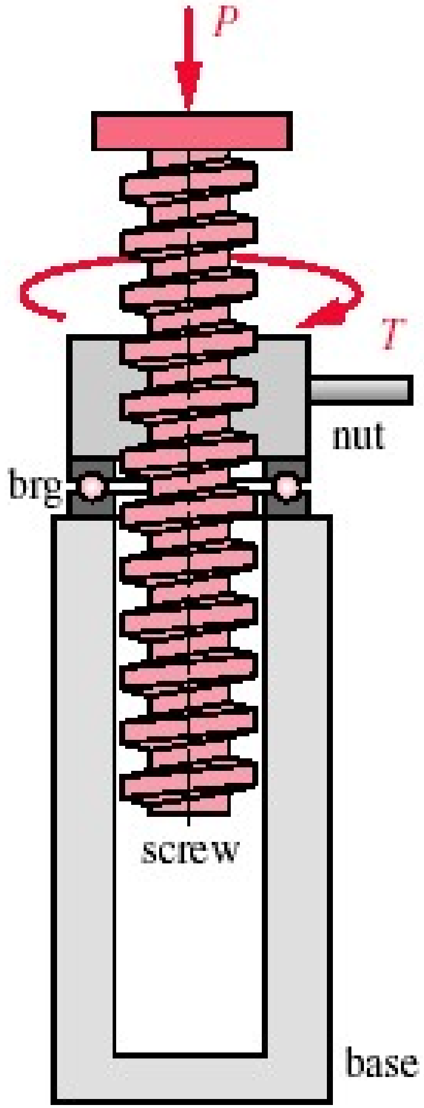
Power Screw

-A **power screw** convert a rotary motion into a linear motion

-Either the **screw** or the nut is held at re other member rotates as it moves axially

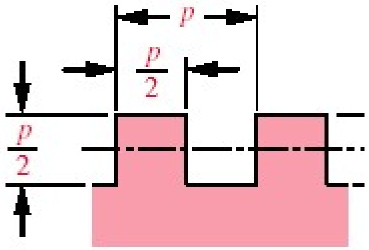


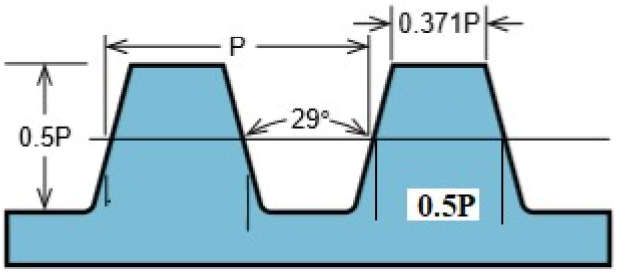
Power Screw Applications

Where have you seen power screws?

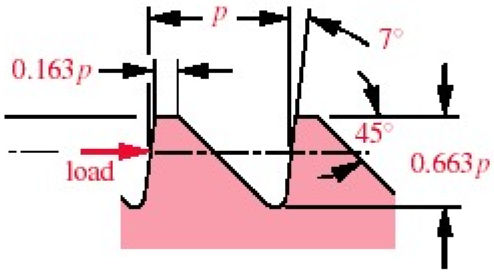
- jacks for cars
- C-clamps
- vises
- Instron material testing machines
- machine tools (for positioning of table)

