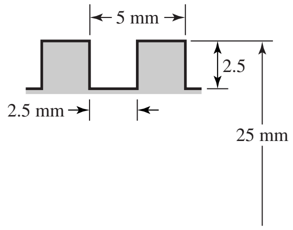
# Chapter 8

**8-1**

**(a)**




Thread depth = 2.5 mm *Ans.*

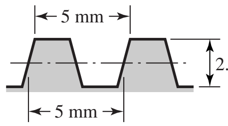
Width = 2.5 mm *Ans.*

$$d_m = 25 - 1.25 - 1.25 = 22.5 \text{ mm}$$

$$d_r = 25 - 5 = 20 \text{ mm}$$

$$l = p = 5 \text{ mm} \quad \textit{Ans.}$$

**(b)**




Thread depth = 2.5 mm *Ans.*

Width at pitch line = 2.5 mm *Ans.*

$$d_m = 22.5 \text{ mm}$$

$$d_r = 20 \text{ mm}$$

$$l = p = 5 \text{ mm} \quad \textit{Ans.}$$

**8-2** From Table 8-1,

$$d_r = d - 1.226\,869p$$

$$d_m = d - 0.649\,519p$$

$$\bar{d} = \frac{d - 1.226\,869p + d - 0.649\,519p}{2} = d - 0.938\,194p$$

$$A_t = \frac{\pi \bar{d}^2}{4} = \frac{\pi}{4}(d - 0.938\,194p)^2 \quad \textit{Ans.}$$

**8-3** From Eq. ($c$) of Sec. 8-2,

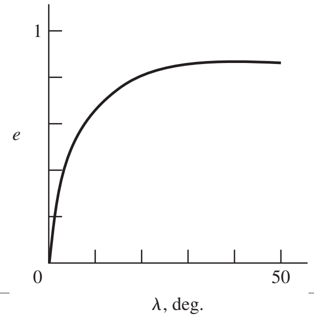
$$P = F\frac{\tan\lambda + f}{1 - f\tan\lambda}$$

$$T = \frac{Pd_m}{2} = \frac{Fd_m}{2}\,\frac{\tan\lambda + f}{1 - f\tan\lambda}$$

$$e = \frac{T_0}{T} = \frac{Fl/(2\pi)}{Fd_m/2}\,\frac{1 - f\tan\lambda}{\tan\lambda + f} = \tan\lambda\frac{1 - f\tan\lambda}{\tan\lambda + f} \quad \textit{Ans.}$$

Using $f = 0.08$, form a table and plot the efficiency curve.

| $\lambda$, deg. | $e$ |
|---|---|
| 0 | 0 |
| 10 | 0.678 |
| 20 | 0.796 |
| 30 | 0.838 |
| 40 | 0.8517 |
| 45 | 0.8519 |



**8-4** Given $F = 6$ kN, $l = 5$ mm, and $d_m = 22.5$ mm, the torque required to raise the load is found using Eqs. (8-1) and (8-6)

$$T_R = \frac{6(22.5)}{2}\left[\frac{5 + \pi(0.08)(22.5)}{\pi(22.5) - 0.08(5)}\right] + \frac{6(0.05)(40)}{2}$$

$$= 10.23 + 6 = 16.23 \text{ N} \cdot \text{m} \quad Ans.$$

The torque required to lower the load, from Eqs. (8-2) and (8-6) is

$$T_L = \frac{6(22.5)}{2}\left[\frac{\pi(0.08)22.5 - 5}{\pi(22.5) + 0.08(5)}\right] + \frac{6(0.05)(40)}{2}$$

$$= 0.622 + 6 = 6.622 \text{ N} \cdot \text{m} \quad Ans.$$

Since $T_L$ is positive, the thread is self-locking. The efficiency is

Eq. (8-4): $$e = \frac{6(5)}{2\pi(16.23)} = 0.294 \quad Ans.$$

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**8-5** Collar (thrust) bearings, at the bottom of the screws, must bear on the collars. The bottom segment of the screws must be in compression. Where as tension specimens and their grips must be in tension. Both screws must be of the same-hand threads.

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**8-6** Screws rotate at an angular rate of

$$n = \frac{1720}{75} = 22.9 \text{ rev/min}$$

**(a)** The lead is 0.5 in, so the linear speed of the press head is

$$V = 22.9(0.5) = 11.5 \text{ in/min} \quad Ans.$$

**(b)** $F = 2500$ lbf/screw

$$d_m = 3 - 0.25 = 2.75 \text{ in}$$

$$\sec\alpha = 1/\cos(29/2) = 1.033$$

Eq. (8-5):

$$T_R = \frac{2500(2.75)}{2}\left(\frac{0.5 + \pi(0.05)(2.75)(1.033)}{\pi(2.75) - 0.5(0.05)(1.033)}\right) = 377.6 \text{ lbf} \cdot \text{in}$$

Eq. (8-6):

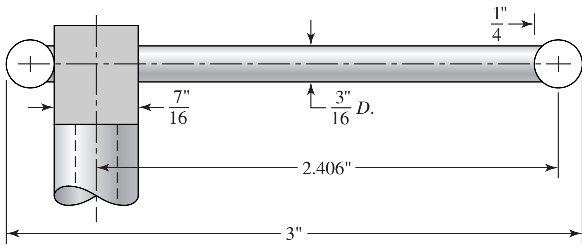
$$T_c = 2500(0.06)(5/2) = 375 \text{ lbf} \cdot \text{in}$$

$$T_{\text{total}} = 377.6 + 375 = 753 \text{ lbf} \cdot \text{in/screw}$$

$$T_{\text{motor}} = \frac{753(2)}{75(0.95)} = 21.1 \text{ lbf} \cdot \text{in}$$

$$H = \frac{Tn}{63\,025} = \frac{21.1(1720)}{63\,025} = 0.58 \text{ hp} \quad Ans.$$

**8-7** The force $F$ is perpendicular to the paper.




$$L = 3 - \frac{1}{8} - \frac{1}{4} - \frac{7}{32} = 2.406 \text{ in}$$

$$T = 2.406F$$

$$M = \left(L - \frac{7}{32}\right)F = \left(2.406 - \frac{7}{32}\right)F = 2.188F$$

$$S_y = 41 \text{ kpsi}$$

$$\sigma = S_y = \frac{32M}{\pi d^3} = \frac{32(2.188)F}{\pi(0.1875)^3} = 41\,000$$

$$F = 12.13 \text{ lbf}$$

$$T = 2.406(12.13) = 29.2 \text{ lbf} \cdot \text{in} \quad \textit{Ans.}$$

**(b)** Eq. (8-5), $2\alpha = 60^\circ$, $l = 1/14 = 0.0714$ in, $f = 0.075$, $\sec\alpha = 1.155$, $p = 1/14$ in

$$d_m = \frac{7}{16} - 0.649\,519\left(\frac{1}{14}\right) = 0.3911 \text{ in}$$

$$T_R = \frac{F_{\text{clamp}}(0.3911)}{2}\left(\frac{\text{Num}}{\text{Den}}\right)$$

$$\text{Num} = 0.0714 + \pi(0.075)(0.3911)(1.155)$$

$$\text{Den} = \pi(0.3911) - 0.075(0.0714)(1.155)$$

$$T = 0.028\,45 F_{\text{clamp}}$$

$$F_{\text{clamp}} = \frac{T}{0.028\,45} = \frac{29.2}{0.028\,45} = 1030 \text{ lbf} \quad \textit{Ans.}$$

**(c)** The column has one end fixed and the other end pivoted. Base decision on the mean diameter column. Input: $C = 1.2$, $D = 0.391$ in, $S_y = 41$ kpsi, $E = 30(10^6)$ psi, $L = 4.1875$ in, $k = D/4 = 0.097\,75$ in, $L/k = 42.8$.

For this J. B. Johnson column, the critical load represents the limiting clamping force for bucking. Thus, $F_{\text{clamp}} = P_{\text{cr}} = 4663$ lbf.

**(d)** This is a subject for class discussion.

**8-8**

$$T = 6(2.75) = 16.5 \text{ lbf} \cdot \text{in}$$

$$d_m = \frac{5}{8} - \frac{1}{12} = 0.5417 \text{ in}$$

$$l = \frac{1}{6} = 0.1667 \text{ in}, \quad \alpha = \frac{29^\circ}{2} = 14.5^\circ, \quad \sec 14.5^\circ = 1.033$$

Eq. (8-5): $$T = 0.5417(F/2)\left[\frac{0.1667 + \pi(0.15)(0.5417)(1.033)}{\pi(0.5417) - 0.15(0.1667)(1.033)}\right] = 0.0696F$$

Eq. (8-6): $$T_c = 0.15(7/16)(F/2) = 0.032\,81F$$

$$T_{\text{total}} = (0.0696 + 0.0328)F = 0.1024F$$

$$F = \frac{16.5}{0.1024} = 161 \text{ lbf} \quad \textit{Ans.}$$

**8-9** $d_m = 40 - 3 = 37$ mm, $l = 2(6) = 12$ mm

From Eq. (8-1) and Eq. (8-6)

$$T_R = \frac{10(37)}{2}\left[\frac{12 + \pi(0.10)(37)}{\pi(37) - 0.10(12)}\right] + \frac{10(0.15)(60)}{2}$$

$$= 38.0 + 45 = 83.0 \text{ N} \cdot \text{m}$$

Since $n = V/l = 48/12 = 4$ rev/s

$$\omega = 2\pi n = 2\pi(4) = 8\pi \text{ rad/s}$$

so the power is

$$H = T\omega = 83.0(8\pi) = 2086\ W \quad \textit{Ans.}$$

**8-10**

**(a)** $d_m = 36 - 3 = 33$ mm, $l = p = 6$ mm

From Eqs. (8-1) and (8-6)

$$T = \frac{33F}{2}\left[\frac{6 + \pi(0.14)(33)}{\pi(33) - 0.14(6)}\right] + \frac{0.09(90)F}{2}$$

$$= (3.292 + 4.050)F = 7.34F \text{ N} \cdot \text{m}$$

$$\omega = 2\pi n = 2\pi(1) = 2\pi \text{ rad/s}$$

$$H = T\omega$$

$$T = \frac{H}{\omega} = \frac{3000}{2\pi} = 477 \text{ N} \cdot \text{m}$$

$$F = \frac{477}{7.34} = 65.0 \text{ kN} \quad \textit{Ans.}$$

**(b)** $e = \dfrac{Fl}{2\pi T} = \dfrac{65.0(6)}{2\pi(477)} = 0.130 \quad \textit{Ans.}$

**8-11**

**(a)** $L_T = 2D + \dfrac{1}{4} = 2(0.5) + 0.25 = 1.25$ in *Ans.*

**(b)** From Table A-32 the washer thickness is 0.109 in. Thus,

$$l = 0.5 + 0.5 + 0.109 = 1.109 \text{ in} \quad \textit{Ans.}$$

**(c)** From Table A-31, $H = \dfrac{7}{16} = 0.4375$ in *Ans.*

**(d)** $l + H = 1.109 + 0.4375 = 1.5465$ in
This would be rounded to 1.75 in per Table A-17. The bolt is long enough. *Ans.*

**(e)** $l_d = L - L_T = 1.75 - 1.25 = 0.500$ in *Ans.*

$l_t = l - l_d = 1.109 - 0.500 = 0.609$ in *Ans.*

These lengths are needed to estimate bolt spring rate $k_b$.

*Note:* In an analysis problem, you need not know the fastener's length at the outset, although you can certainly check, if appropriate.

