A single square-thread power screw has an input power of 3 kW at a speed of 1 rev/s. The screw has a diameter of 40 mm and a pitch of 8 mm. The frictional coefficients are 0.14 for the threads and 0.09 for the collar, with a collar friction radius of 50 mm. Find the axial resisting load *F* and the combined efficiency of the screw and collar.

$d_m = 40 - 4 = 36$ mm, $l = p = 8$ mm

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

$$T = \frac{36F}{2}\left[\frac{8 + \pi(0.14)(36)}{\pi(36) - 0.14(8)}\right] + \frac{0.09(100)F}{2}$$

$$= (3.831 + 4.5)F = 8.33F \quad \text{N} \cdot \text{m} \quad (F \text{ in kN})$$

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

$$H = T\omega$$

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

$$F = \frac{477}{8.33} = 57.3 \text{ kN} \quad \textit{Ans.}$$

$$e = \frac{Fl}{2\pi T} = \frac{57.3(8)}{2\pi(477)} = 0.153 \quad \textit{Ans.}$$

An M14 × 2 hex-head bolt with a nut is used to clamp together two 15-mm steel plates.
(*a*) Determine a suitable length for the bolt, rounded up to the nearest 5 mm.
(*b*) Determine the bolt stiffness.
(*c*) Determine the stiffness of the members.

(**a**) Table A-31, nut height $H = 12.8$ mm. $L \geq l + H = 2(15) + 12.8 = 42.8$ mm. Rounding up,

$$L = 45 \text{ mm} \qquad Ans.$$

(**b**) From Eq. (8-14), $L_T = 2d + 6 = 2(14) + 6 = 34$ mm
From Table 8-7, $l_d = L - L_T = 45 - 34 = 11$ mm, $l_t = l - l_d = 2(15) - 11 = 19$ mm,

$A_d = \pi(14^2)/4 = 153.9$ mm^2. From Table 8-1, $A_t = 115$ mm^2. From Eq. (8-17)

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{153.9(115)207}{153.9(19) + 115(11)} = 874.6 \text{ MN/m} \qquad Ans.$$

(**c**) From Eq. (8-22), with $l = 2(15) = 30$ mm

$$k_m = \frac{0.5774\pi E d}{2\ln\left(5\dfrac{0.5774l + 0.5d}{0.5774l + 2.5d}\right)} = \frac{0.5774\pi(207)14}{2\ln\left[5\dfrac{0.5774(30) + 0.5(14)}{0.5774(30) + 2.5(14)}\right]} = 3\,116.5 \text{ MN/m} \qquad Ans.$$

For a bolted assembly with eight bolts, the stiffness of each bolt is *kb* = 1.0 MN/mm and the stiffness of the members is *km* = 2.6 MN/mm per bolt. The joint is subject to occasional disassembly for maintenance and should be preloaded accordingly. Assume the external load is equally distributed to all the bolts. It has been determined to use M6 × 1 class 5.8 bolts with rolled threads.

(*a*) Determine the maximum external load *P*max that can be applied to the entire joint without exceeding the proof strength of the bolts.

(*b*) Determine the maximum external load *P*max that can be applied to the entire joint without causing the members to come out of compression.

(a) Table 8-1, $A_t = 20.1\ \text{mm}^2$. Table 8-11, $S_p = 380$ MPa.

Eq. (8-31), $F_i = 0.75\,F_p = 0.75\,A_t\,S_p = 0.75(20.1)380(10^{-3}) = 5.73$ kN

Eq. (*f*), p. 436,
$$C = \frac{k_b}{k_b + k_m} = \frac{1}{1+2.6} = 0.278$$

Eq. (8-28) with $n_p = 1$,
$$P = \frac{S_p A_t - F_i}{C} = \frac{0.25 S_p A_t}{C} = \frac{0.25(20.1)380(10^{-3})}{0.278} = 6.869\ \text{kN}$$

