

Tutorial 2: Power Screw

Theory

1. What is a power screw?
2. What is the purpose of a power screw?
3. Draw and make a detail sketch of a square thread, Acme and Modified thread. Explain the difference between these threads and its applications.

Calculations

Question 1

A screw jack has a triple threaded Acme power screw of M30x4, is used to lift a load of a 6kN. Determine;

- (i) The screw lead, mean diameter and helix angle
- (ii) The screw torque required to move the load up
- (iii) Is the screw overhauling
- (iv) The efficiency of the jack, if collar friction is used
- (v) The length of a crank required if $F=150N$ is exerted by an operator

Given: $f=0.12$, $f_c=0.09$ and $d_c=40mm$

Example Solution

$n = 3$ (triple thread)
 $\alpha = 14.5$ (Acme thread)
diameter, $D = 30mm$
pitch, $p = 4$
Load = 6000N
 $f = 0.12$
 $f_c = 0.09$
 $d_c = 40mm$

i-Find lead first,

$$\begin{aligned} \text{Lead, } L &= np \\ &= 3 \times 4mm = 12mm/turn \end{aligned}$$

Find mean diameter,

$$\begin{aligned} d_m &= \frac{D + (D - p)}{2} \\ &= \frac{30 + (30 - 4)}{2} \\ &= 28mm \end{aligned}$$

Find helix angle,

$$\begin{aligned}\tan \lambda &= \frac{L}{\pi d_m} \\ &= \frac{12mm}{\pi 28mm} \\ &= 0.136 \\ \lambda &= \tan^{-1}(0.136) \\ &= 7.768^\circ\end{aligned}$$

ii-Find torque to lift the load,

$$T_u = \frac{W d_m f + \cos \alpha_n \tan \lambda}{2 \cos \alpha_n + f \tan \lambda} + \frac{W f_c d_c}{2}$$

Find α_n

$$\begin{aligned}\tan \alpha_n &= \cos \lambda \tan \alpha \\ &= \cos 7.768 \tan 14.5 \\ &= 14.37^\circ\end{aligned}$$

Substitute known values into torque to lift the load equation,

$$\begin{aligned}T_u &= \frac{W d_m f + \cos \alpha_n \tan \lambda}{2 \cos \alpha_n + f \tan \lambda} + \frac{W f_c d_c}{2} \\ &= \frac{6000(28 \times 10^{-3})}{2} \frac{0.12 + \cos(14.37) \tan(7.768)}{\cos(14.37) + 0.12 \tan(7.768)} + \frac{6000(0.09)(40 \times 10^{-3})}{2} \\ &= 22.3 \times 10^3 Nm\end{aligned}$$

iii-Check if the screw is overhauling,

Screw overhaul when,

$$\begin{aligned}f &\leq \cos \alpha_n \tan \lambda \\ 0.12 &\leq \cos(14.37) \tan(7.768) \\ 0.12 &\leq 0.136\end{aligned}$$

$\cos \alpha_n \tan \lambda$ is greater than f , therefore the screw is overhauling.

OR, can check using torque to lower the load. If the value is negative, it will overhaul.

$$T_d = \frac{W d_m f - \cos \alpha_n \tan \lambda}{2 \cos \alpha_n + f \tan \lambda} + \frac{W f_c d_c}{2}$$

$T_d = -1.02kN$, which is negative, therefore the screw is overhauling.

iv- Find efficiency of the jack, if collar friction is used,

$$\begin{aligned}e &= \frac{d_m \tan \lambda}{d_m \frac{f + \cos \alpha_n \tan \lambda}{\cos \alpha_n - f \tan \lambda} + d_c f_c} \\ &= \frac{28 \times 10^{-3} \tan(7.768)}{28 \times 10^{-3} \frac{0.12 + \cos(14.37) \tan(7.768)}{\cos(14.37) - 0.12 \tan(7.768)} + 40 \times 10^{-3}(0.09)} \\ &= 0.47\end{aligned}$$

v- Find the length of a crank required if $F=150\text{N}$ is exerted by an operator,

$$\begin{aligned}T_u &= F \cdot r \\22.3 \times 10^3 &= 150 \cdot r \\r &= \frac{22.3 \times 10^3}{150} \\&= 148.7\text{mm}\end{aligned}$$

Question 2

The clamp assembly as shown in Figure Q2 consists of member AB and AC, which are pin connected at A. The clamp works by rotating a single start ACME thread ($\alpha = 14.5^\circ$) with the size of 12.5 mm and pitch of 2.5 mm. At this instant, the compressive force, F_c on the wood between B and C is 180 N. The collar at the assembly has a mean diameter of 13.5 mm. Assume all the friction coefficient between all surface contracts is 0.3. Determine:

- (i) the load acting at the screw.
- (ii) the torque required to tighten the screw.
- (iii) the maximum compressive force, F_c , if allowable normal stress at the screw is 10 MPa.

