SCREW FRICTION

The screws, bolts, studs, nuts etc. are widely used in various machines and structures for fastenings. These fastenings have screw threads, which are made by cutting a continuous helical groove on a cylindrical surface. If the threads are cut on the outer surface of a solid rod, these are known as external threads. But if the threads are cut on the internal surface of a hollow rod these are known as internal threads.

The screw threads are mainly of two types *viz.* *V*-threads and square threads. The *V*-threads are stronger and offer more frictional resistance to motion than square threads. Moreover, the *V*-threads have an advantage of preventing the nut from slackening. I will be interesting to know that the V-threads are used for the purpose of tightening pieces together (*e.g.* bolts and nuts etc.). Square threads are used in screw jacks, vice screws etc. which are used for lifting heavy loads. The following terms are important for the study of screws:

1. ***Helix.*** It is the curve traced by a particle, while describing a circular path at a uniform speed and advancing in the axial direction at a uniform rate. Or in other words, it is the curve traced by a particle while moving along a screw thread.
2. ***Pitch.*** It is the distance from one point of a thread to the corresponding point on the next thread. It is measured parallel to the axis of the screw.
3. ***Lead.*** It is the distance through which a screw thread advances axially in one turn.
4. ***Depth of thread.*** It is the distance between the top and bottom surfaces of a thread (also known as crest and root of thread).
5. ***Single-threaded screw.*** If the lead of a screw is equal to its pitch, it is known as single-threaded screw.
6. ***Multi-threaded screw.*** If more than one threads are cut in one lead distance of a screw, it is known as multi-threaded screw *e.g.* in a double-threaded screw, two threads are cut in one lead length. In such cases, all the threads run independently along the length of the rod. Mathematically,

$$\text{Lead} = \text{Pitch} \times \text{No. of threads.}$$

7. ***Slope of the thread.*** It is the inclination of the thread with horizontal. Mathematically,

$$\tan\alpha = \frac{\text{Lead of screw}}{\text{Circumference of screw}}$$

$$= \frac{p}{\pi d} \qquad \text{...(In single-threaded screw)}$$

$$= \frac{np}{\pi d} \qquad \text{...(In multi-threaded screw)}$$

where α = Angle of inclination of the thread,
p = Pitch of the screw,
d = Mean diameter of the screw, and
n = No. of threads in one lead.

Example *A screw jack has a square thread of 75 mm mean diameter and 15 mm pitch. The load on the jack revolves with the screws. The coefficient of friction at the screw thread is 0.05. (i) Find the tangential force to be applied to the jack at 360 mm radius, so as to lift a load of 6 kN weight. (ii) State whether the jack is selflocking. If it is, find the torque necessary to lower the load. If not, find the torque which must be applied to keep the load from descending.*

Solution. Given: Mean diameter of square thread (d) = 75 mm or mean radius (r) = 37.5 mm; Pitch (p) = 15 mm; Coefficient of friction (μ) = 0.05 = tan ϕ; Radius of effort arm = 360 mm and load lifted = 6 kN = 6000 N.

(*i*) *Tangential force to be applied at the jack.*

Let P_1 = Tangential force to be applied at 36 cm radius to lift the load, and

α = Helix angle.

We know that $\tan\alpha = \dfrac{p}{\pi d} = \dfrac{15}{\pi \times 75} = 0.064$

and tangential force required at the mean radius to lift the load,

$$P = W\tan(\alpha + \phi) = W \times \frac{\tan\alpha + \tan\phi}{1 - \tan\alpha.\tan\phi}$$

$$= 6000 \times \frac{0.064 + 0.05}{1 - 0.064 \times 0.05} = 686.2 \text{ N}$$

Now the effort applied at a radius of 36 cm may be found out from the relation

$$P_1 \times 360 = P \times r = 686.2 \times 37.5 = 25\ 732$$

$$\therefore \quad P_1 = \frac{25\ 732}{360} = 71.48 \text{ N} \qquad \textbf{Ans.}$$

(*ii*) *Self-locking of the screw jack*

We know that efficiency of the screw jack,

$$\eta = \frac{\tan\alpha}{\tan(\alpha + \phi)} = \frac{\tan\alpha}{\dfrac{\tan\alpha + \tan\phi}{1 - \tan\alpha.\tan\phi}} = \frac{0.064}{\dfrac{0.064 + 0.05}{1 - (0.064 \times 0.05)}} = \frac{0.064}{0.1144}$$

$$= 0.559 = 55.9\%$$

Since efficiency of the jack is more than 50%, therefore, it is not *self-locking. **Ans.**

Torque, which must be applied to keep the load from descending

We know that the force which must be applied at the mean radius to keep the load from descending (*i.e.* to prevent the load from descending).

$$P_2 = W\tan(\alpha - \phi) = W \times \frac{\tan\alpha - \tan\phi}{1 + \tan\alpha.\tan\phi}$$

$$= 6000 \times \frac{0.064 - 0.05}{1 + 0.064 \times 0.05} = 83.73$$

$\therefore$ Torque, which must be applied to keep the load from descending

$$= P_2 \times r = 83.73 \times 37.5 = 3140 \text{ N-mm} \qquad \textbf{Ans.}$$