$P_{\text{total}} = NP = 8(6.869) = 55.0$ kN *Ans.*

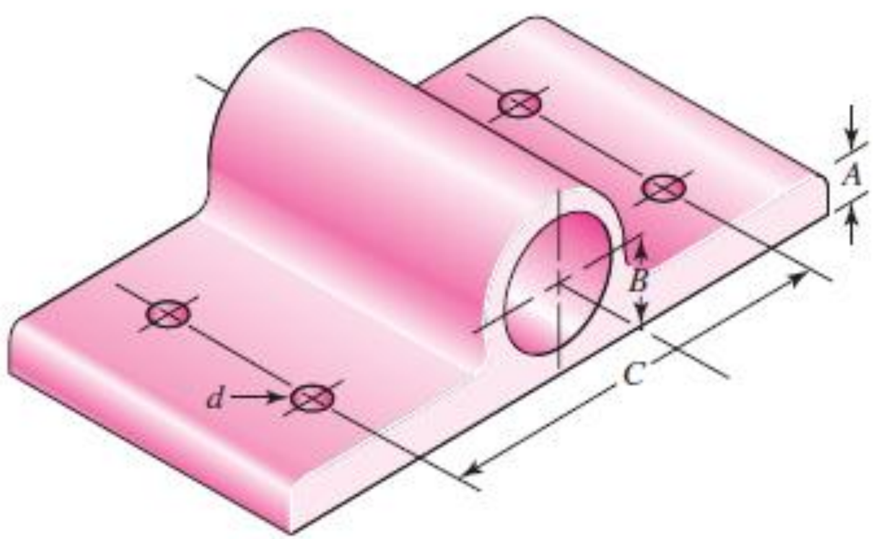
(b) Eq. (8-30) with $n_0 = 1$,
$$P = \frac{F_i}{1-C} = \frac{5.73}{1-0.278} = 7.94\ \text{kN}$$

$P_{\text{total}} = NP = 8(7.94) = 63.5$ kN *Ans.* Bolt stress would exceed proof strength

The figure shows a cast-iron bearing block that is to be bolted to a steel ceiling joist and is to support a gravity load of 18 kN. Bolts used are M24 ISO 8.8 with coarse threads and with 4.6-mm-thick steel washers under the bolt head and nut. The joist flanges are 20 mm in thickness, and the dimension *A*, shown in the figure, is 20 mm. The modulus of elasticity of the bearing block is 135 GPa.

(*a*) Find the wrench torque required if the fasteners are lubricated during assembly and the joint is to be permanent.

(*b*) Determine the factors of safety guarding against yielding, overload, and joint separation.



(**a**) From Table 8-11, S_p = 600 MPa. From Table 8-1, A_t = 353 mm^2.

Eq. (8-31): $F_i = 0.9 A_t S_p = 0.9(353)(600)(10^{-3}) = 190.6 \text{ kN}$

Table 8-15: $K = 0.18$

Eq. (8-27): $T = K F_i d = 0.18(190.6)(24) = 823 \text{ N·m}$ *Ans.*

(**b**) Washers: $t = 4.6$ mm, $d = 24$ mm, $D = 1.5(24) = 36$ mm, $E = 207$ GPa.

Eq. (8-20),

$$k_1 = \frac{0.5774\pi(207)24}{\ln\dfrac{[1.155(4.6)+36-24](36+24)}{[1.155(4.6)+36+24](36-24)}} = 31\,990 \text{ MN/m}$$

Cast iron: $t = 20$ mm, $d = 24$ mm, $D = 36 + 2(4.6)\tan 30° = 41.31$ mm, $E = 135$ GPa.
Eq. (8-20) $\Rightarrow$ $k_2 = 10\,785$ MN/m

Steel joist: $t = 20$ mm, $d = 24$ mm, $D = 41.31$ mm, $E = 207$ GPa. Eq. (8-20) $\Rightarrow$ $k_3 = 16\,537$ MN/m

Eq. (8-18): $k_m = (2 / 31\,990 + 1 / 10\,785 + 1 / 16\,537)^{-1} = 4\,636$ MN/m

Bolt: $l = 2(4.6) + 2(20) = 49.2$ mm. Nut, Table A-31, $H = 21.5$ mm. $L > 49.2 + 21.5 = 70.7$ mm. From Table A-17, use $L = 80$ mm. From Eq. (8-14)

$L_T = 2(24) + 6 = 54$ mm, $l_d = 80 - 54 = 26$ mm, $l_t = 49.2 - 26 = 23.2$ mm

From Table (8-1), $A_t = 353$ mm^2, $A_d = \pi(24^2)/4 = 452.4$ mm^2

Eq. (8-17):

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{452.4(353)207}{452.4(23.2) + 353(26)} = 1680 \text{ MN/m}$$

$C = k_b / (k_b + k_m) = 1680 / (1680 + 4636) = 0.266$, $S_p = 600$ MPa, $F_i = 190.6$ kN,
$P = P_{\text{total}} / N = 18/4 = 4.5$ kN

