Module :- 4

Power screws & Threaded Fasteners

Power screws

screws used for Power transmission are called Power screws, Power screws are used to convert rotary motion into translatory motion (linear motion).

some of the typical examples are

1) To rise the load ex:- screw Jack
2) To load the specimen ex:- UTM
3) To obtain accurate motion in machining operation ex:- Lead screw of lathe
4) To clamp a work piece ex:- vice

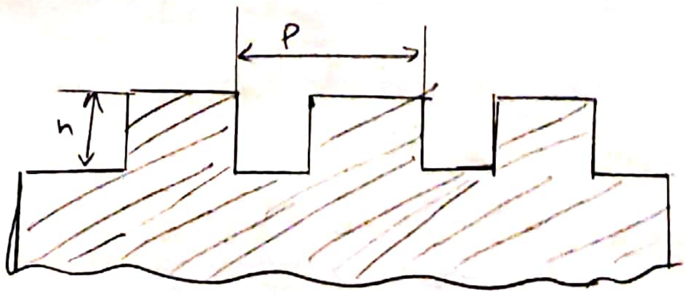
5) Entry

Type of screw thread for power screws

Following are the type of screw thread that are most commonly employeed for power screws.

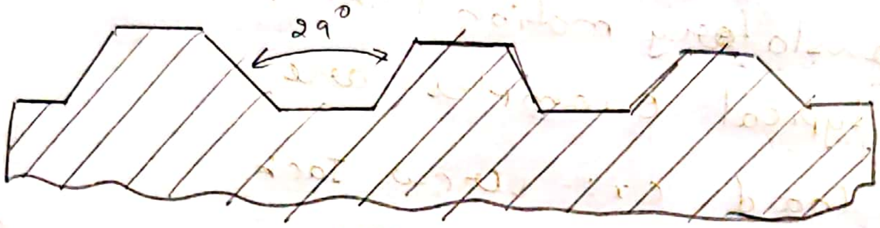
i) Square thread :- A square thread is adopted for the transmission of power in either direction this thread results in maximum efficiency & minimum radial pressure on the nut.

The square threads are employed in screw Jack, Clamping devices & presses.

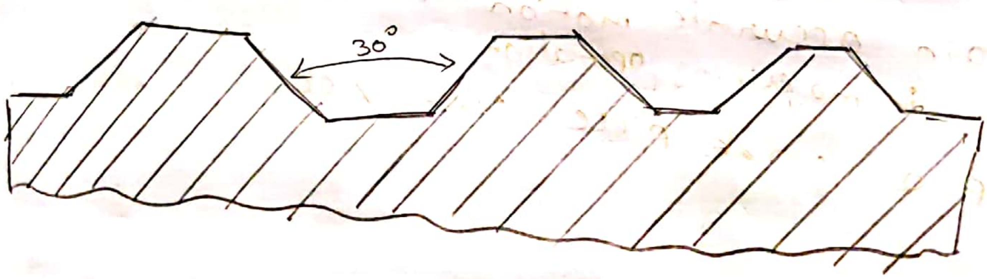


2) **ACME/Trapeozidal thread** :- An ACME (or) Trapeozidal thread is a modification of square thread a slide slope is given to the side lower efficiency slightly than the square thread, the thread angle in trapeozidal thread is 30°. wheas in the ase of ACME thread is 29°

ACME Thread

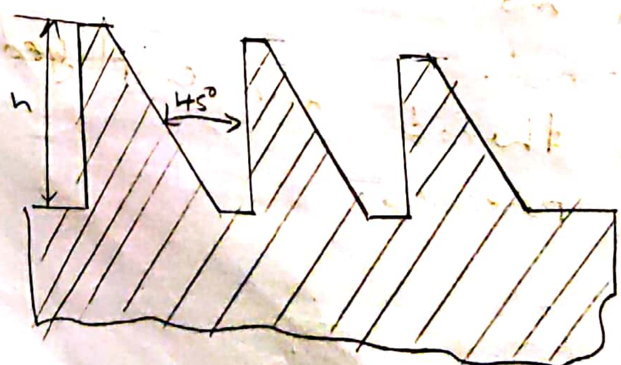


Trapeozidal thread



3) **Buttress thread** :- Buttress thread is used when the large forces acts along the screw axis in one direction only. This thread combines the efficiency of square thread & ease of cutting, adoptability of ACME thread. It is stronger than other thread because of greater thickness at base of the thread.

Fig.



Terminology of Power screw:

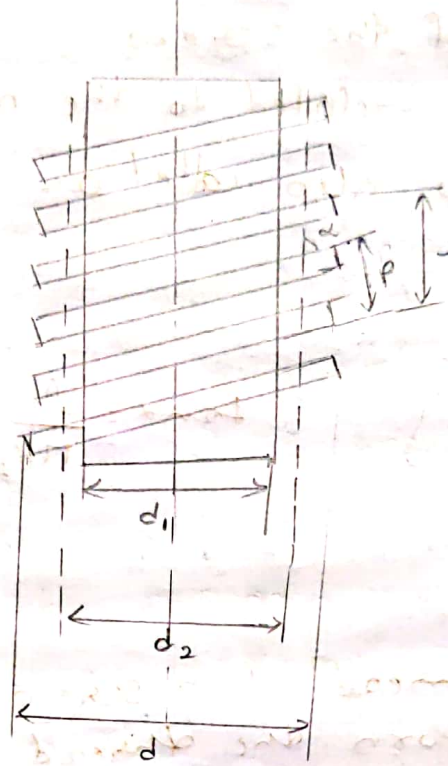


Fig a

1) pitch:- The pitch is defined as the distance ~~btw~~ measured parallel to the axis of screw from a point on one thread to the corresponding point on the adjustant thread. It is denoted by ~~term~~ 'P'.

2) Lead :- The lead is defined as distance measured parallel to the axis of the screw which ~~the~~ nut will advance in revolution of the screw. Denoted by l.

• For single thread screw the lead is same as pitch i.e, $l = P$

For double thread screw the lead is twice of the pitch ~~as~~ i.e $l = 2P$

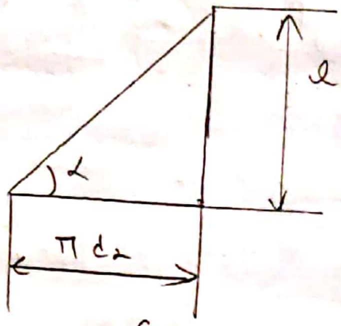
& so, on

3) Nominal diameter :- It is a largest diameter of the screw. Denoted by d.

