2.1 (a) $\delta = \frac{PL}{AE} = \frac{(800\text{ lb})(12\text{ in.})}{\pi(0.25\text{in})^2(0.45\times10^6\text{ psi})}$

$\delta = 0.1086$ in.

(b) $\sigma = \frac{P}{A} = \frac{800\text{ lb}}{\pi(0.25\text{ in.})^2}$ $\qquad \sigma = 4.07$ ksi

2.67 $\epsilon_y = \frac{\delta}{L} = \frac{14\text{ mm}}{150\text{ mm}} = 0.09333$

$\epsilon_x = \frac{\Delta d}{d} = \frac{-0.85\text{mm}}{20\text{ mm}} = -0.0425$

$\nu = -\frac{\epsilon_x}{\epsilon_y} = -\frac{-0.0425}{0.09333} = 0.45536, \quad \nu = 0.455$

$\sigma_y = \frac{P}{A} = \frac{6\times10^3\text{N}}{\pi(0.01\text{m})^2} = 19.099$ MPa

$E = \frac{\sigma_y}{\epsilon_y} = \frac{19.099\text{ MPa}}{0.09333} = 204.63$ MPa $\qquad E = 205$ MPa

From Eq. (2.43'): $G = \frac{E}{2(1+\nu)}$

$G = \frac{204.63\text{ MPa}}{2(1+0.45536)}$ $\qquad G = 70.3$ MPa

3.2 $\tau = \frac{Tc}{J}: \quad T = \frac{J}{c}\tau$

(a) $T = \frac{\frac{\pi}{2}[(0.045\text{m})^4-(0.030\text{m})^4]}{0.045\text{m}}(45\times10^6\text{ Pa}) = 5.1689\times10^3$

$T = 5.17$ kN·m

(b) $A = \pi[(45\text{mm})^2-(30\text{mm})^2] = \pi c^2 \qquad c = 33.541$ mm

$\tau = \frac{Tc}{J} = \frac{Tc}{\frac{\pi}{2}c^4} = \frac{2}{\pi}\frac{T}{c^3} = \frac{2}{\pi}\frac{5.1689\times10^3\text{ N·m}}{(33.541\times10^{-3}\text{m})^3}$

$\tau = 87.2$ MPa

3.15 Shaft AB: $\tau = 50$ MPa $\qquad c = 0.020$ m

Using Eq. (1) of Prob. 3.9:

$T_{AB} = \frac{\pi}{2}c^3\tau = \frac{\pi}{2}(0.020\text{ m})^3(50\times10^6\text{ Pa}) = 628$ N·m

Shaft CD: $\tau = 50$ MPa $\qquad c = 0.030$ m

$T_{CD} = \frac{\pi}{2}c^3\tau = \frac{\pi}{2}(0.030\text{ m})^3(50\times10^6\text{ Pa}) = 2121$ N·m

Recalling Eq. (3) of solution of Prob. 3.13:

$T_{AB} = \frac{r_B}{r_C}T_{CD} = \frac{100\text{mm}}{250\text{mm}}(2121\text{ N·m}) = 848$ N·m

Stress in shaft AB is critical: $\qquad T = 628$ N·m

2.5-8 $\delta_B = -\delta_S \quad P_B = -P_S = \sigma_B A_B = -\sigma_S A_S$

$\frac{P_B L}{E_A A_A} + \alpha_B \Delta T L = \frac{P_S L}{E_B A_B} + \alpha_S \Delta T L$ $\boxed{\text{Because } L_B = L_S = L}$

$\sigma_B/E_B + \alpha_B\Delta T = \frac{\sigma_S}{E_S} + \alpha_S\Delta T$

But $\sigma_B = -\sigma_S A_S/A_B \rightarrow -\frac{\sigma_S A_S}{E_B A_B} + \alpha_B\Delta T = \frac{\sigma_S}{E_S} + \alpha_S\Delta T$

$-\sigma_S\left[\frac{A_S}{A_B}\frac{1}{E_B}+\frac{1}{E_S}\right] = (\alpha_S-\alpha_B)\Delta T$ But $A_S = \frac{\pi}{4}(.036^2-.026^2)$

$A_S = 4.869\times10^{-4}\text{m}^2 \quad A_B = \frac{\pi}{4}(.025)^2 = 4.908\times10^{-6}\text{m}^2$

$A_S/A_B = 0.9919 \quad \Delta T = \sigma_B\left[\frac{A_S}{A_B}\frac{1}{E_B}+\frac{1}{E_S}\right]\left[\frac{1}{\alpha_B-\alpha_S}\right]$