Yield: From Eq. (8-28)

$$n_p = \frac{S_p A_t}{CP + F_i} = \frac{600(353)10^{-3}}{0.266(4.5) + 190.6} = 1.10 \quad \textit{Ans.}$$

Load factor: From Eq. (8-29)

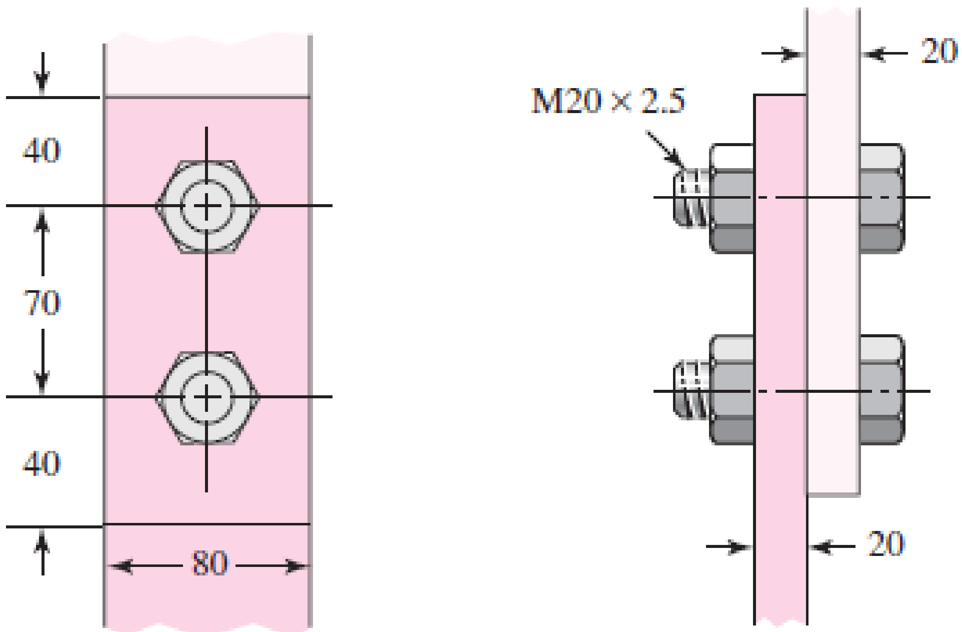
$$n_L = \frac{S_p A_t - F_i}{CP} = \frac{600(353)10^{-3} - 190.6}{0.266(4.5)} = 17.7 \quad \textit{Ans.}$$

Separation: From Eq. (8-30)

$$n_0 = \frac{F_i}{P(1-C)} = \frac{190.6}{4.5(1-0.266)} = 57.7 \qquad \textit{Ans.}$$

As was stated in the text, bolts are typically preloaded such that the yielding factor of safety is not much greater than unity which is the case for this problem. However, the other load factors indicate that the bolts are oversized for the external load.

A bolted lap joint using ISO class 5.8 bolts and members made of cold-drawn SAE 1040 steel is shown in the figure. Find the tensile shear load F that can be applied to this connection to provide a minimum factor of safety of 2.5 for the following failure modes: shear of bolts, bearing on bolts, bearing on members, and tension of members.



Members: Table A-20, $S_y = 490$ MPa, $S_{sy} = 0.577(490) = 282.7$ MPa
Bolts: Table 8-11, ISO class 5.8, $S_y = 420$ MPa, $S_{sy} = 0.577(420) = 242.3$ MPa

Shear in bolts,

$$A_s = 2\left[\frac{\pi(20^2)}{4}\right] = 628.3 \text{ mm}^2$$

$$F_s = \frac{A_s S_{sy}}{n} = \frac{628.3(242.3)10^{-3}}{2.5} = 60.9 \text{ kN}$$

Bearing on bolts,

$$A_b = 2(20)20 = 800 \text{ mm}^2$$

$$F_b = \frac{A_b S_{yc}}{n} = \frac{800(420)10^{-3}}{2.5} = 134 \text{ kN}$$

Bearing on member,

$$F_b = \frac{800(490)10^{-3}}{2.5} = 157 \text{ kN}$$

Tension of members,

$$A_t = (80 - 20)(20) = 1\,200 \text{ mm}^2$$

$$F_t = \frac{1\,200(490)10^{-3}}{2.5} = 235 \text{ kN}$$

$$F = \min(60.9,\ 134,\ 157,\ 235) = 60.9 \text{ kN} \quad \textit{Ans.}$$

The shear in the bolts controls the design.