4) core diameter:- It is a smallest diameter of screw is called as core diameter & denoted by d_1

Helix angle :- The Helix angle defined by the angle made by helix of the thread with the plane perpendicular to the axis of the screw.

The Helix angle is related to the mean diameter & the lead of the screw. also called as lead angle & denoted by 'α'.



$$\tan\alpha = \frac{l}{\pi d_2}$$

Fig(5)

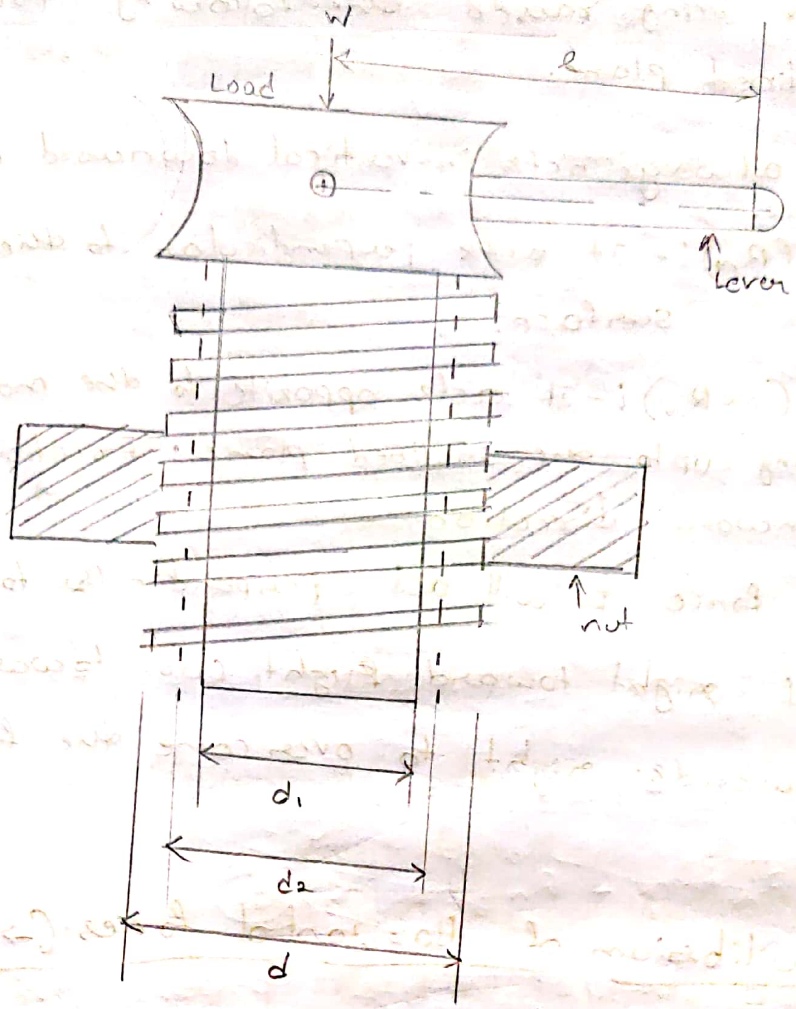
Imagine that one thread of a screw is unwound & develops one complete turn the thread will become the hypotenuse of the right angled triangle where base is πd_2 & heigh is lead (l).

Considering the right angle triangle the relationship b/w helix angle, mean diameter & the lead can be expressed in the following form

$$\boxed{\tan\alpha = \frac{l}{\pi d_2}}$$

v.v.v.Imp

Torque required to lift the load on square thread screw.



Let w = load to be lifted

d = major diameter.

d_1 = minor diameter.

d_2 = mean diameter.

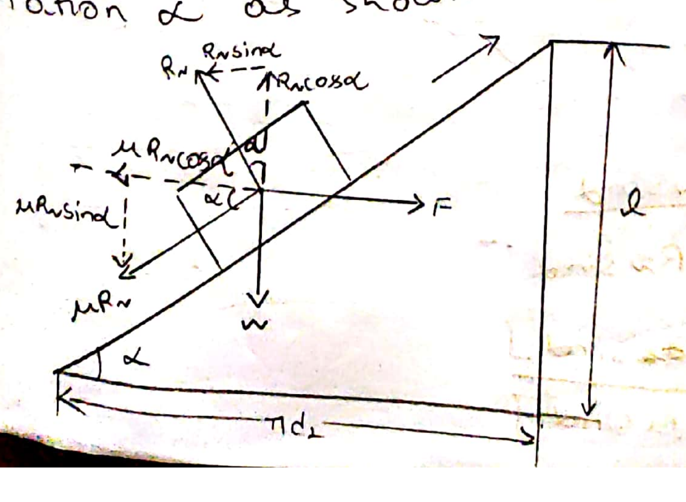
l = lead of the screw

α = helix angle

T = Torque required to rise the load

μ = co-efficient of friction.

The screw is consider as an inclined plane with inclination α as shown in figure.



when the load is being raised the following forces will act on the inclined plane.

1) load (w) :- It always acts in vertical downward direction

2) normal reaction (R_N) :- It acts perpendicular to the inclined surface.

3) Frictional force (μR_N) :- It acts opposite to the motion. since the load is moving upto the inclined plane. Frictional force acts along downward direction.

4) Force (F) :- The force F will act perpendicular to the load (W) it may act right toward right (or) toward left. it will acts towards right to over come the friction to raise the load.

Considering equilibrium of Horizontal forces. ($\rightarrow$ +ve)

$$F - \mu R_N \cos\alpha - R_N \sin\alpha = 0$$

$$F = \mu R_N \cos\alpha + R_N \sin\alpha \rightsquigarrow (a)$$

Considering equilibrium of vertical forces ($\downarrow$ +ve)

$$W - R_N \cos\alpha + \mu R_N \sin\alpha = 0$$

$$W = R_N \cos\alpha - \mu R_N \sin\alpha \rightsquigarrow (b)$$

Dividing the eq^n (a) & (b)

i.e, $\frac{\text{eq}^n (a)}{\text{eq}^n (b)}$

$$\frac{F}{W} = \frac{\mu R_N \cos\alpha + R_N \sin\alpha}{R_N \cos\alpha - \mu R_N \sin\alpha}$$

$$\frac{F}{W} = \frac{R_N [\mu \cos\alpha + \sin\alpha]}{R_N [\cos\alpha - \mu \sin\alpha]}$$

$$\frac{F}{W} = \frac{\mu \cos\alpha + \sin\alpha}{\cos\alpha - \mu \sin\alpha}$$