Power Screw Types





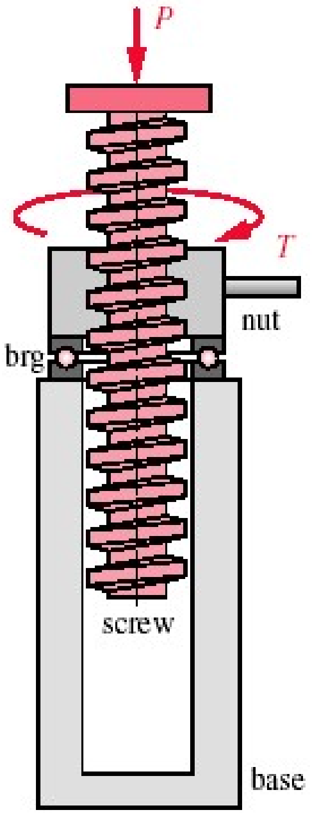
Acme

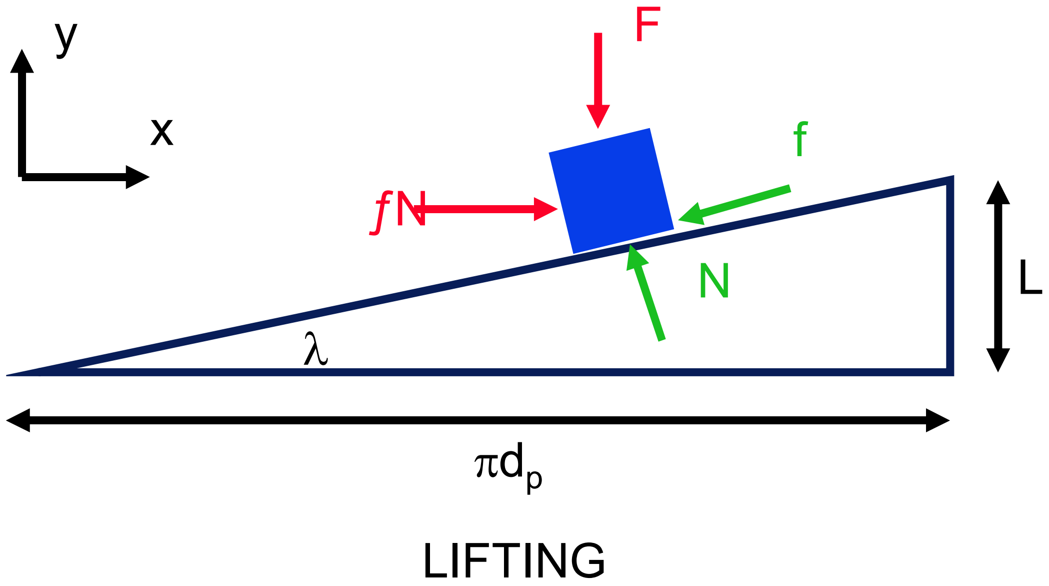


- Square
  - strongest
  - no radial load
  - hard to manufacture
- Acme
  - 29° included angle
  - easier to manufacture
  - common choice for loading in both directions
- Buttress (contrafuerte)
  - great strength
  - only unidirectional loading

Load Analysis

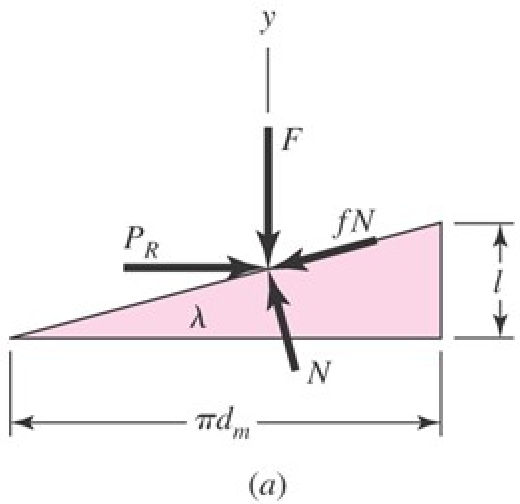
What "simple machine" does a power screw utilize?

