ME3491 THEORY OF MACHINES

UNIT III NOTES

3.10. Screw Friction

The screws, bolts, studs, nuts etc. are widely used in various machines and structures for temporary 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 i.e. 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. In general, the Vthreads are used for the purpose of tightening pieces together e.g. bolts and nuts etc. But the square threads are used in screw jacks, vice screws etc. The following terms are important for the study of screw

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. In other words, it is the curve traced by a particle while moving along a screw thread

2. Pitch. It is the distance from a point of a screw to a corresponding point on the next thread, measured parallel to the axis of the screw.

3. Lead. It is the distance, 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 a 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 thread is 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, Lead = Pitch × Number of threadsHelix.

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. In other words, it is the curve traced by a particle while moving along a screw thread

7. Helix angle. It is the slope or inclination of the thread with the horizontal.

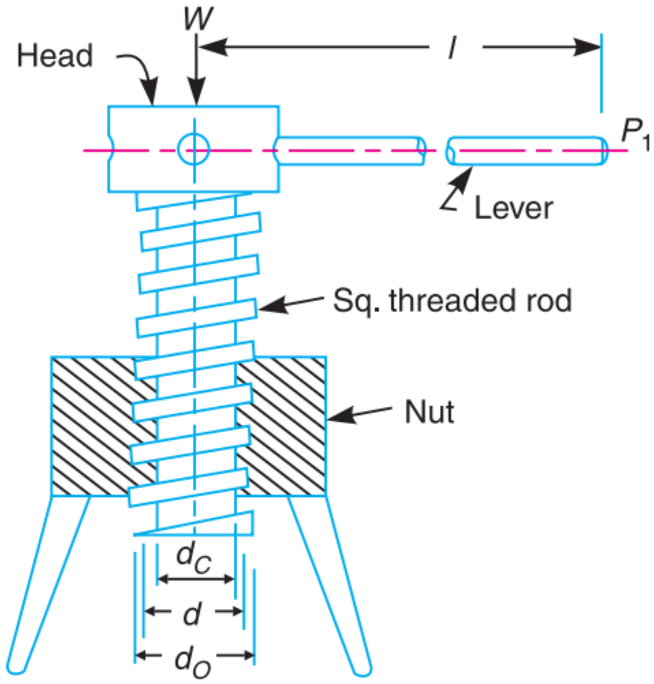
Mathematically, Lead of screw tan Circumference of screw α = = $p/\pi d$ ...(In single-threaded screw) = $n.p/\pi d$ ...(In multi-threaded screw)

where α = Helix angle, p = Pitch of the screw, d = Mean diameter of the screw, and n = Number of threads in one lead.

3.11 Screw Jack

The screw jack is a device, for lifting heavy loads, by applying a comparatively smaller effort at its handle. The principle, on which a screw jack works is similar to that of an inclined plane.

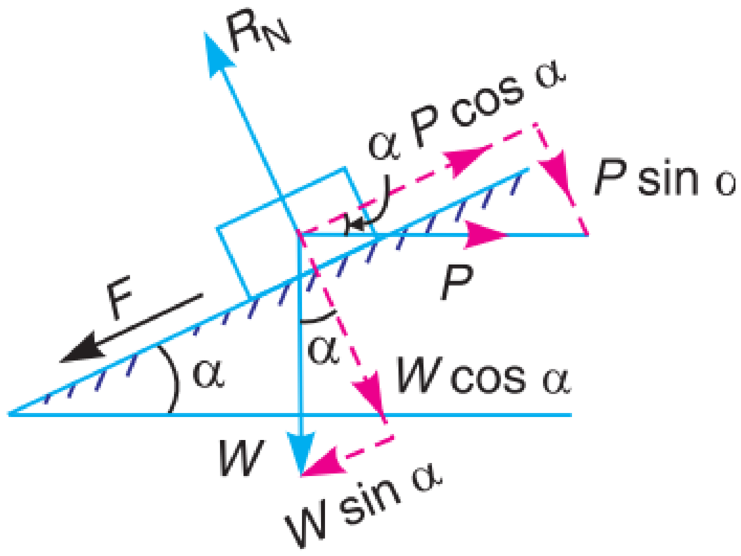
Figure shows a common form of a screw jack, which consists of a square threaded rod (also called screw rod or simply screw) which fits into the inner threads of the nut. The load, to be raised or lowered, is placed on the head of the square threaded rod which is rotated by the application of an effort at the end of the lever for lifting or lowering the load.



