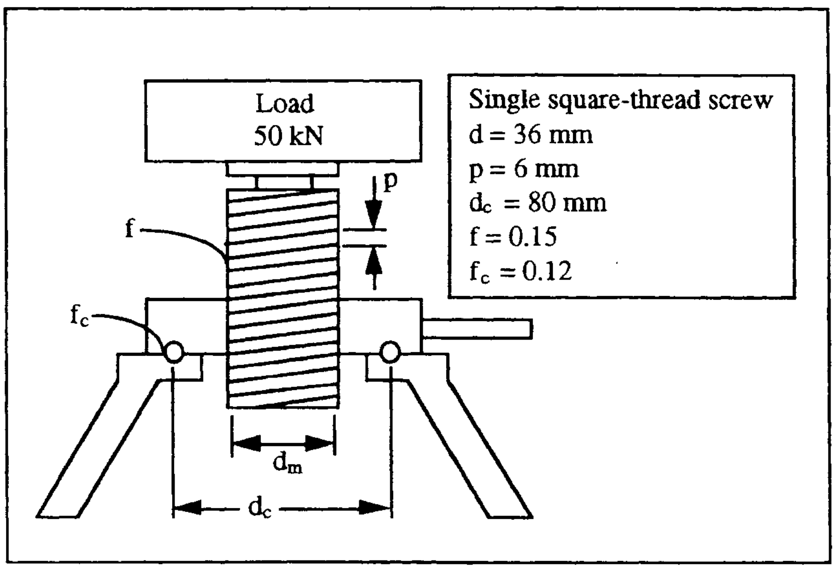
SOLUTION (10.8)

Known: A jack uses a single square-thread screw to raise a known load. The major diameter and pitch of the screw and the thrust collar mean diameter are known. Running friction coefficients are estimated.

Find:

(a) Determine the thread depth and helix angle.
(b) Estimate the starting torque for raising and lowering the load.
(c) Estimate the efficiency of the jack for raising the load.
(d) Estimate the power required to drive the screw at a constant 1 revolution per second.

Schematic and Given Data:



Assumption: The starting friction is about 1/3 higher than running friction.

Analysis:

(a) From Fig. 10.4(c),

Thread depth = p/2 = 6/2 = 3 mm ■

From Eq. (10.1),

$$\lambda = \tan^{-1}\frac{L}{\pi d_m} \quad \text{where } d_m = d - \frac{p}{2} = 33 \text{ mm}$$

$$\lambda = \tan^{-1}\frac{6}{\pi(33)} = 3.31^{\circ}$$ ■

(b) For starting, increase the coefficients of friction by 1/3, then

$f = 0.20, f_c = 0.16$

From Eq. (10.4a),

$$T = \frac{Wd_m}{2}\left(\frac{f\pi d_m + L}{\pi d_m - fL}\right) + \frac{Wf_c d_c}{2}$$

$$= \frac{(50{,}000)(0.033)}{2}\left(\frac{0.20\pi(0.033) + 0.006}{\pi(0.033) - (0.20)(0.006)}\right) + \frac{(50{,}000)(0.16)(0.080)}{2}$$

= 215 + 320

= 535 N•m to raise the load ■

From Eq. (10.5a),

$$T = \frac{Wd_m}{2}\left(\frac{f\pi d_m - L}{\pi d_m + fL}\right) + \frac{Wf_c d_c}{2}$$

$$= \frac{(50{,}000)(0.033)}{2}\left(\frac{0.20\pi(0.033) - 0.006}{\pi(0.033) + (0.20)(0.006)}\right) + \frac{(50{,}000)(0.16)(0.080)}{2}$$

= 116 + 320

= 436 N•m to lower the load ■

(c) From Eq. (10.4a), with $f = 0.15, f_c = 0.12$,

$$T = \frac{(50{,}000)(0.033)}{2}\left(\frac{0.15\pi(0.033) + 0.006}{\pi(0.033) - (0.15)(0.006)}\right) + \frac{(50{,}000)(0.12)(0.080)}{2}$$

= 173 + 240 = 413 N•m

Work input to the screw during one revolution

= 2πT = 2π(413) = 2595 N•m

Work output during one revolution

= W• p = (50,000)(0.006) = 300 N•m

$$\text{Efficiency} = \frac{\text{Work}_{out}}{\text{Work}_{in}} = \frac{300}{2595} = 11.6\%$$ ■

Check:

Torque during load raising with $f = f_c = 0$

$$T = \frac{(50{,}000)(0.033)}{2}\left(\frac{0 + 0.006}{\pi(0.033) - 0}\right) + 0$$

$$= 47.8 \text{ N}\bullet\text{m}$$

$$\text{Efficiency} = \frac{T_{\text{(with zero friction)}}}{T_{\text{(actual)}}} = \frac{47.8}{413} = 11.6\%$$ ■

Check (partial):

Torque during load raising if collar friction is eliminated = 173 N•m

$$\text{Efficiency (screw only)} = \frac{47.8}{173} = 28\%$$

(d) From Eq. (1.2),

$$\dot{W} = \frac{nT}{9549} = \frac{(60)(413)}{9549} = 2.6 \text{ kW}$$ ■