

Mechanics

Module III: Friction

Lesson 17: Friction in Screws

A screw is a simple machine that uses the principle of a wedge. Screws are usually used for fastening parts and converting rotary motion/torque to translator motion/force. Normally, a screw is self-locking due to friction. This makes the conversion of motion/force irreversible. Hence, they can be used in jacks, vices and positioning devices.

Screws are of two types, namely right-handed and left handed screws. The nomenclature is self-explanatory if one recalls the right-hand screw rule. In a right-handed screw, clockwise rotation (by a person) moves the screw forward (away from the person).

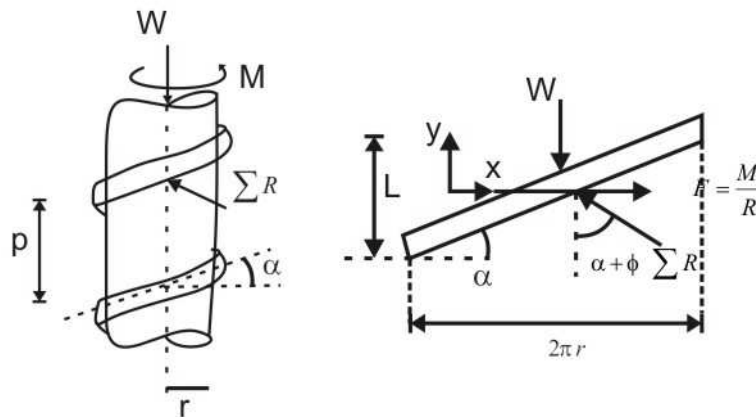


Figure 1:

The axial distance between two adjacent threads is known as the pitch p , while the linear distance moved by the screw in a mating nut (held fixed) in one turn is known as the lead L . For an n start thread, $L = np$. If the helix angle of the screw is α (see Fig. 1), then $L = 2\pi r \tan \alpha$.

1 Force analysis of a square-threaded screw

Consider a square threaded screw under an axial load W and torque M , and in impending upward slip against the fixed threads of a mating nut, as shown (without the nut) in Fig. 1. One turn of a thread is also shown. The equilibrium equations for the thread can be written as

$$\begin{aligned}\sum F_x = 0 &\Rightarrow F = \frac{M}{r} = \sin(\alpha + \phi) \sum R \\ \sum F_y = 0 &\Rightarrow W = \cos(\alpha + \phi) \sum R\end{aligned}$$

where $\phi = \tan^{-1} \mu$. Then $M = rW \tan(\alpha + \phi)$ when the screw is in impending upward slip/rotation in the direction of the moment M . Note that the impending translation of the screw is against the load W . This motion will be denoted as screwing motion (as opposed to unscrewing). In terms of the moment M , the above expression is known as the tightening moment.

In the opposite case of the unscrewing, the moment is reversed and the screw is in impending slippage downwards (in the direction of W). The FBD in this case is shown in Fig. 2. The equations of equilibrium yield

$$\sum F_x = 0 \Rightarrow F = \frac{M}{r} = \sin(\phi - \alpha) \sum R$$

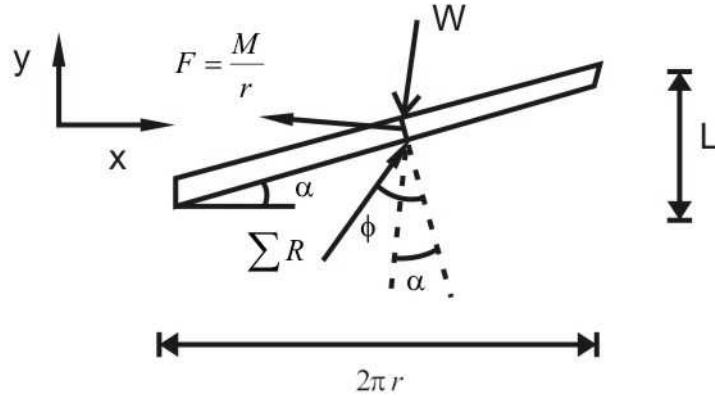


Figure 2:

$$\sum F_y = 0 \Rightarrow W = \cos(\phi - \alpha) \sum R$$

Hence, $M = rW \tan(\phi - \alpha)$. If the screw is to be self-locking, it should require a positive M to bring it to the impending slippage condition depicted in Fig. 2. Hence, from the expression of (loosening) moment above, for self-locking, $\phi > \alpha$.