Screw jack.

3.11.1. Torque Required to Lift the Load by a Screw Jack

p = Pitch of the screw, d = Mean diameter of the screw, α = Helix angle, P = Effort applied at the circumference of the screw to lift the load, W = Load to be lifted, and μ = Coefficient of friction, between the screw and nut = tan φ, where φ is the friction angle (a),



Forces acting on the screw.

$\therefore$ Torque required to overcome friction between the screw and nut,

$$T_1 = P \times \frac{d}{2} = W \tan(\alpha + \phi)\frac{d}{2}$$

When the axial load is taken up by a thrust collar or a flat surface, as shown in Fig. so that the load does not rotate with the screw, then the torque required to overcome friction at the collar,

$$T_2 = \mu_1 . W\left(\frac{R_1 + R_2}{2}\right) = \mu_1 . W . R$$

where R_1 and R_2 = Outside and inside radii of the collar,

R = Mean radius of the collar, and

μ_1 = Coefficient of friction for the collar.

$\therefore$ Total torque required to overcome friction (*i.e.* to rotate the screw),

$$T = T_1 + T_2 = P \times \frac{d}{2} + \mu_1 . W . R$$

Problem

A turnbuckle, with right and left hand single start threads, is used to couple two wagons. Its thread pitch is 12 mm and mean diameter 40 mm. The coefficient of friction between the nut and screw is 0.16. 1. Determine the work done in drawing the wagons together a distance of 240 mm, against a steady load of 2500 N. 2. If the load increases from 2500 N to 6000 N over the distance of 240 mm, what is the work to be done?

Solution

. Given : p = 12 mm ; d = 40 mm ; μ = tan φ = 0.16 ; W = 2500 N

We know that $$\tan\alpha = \frac{p}{\pi d} = \frac{12}{\pi \times 40} = 0.0955$$

∴ Effort required at the circumference of the screw,

$$P = W\tan(\alpha+\phi) = W\left[\frac{\tan\alpha + \tan\phi}{1-\tan\alpha.\tan\phi}\right]$$

$$= 2500\left[\frac{0.0955+0.16}{1-0.0955\times 0.16}\right] = 648.7 \text{ N}$$

and torque required to overcome friction between the screw and nut,

$$T = P \times d/2 = 648.7 \times 40/2 = 12\,947 \text{ N-mm} = 12.974 \text{ N-m}$$

A little consideration will show that for one complete revolution of the screwed rod, the /agons are drawn together through a distance equal to $2p$, *i.e.* $2 \times 12 = 24$ mm. Therefore in order to raw the wagons together through a distance of 240 mm, the number of turns required are given by

$$N = 240/24 = 10$$

∴ $$\text{Work done} = T \times 2\pi N = 12.974 \times 2\pi \times 10 = 815.36 \text{ N-m}$$

3.11.2. Efficiency of a Screw Jack

The efficiency of a screw jack may be defined as the ratio between the ideal effort (i.e. the effort required to move the load, neglecting friction) to the actual effort (i.e. the effort required to move the load taking friction into account).

We know that the effort required to lift the load (W) when friction is taken into account,

$P = W \tan(\alpha + \varphi)$ ...(i)

where α = Helix angle, φ = Angle of friction, and μ = Coefficient of friction, between the screw and nut = $\tan \varphi$

If there would have been no friction between the screw and the nut, then φ will be equal to zero. The value of effort P0 necessary to raise the load, will then be given by the equation, $P0 = W \tan \alpha$

Efficiency = tan(Helix Angle)/(tan(Helix Angle+Angle of friction).

3.11.3 Over Hauling and Self Locking Screws

Effort required at the circumference of the screw to lower the load is $P = W \tan(\varphi - \alpha)$ and the torque required to lower the load

$T = (P \times (d/2)) = W \tan(\varphi - \alpha)\ (d/2)$

In the above expression, if $\varphi < \alpha$, then torque required to lower the load will be negative. In other words, the load will start moving downward without the application of any torque. Such a condition is known as over hauling of screws. If however, $\varphi > \alpha$, the torque required to lower the load will positive, indicating that an effort is applied to lower the load. Such a screw is known as self locking screw. In other words, a screw will be self locking if the friction angle is greater than helix angle or coefficient of friction is greater than tangent of helix angle i.e. μ or $\tan \varphi > \tan \alpha$.