①

MECHANICS OF MACHINES (MEE 342·2)

1.0 Power Screws

A power screw is a mechanical component which is used to convert rotary motion into the linear motion for power transmission. It produces uniform motion and the design of the power screw may be such that either the screw or the nut is held at rest and the other member rotates as it move axially. It uses helical motion of screw to transmit the power rather than holding the parts together. Depending on the type of holding arrangement, power screws can be divided into two parts:

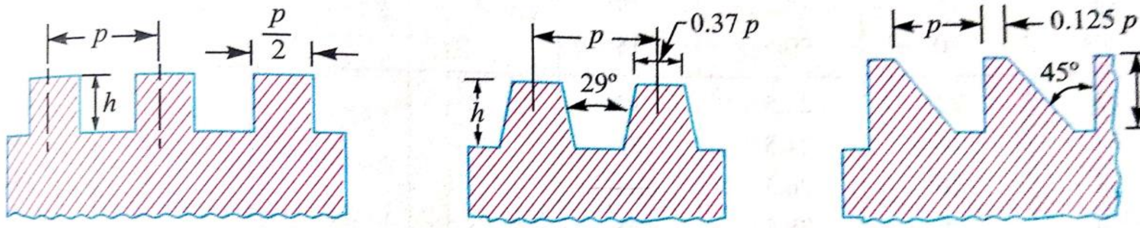
(i) Screw moves in axial direction and nut kept stationary.
   eg. Screw jack and vice

ii) Nut moves in axial direction and screw kept stationary.
   eg. lead screw of a lathe.

1.2 Types of Screw Threads Used for Power Screws

The following are the three types of screw threads mostly used for power screws:

i, Square thread



$h = 0.5\,p$
(*a*) Square thread.

$h = 0.5\,p + 0.25$ mm
(*b*) Acme thread.

$h = 0.75\,p$
(*c*) Buttress thread.

Fig. 17.1. Types of power screws.

2

A square thread, as shown in Fig 17.1 (a) is adapted for the transmission of power in either direction. This thread results in maximum efficiency and minimum radial or bursting pressure on the nut. It is difficult to cut with taps and dies. It is usually cut on lathe with a single point tool and it can not be easily compensated for wear. The square threads are employed in screw jacks, presses and clamping devices.

ii. Acme or trapezoidal thread

Fig 17.1 (b) is a modification of square thread. The slight slope given to its sides lowers the efficiency slightly than square thread and it also introduce some bursting pressure on the nut, but increases its area in shear. It is used where a split nut is required and where provision is made to take up wear as in the lead screw of a lathe. An Acme thread may be cut by means of dies and hence it is more easily manufactured than square thread.

iii, Buttress thread

Fig. is used when large forces act along the screw axis in one direction only. This thread combines the higher efficiency of square thread and the ease of cutting and the adaptability to a split nut of acme thread. It is stronger than other threads because of greater thickness at the base of the thread. The buttress has thread limited use for power transmission. It is employed as the thread for light jack screws and vices.

1.3 Parts of Power Screws

A power screw have the following parts:

i, It consists of Screw
ii, It consists of Nut
iii, It consists of part which holds either nut or bolt in place

1.4 Advantages and Disadvantages of Power Screws

1.4.1 Advantages:

(i) It has large load carrying capacity
ii, It is cheap and reliable because of few parts
iii, It gives smooth and noiseless service
iv, It is simple to design
v, It has compact construction
vi, It gives very high mechanical advantage hence used in screw jacks, clamps, valves and vices.
vii, It provides precise motion which is required in machine tool applications. etc.

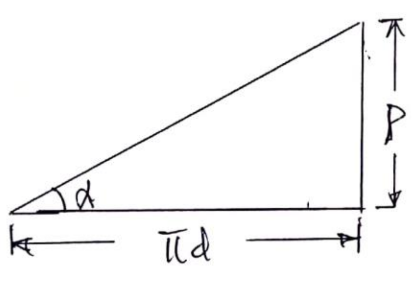
1.4.2 Disadvantages:

i, It has poor efficiency
ii, Due to high friction, wear is a serious problem in Power Screws