$\div \cos\alpha$ in RHS both numerator & denominator

$$\frac{F}{W} = \frac{\frac{\mu \cos\alpha}{\cos\alpha} + \frac{\sin\alpha}{\cos\alpha}}{\frac{\cos\alpha}{\cos\alpha} - \frac{\mu \sin\alpha}{\cos\alpha}}$$

$$\frac{F}{W} = \frac{\mu + \tan\alpha}{1 - \mu \tan\alpha} \qquad \therefore \tan\alpha = \frac{\sin\alpha}{\cos\alpha}$$

$$F = W\left[\frac{\mu + \tan\alpha}{1 - \mu\tan\alpha}\right]$$

WKT co-efficient of friction

$\mu = \tan\phi$

where ϕ is friction angle

$$\Rightarrow F = W\left[\frac{\tan\phi + \tan\alpha}{1 - \tan\phi\tan\alpha}\right]$$

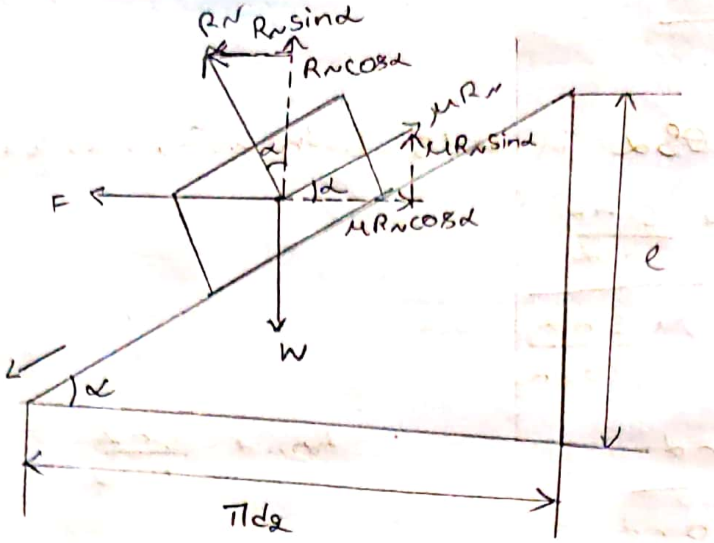
$$\therefore \boxed{F = W\tan[\phi + \alpha]}$$

WKT Torque, T = Force × radius $= F \times r$

$= W\tan[\phi + \alpha] \times \frac{d_2}{2}$

$$\therefore \boxed{T = W \times \frac{d_2}{2} \tan[\phi + \alpha]}$$

Torque required to lower the load on square thread screw



considering equilibrium of Horizontal forces ($\rightarrow$ +ve)

$$-F + \mu R_N \cos\alpha - R_N \sin\alpha = 0$$

$$F = \mu R_N \cos\alpha - R_N \sin\alpha \rightsquigarrow (a)$$

considering equilibrium of vertical forces ($\downarrow$+ve)

$$W - R_N \cos\alpha - \mu R_N \sin\alpha = 0$$

$$W = R_N \cos\alpha + \mu R_N \sin\alpha \rightsquigarrow (b)$$

eqn (a) divided by eqn (b)

i.e $\frac{\text{eq}^n (a)}{\text{eq}^n (b)}$

$$\frac{F}{W} = \frac{\mu R_N \cos\alpha - R_N \sin\alpha}{R_N \cos\alpha + \mu R_N \sin\alpha} = \frac{R_N [\mu \cos\alpha - \sin\alpha]}{R_N [\cos\alpha + \mu \sin\alpha]}$$

$$\frac{F}{W} = \frac{\mu \cos\alpha - \sin\alpha}{\cos\alpha + \mu \sin\alpha}$$

$\div \cos\alpha$ in RHS both numerator & dinominator

$$\frac{F}{W} = \frac{\frac{\mu \cos\alpha}{\cos\alpha} - \frac{\sin\alpha}{\cos\alpha}}{\frac{\cos\alpha}{\cos\alpha} + \frac{\mu \sin\alpha}{\cos\alpha}}$$

$$\frac{F}{W} = \frac{\mu - \tan\alpha}{1 + \mu \tan\alpha}$$

$$F = W\left[\frac{\mu - \tan\alpha}{1 + \mu \tan\alpha}\right]$$

WKT coefficient of friction, $\mu = \tan\phi$

where ϕ is friction angle

$$F = W\left[\frac{\tan\phi - \tan\alpha}{1 + \tan\phi \tan\alpha}\right]$$

$$\therefore \boxed{F = W \tan[\phi - \alpha]}$$

WKT

Torque, T = Force x radius $= F \times r$

$= W \tan[\phi - \alpha] \times \frac{d_2}{2}$

$$\therefore \boxed{T = W.\frac{d_2}{2} \tan[\phi - \alpha]}$$

*** **Self locking & over hauling in power screw**

The torque required to lower the load is given by the equation

$$T = W \times \frac{d_2}{2} \tan(\phi - \alpha)$$

Condition

* If ϕ is less than α the torque required to lower the load is negative.

It indicates the condition that no force is required to lower the load. The load itself begin to turn the screw & descend down. This condition is called over-hauling of the screw.

- If ϕ is greater than (or) equal to α, the positive torque is required to lower the load under this condition the load will not turn the screw &

will not descend on its own unless an effect P is applied. in this case the screw is said to be self locking.

Problem.

1) A Power transmission screw having square thread of 30×6 propells a weight of 20kN at speed of 3m/min. The collar has a inside diameter of 30mm & outside diameter of 60mm. The co-efficient of friction of thread friction is 0.15 & collar friction of 0.2. Determine i) Power required to drive the screw ii) Efficiency iii) length of bronze nut required if allowable bearing pressure 12 MPa iv) The nature & magnitude of stress induced in the screw

Soln :- square thread

Cross-section $(30\times6) = d\times P$

$d = 30mm$

$P = 6mm$

$W = 20kN = 20\times10^3 N$

$V = 3\,m/min = 3000mm/min$

$d_{c_o} = 60mm$

$d_{ci} = 30mm$

$f = \mu = 0.15$

$f_c = \mu_c = 0.2$

To find

$P = ?$

η

$l_n = ?$ $P_b = 120$ MPa

stress = ?