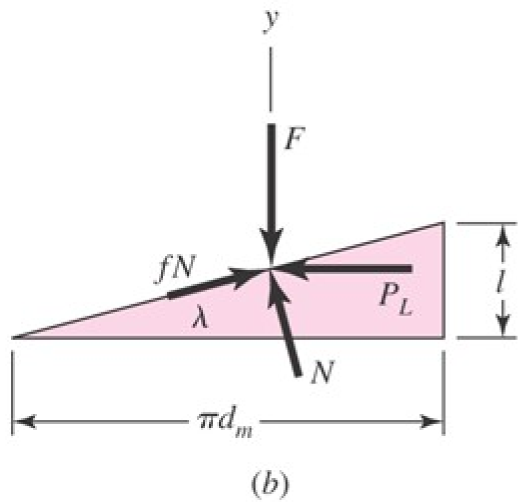




Mechanics of Power Screws

- Used to change angular motion into linear motion
- Find expression for torque required to raise or lower a load
- Unroll one turn of a thread
- Treat thread as inclined plane
- Do force analysis





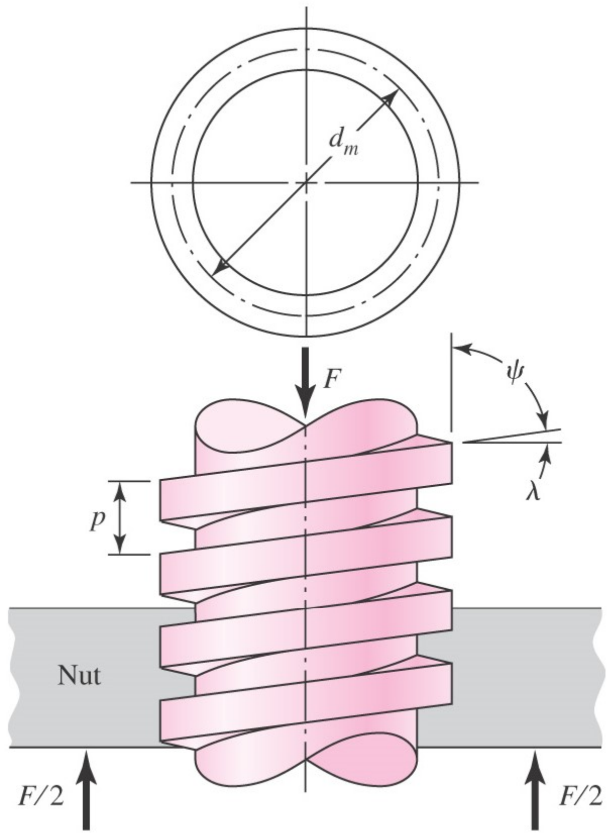


Fig. 8–5

$$\lambda = \tan^{-1} \frac{Lead}{\pi d_m}$$ Lead angle

- For raising the load

$$\sum F_x = P_R - N \sin\lambda - f N \cos\lambda = 0$$

(a)

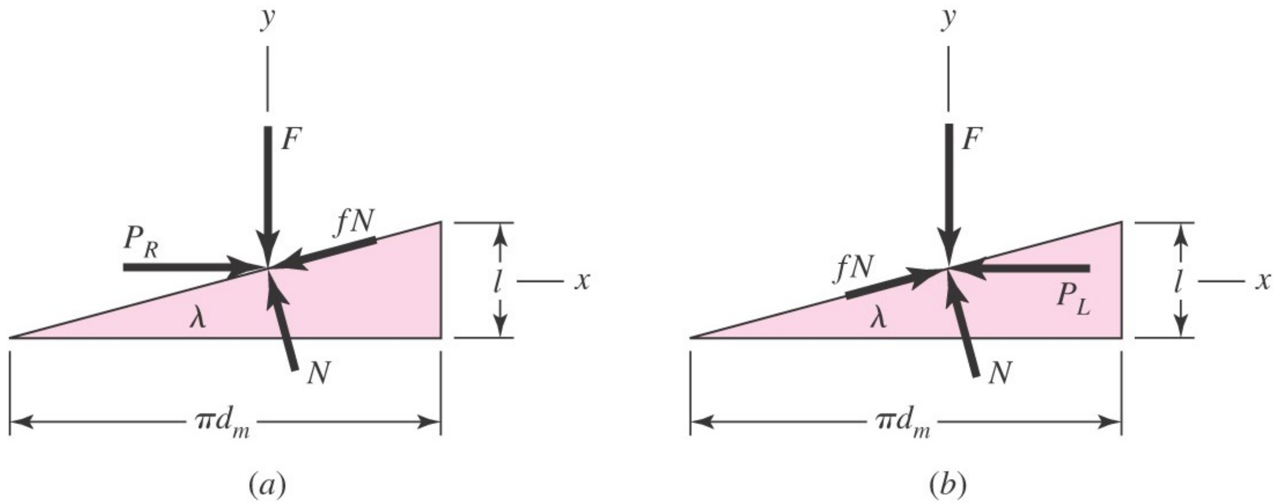
$$\sum F_y = -F - f N \sin\lambda + N \cos\lambda = 0$$