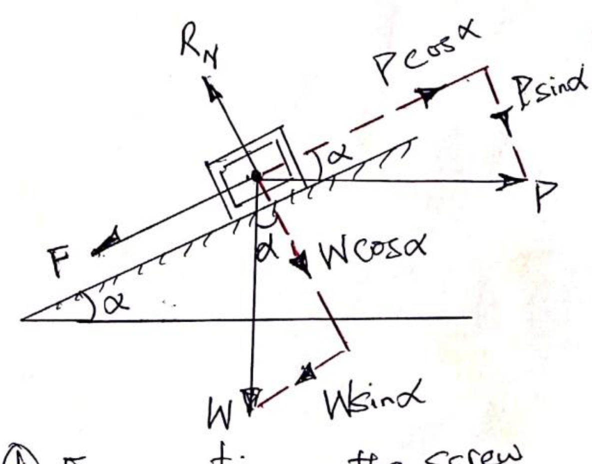
1.5 Torque Required to Raise Load by Square Threaded Screw

The torque required to raise a load by means of square threaded screw may be determined by considering a screw jack as shown in fig. . The load to be raised or lowered is placed in 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.

A little consideration will show that if one complete turn of a screw thread be imagined to be unwound, from the body of the screw and developed, it will form an inclined plane as shown in Figures below.



(a) Development of a Screw



(b) Forces acting on the screw

where 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
μ = Coefficient of friction btw the screw & nut
$= \tan\phi$, where ϕ is the friction angle

from the figure above,

$\tan\alpha = p/\pi d$.. force of friction $F = \mu R_N$

Resolving the forces along the plane

$$P\cos\alpha = W\sin\alpha + F = W\sin\alpha + \mu R_N \quad \text{— (i)}$$

and resolving the forces perpendicular to the plane

$$R_N = P\sin\alpha + W\cos\alpha \quad \text{— (ii)}$$

Substituting equ(ii) into equ(i), we have

$$P\cos\alpha = W\sin\alpha + \mu(P\sin\alpha + W\cos\alpha)$$
$$= W\sin\alpha + \mu P\sin\alpha + \mu W\cos\alpha$$
$$P(\cos\alpha - \mu\sin\alpha) = W(\sin\alpha + \mu\cos\alpha)$$
$$P = W \times \frac{(\sin\alpha + \mu\cos\alpha)}{(\cos\alpha - \mu\sin\alpha)}$$

Substitute for $\mu = \tan\phi$ in the above equation

$$P = W \times \frac{\sin\alpha + \tan\phi\cos\alpha}{\cos\alpha - \tan\phi\sin\alpha}$$

multiplying the numerator and denominator by $\cos\phi$ we have

$$P = W \times \frac{\sin\alpha\cos\phi + \sin\phi\cos\alpha}{\cos\alpha\cos\phi - \sin\alpha\sin\phi}$$

$$= W\frac{\sin(\alpha+\phi)}{\cos(\alpha+\phi)} = W\tan(\alpha+\phi)$$

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 as shown in Fig. (6). So that the load does not rotate with the screw, then the torque required to overcome friction at the collar

$$T_2 = \frac{2}{3} \times \mu_1 \times W\left[\frac{(R_1)^3 - (R_2)^3}{(R_1)^2 - (R_2)^2}\right]$$

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

$$= \mu_1 W R$$

where R_1 and R_2 = Outside and inside radii of Collar

R = Mean radius of Collar $= \frac{R_1 + R_2}{2}$, and

μ_1 = Coefficient of friction for the Collar

Therefore, Total torque required to overcome friction (ie to rotate the screw)

$$T = T_1 + T_2$$

If an effort P_1 is applied at the end of a lever of arm length l, then the total torque required to overcome friction must be equal to the torque applied at the end of lever. ie

$$T = P \times \frac{d}{2} = P_1 \times l$$

1.6 Torque Required to Lower Load by Square Threaded Screws

A little consideration will show that when the load is being lowered, the force of friction ($F = \mu R_N$) will act upwards as shown in Fig.