WKT pitch $(P) = d - d_1$

$6 = 30 - d_1$

$\therefore \boxed{d_1 = 24mm}$

mean diameter (or) pitch diameter

$d_2 = d - P/2 = 30 - (6/2)$

$\therefore \boxed{d_2 = 27mm}$

Core area

$A_c = \frac{\pi d_1^2}{4} = \frac{\pi(24)^2}{4} = 452.38\ mm^2$

mean collar diameter

$d_c = \frac{d_{co} + d_{ci}}{2}$

$= \frac{60+30}{2}$

$\boxed{d_c = 45mm}$

lead (l), l = no. of starts × pitch

Here we assume

no of starts = 1

$l = 1\times6 = 6mm$

$\tan\alpha = \frac{l}{\pi d_2} = \frac{6}{\pi\times(27)}$

$\therefore \boxed{\tan\alpha = 0.07073 5}$

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i) Power, $(P) = \frac{T \times n}{9.55 \times 10^6} = \frac{150.236 \times 10^3 \times 500}{9.55 \times 10^6} = 7.8657 \text{ kW}$

Torque, $T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) + \mu_c d_c\right]$ → [eqn 9.12(a), Pg 135]

$$T = \frac{20 \times 10^3}{2}\left[27\left[\frac{0.07073 + 0.15}{1 - (0.15 \times 0.07073)}\right] + 0.2 \times 45\right]$$

$$\boxed{T = 150.236 \times 10^3} \text{ N-mm}$$

To find speed

$$n = \frac{v}{l} = \frac{3000}{6} = 500 \text{ rpm}$$

ii) Efficiency:-

$$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right)d_2 + \mu_c d_c}$$ → [eqn 9.12(b), Pg 135]

$$\eta = \frac{27 \times 0.07073}{\left(\frac{0.07073 + 0.15}{1 - 0.15(0.07073)}\right) \times 27 + 0.2 \times 45}$$

$$\therefore \boxed{\eta = 12.711\%}$$

iv) length of nut

$P_b = 12 \text{ MPa}$

$$l_n = \frac{4 W \times P}{P_b \pi (d^2 - d_1^2)}$$ → [eqn 9.13(6), Pg 135]

$$= \frac{4 \times 20 \times 10^3 \times 6}{12 \times \pi ((30^2) - (24^2))} = 39.2975 \approx 40 \text{ mm}$$

iv) stress

a) compressive stress

$$\sigma_c = \frac{W}{A_c} = \frac{20 \times 10^3}{452.38} = 44.21 \text{ N/mm}^2$$

b) shear stress in screw

$$\frac{T}{J} = \frac{\tau}{r}$$

$\tau_s = \frac{T \times r}{J}$ | $r = \frac{d_1}{2} = \frac{24}{2} = 12$

$= \frac{150.236 \times 10^3 \times 12}{32,572.0326}$ | $J = \frac{\pi d_1^4}{32} = \frac{\pi (24^4)}{32}$

$\therefore J = 32,572.032$

$\boxed{\tau_s = 55.3490 \ N/mm^2}$

combined stress (or) principal stress

max. normal stress.

$\sigma_{max} = \frac{1}{2}\left[\sigma_c + \sqrt{\sigma_c^2 + 4\tau^2}\right] = \frac{1}{2}\left[44.21 + \sqrt{(44.21)^2 + 4(55.3490)^2}\right]$

$\therefore \boxed{\sigma_{max} = 81.7048 \ N/mm^2}$

max. shear stress

$\tau_{max} = \frac{1}{2}\left[\sigma_c^2 + 4\tau^2\right]^{1/2} = \frac{1}{2}\left[(44.21)^2 + 4(55.3490)^2\right]^{1/2}$

$\rightarrow = 59.50 \ N/mm^2$

2) A square threaded power screw has nominal diameter of 44mm & pitch of 7mm with double threads the load on the screw is 6kN. & mean diameter of thrust washer is 50mm & co-efficient of friction is 0.12. Determine. i) Torque required to raise the load. ii) Torque required to lower the load iii) Efficiency iv) check whether the screw overhauls

Soln:- square thread

$d = 44mm$

$P = 7mm$

no. of starts $= 2$

$W = 6kN = 6 \times 10^3 N$

$\mu = 0.12$

WKT

pitch $(P) = d - d_1$

$7 = 44 - d_1$

$\therefore \boxed{d_1 = 37mm}$

$d_c = 50mm$

mean diameter (or) pitch diameter

$d_2 = d - P/2 = 44 - (7/2)$

$\therefore d_2 = 40.5mm$

$\tan\alpha = \frac{l}{\pi d_2} = \frac{14}{\pi(40.5)}$

$\therefore \boxed{\tan\alpha = 0.110033}$

Area of core

$$A_c = \frac{\pi d_c^2}{4} = \frac{\pi (37)^2}{4} = 1075.2100 mm^2$$

iii) Efficiency

$$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) d_2 + \mu_c d_c}$$ ~> [eqn 9.12(b), Pg. 135]

$$\eta = \frac{40.5 \times 0.11003}{\left[\frac{0.11033 + 0.12}{1 - 0.12 \times 0.1103}\right] 40.5 + 0.12 \times 50}$$

$\therefore \eta = 28.860\%$

iv) To check whether the screw over-hauls.

$$\tan\alpha \geq \left(\frac{\mu d_2 + \mu_c d_c}{d_2 - \mu \mu_c d_c}\right)$$ ~> [eqn 9.12(c), Pg 135]

$$0.1100 \geq \left[\frac{0.12 \times 40.5 + 0.12 \times 50}{40.5 - 0.12 \times 0.12 \times 50}\right]$$

$$0.1100 \geq 0.27300$$

The friction angle is more than lead angle hence the screw is said to be self-locking.

i) Torque required to raise the load

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) + \mu_c d_c\right]$$ ~> [eqn 9.12(a), Pg 135]

$$T = \frac{6 \times 10^3}{2}\left[40.5\left(\frac{0.110033 + 0.12}{1 - 0.12 \times 0.11003}\right) + 0.12 \times 50\right]$$

$\therefore T = 46.3185 \times 10^3 N\text{-}mm$

ii) Torque required to lower the load

$$T = \frac{W}{2}\left[d_2\left(\frac{\mu - \tan\alpha}{1+\mu\tan\alpha}\right) + \mu_c d_c\right]$$

$$T = \frac{6\times10^3}{2}\left[40.5\left(\frac{0.12-0.11033}{1+0.12(0.110033)}\right) + 0.12\times50\right]$$

$\therefore T = 19.195\times10^3$ N-mm

3) The cutter of the broaching machine is pulled by a square thread of 50mm external diameter & 8mm pitch. The operating nut takes a load of 42kN. The flat surface of 84mm external diameter & 56mm internal diameter. The co-efficient of friction is 0.15 for all contact surfaces. Determine the power required to rotate the operating nut, where the cutting speed is 15m/min. Also find the efficiency of the screw.