**8-12**

**(a)** $L_T = 2D + 6 = 2(14) + 6 = 34$ mm *Ans.*

**(b)** From Table A-33, the maximum washer thickness is 3.5 mm. Thus, the grip is, $l = 14 + 14 + 3.5 = 31.5$ mm *Ans.*

**(c)** From Table A-31, $H = 12.8$ mm

**(d)** $l + H = 31.5 + 12.8 = 44.3$ mm
Adding one or two threads and rounding up to $L = 50$ mm. The bolt is long enough. *Ans.*

**(e)** $l_d = L - L_T = 50 - 34 = 16$ mm *Ans.*

$l_t = l - l_d = 31.5 - 16 = 15.5$ mm *Ans.*
These lengths are needed to estimate the bolt spring rate $k_b$.

**8-13**

**(a)** $L_T = 2D + \dfrac{1}{4} = 2(0.5) + 0.25 = 1.25$ in *Ans.*

**(b)** $l' > h + \dfrac{d}{2} = t_1 + \dfrac{d}{2} = 0.875 + \dfrac{0.5}{2} = 1.125$ in *Ans.*

**(c)** $L > h + 1.5d = t_1 + 1.5d = 0.875 + 1.5(0.5) = 1.625$ in
From Table A-17, this rounds to 1.75 in. The cap screw is long enough. *Ans.*

**(d)** $l_d = L - L_T = 1.75 - 1.25 = 0.500$ in *Ans.*

$l_t = l' - l_d = 1.125 - 0.5 = 0.625$ in *Ans.*

**8-14**

**(a)** $L_T = 2(12) + 6 = 30$ mm *Ans.*

**(b)** $l' = h + \dfrac{d}{2} = t_1 + \dfrac{d}{2} = 20 + \dfrac{12}{2} = 26$ mm *Ans.*

**(c)** $L > h + 1.5d = t_1 + 1.5d = 20 + 1.5(12) = 38$ mm
This rounds to 40 mm (Table A-17). The fastener is long enough. *Ans.*

**(d)** $l_d = L - L_T = 40 - 30 = 10$ mm *Ans.*

$l_T = l' - l_d = 26 - 10 = 16$ mm *Ans.*

**8-15**

**(a)**

$$A_d = 0.7854(0.75)^2 = 0.442 \text{ in}^2$$

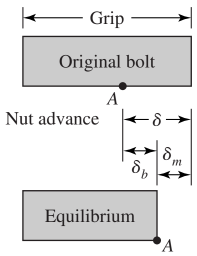
$$A_{\text{tube}} = 0.7854(1.125^2 - 0.75^2) = 0.552 \text{ in}^2$$

$$k_b = \frac{A_d E}{\text{grip}} = \frac{0.442(30)(10^6)}{13} = 1.02(10^6) \text{ lbf/in} \quad \textit{Ans.}$$

$$k_m = \frac{A_{\text{tube}} E}{13} = \frac{0.552(30)(10^6)}{13} = 1.27(10^6) \text{ lbf/in} \quad \textit{Ans.}$$

$$C = \frac{1.02}{1.02 + 1.27} = 0.445 \quad \textit{Ans.}$$

**(b)**




$$\delta = \frac{1}{16} \cdot \frac{1}{3} = \frac{1}{48} = 0.020\,83 \text{ in}$$

$$|\delta_b| = \left(\frac{|P|l}{AE}\right)_b = \frac{(13 - 0.020\,83)}{0.442(30)(10^6)}|P| = 9.79(10^{-7})|P| \text{ in}$$

$$|\delta_m| = \left(\frac{|P|l}{AE}\right)_m = \frac{|P|(13)}{0.552(30)(10^6)} = 7.85(10^{-7})|P| \text{ in}$$

$$|\delta_b| + |\delta_m| = \delta = 0.020\,83$$

$$9.79(10^{-7})|P| + 7.85(10^{-7})|P| = 0.020\,83$$

$$F_i = |P| = \frac{0.020\,83}{9.79(10^{-7}) + 7.85(10^{-7})} = 11\,810 \text{ lbf} \quad \textit{Ans.}$$

**(c)** At opening load $P_0$

$$9.79(10^{-7})P_0 = 0.020\,83$$

$$P_0 = \frac{0.020\,83}{9.79(10^{-7})} = 21\,280 \text{ lbf} \quad \textit{Ans.}$$

As a check use $F_i = (1 - C)P_0$

$$P_0 = \frac{F_i}{1 - C} = \frac{11\,810}{1 - 0.445} = 21\,280 \text{ lbf}$$

**8-16** The movement is known at one location when the nut is free to turn

$$\delta = pt = t/N$$

Letting $N_t$ represent the turn of the nut from snug tight, $N_t = \theta/360^\circ$ and $\delta = N_t/N$.

The elongation of the bolt $\delta_b$ is

$$\delta_b = \frac{F_i}{k_b}$$

The advance of the nut along the bolt is the algebraic sum of $|\delta_b|$ and $|\delta_m|$

$$|\delta_b| + |\delta_m| = \frac{N_t}{N}$$

$$\frac{F_i}{k_b} + \frac{F_i}{k_m} = \frac{N_t}{N}$$

$$N_t = NF_i\left[\frac{1}{k_b} + \frac{1}{k_m}\right] = \left(\frac{k_b + k_m}{k_b k_m}\right)F_i N = \frac{\theta}{360^\circ} \quad Ans.$$

As a check invert Prob. 8-15. What Turn-of-Nut will induce $F_i = 11\,808$ lbf?

$$N_t = 16(11\,808)\left(\frac{1}{1.02(10^6)} + \frac{1}{1.27(10^6)}\right)$$
$$= 0.334 \text{ turns} \doteq 1/3 \text{ turn} \quad \text{(checks)}$$

The relationship between the Turn-of-Nut method and the Torque Wrench method is as follows.

$$N_t = \left(\frac{k_b + k_m}{k_b k_m}\right)F_i N \qquad \text{(Turn-of-Nut)}$$

$$T = KF_i d \qquad \text{(Torque Wrench)}$$

Eliminate $F_i$

$$N_t = \left(\frac{k_b + k_m}{k_b k_m}\right)\frac{NT}{Kd} = \frac{\theta}{360^\circ} \quad Ans.$$

**8-17**

**(a)** From Ex. 8-4, $F_i = 14.4$ kip, $k_b = 5.21(10^6)$ lbf/in, $k_m = 8.95(10^6)$ lbf/in

Eq. (8-27): $T = kF_i d = 0.2(14.4)(10^3)(5/8) = 1800 \text{ lbf} \cdot \text{in} \quad Ans.$

From Prob. 8-16,

$$t = NF_i\left(\frac{1}{k_b} + \frac{1}{k_m}\right) = 16(14.4)(10^3)\left[\frac{1}{5.21(10^6)} + \frac{1}{8.95(10^6)}\right]$$
$$= 0.132 \text{ turns} = 47.5^\circ \quad Ans.$$

Bolt group is $(1.5)/(5/8) = 2.4$ diameters. Answer is lower than RB&W recommendations.

**(b)** From Ex. 8-5, $F_i = 14.4$ kip, $k_b = 6.78$ Mlbf/in, and $k_m = 17.4$ Mlbf/in

$$T = 0.2(14.4)(10^3)(5/8) = 1800 \text{ lbf} \cdot \text{in} \quad Ans.$$

$$t = 11(14.4)(10^3)\left[\frac{1}{6.78(10^6)} + \frac{1}{17.4(10^6)}\right]$$
$$= 0.0325 = 11.7^\circ \quad Ans. \quad \text{Again lower than RB\&W.}$$

**8-18** From Eq. (8-22) for the conical frusta, with $d/l = 0.5$

$$\left.\frac{k_m}{Ed}\right|_{(d/l)=0.5} = \frac{0.5774\pi}{2\ln\{5[0.5774 + 0.5(0.5)]/[0.5774 + 2.5(0.5)]\}} = 1.11$$

Eq. (8-23), from the Wileman *et al.* finite element study, using the general expression,

$$\left.\frac{k_m}{Ed}\right|_{(d/l)=0.5} = 0.789\,52\exp[0.629\,14(0.5)] = 1.08$$

**8-19** For cast iron, from Table 8-8: $A = 0.778\,71$, $B = 0.616\,16$, $E = 14.5$ Mpsi

$$k_m = 14.5(10^6)(0.625)(0.778\,71)\exp\left(0.616\,16\frac{0.625}{1.5}\right) = 9.12(10^6)\text{ lbf/in}$$

This member's spring rate applies to both members. We need $k_m$ for the upper member which represents half of the joint.

$$k_{ci} = 2k_m = 2[9.12(10^6)] = 18.24(10^6)\text{ lbf/in}$$

For steel from Table 8-8: $A = 0.787\,15$, $B = 0.628\,73$, $E = 30$ Mpsi

$$k_m = 30(10^6)(0.625)(0.787\,15)\exp\left(0.628\,73\frac{0.625}{1.5}\right) = 19.18(10^6)\text{ lbf/in}$$

$$k_{\text{steel}} = 2k_m = 2(19.18)(10^6) = 38.36(10^6)\text{ lbf/in}$$

For springs in series

$$\frac{1}{k_m} = \frac{1}{k_{ci}} + \frac{1}{k_{\text{steel}}} = \frac{1}{18.24(10^6)} + \frac{1}{38.36(10^6)}$$

$$k_m = 12.4(10^6)\text{ lbf/in} \quad \textit{Ans.}$$

**8-20** The external tensile load per bolt is

$$P = \frac{1}{10}\left(\frac{\pi}{4}\right)(150)^2(6)(10^{-3}) = 10.6\text{ kN}$$

Also, $l = 40$ mm and from Table A-31, for $d = 12$ mm, $H = 10.8$ mm. No washer is specified.

$$L_T = 2D + 6 = 2(12) + 6 = 30\text{ mm}$$

$$l + H = 40 + 10.8 = 50.8\text{ mm}$$

Table A-17: $L = 60$ mm

$$l_d = 60 - 30 = 30\text{ mm}$$

$$l_t = 45 - 30 = 15\text{ mm}$$

$$A_d = \frac{\pi(12)^2}{4} = 113\text{ mm}^2$$

Table 8-1: $A_t = 84.3\text{ mm}^2$

Eq. (8-17):

$$k_b = \frac{113(84.3)(207)}{113(15) + 84.3(30)} = 466.8\text{ MN/m}$$

Steel: Using Eq. (8-23) for $A = 0.787\,15$, $B = 0.628\,73$ and $E = 207$ GPa

Eq. (8-23): $k_m = 207(12)(0.787\,15)\exp[(0.628\,73)(12/40)] = 2361$ MN/m

$$k_s = 2k_m = 4722 \text{ MN/m}$$

Cast iron: $A = 0.778\,71$, $B = 0.616\,16$, $E = 100$ GPa

$$k_m = 100(12)(0.778\,71)\exp[(0.616\,16)(12/40)] = 1124 \text{ MN/m}$$

$$k_{ci} = 2k_m = 2248 \text{ MN/m}$$

$$\frac{1}{k_m} = \frac{1}{k_s} + \frac{1}{k_{ci}} \quad \Rightarrow \quad k_m = 1523 \text{ MN/m}$$

$$C = \frac{466.8}{466.8 + 1523} = 0.2346$$

Table 8-1: $A_t = 84.3$ mm$^2$, Table 8-11, $S_p = 600$ MPa

Eqs. (8-30) and (8-31): $F_i = 0.75(84.3)(600)(10^{-3}) = 37.9$ kN

Eq. (8-28):

$$n = \frac{S_p A_t - F_i}{CP} = \frac{600(10^{-3})(84.3) - 37.9}{0.2346(10.6)} = 5.1 \quad Ans.$$