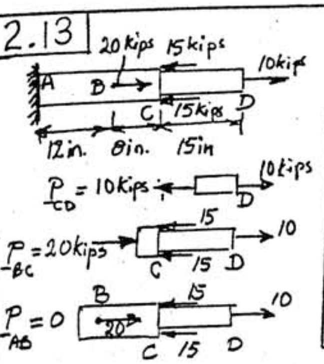
$\Delta T = -75\times10^6\left[\frac{.9918}{200\times10^9}+\frac{1}{100\times10^9}\right]\left[\frac{1}{10\times10^{-6}-21\times10^{-6}}\right]$

$\Delta T = 33.998 = 34°C$

note subscript S for sleeve B for Bolt

2.13 $d_{AB} = d_{BC} = 2.25$ in

$d_{CD} = 1.75$ in. $\quad E = 10\times10^6$ psi



Portion	P_i	L_i	A_i	$\frac{P_iL_i}{A_iE}$
CD	10×10^3	15	2.405	6.236×10^{-3}
BC	-20×10^3	8	3.976	-4.024×10^{-3}
AB	0	12	3.976	0

(a) $\delta_{AD} = \sum\frac{P_iL_i}{A_iE} = 6.236\times10^{-3} - 4.024\times10^{-3} = +2.21\times10^{-3}$ in.

(b) $\delta_C = -4.024\times10^{-3} + 0$ $\qquad \delta_C = 4.02\times10^{-3}$ in. ←

2.98 (a) Considering the hole: $t = \frac{3}{4}$ in.

$D = b = 3$ in., $d = 3 - 0.6 = 2.4$ in., $r = \frac{1}{2}(0.6) = 0.3$in.

$\frac{r}{d} = \frac{0.3\text{ in.}}{2.4\text{ in.}} = 0.125.$ Fig. 2.59 → $K = 2.45$

$\sigma_{max} = K\frac{P}{A}: \quad P = \frac{A\sigma_{max}}{K} = \frac{td\sigma_{all}}{K}$ with $\sigma_{all} = 24$ ksi

$P = \frac{(\frac{3}{4}\text{in.})(2.4\text{in.})(24\text{ ksi})}{2.45}$, $\quad P = 17.63$ kips

(b) Considering the fillet: $d = b = 3$in., $t = \frac{3}{4}$ in.

$\sigma_{max} = K\frac{P}{A}: \quad K = \frac{A\sigma_{max}}{P} = \frac{td\sigma_{all}}{P}$ with $\sigma_{all} = 24$ ksi

$K = \frac{(\frac{3}{4}\text{ in.})(3\text{ in.})(24\text{ ksi})}{17.63\text{ kips}} = 3.06$

From Fig. 2.59 for $K = 3.06$ and $\frac{D}{d} = \frac{4.5\text{ in.}}{3\text{ in.}} = 1.5$,

we obtain $r_f/d = 0.05$

Thus: $r_f = 0.05d = 0.05(3\text{ in.}), \quad r_f = 0.15$ in.

3.23 (a) Hollow shaft

$J = \frac{\pi}{2}(c_2^4 - c_1^4) = \frac{\pi}{2}[(0.045\text{ m})^4 - (0.030\text{ m})^4] = 5.1689\times10^{-6}$

$\phi = \frac{TL}{JG}, \quad T = \frac{JG}{L}\phi = \frac{(5.1689\times10^{-6})(77\times10^9)}{2.4}\left(3°\times\frac{\pi\text{ rad}}{180°}\right)$

$T = 8.6831\times10^3$ N·m $\qquad T = 8.68$ kN·m

(b) Solid shaft of same cross-sectional area

$A = \pi c^2 = \pi(c_2^2 - c_1^2) \qquad c^2 = c_2^2 - c_1^2 = (45\text{mm})^2 - (30\text{mm})^2$

$c^2 = 1125\text{ mm}^2$

For solid shaft: $\phi_s = \frac{TL}{J_s G}$ $\qquad$ (same T, same L, same G)

For hollow shaft: $\phi_h = \frac{TL}{J_h G}$

$\frac{\phi_s}{\phi_h} = \frac{J_h}{J_s} = \frac{\frac{\pi}{2}(c_2^4 - c_1^4)}{\frac{\pi}{2}c^4} = \frac{c_2^4 - c_1^4}{(c^2)^2} = \frac{(45)^4 - (30)^4}{(1125)^2} = 2.600$

Thus: $\phi_s = 2.6\,\phi_h = 2.6(3°) \qquad \phi_s = 7.80°$

Alternative computation:

$\phi_s = \frac{TL}{J_s G} = \frac{(8.6831\times10^3)(2.4)}{\frac{\pi}{2}(1125\times10^{-6})^2(77\times10^9)} = 0.13614$ rad

$\phi_s = (0.13614\text{ rad})\frac{180°}{\pi} = 7.80°$