Soln:-

Square thread

$d = 50$mm

$p = 8$mm

$W = 42$kN

$d_{co} = 84$mm

$d_{ci} = 56$mm

$\mu_c = \mu = 0.15$

$V = 15$m/min

From Table 9.10 Pg 149

$d = 50$mm

$d_1 = 42$mm

$A_c = 1385$mm^2

mean diameter

$d_2 = d - (P/2) = 50 - (8/2)$

$\therefore d_2 = 46$mm

lead (l) = no. of starts × pitch

Here we assume

no. of starts = 1

lead (l) = 1×8 = 8mm

$$\tan\alpha = \frac{l}{\pi d_2} = \frac{8}{\pi(46)} = 0.055358$$

$$d_c = \frac{d_{co}+d_{ci}}{2} = \frac{84+56}{2}$$

$\therefore d_c = 70$mm

) Power, $P = \frac{T \times n}{9.55 \times 10^6}$

$$n = \frac{V}{l} = \frac{15 \times 10^3}{8} = 1875 \text{ rpm}$$

$$P = \frac{T \times n}{9.55 \times 10^6} = \frac{420.528 \times 10^3 \times 1875}{9.55 \times 10^6} = 82.564 \text{ kW}$$

ii) Torque, T

$$T = \frac{W}{2}\left[d_2\left[\frac{\mu + \tan\alpha}{1 - \mu\tan\alpha}\right] + \mu_c d_c\right]$$

$$T = \frac{42 \times 10^3}{2}\left[46\left[\frac{0.15 + 0.05535}{1 - (0.15 \times 0.05535)}\right] + 0.15 \times 70\right]$$

$$\therefore T = 420.5288 \times 10^3 \text{ N-mm}$$

iii) Efficiency

$$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right)d_2 + \mu_c d_c}$$

$$= \frac{46 \times 0.05535}{\left(\frac{0.05535 + 0.15}{1 - (0.15 \times 0.05535)}\right)46 + 0.15 \times 70}$$

$$\eta = 12.714\ \%$$

4) A triple headed power screw is used in screw jack, has nominal diameter of 50mm & the pitch of 8mm. The threads are square shape & the length of nut is 48mm. The screw is used to lift a load of 7.5kN, the co-efficient of friction at threads is 0.12 & collar friction is negligible. Calculate principle shear stress in screw rod, transverse shear stress in screw & nut, unit

varying pressure for threads state whether screw is self locking.

Soln:- square thread
no. of starts = 3
d = 50mm
p = 8mm l_n = 48mm
w = 7.5kN
μ = 0.12

lead (l) = no. of starts × pitch
= 3×8
= 24mm

From Table 9.10 pg 149

$d_1 = 42mm$
$d_2 = 46mm$
$A_c = 1385mm^2$

$d_2 = d - P/2 = 50 - (8/2) = 46mm$

$\tan\alpha = \frac{l}{\pi d_2} = \frac{24}{\pi \times 46} = 0.16607$

i) principal max. shear stress.

$\tau_{max} = \frac{1}{2}\left[\sqrt{\sigma_c^2 + 4\tau^2}\right]$

compressive stress, $\sigma_c = \frac{w}{A_c} = \frac{7.5\times10^3}{1385} = 5.4151 N/mm^2$

shear stress, $\tau_s = \frac{T\times r}{J} = \frac{16T}{\pi d_1^3}$ ~~$= \frac{16\times50.350\times10^3}{\pi(42)^3}$~~

Torque, $T = \frac{w}{2}\left[d_2\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) + \mu_c d_c\right]$ → 0

$T = \frac{7.5\times10^3}{2}\left[46\left(\frac{0.16607 + 0.12}{1 - 0.12\times0.16607}\right)\right]$

$\therefore T = 50.350\times10^3 N\text{-}mm$

$\tau_s = \frac{16T}{\pi d_1^3} = \frac{16\times50.350\times10^3}{\pi(42^3)} = 3.4611 N/mm^2$

$\therefore \tau_{max} = \frac{1}{2}\left[\sqrt{(5.4151)^2 + 4(3.4611)^2}\right] = 4.3943 N/mm^2$

To calculate P_b (bearing pressure)

$l_n = \frac{4wP}{P_b\pi(d^2 - d_1^2)}$ ⇝ [eqn 9.13(b), Pg 135]

$48 = \frac{4\times7.5\times10^3\times8}{P_b\pi((50^2) - (42^2))}$

$\Rightarrow P_b = 2.162MPa$

Efficiency

$$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) d_2 + \mu_c d_c} = \frac{46 \times 0.16607}{\left[\frac{0.16607 + 0.12}{1 - (0.12 \times 0.16607)}\right] 46}$$

$$\boxed{\eta = 56.895\%}$$

note
Transverse shear stress in screw & nut is given

In screw, $\tau_s = \frac{W}{\pi d_1 t i}$

In nut, $\tau_n = \frac{W}{\pi d t i}$

t = thickness
i = no. of threads

Thickness, $t = \frac{P}{2} = \frac{8}{2} = 4mm$

length of nut, $l_n = i \times P$

$48 = i \times 8$

$\therefore \boxed{i = 6mm}$

$\tau_s = \frac{7.5 \times 10^3}{\pi \times 42 \times 4 \times 6} = 2.36837 \ N/mm^2$

$\tau_n = \frac{W}{\pi d t i} = \frac{7.5 \times 10^3}{\pi \times 50 \times 4 \times 6} = 1.9894 \ N/mm^2$

$= 1.9894 N/mm^2$

5) Bench vice is operated by a square threaded of screw 24mm diameter & 5mm pitch a force of 180N is applied at the end of lever of length 200mm. The mean diameter of the collar is 30mm the co-efficient of thread friction & collar friction are 0.12 & 0.15. Determine the clamping force develop & the efficiency.

