text{ kN}\cdot\text{m}$ (a)

Deformations: $\theta_{BC,s} = \theta_{BC,b}$ $\theta = TL/JG$

$$\frac{T_s(1.5)}{(54.52234\times10^{-6})(80\times10^9)} = \frac{T_b(1.5)}{(9.81748\times10^{-6})(40\times10^9)}$$

$$T_s = 11.10720 T_b \qquad \text{(b)}$$

$$T_b = 6.19466\text{ kN}\cdot\text{m} \qquad T_s = 68.80534\text{ kN}\cdot\text{m}$$

In *AB*: $\tau_s = \dfrac{Tc}{J} = \dfrac{(85{,}000)(0.08)}{(64.33982\times10^{-6})} = 105.6888(10^6)\text{ N/m}^2 = 105.6888\text{ MPa}$

In *BC*: $\tau_s = \dfrac{(68{,}805.34)(0.08)}{(54.52234\times10^{-6})} = 101.0(10^6)\text{ N/m}^2 = 101.0\text{ MPa}$

$$\tau_b = \frac{(6194.66)(0.05)}{(9.81748\times10^{-6})} = 31.5(10^6)\text{ N/m}^2 = 31.5\text{ MPa}$$

(a) $\tau_{\max,s} = 105.7\text{ MPa}$ .... $\tau_{\max,b} = 31.5\text{ MPa}$ .... **Ans.**

(b) $\theta_D = \theta_{B/A} + \theta_{C/B} + \theta_{D/C}$ $\theta_D = TL/JG$

$$\theta_D = \frac{(85{,}000)(2)}{(64.33982\times10^{-6})(80\times10^9)} + \frac{(-68{,}805.34)(1.5)}{(54.52234\times10^{-6})(80\times10^9)} + 0$$

$\theta_D = 0.00937\text{ rad}$ .... **Ans.**