- For lowering the load

$$\sum F_x = -P_L - N \sin\lambda + f N \cos\lambda = 0$$

(b)

$$\sum F_y = -F + f N \sin\lambda + N \cos\lambda = 0$$



Mechanics of Power Screws

- Eliminate *N* and solve for *P* to raise and lower the load

$$P_R = \frac{F(\sin\lambda + f\cos\lambda)}{\cos\lambda - f\sin\lambda} \qquad (c)$$

$$P_L = \frac{F(f\cos\lambda - \sin\lambda)}{\cos\lambda + f\sin\lambda} \qquad (d)$$

- Divide numerator and denominator by cosλ and use relation tanλ = $l/\pi\, d_m$

$$P_R = \frac{F[(l/\pi d_m) + f]}{1 - (fl/\pi d_m)} \qquad (e)$$

$$P_L = \frac{F[f - (l/\pi d_m)]}{1 + (fl/\pi d_m)} \qquad (f)$$

Raising and Lowering Torque

- Noting that the torque is the product of the force P and the mean radius r_m,

$$T_R = \frac{F d_m}{2} \left(\frac{l + \pi f d_m}{\pi d_m - f l} \right) \qquad (8\text{–}1)$$

$$T_L = \frac{F d_m}{2} \left(\frac{\pi f d_m - l}{\pi d_m + f l} \right) \qquad (8\text{–}2)$$

Self-locking Condition

$$T_L = \frac{F d_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + f l}\right) \tag{8–2}$$

- If the lowering torque is negative, the load will lower itself by causing the screw to spin without any external effort.
- If the lowering torque is positive, the screw is *self-locking*.
- Self-locking condition is $\pi f d_m > l$
- Noting that $l / \pi d_m = \tan \lambda$, the self-locking condition can be seen to only involve the coefficient of friction and the lead angle.

$$f > \tan \lambda \tag{8–3}$$

Power Screw Efficiency

- The torque needed to raise the load with no friction losses can be found from Eq. (8–1) with *f* = 0.

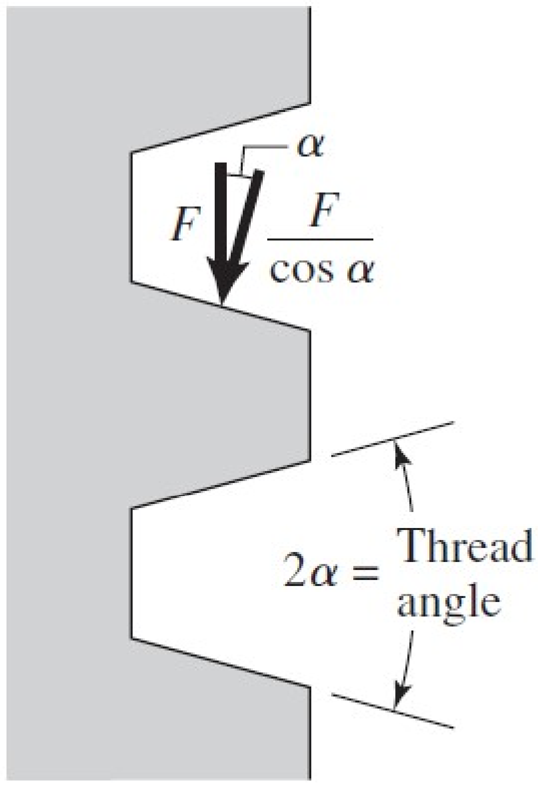
$$T_0 = \frac{Fl}{2\pi} \qquad (g)$$

- The efficiency of the power screw is therefore

$$e = \frac{T_0}{T_R} = \frac{Fl}{2\pi T_R} \qquad (8\text{–}4)$$

Power Screws with Acme Threads

- If Acme threads are used instead of square threads, the thread angle creates a wedging action.
- The friction components are increased.
- The torque necessary to raise a load (or tighten a screw) is found by dividing the friction terms in Eq. (8–1) by cosα.