**8-21** Computer programs will vary.

**8-22** $D_3 = 150$ mm, $A = 100$ mm, $B = 200$ mm, $C = 300$ mm, $D = 20$ mm, $E = 25$ mm. ISO 8.8 bolts: $d = 12$ mm, $p = 1.75$ mm, coarse pitch of $p = 6$ MPa.

$$P = \frac{1}{10}\left(\frac{\pi}{4}\right)(150^2)(6)(10^{-3}) = 10.6 \text{ kN/bolt}$$

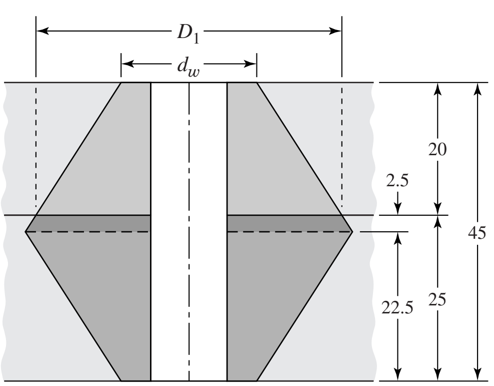
$$l = D + E = 20 + 25 = 45 \text{ mm}$$

$$L_T = 2D + 6 = 2(12) + 6 = 30 \text{ mm}$$

Table A-31: $H = 10.8$ mm

$$l + H = 45 + 10.8 = 55.8 \text{ mm}$$

Table A-17: $L = 60$ mm




$$l_d = 60 - 30 = 30 \text{ mm}, \quad l_t = 45 - 30 = 15 \text{ mm}, \quad A_d = \pi(12^2/4) = 113 \text{ mm}^2$$

Table 8-1: $A_t = 84.3$ mm$^2$

Eq. (8-17):

$$k_b = \frac{113(84.3)(207)}{113(15) + 84.3(30)} = 466.8 \text{ MN/m}$$

There are three frusta: $d_m = 1.5(12) = 18$ mm

$$D_1 = (20 \tan 30^\circ)2 + d_w = (20 \tan 30^\circ)2 + 18 = 41.09 \text{ mm}$$

*Upper Frustum:* $t = 20$ mm, $E = 207$ GPa, $D = 1.5(12) = 18$ mm

Eq. (8-20): $k_1 = 4470$ MN/m

*Central Frustum:* $t = 2.5$ mm, $D = 41.09$ mm, $E = 100$ GPa (Table A-5) $\Rightarrow$ $k_2 =$ 52 230 MN/m

*Lower Frustum:* $t = 22.5$ mm, $E = 100$ GPa, $D = 18$ mm $\Rightarrow$ $k_3 = 2074$ MN/m

From Eq. (8-18): $k_m = [(1/4470) + (1/52\,230) + (1/2074)]^{-1} = 1379$ MN/m

Eq. (*e*), p. 421: $C = \dfrac{466.8}{466.8 + 1379} = 0.253$

Eqs. (8-30) and (8-31):

$$F_i = K F_p = K A_t S_p = 0.75(84.3)(600)(10^{-3}) = 37.9 \text{ kN}$$

Eq. (8-28): $n = \dfrac{S_p A_t - F_i}{CP} = \dfrac{600(10^{-3})(84.3) - 37.9}{0.253(10.6)} = 4.73$ *Ans.*

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**8-23** $P = \dfrac{1}{8}\left(\dfrac{\pi}{4}\right)(120^2)(6)(10^{-3}) = 8.48$ kN

From Fig. 8-21, $t_1 = h = 20$ mm and $t_2 = 25$ mm

$$l = 20 + 12/2 = 26 \text{ mm}$$

$$t = 0 \quad \text{(no washer)}, \qquad L_T = 2(12) + 6 = 30 \text{ mm}$$

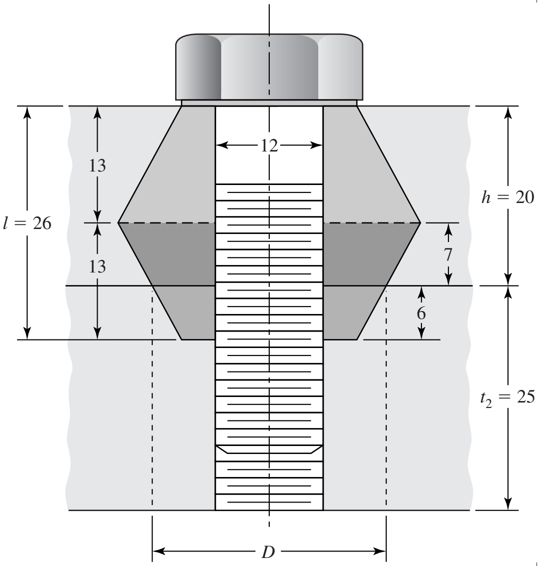
$$L > h + 1.5d = 20 + 1.5(12) = 38 \text{ mm}$$

Use 40 mm cap screws.

$$l_d = 40 - 30 = 10 \text{ mm}$$

$$l_t = l - l_d = 26 - 10 = 16 \text{ mm}$$

$$A_d = 113 \text{ mm}^2, \quad A_t = 84.3 \text{ mm}^2$$




Eq. (8-17):

$$k_b = \frac{113(84.3)(207)}{113(16) + 84.3(10)}$$

$$= 744 \text{ MN/m} \quad \textit{Ans.}$$

$$d_w = 1.5(12) = 18 \text{ mm}$$

$$D = 18 + 2(6)(\tan 30) = 24.9 \text{ mm}$$

From Eq. (8-20):

*Top frustum:* $D = 18, t = 13, E = 207$ GPa $\Rightarrow$ $k_1 = 5316$ MN/m

*Mid-frustum:* $t = 7, E = 207$ GPa, $D = 24.9$ mm $\Rightarrow$ $k_2 = 15\,620$ MN/m

*Bottom frustum:* $D = 18, t = 6, E = 100$ GPa $\Rightarrow$ $k_3 = 3887$ MN/m

$$k_m = \frac{1}{(1/5316) + (1/55\,620) + (1/3887)} = 2158 \text{ MN/m} \quad Ans.$$

$$C = \frac{744}{744 + 2158} = 0.256 \quad Ans.$$

From Prob. 8-22, $F_i = 37.9$ kN

$$n = \frac{S_p A_t - F_i}{CP} = \frac{600(0.0843) - 37.9}{0.256(8.48)} = 5.84 \quad Ans.$$

**8-24** Calculation of bolt stiffness:

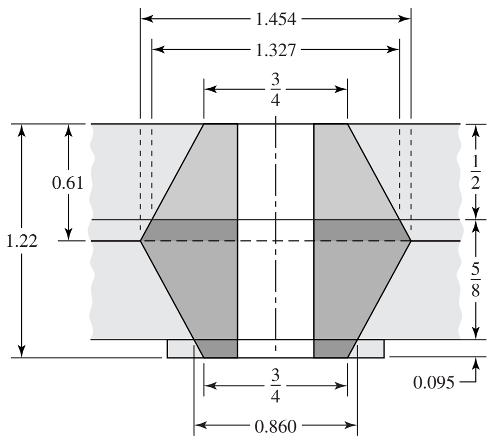
$$H = 7/16 \text{ in}$$

$$L_T = 2(1/2) + 1/4 = 1\,1/4 \text{ in}$$

$$l = 1/2 + 5/8 + 0.095 = 1.22 \text{ in}$$

$$L > 1.125 + 7/16 + 0.095 = 1.66 \text{ in}$$

Use $L = 1.75$ in




$$l_d = L - L_T = 1.75 - 1.25 = 0.500 \text{ in}$$

$$l_t = 1.125 + 0.095 - 0.500 = 0.72 \text{ in}$$

$$A_d = \pi(0.50^2)/4 = 0.1963 \text{ in}^2$$

$$A_t = 0.1419 \text{ in}^2 \text{ (UNC)}$$

$$k_t = \frac{A_t E}{l_t} = \frac{0.1419(30)}{0.72} = 5.9125 \text{ Mlbf/in}$$

$$k_d = \frac{A_d E}{l_d} = \frac{0.1963(30)}{0.500} = 11.778 \text{ Mlbf/in}$$

$$k_b = \frac{1}{(1/5.9125) + (1/11.778)} = 3.936 \text{ Mlbf/in} \quad Ans.$$

Member stiffness for four frusta and joint constant $C$ using Eqs. (8-20) and ($e$).

*Top frustum:* $D = 0.75, t = 0.5, d = 0.5, E = 30 \Rightarrow k_1 = 33.30$ Mlbf/in

*2nd frustum:* $D = 1.327, t = 0.11, d = 0.5, E = 14.5 \Rightarrow k_2 = 173.8$ Mlbf/in

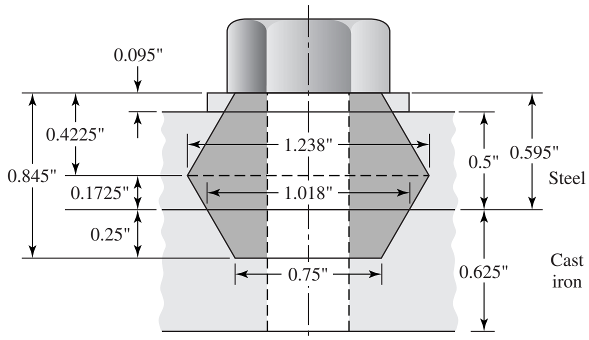
*3rd frustum:* $D = 0.860, t = 0.515, E = 14.5 \Rightarrow k_3 = 21.47$ Mlbf/in

*Fourth frustum:* $D = 0.75, t = 0.095, d = 0.5, E = 30 \Rightarrow k_4 = 97.27$ Mlbf/in

$$k_m = \left(\sum_{i=1}^{4} 1/k_i\right)^{-1} = 10.79 \text{ Mlbf/in} \quad Ans.$$

$$C = 3.94/(3.94 + 10.79) = 0.267 \quad Ans.$$

**8-25**




$$k_b = \frac{A_t E}{l} = \frac{0.1419(30)}{0.845} = 5.04 \text{ Mlbf/in} \quad Ans.$$

From Fig. 8-21,

$$h = \frac{1}{2} + 0.095 = 0.595 \text{ in}$$

$$l = h + \frac{d}{2} = 0.595 + \frac{0.5}{2} = 0.845$$

$$D_1 = 0.75 + 0.845 \tan 30^\circ = 1.238 \text{ in}$$

$$l/2 = 0.845/2 = 0.4225 \text{ in}$$

From Eq. (8-20):

*Frustum 1:* $D = 0.75, t = 0.4225$ in, $d = 0.5$ in, $E = 30$ Mpsi $\Rightarrow k_1 = 36.14$ Mlbf/in

*Frustum 2:* $D = 1.018$ in, $t = 0.1725$ in, $E = 70$ Mpsi, $d = 0.5$ in $\Rightarrow k_2 = 134.6$ Mlbf/in

