

## 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:  $f=0.12$ ,  $f_c=0.09$  and  $d_c=40\text{mm}$

### Example Solution

$n = 3$ (triple thread)

$\alpha = 14.5$  (Acme thread)

diameter,  $D = 30\text{mm}$

pitch,  $p = 4$

Load =  $6000\text{N}$

$f = 0.12$

$f_c = 0.09$

$d_c = 40\text{mm}$

i-Find lead first,

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

Find mean diameter,

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

Find helix angle,

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

ii-Find torque to lift the load,

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

Find  $\alpha_n$

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

Substitute known values into torque to lift the load equation,

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

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.

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

$T_d = -1.02kN$ , 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  $F=150N$  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

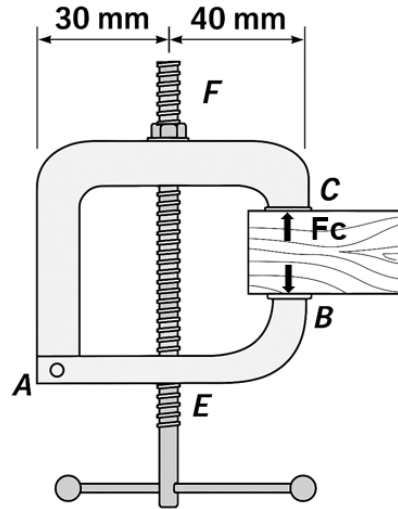


Figure Q2

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 ( $\alpha = 14.5^\circ$ ) 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.

### 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.

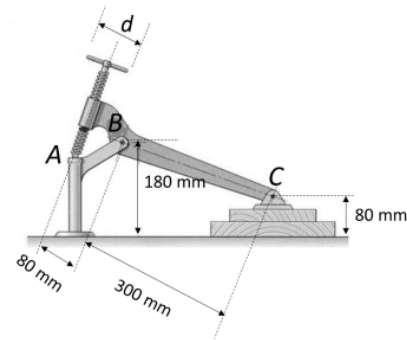


Figure Q3

#### Question 4

The screw is a double-start ACME thread of M12x 1.5. The clamping force exerted at G is  $F_G = 900 \text{ N}$ . The mean diameter of the collar is  $d_c = 22 \text{ mm}$ . 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  $95 \text{ mm/s}$ . 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 the screw is  $30 \text{ MPa}$ .
2. Recommend the suitable length of the handle if the compression force is increased to  $1.5 \text{ kN}$ , thus the user needs to apply force of  $100 \text{ N}$  on the handle.
3. Determine the new efficiency on the screw if a SQUARE thread is used. Compare the efficiency.

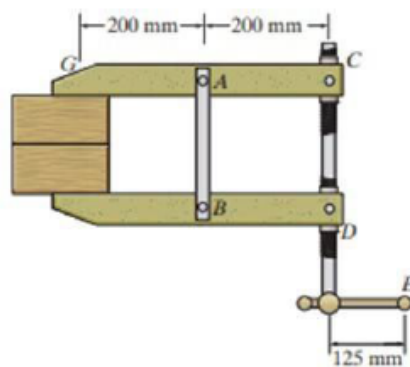


Figure Q4

### 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,  $T = 1.67Nm$
- ii- Compression force exerted on the boards,  $F_c = 420N$
- iii- Suitable handle length,  $d = 0.25m$

#### Q4

- i- Screw lead,  $L = 3mm$ , mean diameter,  $d_m = 10.5mm$  and helix angle,  $\lambda = 8.21^\circ$
- ii- Force acting on the screw,  $F = 1088.9N$  and axial stress,  $\sigma = 12.47MPa$
- iii- Torque for lifting,  $T_u = 2.98Nm$  and for lowering the load,  $T_d = -0.48Nm$
- iv- Force needed to apply perpendicular at E,  $F = 29.8N$
- v- Angular rotation of the screw,  $n = 3030rpm$
- vi- Power produced by the power screw,  $P = 94.8W$
- vii- Efficiency of the jack when lifting the load,  $e = 0.36$
- viii- The screw is overhauling

#### Well-defined Problem

- 1- Maximum compressive force,  $F_c = 2412N$
- 2- Suitable length of the handle,  $d = 0.3m$
- 3- New efficiency on the screw if a SQUARE thread is used,  $e = 0.44$ . The efficiency is increased by 0.08 or 8%.