Tutorial 2: Power Screw

In-class activity

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.

Example Solution

(i) Mean diameter of the screw:

$$d_m = \frac{D + (D - p)}{2} = \frac{10 + (10 - 1.5)}{2} = 9.25 \text{ mm}$$

(ii) Angular speed of the screw in rpm:

$$\begin{aligned}
V_{linear} &= Lead \times n_{rpm} \times \frac{1min}{60s} \\
\frac{10mm}{1s} &= \frac{1.5mm}{1rev} \times n_{rpm} \times \frac{1min}{60s} \\
n_{rpm} &= 400rpm
\end{aligned}$$

(iii) Power carried by the screw:

$$\begin{aligned}
P = \omega T &= \frac{2\pi n}{60} T \\
&= \frac{2\pi(400)}{60}(10) \\
&= 418.88W
\end{aligned}$$

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,

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

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,

$$\begin{aligned} T_u &= \frac{Wd_m}{2} \frac{f + \cos\alpha_n \tan\lambda}{\cos\alpha_n + f\tan\lambda} + \frac{Wf_c d_c}{2} \\ &= \frac{6000(28 \times 10^{-3})}{2} \times \frac{0.12 + \cos(14.37)\tan(7.768)}{\cos(14.37) - 0.12\tan(7.768)} + \frac{6000(0.09)(40 \times 10^{-3})}{2} \\ &= 33Nm \end{aligned}$$

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.

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

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

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

$$\begin{aligned} e &= \frac{d_m \tan\lambda}{d_m \frac{f + \cos\alpha_n \tan\lambda}{\cos\alpha_n - f\tan\lambda} + d_c f_c} \\ &= \frac{28 \times 10^{-3} \tan(7.768)}{28 \times 10^{-3} \frac{0.12 + \cos(14.37)\tan(7.768)}{\cos(14.37) - 0.12\tan(7.768)} + 40 \times 10^{-3}(0.09)} \\ &= 0.347 \end{aligned}$$

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

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

Question 2

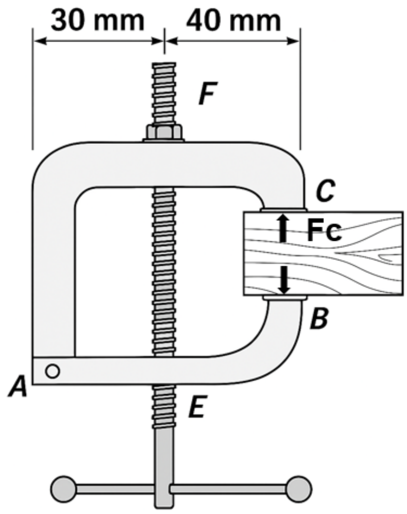

Figure Q2

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.

Question 3
The bench hold-down clamp is being used to clamp two boards together while they are being glued as shown in Figure Q3. 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.

(i) the torque acting at the screw

(ii) the compression force exerted on the boards when torque as (i) is applied

(iii) Recommend the suitable handle length, d if the compression force is increased to 1.5 kN, thus the user need to apply force of 100 N on the handle.

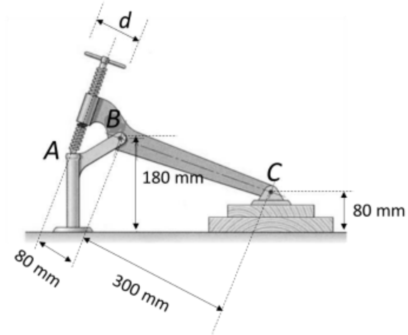

Figure Q3

Question 4

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,

(i) The screw lead, mean diameter, and helix angle

(ii) The force and axial stress acting on the screw

(iii) The torque for lifting and for lowering the load

(iv) The force needed to apply perpendicular at E to produce the clamping force

(v) The angular rotation of the screw in rpm

(vi) The power produced by the power screw

(vii) The efficiency of the jack when lifting the load

(viii) Whether the screw is overhauling

Well-defined Problem

1. Determine the maximum compressive force, if the new allowable normal stress at thescrew is 30 MPa.
2. Recommend the suitable length of the handle if the compression force is increased to1.5 kN, thus the user needs to apply force of 100 N on the handle.
3. Determine the new efficiency on the screw if a SQUARE thread is used. Compare the efficiency.

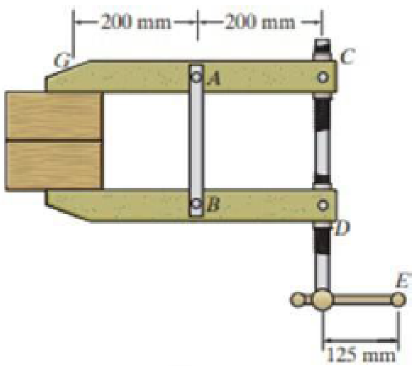

Figure Q4

Answer

Q2
i- Load acting at the screw, $F_E = 420N$
ii- Torque required to tighten the screw, $T = 1.77Nm$
iii- Maximum compressive force, $F_c = 336.6N$

Q3
i- Torque acting at the screw, $T = 5.57Nm$
ii- Compression force exerted on the boards, $F_{cy} = 976.01N$
iii- Suitable handle length, $d = 0.171m$

Q4
i- Screw lead, $L = 3mm$, mean diameter, $d_m = 11.25mm$ and helix angle, $\lambda = 4.85°$
ii- Force acting on the screw, $F = 900N$ and axial stress, $\sigma = 10.394MPa$
iii- Torque for lifting, $T_u = 3.54Nm$ and for lowering the load, $T_d = 2.59Nm$
iv- Force needed to apply perpendicular at E, $F = 28.32N$
v- Angular rotation of the screw, $n = 31.67rev/s$
vi- Power produced by the power screw, $P = 704.35W$
vii- Efficiency of the jack when lifting the load, $e = 0.121$
viii- The screw is overhauling

Well-defined Problem
1- Maximum compressive force, $F_c = 2597.7N$
2- Suitable length of the handle, $r = 58.95mm$
3- New efficiency on the screw if a SQUARE thread is used, $e = 0.123$. Square thread has higher efficiency than ACME thread.