Sol^n:-

Square threaded screw

$d = 24mm$

$p = 5mm$

$F = 180N$

$l = 200mm$

$d_c = 30mm$

$\mu = 0.12$

$\mu_c = 0.15$

$W = ?$

$\eta = ?$

From Table 9.10 (Pg 149)

$d_1 = 19mm$

$A_c = 284mm^2$

$d_2 = \frac{d_1 + d}{2} = \frac{19+24}{2} = 21.5mm$

lead l = no. of shaft × pitch

$l = 1 \times 5 = 5mm$

WKT

$\tan\alpha = \frac{l}{\pi d_2} = \frac{5}{\pi \times 21.5} = 0.074$

WKT

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) + \mu_c d_c\right]$$

Torque, $T = F \times l = 180 \times 200$

$T = 36 \times 10^3 N\text{-}mm$

$$2 \times 36 \times 10^3 = W\left[21.5\left(\frac{0.074 + 0.12}{1 - 0.12 \times 0.074}\right) + 0.15 \times 30\right]$$

$W = 8.2679 \times 10^3 N$

$\therefore W = 8.267kN$

WKT

$$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) d_2 + \mu_c d_c} = \frac{21.5 \times 0.074}{\left(\frac{0.074 + 0.12}{1 - 0.12 \times 0.074}\right) 21.5 + 0.15 \times 30}$$

$\therefore \eta = 0.1826 = 18.26\%$

Q) A sluice gate weighs 500kN is raised at a speed of 6m/min by two screw rod with square thread 50x8mm that two screw rods are driven by bevel gear & motor. determine torque required for rise the gate, the speed of rotation of screw rod assuming the triple start. The maximum stress induced in a screw; efficiency of the screw the length of nut required to support the load taking allowable bearing pressure as 12MPa check for overhauling.

Sol^n:- Triple start

i) $T = ?$

ii) $n = ?$

iii) $l_n = ?$ $(P_b = 12 MPa)$

iv) self locking/over hauling

v) stress

$W = 500kN$

$V = 6m/min$

2 Screw rods (50x8)

From Table 9.10. pg149

$d = 50mm$

$P = 8mm$

$d_1 = 42mm$

$d_2 = \frac{d_1 + d_0}{2} = 46mm$

$A_c = 1385 mm^2$

lead, l = no of starts x pitch.

$l = 3 \times 8 = 24mm$

$\tan\alpha = \frac{l}{\pi d_2} = \frac{24}{\pi \times 46} = 0.1660$

i) Torque required to raise load

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right)\right] \times \cancel{\mu_c d_c} \to 0$$

assuming $\mu = 0.12$

$$T = \frac{500 \times 10^3}{2}\left[46\left[\frac{0.166 + 0.12}{1 - 0.12 \times 0.166}\right]\right]$$

$$\boxed{T = 3.3558 \times 10^6 \, N\text{-}mm}$$

For individual screw rod

$T_i = \frac{\text{Total torque}}{2} = \frac{T}{2} = \frac{3.3558 \times 10^6}{2} = 1.67 \times 10^6 \, N\text{-}mm$

i) Efficiency (η) = $\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) d_2 + \mu_c d_c}$ ($\mu_c d_c \to 0$)

$\eta = \frac{d_2 \tan\alpha}{\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) d_2} = \frac{46 \times 0.166}{\left(\frac{0.166 + 0.12}{1 - 0.12 \times 0.166}\right) 46}$

$\eta = 0.5688$

$\eta = 56.88\%$

iii) length of the nut [eq 9.13(b) pg 135] $W = \frac{500}{2} = 250 \times 10^3$

$l_n = \frac{4 \times W \times P}{P_b \pi (d^2 - d_1^2)} = \frac{4 \times 250 \times 8 \times 10^3}{12 \times \pi (50^2 - 42^2)}$

$\therefore l_n = 288.324 \, mm$

v) i) $\sigma_c = \frac{W}{A_c} = \frac{250 \times 10^3}{1385} = 180.505 \, N/mm^2$

ii) $\tau = \frac{16 T_i}{\pi d_1^3} = \frac{16 \times 1.67 \times 10^6}{\pi \times (42^3)} = 114.799 \, N/mm^2$

iii) $\sigma_{max} = \frac{1}{2}\left[\sigma_c + 4\sqrt{\sigma_c^2 + 4\tau^2}\right]$

$= \frac{1}{2} \left[180.505 + \sqrt{(180.505)^2 + 4(114.799)^2}\right]$

$\sigma_{max} = 236.1$ ~~12~~ N/mm^2

iv) $\tau_{max} = \frac{1}{2}\left[\sigma_c^2 + 4\tau^2\right]^{1/2} = \frac{1}{2}\left[(180.505)^2 + 4(114.799)^2\right]^{1/2}$

$= 145.8 \, N/mm^2$

condition for overhauling.

$\tan\alpha \geq \left(\frac{\mu d_2}{d_2}\right) \quad \therefore 0.166 > 0.12$

overhauls

4) A power screw for a Jack has a Acme thread of proportion 36×30×6 friction of co-efficient threads is 0.1 & at the collar is 0.12. Determine the weight that can be lifted by this Jack through a human effort of 300N at the end of the lever, span of 500mm. what the efficiency & the length of the nut required considering the bearing pressure as 9MPa mean collar diameter 40mm

Soln ACME thread

36×30×6

d × d_1 × p

d = 36mm

d_1 = 30mm

p = 6mm

$A_c = \frac{\pi}{4} \times d_1^2 = \frac{\pi \times 30^2}{4} = 706.8583 mm^2$

$\mu = 0.1$

$\mu_c = 0.12$

$d_2 = \frac{d+d_1}{2} = \frac{36+30}{2} = 33mm$

W = ? , η = ?

Effort = 300N

l = 500mm

Torque, T = Effort × l

= 300 × 500

T = 150×10^3 N-mm

l_n = ? [P_b = 9MPa]

d_c = 40mm

For ACME thread

$2\theta = 29°$

$\theta = 29/2 = 14.5°$

lead, l = no of starts × pitch

= 1 × 6

l = 6mm

$\tan\alpha = \frac{l}{\pi d_2} = \frac{6}{\pi \times 33} = 0.0578$

sec(14.5) = 1.0329

i) $T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu\sec\theta}{1-\mu\tan\alpha\sec\theta}\right) + \mu_c d_c\right]$

$2 \times 150 \times 10^3 = W\left[33\left(\frac{0.0578 + 0.1 \times \sec(14.5°)}{1 - 0.1 \times 0.0578 \times \sec(14.5°)}\right) + 0.12 \times 40mm\right]$

W = 29.5627 kN

$$\eta = \frac{d_2 \tan\alpha}{d_2\left[\frac{\tan\alpha + \mu\sec\theta}{1-\mu\tan\alpha\sec\theta}\right] + \mu_c d_c}$$

$\sec(14.5) = 1.0329$

$$\eta = \frac{33 \times 0.0578}{33\left[\frac{0.0578 + 0.1\times\sec(14.5)}{1 - 0.1\times 0.0578\times\sec(14.5)}\right] + 0.12\times 40}$$

~~8~~ $\eta = 0.1879$

$\therefore \boxed{\eta = 18.79\%}$

$$l_n = \frac{4WP}{P_b\pi(d^2 - d_1^2)} = \frac{4\times 29.5627\times 10^3\times 6}{(9\times\pi(36^2 - 30^2))}$$

$\therefore l_n = 63.36\,mm$

8) A Triple start ISO tropezoidal threaded screw is operated by a torque of 40N-m at is lower end. The nut is loaded & prevented from turning the screw has 48mm outside diameter with pitch of 8mm. The end of the screw is mounted on a thrust ball bearing co-efficient of thread is 0.15. Determine i) the load that to be lifted. ii) whether the screw over hauls comment iii) the average bearing pressure b/w screw & nut threads assuming nut length of 50mm.