Example Solution

Given: $n = 1$ (single start)

$\alpha = 14.5$ (Acme thread)

diameter, $D = 12.5$

pitch, $p = 2.5$

$F_c = 180$

$d_c = 13.5$

$f = 0.3$

$f_c = 0.3$

i - Load acting at the screw, F_E

$$\begin{aligned}
 + \circlearrowleft \sum M_A &= 0 \\
 -F_E(0.03) - F_B(0.07) &= 0 \\
 -F_E(0.2) - (180)(0.2) &= 0 \\
 F_E &= 420N
 \end{aligned}$$

ii - Torque required to tighten the screw

$$T_u = \frac{W d_m}{2} \frac{f + \cos \alpha_n \tan \lambda}{\cos \alpha_n + f \tan \lambda} + \frac{W f_c d_c}{2}$$

Find helix angle,

$$\tan \lambda = \frac{L}{\pi d_m}$$

Find lead,

$$\begin{aligned}
 \text{Lead, } L &= np \\
 &= 1(2.5) \\
 &= 2.5mm
 \end{aligned}$$

Find mean diameter,

$$\begin{aligned}
 d_m &= \frac{D + (D - p)}{2} \\
 &= \frac{12.5 + (12.5 - 2.5)}{2} \\
 &= 11.25mm
 \end{aligned}$$

From $\tan \lambda$ equation,

$$\begin{aligned}\tan \lambda &= \frac{2.5mm}{\pi 11.25mm} \\ &= 0.0707 \\ \lambda &= \tan^{-1}(0.0707) \\ &= 4.05^\circ\end{aligned}$$

Find α_n ,

$$\begin{aligned}\tan \alpha_n &= \cos \lambda \tan \alpha \\ &= \cos 4.05 \tan 14.5 \\ &= 14.45^\circ\end{aligned}$$

Insert into torque to lift the load equation,

$$\begin{aligned}T_u &= \frac{420(11.25 \times 10^{-3})}{2} \frac{0.3 + \cos(14.45) \tan(4.05)}{\cos(14.45) + f \tan(4.05)} + \frac{420(0.3)(13.5 \times 10^{-3})}{2} \\ &= 1.77 Nm\end{aligned}$$

iii - Maximum compressive force, F_c if allowable normal stress at the screw is 10 MPa.

$$\begin{aligned}\sigma &= \frac{F_E}{A} \\ 10 \times 10^6 &= \frac{F_E}{\pi \left(\frac{0.01^2}{4}\right)} \\ F_E &= 785.4 N\end{aligned}$$

Calculat the force at B when force at E changed

$$\begin{aligned}+ \circlearrowleft \sum M_A &= 0 \\ F'_E(0.03) + F'_B(0.07) &= 0 \\ (785.4)(0.2) + (180)(0.2) &= 0 \\ F'_B &= 336.6 N\end{aligned}$$

Force at C = Force at B = 336.6 N

Question 3 A screw of M10x1.5 is used as a lead screw for a machine with a torque of 10 Nm travelled linearly at 10mm/s. Determine;

- (i) the mean diameter of the screw.
- (ii) angular speed of the screw in rpm.
- (iii) power carried by the screw.

Question 4

The bench hold-down clamp is being used to clamp two boards together while they are being glued as shown in Figure Q1(c). The clamp consists of a screw having single square threads of M12 X 2 and coefficient of friction in the screw thread is taken as 0.2. The screw producing maximum power of 35 W when moving at 2mm/s axially.

Question 5

The screw is a double-start ACME thread of M12x 1.5. The clamping force exerted at G is $F_G=900$ N. The mean diameter of the collar is $d_c = 22$ mm. Coefficients of friction for screw and collar are estimated as $f = 0.3$ and $f_c = 0.15$ respectively. The screw will travel axially at 95 mm/s. Find,