(a)

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m \sec\alpha}{\pi d_m - f l \sec\alpha}\right) \qquad (8\text{–}5)$$

Collar Friction

- An additional component of torque is often needed to account for the friction between a collar and the load.
- Assuming the load is concentrated at the mean collar diameter d_c

$$T_c = \frac{F f_c d_c}{2} \qquad (8\text{–}6)$$

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m}{\pi d_m - f l}\right) + \frac{F f_c d_c}{2}$$

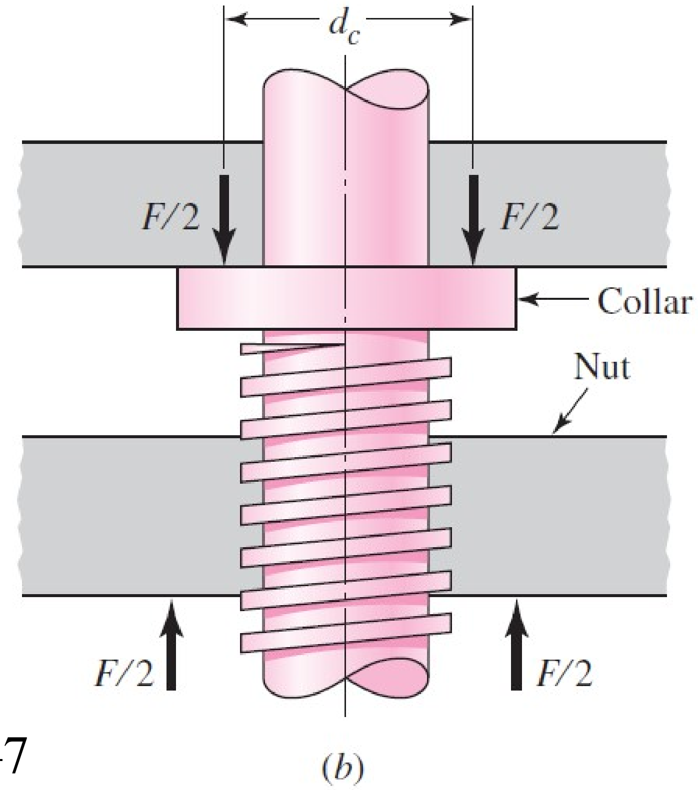
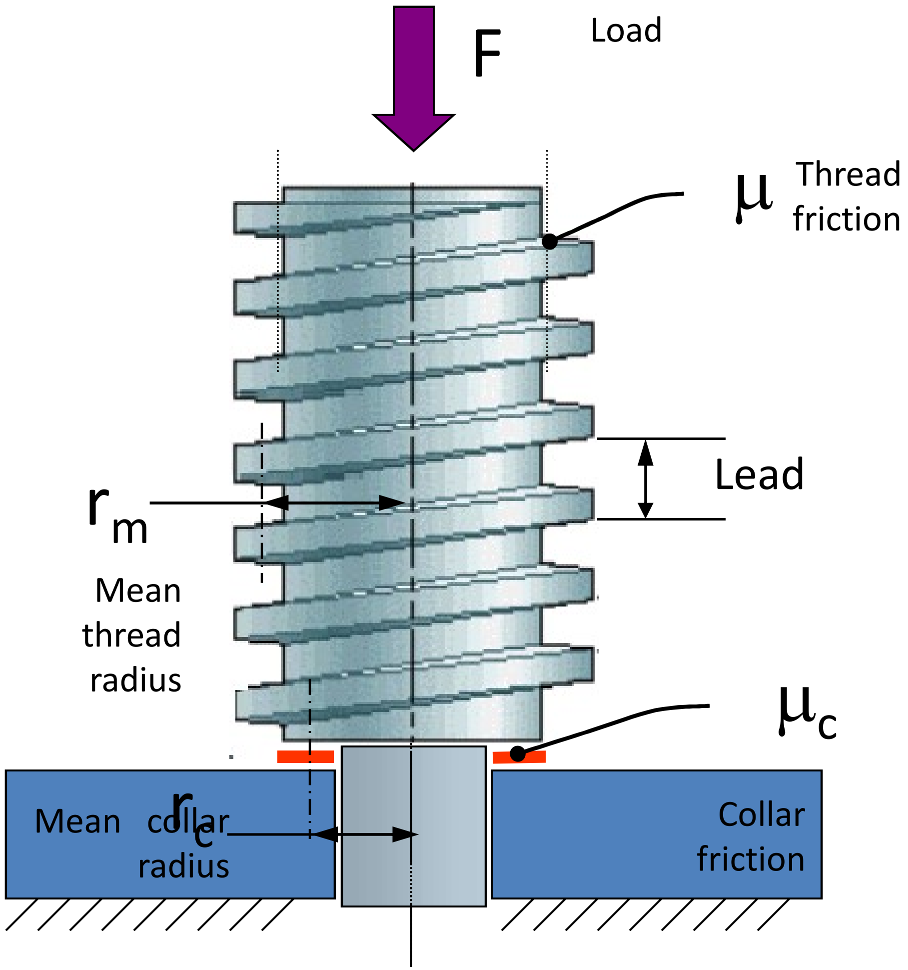


