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, fc=0.09 and dc=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,

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

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,

$$T_u = \frac{Wd_m}{2}\frac{f+\cos\alpha_n\tan\lambda}{\cos\alpha_n + f\tan\lambda} + \frac{Wf_cd_c}{2}$$

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,

$$\begin{aligned}
T_u &= \frac{Wd_m}{2}\frac{f+\cos\alpha_n\tan\lambda}{\cos\alpha_n + f\tan\lambda} + \frac{Wf_cd_c}{2} \\
&= \frac{6000(28\times10^{-3})}{2}\times\frac{0.12+\cos(14.37)\tan(7.768)}{\cos(14.37)-0.12\tan(7.768)} + \frac{6000(0.09)(40\times10^{-3})}{2} \\
&= 33kN
\end{aligned}$$

iii-Check if the screw is overhauling,
Screw overhaul when,

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

$\cos\alpha_n\tan\lambda$ 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.

$$T_d = \frac{Wd_m}{2}\frac{f-\cos\alpha_n\tan\lambda}{\cos\alpha_n + f\tan\lambda} + \frac{Wf_cd_c}{2}$$

$T_d = -1.02kN$, which is negative, therefore the screw is overhauling.
iv- Find efficiency of the jack, if collar friction is used,

$$\begin{aligned}
e &= \frac{d_m\tan\lambda}{d_m\frac{f+\cos\alpha_n\tan\lambda}{\cos\alpha_n - f\tan\lambda} + d_cf_c} \\
&= \frac{28\times10^{-3}\tan(7.768)}{28\times10^{-3}\frac{0.12+\cos(14.37)\tan(7.768)}{\cos(14.37)-0.12\tan(7.768)} + 40\times10^{-3}(0.09)} \\
&= 0.47
\end{aligned}$$

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

$$\begin{aligned} T_u &= F \cdot r \\ 33 \times 10^3 &= 150 \cdot r \\ r &= \frac{33 \times 10^3}{150} \\ &= 0.22m \end{aligned}$$

Question 2

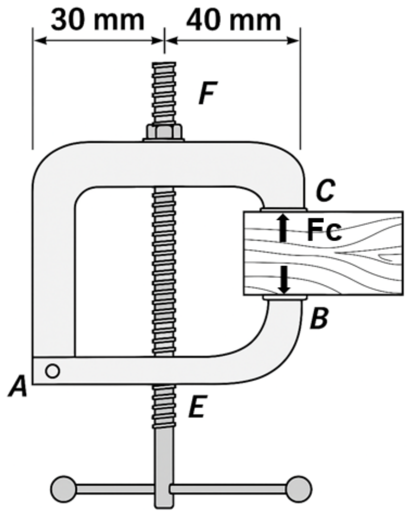

Figure 1: Figure Q2

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 ($\alpha = 14.5°$) with the size of 12.5 mm and pitch of 2.5 mm. At this instant, the compressive force, Fc 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, Fc, if allowable normal stress at the screw is 10 MPa.

Example Solution
Given: $n = 1$(single start)
$\alpha = 14.5$ (Acme thread)
$diameter, D = 12.5$
$pitch, p = 2.5$
$Fc = 180$
$d_c = 13.5$
$f = 0.3$

$f_c = 0.3$

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,

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

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,

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

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

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

Calculat the force at B when force at E changed

$$+\circlearrowleft \sum M_A = 0$$
$$F'_E(0.03) + F'_B(0.07) = 0$$
$$(785.4)(0.2) + (180)(0.2) = 0$$
$$F'_B = 336.6N$$

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 FG=900 N. The mean diameter of the collar is dc = 22 mm. Coefficients of friction for screw and collar are estimated as f = 0.3 and fc = 0.15 respectively. The screw will travel axially at 95 mm/s. Find,