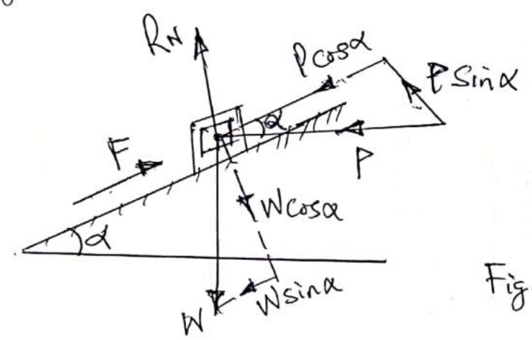


Fig. C

Resolving the forces along the plane,

$$P\cos\alpha = F - W\sin\alpha$$
$$= \mu R_N - W\sin\alpha \qquad \text{——— (i)}$$

forces perpendicular to the plane,

$$R_N = W\cos\alpha - P\sin\alpha \qquad \text{——— (ii)}$$

Applying the same method as shown in Art (1.5) above

$$P = W\frac{\sin(\phi-\alpha)}{\cos(\phi-\alpha)} = W\tan(\phi-\alpha)$$

Therefore, Torque required to overcome friction btw screw and nut

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

1.7 Efficiency of Square Threaded Screws

The efficiency of square threaded screws may be defined as the ratio between the ideal effort to the actual efforts.

If there would have been no friction between the screw and the nut, then ϕ will be equal to zero.

The value of effort P_o necessary to raise the load is given by the equation

$$P_o = W \tan\alpha$$

Therefore, Efficiency, $\eta = \frac{\text{Ideal effort}}{\text{Actual Effort}} = \frac{P_o}{P}$

$$= \frac{W\tan\alpha}{W\tan(\alpha+\phi)} = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

[The equations shows that:
Efficiency of a Screw jack is independent of the load raised.]

In the above equation expression of Efficiency, only the screw friction is considered. However, if the screw friction and collar friction is taken into account, then

Efficiency, $\eta = \frac{\text{Torque required to move the load neglecting friction}}{\text{Torque required to move } \underline{d} \text{ load including Screw \& Collar friction}}$

$$= \frac{T_o}{T} = \frac{P_o \times d/2}{P \times d/2 + \mu_1 \cdot W \cdot R}$$

Mechanical Advantage (M.A) $= \frac{W}{P_1} = \frac{W \times 2L}{P \times d} = \frac{W \times 2L}{W\tan(\alpha+\phi)d} = \frac{2L}{d\tan(\alpha+\phi)}$

and Velocity Ratio (VR) $= \frac{\text{Distance moved by the effort } (P_1) \text{ in one revolution}}{\text{Distance moved by the load } (W) \text{ in one revolution}}$

$$= \frac{2\pi L}{P} = \frac{2\pi L}{d\tan\alpha \times \pi d} = \frac{2L}{d\tan\alpha}$$

Therefore, Efficiency, $\eta = \frac{M.A}{V.R} = \frac{2L}{d\tan(\alpha+\phi)} \times \frac{d\tan\alpha}{2L} = \frac{\tan\alpha}{\tan(\alpha+\phi)}$

9

1·7 Maximum Efficiency of Square Threaded Screw (9)

As shown in Art. 1·6, the efficiency of a square threaded screw is given as

$$\text{Efficiency}, \ \eta = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

$$= \frac{\sin\alpha/\cos\alpha}{\sin(\alpha+\phi)/\cos(\alpha+\phi)}$$

$$= \frac{\sin\alpha \times \cos(\alpha+\phi)}{\cos\alpha \times \sin(\alpha+\phi)} \quad \text{---(i)}$$

Multiplying the numerator and denominator by 2, we have

$$\eta = \frac{2\sin\alpha \times \cos(\alpha+\phi)}{2\cos\alpha \times \sin(\alpha+\phi)} = \frac{\sin(2\alpha+\phi) - \sin\phi}{\sin(2\alpha+\phi) + \sin\phi} \quad \text{-(ii)}$$

The efficiency given by equ (ii) will be maximum when $\sin(2\alpha+\phi)$ is maximum, ie when

$$\sin(2\alpha+\phi) = 1 \quad \text{or when } 2\alpha+\phi = 90^\circ$$

$$2\alpha = 90^\circ - \phi \quad \text{---(iii)}$$

Substituting Equ (iii) into Equ (ii) we have

$$\eta = \frac{\sin(90^\circ - \phi + \phi) - \sin\phi}{\sin(90^\circ - \phi + \phi)} = \frac{\sin 90^\circ - \sin\phi}{\sin 90^\circ + \sin\phi} = \frac{1 - \sin\phi}{1 + \sin\phi}$$