*Frustum 3:* $D = 0.75, t = 0.25$ in, $d = 0.5$ in, $E = 14.5$ Mpsi $\Rightarrow k_3 = 23.49$ Mlbf/in

$$k_m = \frac{1}{(1/36.14) + (1/134.6) + (1/23.49)} = 12.87 \text{ Mlbf/in} \quad Ans.$$

$$C = \frac{5.04}{5.04 + 12.87} = 0.281 \quad Ans.$$

**8-26** Refer to Prob. 8-24 and its solution. Additional information: $A = 3.5$ in, $D_s = 4.25$ in, static pressure 1500 psi, $D_b = 6$ in, $C$ (joint constant) $= 0.267$, ten SAE grade 5 bolts.

$$P = \frac{1}{10}\,\frac{\pi(4.25^2)}{4}(1500) = 2128 \text{ lbf}$$

From Tables 8-2 and 8-9,

$$A_t = 0.1419 \text{ in}^2$$
$$S_p = 85\,000 \text{ psi}$$
$$F_i = 0.75(0.1419)(85) = 9.046 \text{ kip}$$

From Eq. (8-28),

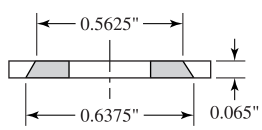
$$n = \frac{S_p A_t - F_i}{CP} = \frac{85(0.1419) - 9.046}{0.267(2.128)} = 5.31 \quad \textit{Ans.}$$

---

**8-27** From Fig. 8-21, $t_1 = 0.25$ in

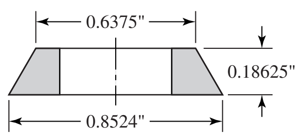
$$h = 0.25 + 0.065 = 0.315 \text{ in}$$
$$l = h + (d/2) = 0.315 + (3/16) = 0.5025 \text{ in}$$
$$D_1 = 1.5(0.375) + 0.577(0.5025) = 0.8524 \text{ in}$$
$$D_2 = 1.5(0.375) = 0.5625 \text{ in}$$
$$l/2 = 0.5025/2 = 0.251\,25 \text{ in}$$

*Frustum 1:* Washer



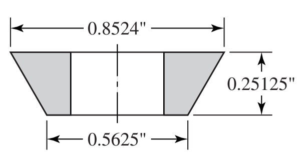

$$E = 30 \text{ Mpsi}, \quad t = 0.065 \text{ in}, \quad D = 0.5625 \text{ in}$$
$$k = 78.57 \text{ Mlbf/in} \qquad \text{(by computer)}$$

*Frustum 2:* Cap portion




$$E = 14 \text{ Mpsi}, \quad t = 0.186\,25 \text{ in}$$
$$D = 0.5625 + 2(0.065)(0.577) = 0.6375 \text{ in}$$
$$k = 23.46 \text{ Mlbf/in} \qquad \text{(by computer)}$$

*Frustum 3:* Frame and Cap




$$E = 14 \text{ Mpsi}, \quad t = 0.251\,25 \text{ in}, \quad D = 0.5625 \text{ in}$$
$$k = 14.31 \text{ Mlbf/in} \qquad \text{(by computer)}$$
$$k_m = \frac{1}{(1/78.57) + (1/23.46) + (1/14.31)} = 7.99 \text{ Mlbf/in} \quad \textit{Ans.}$$

For the bolt, $L_T = 2(3/8) + (1/4) = 1$ in. So the bolt is threaded all the way. Since $A_t = 0.0775\text{ in}^2$

$$k_b = \frac{0.0775(30)}{0.5025} = 4.63\text{ Mlbf/in} \quad Ans.$$

**8-28**

**(a)** $F'_b = RF'_{b,\max}\sin\theta$

Half of the external moment is contributed by the line load in the interval $0 \le \theta \le \pi$.

$$\frac{M}{2} = \int_0^\pi F'_b R^2 \sin\theta\, d\theta = \int_0^\pi F'_{b,\max} R^2 \sin^2\theta\, d\theta$$

$$\frac{M}{2} = \frac{\pi}{2} F'_{b,\max} R^2$$

from which $F'_{b,\max} = \dfrac{M}{\pi R^2}$

$$F_{\max} = \int_{\phi_1}^{\phi_2} F'_b R\sin\theta\, d\theta = \frac{M}{\pi R^2}\int_{\phi_1}^{\phi_2} R\sin\theta\, d\theta = \frac{M}{\pi R}(\cos\phi_1 - \cos\phi_2)$$

Noting $\phi_1 = 75^\circ, \phi_2 = 105^\circ$

$$F_{\max} = \frac{12\,000}{\pi(8/2)}(\cos 75^\circ - \cos 105^\circ) = 494\text{ lbf} \quad Ans.$$

**(b)**

$$F_{\max} = F'_{b,\max} R\Delta\phi = \frac{M}{\pi R^2}(R)\left(\frac{2\pi}{N}\right) = \frac{2M}{RN}$$

$$F_{\max} = \frac{2(12\,000)}{(8/2)(12)} = 500\text{ lbf} \quad Ans.$$

**(c)** $F = F_{\max}\sin\theta$

$$M = 2F_{\max}R[(1)\sin^2 90^\circ + 2\sin^2 60^\circ + 2\sin^2 30^\circ + (1)\sin^2(0)] = 6F_{\max}R$$

from which

$$F_{\max} = \frac{M}{6R} = \frac{12\,000}{6(8/2)} = 500\text{ lbf} \quad Ans.$$

The simple general equation resulted from part (*b*)

$$F_{\max} = \frac{2M}{RN}$$

**8-29** **(a)** Table 8-11: $S_p = 600$ MPa

Eq. (8-30): $F_i = 0.9A_tS_p = 0.9(245)(600)(10^{-3}) = 132.3$ kN

Table (8-15): $K = 0.18$

Eq. (8-27) $T = 0.18(132.3)(20) = 476\text{ N}\cdot\text{m}$ *Ans.*

**(b)** Washers: $t = 3.4$ mm, $d = 20$ mm, $D = 30$ mm, $E = 207$ GPa $\Rightarrow k_1 = 42\,175$ MN/m

Cast iron: $t = 20$ mm, $d = 20$ mm, $D = 30 + 2(3.4)\tan 30^\circ = 33.93$ mm,

$E = 135$ GPa $\Rightarrow k_2 = 7885$ MN/m

Steel: $t = 20$ mm, $d = 20$ mm, $D = 33.93$ mm, $E = 207$ GPa $\Rightarrow k_3 = 12\,090$ MN/m

$$k_m = (2/42\,175 + 1/7885 + 1/12\,090)^{-1} = 3892 \text{ MN/m}$$

Bolt: $l = 46.8$ mm. Nut: $H = 18$ mm. $L > 46.8 + 18 = 64.8$ mm. Use $L = 80$ mm.

$$L_T = 2(20) + 6 = 46 \text{ mm}, \; l_d = 80 - 46 = 34 \text{ mm}, \; l_t = 46.8 - 34 = 12.8 \text{ mm},$$

$$A_t = 245 \text{ mm}^2, \quad A_d = \pi 20^2/4 = 314.2 \text{ mm}^2$$

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{314.2(245)(207)}{314.2(12.8) + 245(34)} = 1290 \text{ MN/m}$$

$$C = 1290/(1290 + 3892) = 0.2489, \quad S_p = 600 \text{ MPa}, \quad F_i = 132.3 \text{ kN}$$

$$n = \frac{S_p A_t - F_i}{C(P/N)} = \frac{600(0.245) - 132.3}{0.2489(15/4)} = 15.7 \quad Ans.$$

Bolts are a bit oversized for the load.

**8-30** **(a)** ISO M $20 \times 2.5$ grade 8.8 coarse pitch bolts, lubricated.

Table 8-2 $\quad A_t = 245 \text{ mm}^2$

Table 8-11 $\quad S_p = 600$ MPa

$$A_d = \pi(20)^2/4 = 314.2 \text{ mm}^2$$

$$F_p = 245(0.600) = 147 \text{ kN}$$

$$F_i = 0.90 F_p = 0.90(147) = 132.3 \text{ kN}$$

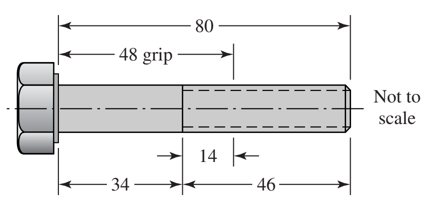
$$T = 0.18(132.3)(20) = 476 \text{ N}\cdot\text{m} \quad Ans.$$

**(b)** $L \geq l + H = 48 + 18 = 66$ mm. Therefore, set $L = 80$ mm per Table A-17.

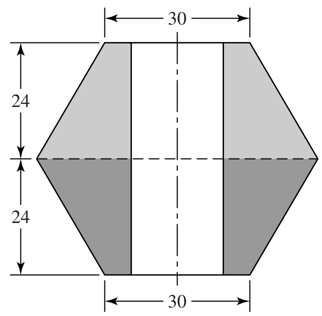
$$L_T = 2D + 6 = 2(20) + 6 = 46 \text{ mm}$$

$$l_d = L - L_T = 80 - 46 = 34 \text{ mm}$$

$$l_t = l - l_d = 48 - 34 = 14 \text{ mm}$$



$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{314.2(245)(207)}{314.2(14) + 245(34)} = 1251.9 \text{ MN/m}$$




Use Wileman *et al.*

Eq. (8-23)

$$A = 0.787\,15, \quad B = 0.628\,73$$

$$\frac{k_m}{Ed} = A \exp\left(\frac{Bd}{L_G}\right) = 0.787\,15 \exp\left[0.628\,73\left(\frac{20}{48}\right)\right] = 1.0229$$

$$k_m = 1.0229(207)(20) = 4235 \text{ MN/m}$$

$$C = \frac{1251.9}{1251.9 + 4235} = 0.228$$

Bolts carry 0.228 of the external load; members carry 0.772 of the external load. *Ans.*
Thus, the actual loads are

$$F_b = CP + F_i = 0.228(20) + 132.3 = 136.9 \text{ kN}$$

$$F_m = (1 - C)P - F_i = (1 - 0.228)20 - 132.3 = -116.9 \text{ kN}$$

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**8-31** Given $p_{\max} = 6$ MPa, $p_{\min} = 0$ and from Prob. 8-20 solution, $C = 0.2346$, $F_i = 37.9$ kN, $A_t = 84.3$ mm$^2$.