Fig. 8–7

Power Screws



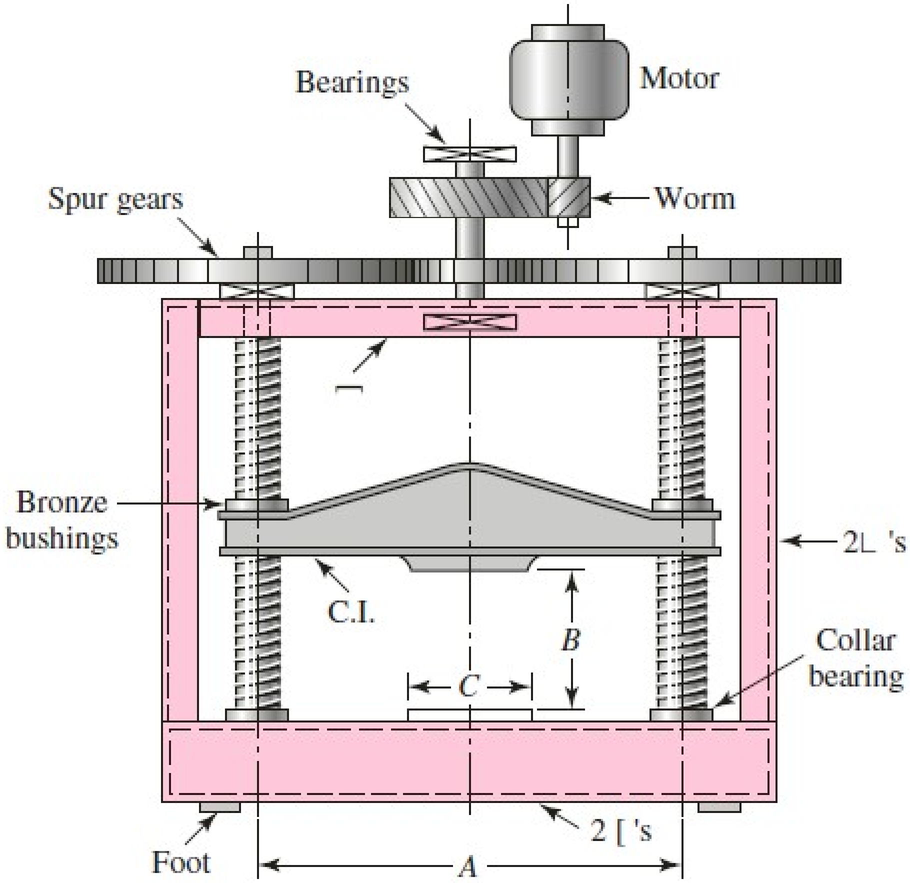
$$T_c = \frac{F f_c d_c}{2}$$

8–6 The press shown for Prob. 8–5 has a rated load of 5000 lbf. The twin screws have Acme threads, a diameter of 2 in, and a pitch of $\frac{1}{4}$ in. Coefficients of friction are 0.05 for the threads and 0.08 for the collar bearings. Collar diameters are 3.5 in. The gears have an efficiency of 95 percent and a speed ratio of 60:1. A slip clutch, on the motor shaft, prevents overloading. The full-load motor speed is 1720 rev/min.

(*a*) When the motor is turned on, how fast will the press head move?

(*b*) What should be the horsepower rating of the motor?

Problem 8–5



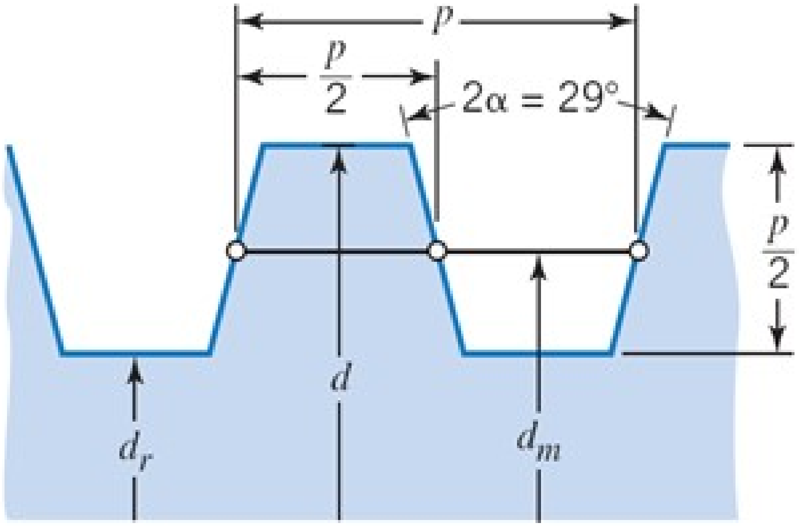
The gear rotates with a rotational speed of

$$n = \frac{1720}{60} = 28.67 \text{ rev/min}$$

The linear speed of the twin screws is