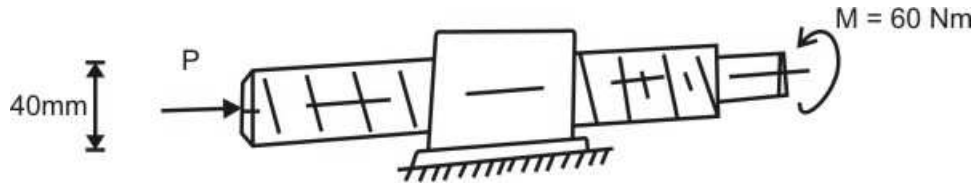


Figure 3:

Problem 1

A 2-start right-handed square threaded screw of diameter 40 mm shown in Fig. 3 has a lead $L = 24$ mm. It mates with a fixed nut and the coefficient of friction $\mu = 0.15$. A torque $M = 60$ Nm is applied as shown. Determine if the screw is self-locking, and the value(s) of P that can move the screw to

the left/right (if possible) at a constant speed.

Solution

In this problem, the helix angle $\alpha = \tan^{-1} \frac{24}{40\pi} = 10.81^\circ$. Friction angle $\phi = \tan^{-1} 0.15 = 8.53^\circ$. Since $\phi < \alpha$, the screw is not self-locking. Hence, P can also move the screw to the right (unscrew). In this case, since the torque is tightening (but motion is unscrewing),

$$-M = rP \tan(\phi - \alpha) \Rightarrow P = \frac{60}{0.02 \tan 2.28^\circ} = 75.3 \text{ kN}.$$

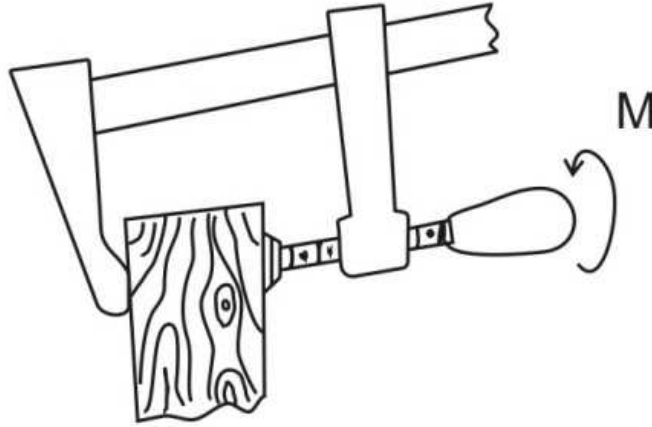


Figure 4:

Problem 2

A clamp shown in Fig. 4 has a screw of diameter 10 mm and lead $L = 1.5$ mm. It is used to clamp a board with a force of 400 N. Determine the moment required to clamp and unclamp the board if the coefficient of friction in the screw is $\mu = 0.2$. Neglect the friction between the clamp and the board.

Solution

In this problem, the helix angle $\alpha = \tan^{-1} \frac{1.5}{10\pi} = 2.73^\circ$. Friction angle $\phi =$

$\tan^{-1} 0.2 = 11.31^\circ$. Since $\phi > \alpha$, the screw is self-locking. Axial force $W = 400$ N. Tightening moment required to produce this axial force is given by

$$M = rW \tan(\phi + \alpha) = 0.5 \text{ Nm.}$$

Loosening moment required to unscrew

$$M = rW \tan(\phi - \alpha) = 0.302 \text{ Nm.}$$