For 6 MPa, $P = 10.6$ kN per bolt

$$\sigma_i = \frac{F_i}{A_t} = \frac{37.9(10^3)}{84.3} = 450 \text{ MPa}$$

Eq. (8-35):

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.2346(10.6)(10^3)}{2(84.3)} = 14.75 \text{ MPa}$$

$$\sigma_m = \sigma_a + \sigma_i = 14.75 + 450 = 464.8 \text{ MPa}$$

**(a)** Goodman Eq. (8-40) for 8.8 bolts with $S_e = 129$ MPa, $S_{ut} = 830$ MPa

$$S_a = \frac{S_e(S_{ut} - \sigma_i)}{S_{ut} + S_e} = \frac{129(830 - 450)}{830 + 129} = 51.12 \text{ MPa}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{51.12}{14.75} = 3.47 \quad \textit{Ans.}$$

**(b)** Gerber Eq. (8-42)

$$S_a = \frac{1}{2S_e}\left[S_{ut}\sqrt{S_{ut}^2 + 4S_e(S_e + \sigma_i)} - S_{ut}^2 - 2\sigma_i S_e\right]$$

$$= \frac{1}{2(129)}\left[830\sqrt{830^2 + 4(129)(129 + 450)} - 830^2 - 2(450)(129)\right]$$

$$= 76.99 \text{ MPa}$$

$$n_f = \frac{76.99}{14.75} = 5.22 \quad Ans.$$

**(c)** ASME-elliptic Eq. (8-43) with $S_p = 600$ MPa

$$S_a = \frac{S_e}{S_p^2 + S_e^2}\left(S_p\sqrt{S_p^2 + S_e^2 - \sigma_i^2} - \sigma_i S_e\right)$$

$$= \frac{129}{600^2 + 129^2}\left[600\sqrt{600^2 + 129^2 - 450^2} - 450(129)\right] = 65.87 \text{ MPa}$$

$$n_f = \frac{65.87}{14.75} = 4.47 \quad Ans.$$

**8-32**

$$P = \frac{pA}{N} = \frac{\pi D^2 p}{4N} = \frac{\pi(0.9^2)(550)}{4(36)} = 9.72 \text{ kN/bolt}$$

Table 8-11: $S_p = 830$ MPa, $S_{ut} = 1040$ MPa, $S_y = 940$ MPa

Table 8-1:

$$A_t = 58 \text{ mm}^2$$

$$A_d = \pi(10^2)/4 = 78.5 \text{ mm}^2$$

$$l = D + E = 20 + 25 = 45 \text{ mm}$$

$$L_T = 2(10) + 6 = 26 \text{ mm}$$

Table A-31: $H = 8.4$ mm

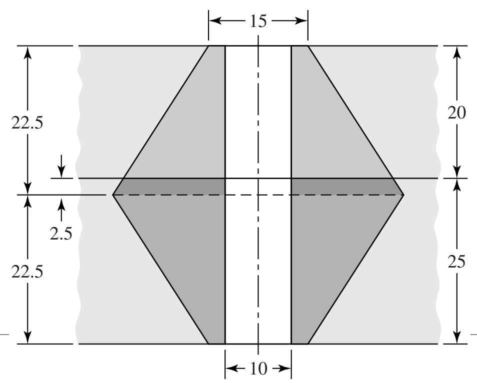
$$L \geq l + H = 45 + 8.4 = 53.4 \text{ mm}$$

Choose $L = 60$ mm from Table A-17

$$l_d = L - L_T = 60 - 26 = 34 \text{ mm}$$

$$l_t = l - l_d = 45 - 34 = 11 \text{ mm}$$

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{78.5(58)(207)}{78.5(11) + 58(34)} = 332.4 \text{ MN/m}$$



*Frustum 1:* Top, $E = 207, t = 20$ mm, $d = 10$ mm, $D = 15$ mm

$$k_1 = \frac{0.5774\pi(207)(10)}{\ln\left\{\left[\frac{1.155(20)+15-10}{1.155(20)+15+10}\right]\left(\frac{15+10}{15-10}\right)\right\}}$$

$$= 3503 \text{ MN/m}$$

*Frustum 2:* Middle, $E = 96$ GPa, $D = 38.09$ mm, $t = 2.5$ mm, $d = 10$ mm

$$k_2 = \frac{0.5774\pi(96)(10)}{\ln\left\{\left[\frac{1.155(2.5)+38.09-10}{1.155(2.5)+38.09+10}\right]\left(\frac{38.09+10}{38.09-10}\right)\right\}}$$

$$= 44\,044 \text{ MN/m}$$

could be neglected due to its small influence on $k_m$.

*Frustum 3:* Bottom, $E = 96$ GPa, $t = 22.5$ mm, $d = 10$ mm, $D = 15$ mm

$$k_3 = \frac{0.5774\pi(96)(10)}{\ln\left\{\left[\frac{1.155(22.5)+15-10}{1.155(22.5)+15+10}\right]\left(\frac{15+10}{15-10}\right)\right\}}$$

$$= 1567 \text{ MN/m}$$

$$k_m = \frac{1}{(1/3503)+(1/44\,044)+(1/1567)} = 1057 \text{ MN/m}$$

$$C = \frac{332.4}{332.4+1057} = 0.239$$

$$F_i = 0.75A_tS_p = 0.75(58)(830)(10^{-3}) = 36.1 \text{ kN}$$

Table 8-17: $S_e = 162$ MPa

$$\sigma_i = \frac{F_i}{A_t} = \frac{36.1(10^3)}{58} = 622 \text{ MPa}$$

**(a)** Goodman Eq. (8-40)

$$S_a = \frac{S_e(S_{ut}-\sigma_i)}{S_{ut}+S_e} = \frac{162(1040-622)}{1040+162} = 56.34 \text{ MPa}$$

$$n_f = \frac{56.34}{20} = 2.82 \quad \textit{Ans.}$$

**(b)** Gerber Eq. (8-42)

$$S_a = \frac{1}{2S_e}\left[S_{ut}\sqrt{S_{ut}^2+4S_e(S_e+\sigma_i)} - S_{ut}^2 - 2\sigma_iS_e\right]$$

$$= \frac{1}{2(162)}\left[1040\sqrt{1040^2+4(162)(162+622)} - 1040^2 - 2(622)(162)\right]$$

$$= 86.8 \text{ MPa}$$

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.239(9.72)(10^3)}{2(58)} = 20 \text{ MPa}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{86.8}{20} = 4.34 \quad Ans.$$

**(c)** ASME elliptic

$$S_a = \frac{S_e}{S_p^2 + S_e^2}\left(S_p\sqrt{S_p^2 + S_e^2 - \sigma_i^2} - \sigma_i S_e\right)$$

$$= \frac{162}{830^2 + 162^2}\left[830\sqrt{830^2 + 162^2 - 622^2} - 622(162)\right] = 84.90 \text{ MPa}$$

$$n_f = \frac{84.90}{20} = 4.24 \quad Ans.$$

**8-33** Let the repeatedly-applied load be designated as $P$. From Table A-22, $S_{ut} =$ 93.7 kpsi. Referring to the Figure of Prob. 3-74, the following notation will be used for the radii of Section AA.

$$r_i = 1 \text{ in}, \quad r_o = 2 \text{ in}, \quad r_c = 1.5 \text{ in}$$

From Table 4-5, with $R = 0.5$ in

$$r_n = \frac{0.5^2}{2\left(1.5 - \sqrt{1.5^2 - 0.5^2}\right)} = 1.457\,107 \text{ in}$$

$$e = r_c - r_n = 1.5 - 1.457\,107 = 0.042\,893 \text{ in}$$

$$c_o = r_o - r_n = 2 - 1.457\,109 = 0.542\,893 \text{ in}$$

$$c_i = r_n - r_i = 1.457\,107 - 1 = 0.457\,107 \text{ in}$$

$$A = \pi(1^2)/4 = 0.7854 \text{ in}^2$$

If $P$ is the maximum load

$$M = Pr_c = 1.5P$$

$$\sigma_i = \frac{P}{A}\left(1 + \frac{r_c c_i}{e r_i}\right) = \frac{P}{0.7854}\left(1 + \frac{1.5(0.457)}{0.0429(1)}\right) = 21.62P$$

$$\sigma_a = \sigma_m = \frac{\sigma_i}{2} = \frac{21.62P}{2} = 10.81P$$

**(a)** *Eye:* Section AA

$$k_a = 14.4(93.7)^{-0.718} = 0.553$$

$$d_e = 0.37d = 0.37(1) = 0.37 \text{ in}$$

$$k_b = \left(\frac{0.37}{0.30}\right)^{-0.107} = 0.978$$

$$k_c = 0.85$$

$$S'_e = 0.5(93.7) = 46.85 \text{ kpsi}$$

$$S_e = 0.553(0.978)(0.85)(46.85) = 21.5 \text{ kpsi}$$

Since no stress concentration exists, use a load line slope of 1. From Table 7-10 for Gerber

$$S_a = \frac{93.7^2}{2(21.5)}\left[-1+\sqrt{1+\left(\frac{2(21.5)}{93.7}\right)^2}\,\right] = 20.47 \text{ kpsi}$$

Note the mere 5 percent degrading of $S_e$ in $S_a$

$$n_f = \frac{S_a}{\sigma_a} = \frac{20.47(10^3)}{10.81P} = \frac{1894}{P}$$

*Thread:* Die cut. Table 8-17 gives 18.6 kpsi for rolled threads. Use Table 8-16 to find $S_e$ for die cut threads

$$S_e = 18.6(3.0/3.8) = 14.7 \text{ kpsi}$$

Table 8-2:

$$A_t = 0.663 \text{ in}^2$$
$$\sigma = P/A_t = P/0.663 = 1.51P$$
$$\sigma_a = \sigma_m = \sigma/2 = 1.51P/2 = 0.755P$$

From Table 7-10, Gerber

$$S_a = \frac{120^2}{2(14.7)}\left[-1+\sqrt{1+\left(\frac{2(14.7)}{120}\right)^2}\,\right] = 14.5 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{14\,500}{0.755P} = \frac{19\,200}{P}$$

Comparing $1894/P$ with $19\,200/P$, we conclude that the *eye* is weaker in fatigue. *Ans.*

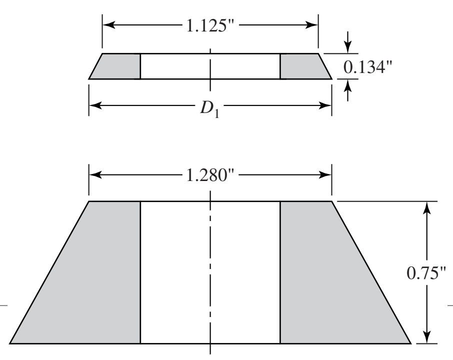
**(b)** Strengthening steps can include heat treatment, cold forming, cross section change (a round is a poor cross section for a curved bar in bending because the bulk of the material is located where the stress is small). *Ans.*

**(c)** For $n_f = 2$

$$P = \frac{1894}{2} = 947 \text{ lbf, max. load} \quad \textit{Ans.}$$

**8-34** **(a)** $L \ge 1.5 + 2(0.134) + \dfrac{41}{64} = 2.41$ in. Use $L = 2\frac{1}{2}$ in *Ans.*

**(b)** Four frusta: Two washers and two members



*Washer:* $E = 30$ Mpsi, $t = 0.134$ in, $D = 1.125$ in, $d = 0.75$ in

Eq. (8-20): $k_1 = 153.3$ Mlbf/in

*Member:* $E = 16$ Mpsi, $t = 0.75$ in, $D = 1.280$ in, $d = 0.75$ in

Eq. (8-20): $k_2 = 35.5$ Mlbf/in

$$k_m = \frac{1}{(2/153.3) + (2/35.5)} = 14.41 \text{ Mlbf/in} \quad Ans.$$

*Bolt:*

$$L_T = 2(3/4) + 1/4 = 1\tfrac{3}{4} \text{ in}$$

$$l = 2(0.134) + 2(0.75) = 1.768 \text{ in}$$

$$l_d = L - L_T = 2.50 - 1.75 = 0.75 \text{ in}$$

$$l_t = l - l_d = 1.768 - 0.75 = 1.018 \text{ in}$$

$$A_t = 0.373 \text{ in}^2 \quad \text{(Table 8-2)}$$

$$A_d = \pi(0.75)^2/4 = 0.442 \text{ in}^2$$

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{0.442(0.373)(30)}{0.442(1.018) + 0.373(0.75)} = 6.78 \text{ Mlbf/in} \quad Ans.$$

$$C = \frac{6.78}{6.78 + 14.41} = 0.320 \quad Ans.$$

**(c)** From Eq. (8-40), Goodman with $S_e = 18.6$ kpsi, $S_{ut} = 120$ kpsi

$$S_a = \frac{18.6[120 - (25/0.373)]}{120 + 18.6} = 7.11 \text{ kpsi}$$

The stress components are

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.320(6)}{2(0.373)} = 2.574 \text{ kpsi}$$

$$\sigma_m = \sigma_a + \frac{F_i}{A_t} = 2.574 + \frac{25}{0.373} = 69.6 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{7.11}{2.574} = 2.76 \quad Ans.$$