$$V = 28.67(0.25) = 7.17 \text{ in/min}$$

To find the dimensions of the screw



(a) Acme

$$d_m = 2 - 0.25 / 2 = 1.875 \text{ in}$$

$$\alpha = 29° / 2$$

$$\cos(29° / 2) = \frac{1}{1.033}$$

The Raising torque can be calculated using

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m \sec\alpha}{\pi d_m - f l \sec\alpha}\right) \qquad (8\text{–}5)$$

$$T_R = \frac{2500(1.875)}{2}\left(\frac{0.25 + \pi(0.05)(1.875)(1.033)}{\pi(1.875) - 0.05(0.25)(1.033)}\right) = 221.0 \text{ lbf} \cdot \text{in}$$

The collar torque is calculated using>

$$T_c = \frac{F f_c d_c}{2}$$

$$T_c = 2500(0.08)(3.5 / 2) = 350 \text{ lbf} \cdot \text{in}$$

$$T_{total} = 350 + 221.0 = 571 \text{ lbf} \cdot \text{in/screw}$$

$$T_{motor} = \frac{571(2)}{60(0.95)} = 20.04 \text{ lbf} \cdot \text{in}$$

$$H = \frac{Tn}{63\ 025} = \frac{20.04(1720)}{63\ 025} = 0.547 \text{ hp}$$