Soln :-

i) $W = ?$

ii) condition for over hauling.

iii) P_b/σ_b', $l_n = 50mm$

Triple start, $n = 3$

ISO - tropezoidal

$2\theta = 30$

$\therefore \boxed{\theta = 15°}$

Torque, $T = 40N\text{-}m = 40\times 10^3 N\text{-}mm$

$d = 48mm$, $P = 8mm$

$\mu = 0.15$

$d_1 = d - P = 48 - 8 = 40mm$

$d_2 = d - P/2$ (or) $\frac{d + d_1}{2}$

$= 48 - 8/2 = 48 - 4$

$\therefore \boxed{d_2 = 44mm}$

Core Area, $A_c = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}\times(40^2)$

$\boxed{A_c = 1256.63mm^2}$

lead, l = no of starts × pitch

$= 3\times 8$

$\therefore \boxed{l = 24\,mm}$

$\therefore \tan\alpha = \frac{l}{\pi d_2} = \frac{24}{\pi\times 44} = 0.1736$

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu\sec\theta}{1-\mu\tan\alpha\sec\theta}\right) + \mu_c d_c\right]$$ (the $\mu_c d_c$ term is struck out and marked $\to 0$)

$\sec(15^\circ) = 1.0352$

सक $40\times10^3 = \frac{W}{2}\left[44\left(\frac{0.1736 + 0.15\times\sec(15^\circ)}{1 - 0.15\times0.1736\times\sec(15^\circ)}\right)\right]$

$$W = \frac{40\times10^3\times2}{44\left(\frac{0.1736+0.15\times\sec(15^\circ)}{1-0.15\times0.1736\times\sec(15^\circ)}\right)}$$

$W = 5.3793\times10^3 N$

$\therefore$ $\boxed{W = 5.3793 kN}$

ii) ACME / Trapezoidal thread

$$\tan\alpha \geq \left(\frac{d_2\mu\sec\theta}{d_2-\mu\sec\theta}\right) \geq \frac{d_2 f\sec\theta}{d_2 - f\sec\theta}$$

$$0.1736 \geq \left(\frac{44\times0.15\times\sec(15^\circ)}{44-0.15\times\sec(15^\circ)}\right)$$

$0.1736 \geq 0.1558$

Since, the screw over hauling because LHS is greater than RHS i.e $0.1736 \geq 0.1558$

iii) $l_n = 50mm$

$$l_n = \frac{4WP}{P_b\pi(d^2-d_1^2)}$$

$$P_b = \frac{4\times W\times P}{l_n\times\pi(d^2-d_1^2)} = \frac{4\times5.3793\times10^3\times8}{50\times\pi(48^2-40^2)}$$

$\therefore$ $\boxed{P_b = 1.556 N/mm^2}$

100

General Procedure for Design of screw Jack

(16m problem is come)

Problem

1) A screw Jack is to lift a load of 80kN through a height of 400mm. ultimate strength of screw material in tension & compression is 200 N/mm² & in shear 120 N/mm². The material for the nut is phosphor Bronze for which ultimate strength is 100MPa in tension, 90MPa in compression & 80MPa in shear. The bearing pressure b/w the nut & the screw is not exceed 18MPa design the screw & nut. Check for the stresses take FOS = 2 assume 25% overload for screw rod design.

Soln:- $W = 80\,kN$

height = 400mm

$(\sigma_{ut})_{screw} = 200\,N/mm^2$

$(\sigma_{uc})_{screw} = 200\,N/mm^2$

$(\tau)_{screw} = 120\,N/mm^2$

$(\sigma_{ut})_{nut} = 100\,MPa$

$(\sigma_{uc})_{nut} = 90\,MPa$

$(\tau)_{nut} = 80\,MPa$

$\sigma_b' / P_b = 18\,MPa$

$n = 2$

Design : screw, nut } stress

25% overload

~~$W = 80 + (80\times0.25)$~~

~~$W = 100\,kN$~~

$n = \frac{\sigma_u}{\sigma_{all}}$

Step 1:-

allowalable stress for screw in tension

WKT $FOS = \frac{\sigma_{ut}}{(\sigma_{all})_t}$

$(\sigma_{all})_t = \frac{\sigma_{ut}}{n} = \frac{200}{2}$

$\therefore (\sigma_{all})_{screw} = 100\,MPa$

allowable stress for screw in compression

$n = \frac{\sigma_{uc}}{(\sigma_{all})_c}$

$(\sigma_{all})_c = \frac{\sigma_{uc}}{n} = \frac{200}{2}$

$\therefore (\sigma_{allc})_{screw} = 100\,MPa$

all. stress for screw

$\tau = \frac{\tau_y}{n} = \frac{120}{2}$

$\therefore (\tau_{all})_{screw} = 60\,MPa$

allowable stress for nut

In tension

$(\sigma_{allt})_{nut} = \frac{\sigma_{ut}}{n} = \frac{100}{2} = 50\,MPa$

$(\sigma_{allc})_{nut} = \frac{\sigma_{uc}}{n} = \frac{90}{2} = 45\,MPa$

$(\tau)_{nut} = \frac{\tau_y}{2} = \frac{80}{2} = 40\,MPa$

wkt step:-2

Design of Screw rod

wkt $(\sigma_c)_{screw} = \frac{W}{A_c}$

load $= 80 \times 10^3 * (1.25)$ (25% over load)

load $= 100 \times 10^3 N$

Core Area, $A_c = \frac{W}{(\sigma_c)_{screw}} = \frac{100 \times 10^3}{100} = 1{,}000 mm^2$

step 3

From Table 9.10 Pg 149

standard core Area $= 1075 mm^2$

$d = 44$ (nominal/major diameter)

$d_1 = 37$ (minor diameter)

$P = 7$ (Pitch) , Diameter of Nut, $D_{nut} = 44.5mm$

$d_2 = 44 - P/2 = 44 - 7/2 = 40.5mm$

~~diameter~~.