**(d)** Eq. (8-42) for Gerber

$$S_a = \frac{1}{2(18.6)}\left[120\sqrt{120^2 + 4(18.6)\left(18.6 + \frac{25}{0.373}\right)} - 120^2 - 2\left(\frac{25}{0.373}\right)18.6\right]$$

$$= 10.78 \text{ kpsi}$$

$$n_f = \frac{10.78}{2.574} = 4.19 \quad Ans.$$

**(e)** $n_{\text{proof}} = \dfrac{85}{2.654 + 69.8} = 1.17 \quad Ans.$

**8-35**

**(a)** Table 8-2: $A_t = 0.1419 \text{ in}^2$

Table 8-9: $S_p = 85 \text{ kpsi}, \ S_{ut} = 120 \text{ kpsi}$

Table 8-17: $S_e = 18.6 \text{ kpsi}$

$$F_i = 0.75 A_t S_p = 0.75(0.1419)(85) = 9.046 \text{ kip}$$

$$C = \frac{4.94}{4.94 + 15.97} = 0.236$$

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.236P}{2(0.1419)} = 0.832P \text{ kpsi}$$

Eq. (8-40) for Goodman criterion

$$S_a = \frac{18.6(120 - 9.046/0.1419)}{120 + 18.6} = 7.55 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{7.55}{0.832P} = 2 \quad \Rightarrow \quad P = 4.54 \text{ kip} \quad \textit{Ans.}$$

**(b)** Eq. (8-42) for Gerber criterion

$$S_a = \frac{1}{2(18.6)}\left[120\sqrt{120^2 + 4(18.6)\left(18.6 + \frac{9.046}{0.1419}\right)} - 120^2 - 2\left(\frac{9.046}{0.1419}\right)18.6\right]$$

$$= 11.32 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{11.32}{0.832P} = 2$$

From which

$$P = \frac{11.32}{2(0.832)} = 6.80 \text{ kip} \quad \textit{Ans.}$$

**(c)** $\sigma_a = 0.832P = 0.832(6.80) = 5.66 \text{ kpsi}$

$\sigma_m = S_a + \sigma_a = 11.32 + 63.75 = 75.07 \text{ kpsi}$

Load factor, Eq. (8-28)

$$n = \frac{S_p A_t - F_i}{CP} = \frac{85(0.1419) - 9.046}{0.236(6.80)} = 1.88 \quad \textit{Ans.}$$

Separation load factor, Eq. (8-29)

$$n = \frac{F_i}{(1-C)P} = \frac{9.046}{6.80(1 - 0.236)} = 1.74 \quad \textit{Ans.}$$

**8-36** Table 8-2: $A_t = 0.969 \text{ in}^2$ (coarse)

$A_t = 1.073 \text{ in}^2$ (fine)

Table 8-9: $S_p = 74 \text{ kpsi}, \quad S_{ut} = 105 \text{ kpsi}$

Table 8-17: $S_e = 16.3 \text{ kpsi}$

*Coarse thread, UNC*

$$F_i = 0.75(0.969)(74) = 53.78 \text{ kip}$$

$$\sigma_i = \frac{F_i}{A_t} = \frac{53.78}{0.969} = 55.5 \text{ kpsi}$$

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.30P}{2(0.969)} = 0.155P \text{ kpsi}$$

Eq. (8-42):

$$S_a = \frac{1}{2(16.3)}\left[105\sqrt{105^2 + 4(16.3)(16.3 + 55.5)} - 105^2 - 2(55.5)(16.3)\right] = 9.96 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{9.96}{0.155P} = 2$$

From which

$$P = \frac{9.96}{0.155(2)} = 32.13 \text{ kip} \quad Ans.$$

*Fine thread, UNF*

$$F_i = 0.75(1.073)(74) = 59.55 \text{ kip}$$

$$\sigma_i = \frac{59.55}{1.073} = 55.5 \text{ kpsi}$$

$$\sigma_a = \frac{0.32P}{2(1.073)} = 0.149P \text{ kpsi}$$

$$S_a = 9.96 \quad \text{(as before)}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{9.96}{0.149P} = 2$$

From which

$$P = \frac{9.96}{0.149(2)} = 33.42 \text{ kip} \quad Ans.$$

Percent improvement

$$\frac{33.42 - 32.13}{32.13}(100) \doteq 4\% \quad Ans.$$

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**8-37** For a M 30 × 3.5 ISO 8.8 bolt with $P = 80$ kN/bolt and $C = 0.33$

Table 8-1: $A_t = 561 \text{ mm}^2$

Table 8-11: $S_p = 600$ MPa

$S_{ut} = 830$ MPa

Table 8-17: $S_e = 129$ MPa

$$F_i = 0.75(561)(10^{-3})(600) = 252.45 \text{ kN}$$

$$\sigma_i = \frac{252.45(10^{-3})}{561} = 450 \text{ MPa}$$

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.33(80)(10^3)}{2(561)} = 23.53 \text{ MPa}$$

Eq. (8-42):

$$S_a = \frac{1}{2(129)}\left[830\sqrt{830^2 + 4(129)(129+450)} - 830^2 - 2(450)(129)\right] = 77.0 \text{ MPa}$$

Fatigue factor of safety

$$n_f = \frac{S_a}{\sigma_a} = \frac{77.0}{23.53} = 3.27 \quad Ans.$$

Load factor from Eq. (8-28),

$$n = \frac{S_p A_t - F_i}{CP} = \frac{600(10^{-3})(561) - 252.45}{0.33(80)} = 3.19 \quad Ans.$$

Separation load factor from Eq. (8-29),

$$n = \frac{F_i}{(1-C)P} = \frac{252.45}{(1-0.33)(80)} = 4.71 \quad Ans.$$

**8-38**

**(a)** Table 8-2: $A_t = 0.0775 \text{ in}^2$

Table 8-9: $S_p = 85 \text{ kpsi}, \quad S_{ut} = 120 \text{ kpsi}$

Table 8-17: $S_e = 18.6 \text{ kpsi}$

Unthreaded grip

$$k_b = \frac{A_d E}{l} = \frac{\pi(0.375)^2(30)}{4(13.5)} = 0.245 \text{ Mlbf/in per bolt} \quad Ans.$$

$$A_m = \frac{\pi}{4}[(D+2t)^2 - D^2] = \frac{\pi}{4}(4.75^2 - 4^2) = 5.154 \text{ in}^2$$

$$k_m = \frac{A_m E}{l} = \frac{5.154(30)}{12}\left(\frac{1}{6}\right) = 2.148 \text{ Mlbf/in/bolt.} \quad Ans.$$

**(b)**

$$F_i = 0.75(0.0775)(85) = 4.94 \text{ kip}$$

$$\sigma_i = 0.75(85) = 63.75 \text{ kpsi}$$

$$P = pA = \frac{2000}{6}\left[\frac{\pi}{4}(4)^2\right] = 4189 \text{ lbf/bolt}$$

$$C = \frac{0.245}{0.245 + 2.148} = 0.102$$

$$\sigma_a = \frac{CP}{2A_t} = \frac{0.102(4.189)}{2(0.0775)} = 2.77 \text{ kpsi}$$

Eq. (8-40) for Goodman

$$S_a = \frac{18.6(120 - 63.75)}{120 + 18.6} = 7.55 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{7.55}{2.77} = 2.73 \quad \textit{Ans.}$$

**(c)** From Eq. (8-42) for Gerber fatigue criterion,

$$S_a = \frac{1}{2(18.6)}\left[120\sqrt{120^2 + 4(18.6)(18.6 + 63.75)} - 120^2 - 2(63.75)(18.6)\right]$$

$$= 11.32 \text{ kpsi}$$

$$n_f = \frac{S_a}{\sigma_a} = \frac{11.32}{2.77} = 4.09 \quad \textit{Ans.}$$

**(d)** Pressure causing joint separation from Eq. (8-29)

$$n = \frac{F_i}{(1 - C)P} = 1$$

$$P = \frac{F_i}{1 - C} = \frac{4.94}{1 - 0.102} = 5.50 \text{ kip}$$

$$p = \frac{P}{A} = \frac{5500}{\pi(4^2)/4} 6 = 2626 \text{ psi} \quad \textit{Ans.}$$

**8-39** This analysis is important should the initial bolt tension fail. Members: $S_y = 71$ kpsi, $S_{sy} = 0.577(71) = 41.0$ kpsi. Bolts: SAE grade 8, $S_y = 130$ kpsi, $S_{sy} = 0.577(130) = 75.01$ kpsi

*Shear in bolts*

$$A_s = 2\left[\frac{\pi(0.375^2)}{4}\right] = 0.221 \text{ in}^2$$

$$F_s = \frac{A_s S_{sy}}{n} = \frac{0.221(75.01)}{3} = 5.53 \text{ kip}$$

*Bearing on bolts*

$$A_b = 2(0.375)(0.25) = 0.188 \text{ in}^2$$

$$F_b = \frac{A_b S_{yc}}{n} = \frac{0.188(130)}{2} = 12.2 \text{ kip}$$

*Bearing on member*

$$F_b = \frac{0.188(71)}{2.5} = 5.34 \text{ kip}$$

*Tension of members*

$$A_t = (1.25 - 0.375)(0.25) = 0.219 \text{ in}^2$$

$$F_t = \frac{0.219(71)}{3} = 5.18 \text{ kip}$$

$$F = \min(5.53, 12.2, 5.34, 5.18) = 5.18 \text{ kip} \quad \textit{Ans.}$$

The tension in the members controls the design.

