7-4 $F\cos 20°(d/2) = T_A$, $F = 2T_A/(d\cos 20°) = 2(340)/(0.150\cos 20°) = 4824$ N.
The maximum bending moment will be at point C, with $M_C = 4824(0.100) = 482.4$ N·m.
Due to the rotation, the bending is completely reversed, while the torsion is constant.
Thus, $M_a = 482.4$ N·m, $T_m = 340$ N·m, $M_m = T_a = 0$.

For sharp fillet radii at the shoulders, from Table 7-1, $K_t = 2.7$, and $K_{ts} = 2.2$. Examining Figs. 6-26 and 6-27 with $S_{ut} = 560$ MPa, conservatively estimate $q = 0.8$ and $q_s = 0.9$. These estimates can be checked once a specific fillet radius is determined.

Eq. (6-32): $K_f = 1 + 0.8(2.7 - 1) = 2.4$

$K_{fs} = 1 + 0.9(2.2 - 1) = 2.1$

(a) We will choose to include fatigue stress concentration factors even for the static analysis to avoid localized yielding.

Eq. (7-15): $$\sigma'_{\max} = \left[\left(\frac{32K_f M_a}{\pi d^3}\right)^2 + 3\left(\frac{16K_{fs}T_m}{\pi d^3}\right)^2\right]^{1/2}$$

Eq. (7-16): $$n = \frac{S_y}{\sigma'_{\max}} = \frac{\pi d^3 S_y}{16}\left[4\left(K_f M_a\right)^2 + 3\left(K_{fs}T_m\right)^2\right]^{-1/2}$$

Solving for d,

$$d = \left\{\frac{16n}{\pi S_y}\left[4(K_f M_a)^2 + 3(K_{fs}T_a)^2\right]^{1/2}\right\}^{1/3}$$

$$= \left(\frac{16(2.5)}{\pi(420)(10^6)}\left\{4\left[(2.4)(482.4)\right]^2 + 3\left[(2.1)(340)\right]^2\right\}^{1/2}\right)^{1/3}$$

$d = 0.0430$ m $= 43.0$ mm *Ans.*

(b) Eq. (6-18): $k_a = 3.04(560)^{-0.217} = 0.77$

Assume $k_b = 0.85$ for now. Check later once a diameter is known.

$S_e = 0.77(0.85)(0.5)(560) = 183$ MPa

Selecting the DE-Goodman criteria, use Eqs. (7-6) and (7-8) with $M_m = T_a = 0$.

$$d=\left(\frac{16n}{\pi}\left\{\frac{1}{S_e}\left[4\left(K_f M_a\right)^2\right]^{1/2}+\frac{1}{S_{ut}}\left[3\left(K_{fs}T_m\right)^2\right]^{1/2}\right\}\right)^{1/3}$$

$$=\left(\frac{16(2.5)}{\pi}\left\{\frac{1}{183\left(10^6\right)}\left[4\left(2.4\times 482.4\right)^2\right]^{1/2}+\frac{1}{560\left(10^6\right)}\left[3\left(2.1\times 340\right)^2\right]^{1/2}\right\}\right)^{1/3}$$

$$=0.0574\text{ m}=57.4\text{ mm}\qquad \textit{Ans.}$$

With this diameter, we can refine our estimates for k_b and q.

Eq. (6-19): $k_b=1.51d^{-0.157}=1.51(57.4)^{-0.157}=0.80$

Assuming a sharp fillet radius, from Table 7-1, $r = 0.02d = 0.02\ (57.4) = 1.15$ mm.

Fig. (6-26): $q = 0.72$
Fig. (6-27): $q_s = 0.77$

Iterating with these new estimates,

Eq. (6-32): $K_f = 1 + 0.72\ (2.7 - 1) = 2.2$
$K_{fs} = 1 + 0.77(2.2 - 1) = 1.9$
Eq. (6-18): $S_e = 0.77(0.80)(0.5)(560) = 172.5$ MPa
Eq. (7-8): $d = 57$ mm *Ans.*

Further iteration does not change the results.