**8-40** Members: $S_y = 32$ kpsi

Bolts: $S_y = 92$ kpsi, $S_{sy} = (0.577)92 = 53.08$ kpsi

*Shear of bolts*

$$A_s = 2\left[\frac{\pi(0.375)^2}{4}\right] = 0.221 \text{ in}^2$$

$$\tau = \frac{F_s}{A_s} = \frac{4}{0.221} = 18.1 \text{ kpsi}$$

$$n = \frac{S_{sy}}{\tau} = \frac{53.08}{18.1} = 2.93 \quad Ans.$$

*Bearing on bolts*

$$A_b = 2(0.25)(0.375) = 0.188 \text{ in}^2$$

$$\sigma_b = \frac{-4}{0.188} = -21.3 \text{ kpsi}$$

$$n = \frac{S_y}{|\sigma_b|} = \frac{92}{|-21.3|} = 4.32 \quad Ans.$$

*Bearing on members*

$$n = \frac{S_{yc}}{|\sigma_b|} = \frac{32}{|-21.3|} = 1.50 \quad Ans.$$

*Tension of members*

$$A_t = (2.375 - 0.75)(1/4) = 0.406 \text{ in}^2$$

$$\sigma_t = \frac{4}{0.406} = 9.85 \text{ kpsi}$$

$$n = \frac{S_y}{A_t} = \frac{32}{9.85} = 3.25 \quad Ans.$$

**8-41** Members: $S_y = 71$ kpsi

Bolts: $S_y = 92$ kpsi, $S_{sy} = 0.577(92) = 53.08$ kpsi

*Shear of bolts*

$$F = S_{sy}A/n$$

$$F_s = \frac{53.08(2)(\pi/4)(7/8)^2}{1.8} = 35.46 \text{ kip}$$

*Bearing on bolts*

$$F_b = \frac{2(7/8)(3/4)(92)}{2.2} = 54.89 \text{ kip}$$

*Bearing on members*

$$F_b = \frac{2(7/8)(3/4)(71)}{2.4} = 38.83 \text{ kip}$$

*Tension in members*

$$F_t = \frac{(3 - 0.875)(3/4)(71)}{2.6} = 43.52 \text{ kip}$$

$$F = \min(35.46, 54.89, 38.83, 43.52) = 35.46 \text{ kip} \quad \textit{Ans.}$$

**8-42** Members: $S_y = 47$ kpsi

Bolts: $S_y = 92$ kpsi, $S_{sy} = 0.577(92) = 53.08$ kpsi

*Shear of bolts*

$$A_d = \frac{\pi(0.75)^2}{4} = 0.442 \text{ in}^2$$

$$\tau_s = \frac{20}{3(0.442)} = 15.08 \text{ kpsi}$$

$$n = \frac{S_{sy}}{\tau_s} = \frac{53.08}{15.08} = 3.52 \quad \textit{Ans.}$$

*Bearing on bolt*

$$\sigma_b = -\frac{20}{3(3/4)(5/8)} = -14.22 \text{ kpsi}$$

$$n = -\frac{S_y}{\sigma_b} = -\left(\frac{92}{-14.22}\right) = 6.47 \quad \textit{Ans.}$$

*Bearing on members*

$$\sigma_b = -\frac{F}{A_b} = -\frac{20}{3(3/4)(5/8)} = -14.22 \text{ kpsi}$$

$$n = -\frac{S_y}{\sigma_b} = -\frac{47}{14.22} = 3.31 \quad \textit{Ans.}$$

*Tension on members*

$$\sigma_t = \frac{F}{A} = \frac{20}{(5/8)[7.5 - 3(3/4)]} = 6.10 \text{ kpsi}$$

$$n = \frac{S_y}{\sigma_t} = \frac{47}{6.10} = 7.71 \quad \textit{Ans.}$$

**8-43** Members: $S_y = 57$ kpsi

Bolts: $S_y = 92$ kpsi, $S_{sy} = 0.577(92) = 53.08$ kpsi

*Shear of bolts*

$$A_s = 3\left[\frac{\pi(3/8)^2}{4}\right] = 0.3313 \text{ in}^2$$

$$\tau_s = \frac{F}{A} = \frac{5.4}{0.3313} = 16.3 \text{ kpsi}$$

$$n = \frac{S_{sy}}{\tau_s} = \frac{53.08}{16.3} = 3.26 \quad \textit{Ans.}$$

*Bearing on bolt*

$$A_b = 3\left(\frac{3}{8}\right)\left(\frac{5}{16}\right) = 0.3516 \text{ in}^2$$

$$\sigma_b = -\frac{F}{A_b} = -\frac{5.4}{0.3516} = -15.36 \text{ kpsi}$$

$$n = -\frac{S_y}{\sigma_b} = -\left(\frac{92}{-15.36}\right) = 5.99 \quad Ans.$$

*Bearing on members*

$$A_b = 0.3516 \text{ in}^2 \text{ (From bearing on bolt calculations)}$$

$$\sigma_b = -15.36 \text{ kpsi (From bearing on bolt calculations)}$$

$$n = -\frac{S_y}{\sigma_b} = -\left(\frac{57}{-15.36}\right) = 3.71 \quad Ans.$$

*Tension in members*

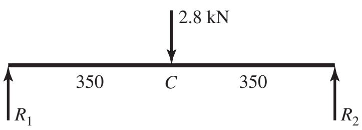
Failure across two bolts

$$A = \frac{5}{16}\left[2\frac{3}{8} - 2\left(\frac{3}{8}\right)\right] = 0.5078 \text{ in}^2$$

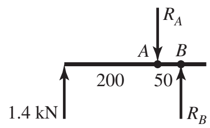
$$\sigma = \frac{F}{A} = \frac{5.4}{0.5078} = 10.63 \text{ kpsi}$$

$$n = \frac{S_y}{\sigma_t} = \frac{57}{10.63} = 5.36 \quad Ans.$$

**8-44**




By symmetry, $R_1 = R_2 = 1.4$ kN




$$\sum M_B = 0 \quad 1.4(250) - 50R_A = 0 \quad \Rightarrow \quad R_A = 7 \text{ kN}$$

$$\sum M_A = 0 \quad 200(1.4) - 50R_B = 0 \quad \Rightarrow \quad R_B = 5.6 \text{ kN}$$

Members: $S_y = 370$ MPa

Bolts: $S_y = 420$ MPa, $S_{sy} = 0.577(420) = 242.3$ MPa

*Bolt shear:*

$$A_s = \frac{\pi}{4}(10^2) = 78.54 \text{ mm}^2$$

$$\tau = \frac{7(10^3)}{78.54} = 89.13 \text{ MPa}$$

$$n = \frac{S_{sy}}{\tau} = \frac{242.3}{89.13} = 2.72$$

*Bearing on member:* $A_b = td = 10(10) = 100\text{ mm}^2$

$$\sigma_b = \frac{-7(10^3)}{100} = -70\text{ MPa}$$

$$n = -\frac{S_y}{\sigma} = \frac{-370}{-70} = 5.29$$

*Strength of member*

At $A$, $M = 1.4(200) = 280\text{ N}\cdot\text{m}$

$$I_A = \frac{1}{12}[10(50^3) - 10(10^3)] = 103.3(10^3)\text{ mm}^4$$

$$\sigma_A = \frac{Mc}{I_A} = \frac{280(25)}{103.3(10^3)}(10^3) = 67.76\text{ MPa}$$

$$n = \frac{S_y}{\sigma_A} = \frac{370}{67.76} = 5.46$$

At $C$, $M = 1.4(350) = 490\text{ N}\cdot\text{m}$

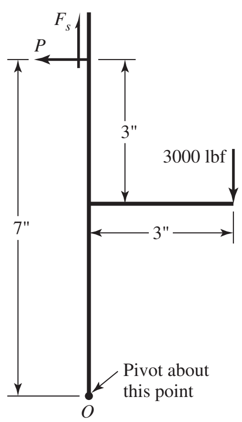
$$I_C = \frac{1}{12}(10)(50^3) = 104.2(10^3)\text{ mm}^4$$

$$\sigma_C = \frac{490(25)}{104.2(10^3)}(10^3) = 117.56\text{ MPa}$$

$$n = \frac{S_y}{\sigma_C} = \frac{370}{117.56} = 3.15 < 5.46 \qquad C\text{ more critical}$$

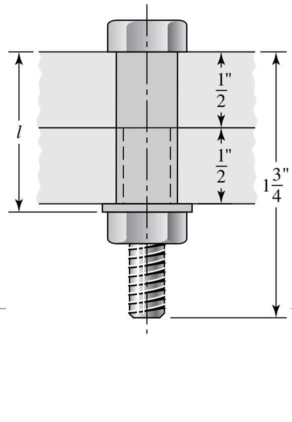
$$n = \min(2.72, 5.29, 3.15) = 2.72 \quad \textit{Ans.}$$

**8-45**




$$F_s = 3000\text{ lbf}$$

$$P = \frac{3000(3)}{7} = 1286\text{ lbf}$$



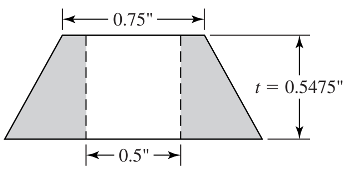

$$H = \frac{7}{16}\text{ in}$$

$$l = \frac{1}{2} + \frac{1}{2} + 0.095 = 1.095\text{ in}$$

$$L \ge l + H = 1.095 + (7/16) = 1.532\text{ in}$$

Use $1\frac{3}{4}$" bolts

$$L_T = 2D + \frac{1}{4} = 2(0.5) + 0.25 = 1.25 \text{ in}$$
$$l_d = 1.75 - 1.25 = 0.5$$
$$l_t = 1.095 - 0.5 = 0.595$$
$$A_d = \frac{\pi(0.5)^2}{4} = 0.1963 \text{ in}^2$$
$$A_t = 0.1419 \text{ in}$$
$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d}$$
$$= \frac{0.1963(0.1419)(30)}{0.1963(0.595) + 0.1419(0.5)}$$
$$= 4.451 \text{ Mlbf/in}$$




Two identical frusta

$$A = 0.787\,15,\ B = 0.628\,73$$
$$k_m = EdA \exp\left(0.628\,73 \frac{d}{L_G}\right)$$
$$= 30(0.5)(0.787\,15)\left[\exp\left(0.628\,73 \frac{0.5}{1.095}\right)\right]$$
$$k_m = 15.733 \text{ Mlbf/in}$$
$$C = \frac{4.451}{4.451 + 15.733} = 0.2205$$
$$S_p = 85 \text{ kpsi}$$
$$F_i = 0.75(0.1419)(85) = 9.046 \text{ kip}$$
$$\sigma_i = 0.75(85) = 63.75 \text{ kpsi}$$
$$\sigma_b = \frac{CP + F_i}{A_t} = \frac{0.2205(1.286) + 9.046}{0.1419} = 65.75 \text{ kpsi}$$
$$\tau_s = \frac{F_s}{A_s} = \frac{3}{0.1963} = 15.28 \text{ kpsi}$$

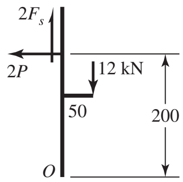
von Mises stress

$$\sigma' = \left(\sigma_b^2 + 3\tau_s^2\right)^{1/2} = [65.74^2 + 3(15.28^2)]^{1/2} = 70.87 \text{ kpsi}$$

Stress margin

$$m = S_p - \sigma' = 85 - 70.87 = 14.1 \text{ kpsi} \quad \textit{Ans.}$$

**8-46**




$$2P(200) = 12(50)$$

$$P = \frac{12(50)}{2(200)} = 1.5 \text{ kN per bolt}$$

$$F_s = 6 \text{ kN/bolt}$$

$$S_p = 380 \text{ MPa}$$

$$A_t = 245 \text{ mm}^2,\ A_d = \frac{\pi}{4}(20^2) = 314.2 \text{ mm}^2$$

$$F_i = 0.75(245)(380)(10^{-3}) = 69.83 \text{ kN}$$

$$\sigma_i = \frac{69.83(10^3)}{245} = 285 \text{ MPa}$$

$$\sigma_b = \frac{CP + F_i}{A_t} = \left(\frac{0.30(1.5) + 69.83}{245}\right)(10^3) = 287 \text{ MPa}$$

$$\tau = \frac{F_s}{A_d} = \frac{6(10^3)}{314.2} = 19.1 \text{ MPa}$$

$$\sigma' = [287^2 + 3(19.1^2)]^{1/2} = 289 \text{ MPa}$$

$$m = S_p - \sigma' = 380 - 289 = 91 \text{ MPa}$$

Thus the bolt will *not* exceed the proof stress. *Ans.*

**8-47** Using the result of Prob. 5-31 for lubricated assembly

$$F_x = \frac{2\pi f T}{0.18d}$$

With a design factor of $n_d$ gives

$$T = \frac{0.18 n_d F_x d}{2\pi f} = \frac{0.18(3)(1000)d}{2\pi(0.12)} = 716d$$

or $T/d = 716$. Also

$$\frac{T}{d} = K(0.75 S_p A_t)$$

$$= 0.18(0.75)(85\,000)A_t$$

$$= 11\,475 A_t$$

Form a table

| Size | $A_t$ | $T/d = 11\,475A_t$ | $n$ |
|---|---|---|---|
| $\frac{1}{4} - 28$ | 0.0364 | 417.7 | 1.75 |
| $\frac{5}{16} - 24$ | 0.058 | 665.55 | 2.8 |
| $\frac{3}{8} - 24$ | 0.0878 | 1007.5 | 4.23 |

The factor of safety in the last column of the table comes from

$$n = \frac{2\pi f(T/d)}{0.18F_x} = \frac{2\pi(0.12)(T/d)}{0.18(1000)} = 0.0042(T/d)$$

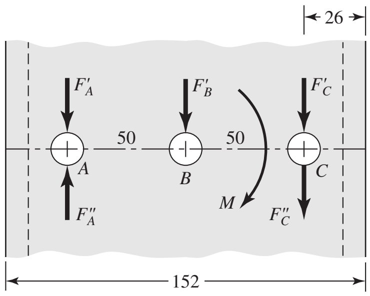
Select a $\frac{3}{8}$" − 24 UNF capscrew. The setting is given by

$$T = (11\,475 A_t)d = 1007.5(0.375) = 378 \text{ lbf} \cdot \text{in}$$

Given the coarse scale on a torque wrench, specify a torque wrench setting of 400 lbf · in. Check the factor of safety

$$n = \frac{2\pi f T}{0.18 F_x d} = \frac{2\pi(0.12)(400)}{0.18(1000)(0.375)} = 4.47$$

**8-48**




Bolts: $S_p = 380$ MPa, $S_y = 420$ MPa
Channel: $t = 6.4$ mm, $S_y = 170$ MPa
Cantilever: $S_y = 190$ MPa
Nut: $H = 10.8$ mm

$$F'_A = F'_B = F'_C = F/3$$

$$M = (50 + 26 + 125)F = 201F$$

$$F''_A = F''_C = \frac{201F}{2(50)} = 2.01F$$

$$F_C = F'_C + F''_C = \left(\frac{1}{3} + 2.01\right) F = 2.343F$$

*Bolts:*
The shear bolt area is $A = \pi(12^2)/4 = 113.1 \text{ mm}^2$

$$S_{sy} = 0.577(420) = 242.3 \text{ MPa}$$

$$F = \frac{S_{sy}}{n}\left(\frac{A}{2.343}\right) = \frac{242.3(113.1)(10^{-3})}{2.8(2.343)} = 4.18 \text{ kN}$$

*Bearing on bolt:* For a 12-mm bolt, at the channel,

$$A_b = td = (6.4)(12) = 76.8 \text{ mm}^2$$

$$F = \frac{S_y}{n}\left(\frac{A_b}{2.343}\right) = \frac{420}{2.8}\left[\frac{76.8(10^{-3})}{2.343}\right] = 4.92 \text{ kN}$$

*Bearing on channel:* $A_b = 76.8 \text{ mm}^2$, $S_y = 170$ MPa

$$F = \frac{170}{2.8}\left[\frac{76.8(10^{-3})}{2.343}\right] = 1.99 \text{ kN}$$

*Bearing on cantilever:*

$$A_b = 12(12) = 144 \text{ mm}^2$$

$$F = \frac{190}{2.8}\left[\frac{(144)(10^{-3})}{2.343}\right] = 4.17 \text{ kN}$$

*Bending of cantilever:*

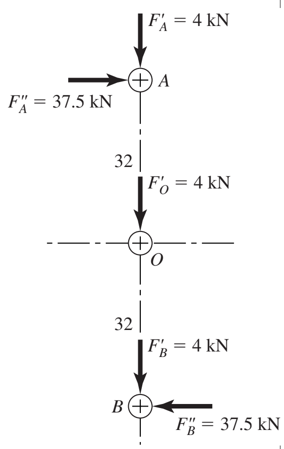
$$I = \frac{1}{12}(12)(50^3 - 12^3) = 1.233(10^5) \text{ mm}^4$$

$$\frac{I}{c} = \frac{1.233(10^5)}{25} = 4932$$

$$F = \frac{M}{151} = \frac{4932(190)}{2.8(151)(10^3)} = 2.22 \text{ kN}$$

So $F = 1.99$ kN based on bearing on channel *Ans.*

**8-49** $F' = 4$ kN; $M = 12(200) = 2400$ N · m




$$F''_A = F''_B = \frac{2400}{64} = 37.5 \text{ kN}$$

$$F_A = F_B = \sqrt{(4)^2 + (37.5)^2} = 37.7 \text{ kN} \quad \textit{Ans.}$$

$$F_O = 4 \text{ kN} \quad \textit{Ans.}$$

*Bolt shear:*

$$A_s = \frac{\pi(12)^2}{4} = 113 \text{ mm}^2$$

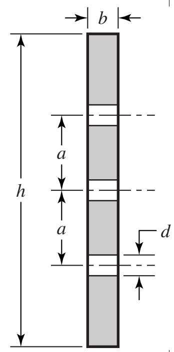
$$\tau = \frac{37.7(10)^3}{113} = 334 \text{ MPa} \quad \textit{Ans.}$$

*Bearing on member:*

$$A_b = 12(8) = 96 \text{ mm}^2$$

$$\sigma = -\frac{37.7(10)^3}{96} = -393 \text{ MPa} \quad \textit{Ans.}$$

*Bending stress in plate:*




$$I = \frac{bh^3}{12} - \frac{bd^3}{12} - 2\left(\frac{bd^3}{12} + a^2bd\right)$$

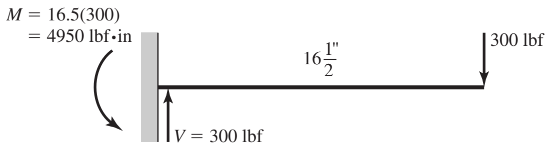
$$= \frac{8(136)^3}{12} - \frac{8(12)^3}{12} - 2\left[\frac{8(12)^3}{12} + (32)^2(8)(12)\right]$$

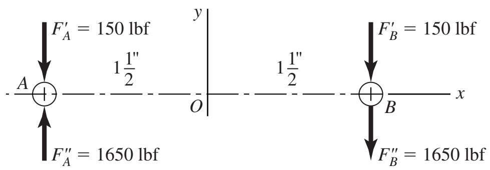
$$= 1.48(10)^6 \text{ mm}^4 \quad \textit{Ans.}$$

$$M = 12(200) = 2400 \text{ N} \cdot \text{m}$$

$$\sigma = \frac{Mc}{I} = \frac{2400(68)}{1.48(10)^6}(10)^3 = 110 \text{ MPa} \quad \textit{Ans.}$$

**8-50**




*Shear of bolt:*

$$A_s = \frac{\pi}{4}(0.5)^2 = 0.1963 \text{ in}^2$$

$$\tau = \frac{F}{A} = \frac{1800}{0.1963} = 9170 \text{ psi}$$

$$S_{sy} = 0.577(92) = 53.08 \text{ kpsi}$$

$$n = \frac{53.08}{9.17} = 5.79 \quad \textit{Ans.}$$

$$F''_A = F''_B = \frac{4950}{3} = 1650 \text{ lbf}$$

$$F_A = 1500 \text{ lbf}, \qquad F_B = 1800 \text{ lbf}$$

*Bearing on bolt:*

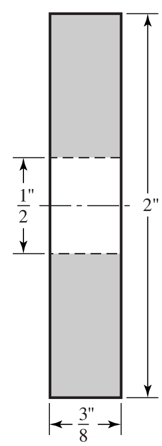
$$A_b = \frac{1}{2}\left(\frac{3}{8}\right) = 0.1875 \text{ in}^2$$

$$\sigma = -\frac{F}{A} = -\frac{1800}{0.1875} = -9600 \text{ psi}$$

$$n = \frac{92}{9.6} = 9.58 \quad \textit{Ans.}$$

*Bearing on members:* $S_y = 54$ kpsi, $n = \dfrac{54}{9.6} = 5.63$ *Ans.*

*Bending of members:* Considering the right-hand bolt




$$M = 300(15) = 4500 \text{ lbf} \cdot \text{in}$$

$$I = \frac{0.375(2)^3}{12} - \frac{0.375(0.5)^3}{12} = 0.246 \text{ in}^4$$

$$\sigma = \frac{Mc}{I} = \frac{4500(1)}{0.246} = 18\,300 \text{ psi}$$

$$n = \frac{54(10)^3}{18\,300} = 2.95 \quad \textit{Ans.}$$

**8-51** The direct shear load per bolt is $F' = 2500/6 = 417$ lbf. The moment is taken only by the four outside bolts. This moment is $M = 2500(5) = 12\,500$ lbf · in.

Thus $F'' = \dfrac{12\,500}{2(5)} = 1250$ lbf and the resultant bolt load is

$$F = \sqrt{(417)^2 + (1250)^2} = 1318 \text{ lbf}$$

Bolt strength, $S_y = 57$ kpsi; Channel strength, $S_y = 46$ kpsi; Plate strength, $S_y = 45.5$ kpsi

*Shear of bolt:* $A_s = \pi(0.625)^2/4 = 0.3068 \text{ in}^2$

$$n = \frac{S_{sy}}{\tau} = \frac{(0.577)(57\,000)}{1318/0.3068} = 7.66 \quad \textit{Ans.}$$

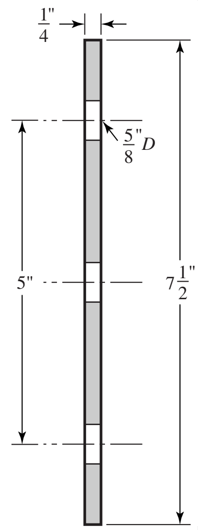
*Bearing on bolt:* Channel thickness is $t = 3/16$ in;

$$A_b = (0.625)(3/16) = 0.117\ \text{in}^2;\ n = \frac{57\,000}{1318/0.117} = 5.07 \quad \textit{Ans.}$$

*Bearing on channel:* $$n = \frac{46\,000}{1318/0.117} = 4.08 \quad \textit{Ans.}$$

*Bearing on plate:* $$A_b = 0.625(1/4) = 0.1563\ \text{in}^2$$

$$n = \frac{45\,500}{1318/0.1563} = 5.40 \quad \textit{Ans.}$$




*Bending of plate:*

$$I = \frac{0.25(7.5)^3}{12} - \frac{0.25(0.625)^3}{12}$$

$$- 2\left[\frac{0.25(0.625)^3}{12} + \left(\frac{1}{4}\right)\left(\frac{5}{8}\right)(2.5)^2\right] = 6.821\ \text{in}^4$$

$$M = 6250\ \text{lbf} \cdot \text{in per plate}$$

$$\sigma = \frac{Mc}{I} = \frac{6250(3.75)}{6.821} = 3436\ \text{psi}$$

$$n = \frac{45\,500}{3436} = 13.2 \quad \textit{Ans.}$$

**8-52** Specifying bolts, screws, dowels and rivets is the way a student learns about such components. However, choosing an array a priori is based on experience. Here is a chance for students to build some experience.

**8-53** Now that the student can put an a priori decision of an array together with the specification of fasteners.

**8-54** A computer program will vary with computer language or software application.