Step 4 :-

Check for stress.

$\sigma_{max} = \frac{1}{2}\left[\sigma_c + \sqrt{\sigma_c^2 + 4\tau^2}\right]$ & $\tau_{max} = \frac{1}{2}\left(\sqrt{\sigma_c^2 + 4\tau^2}\right)$

where

Direct stress compressive stress, $\sigma_{c_{std}} = \frac{W}{A_c} = \frac{80 \times 10^3}{1075} = 74.4186 N/mm^2$

shear stress, $\tau = \frac{16T}{\pi d_1^3}$

wkT $T = \frac{W}{2}\left[d_2\left[\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right]\right]$

From Table 9.3, Pg 136

Assume Heavy m/c oil, $\mu = 0.14$

$\tan\alpha = \frac{l}{\pi d_2}$

where l = no of starts x Pitch

assume no of starts = 1

$l = 1 \times 7 = 7mm$

$\tan\alpha = \frac{7}{\pi \times 40.5} = 0.0550$

$$T = \frac{80\times10^3}{2}\left[40.5\left[\frac{0.055 + 0.14}{1 - 0.14\times0.055}\right]\right]$$

$T = 318.3513\times10^3$ N-mm

$$\tau = \frac{16T}{\pi d_1^3} = \frac{16\times318.3513\times10^3}{\pi\times(37^3)}$$

$\therefore$ $\boxed{\tau = 32\ N/mm^2}$

$$\sigma_{max} = \frac{1}{2}\left[\sigma_c + \sqrt{(\sigma_c^2 + 4\tau^2)}\right]$$

$$= \frac{1}{2}\left[74.4186 + \sqrt{(74.4186)^2 + 4(32^2)}\right]$$

$\therefore$ $\sigma_{max} = 86.286\ N/mm^2 < (\sigma_{all})_{screw}$ (100 MPa)

$$\tau_{max} = \frac{1}{2}\left[\sqrt{\sigma_c^2 + 4\tau^2}\right] = \frac{1}{2}\left[\sqrt{(74.4186)^2 + 4(32^2)}\right]$$

$\therefore$ $\tau_{max} = 49.076\ N/mm^2 < (\tau_{all})_{screw}$ (60 MPa)

The design of screw rod is safe.

step 5

The length of screw rod will be equals to the lift + length of nut + some margin.

length of screw rod = lift + length of nut + margin

where, length of nut, $l_n = \frac{4\times W\times P}{P_b\times\pi\times(d^2 - d_1^2)} = \frac{4\times80\times10^3\times7}{18\times\pi(44^2 - 37^2)}$

$l_n = 69.8622 \approx 70$ mm

length of screw rod = 400 + 70 + 20

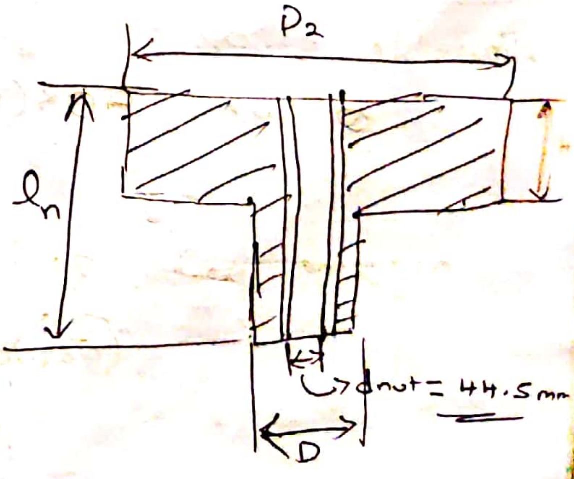
$L_s = 490$ mm

step 6

Design of nut

① length of nut, $l_n = 70$ mm

② Tearing strength of nut



$$W = \frac{\pi}{4}(D^2 - d_{nut}^2)(\sigma_t)_{nut}$$

$$80\times10^3 = \frac{\pi}{4}(D^2 - (44.5)^2)(50)$$

$D = 63.3832$ mm ≈ 64 mm

③ ~~T(πD)H~~ ~~To find length of nut~~

$W = (\pi D)H \times \tau_{nut}$

$80 \times 10^3 = (\pi \times 64)H \times 40$

$\therefore H = 9.9471\ mm \simeq 10mm$

④ Crushing strength of collar.

$W = \frac{\pi}{4}(D_2^2 - D^2) \times (\sigma_c)_{nut}$

$80 \times 10^3 = \frac{\pi}{4}(D_2^2 - (64^2)) \times 45$

$\therefore D_2 = 79.746mm \simeq 80mm$

2) Design a screw Jack with a lift of 300mm to lift a load of 50kN select C-40 steel ($\sigma_y = 328.6\ MPa$) for the screw & soft phosphorous bronze ($\sigma_u = 345\ MPa$ & $\sigma_y = 138\ MPa$ for nut.

Soln:- lift = 300mm

For screw

$W = 50kN$

$\sigma_y = 328.6\ MPa$

For nut

$\sigma_u = 345\ MPa$

$\sigma_y = 138\ MPa$

For screw

allowable stress

WKT $FOS(n) = \frac{\sigma_y}{(\sigma_{all})_{screw}}$

assume carbon steel as the screw rod material & FOS=3

$(\sigma_{all})_{screw} = \frac{\sigma_y}{n} = \frac{328.6}{3}$

$(\sigma_{all})_{screw} = 109.533\ MPa$

For nut

allowable stress

assume For FOS (n) = 6 for σ_u

$$FOS(n) = \frac{\sigma_u}{(\sigma_{uall})_{nut}}$$

$$(\sigma_{all})_{nut} = \frac{\sigma_u}{n} = \frac{345}{6} = 57.5\ MPa = (\sigma_{all})_{nut}$$

$$FOS(n) = \frac{\sigma_y}{(\sigma_{all})_{nut}}$$

FOS(n) = 3 for σ_y

$$(\sigma_{all})_{nut} = \frac{\sigma_y}{FOS} = \frac{138}{3} = 46\ MPa = (\sigma_{all})_{nut}$$

$$\therefore (\tau_{all})_{nut} = \frac{46}{2} = 23\ MPa$$

$(\tau_{all})_{nut} = 23\ MPa$

Design of screw rod

$$(\sigma_c)_{screw} = \frac{W}{A_c}$$

load = $50 \times 10^3 \times 1.25$ (over load 25%.)

load = 62.5×10^3 N

core area, $A_c = \frac{W}{(\sigma_c)_{screw}} = \frac{62.5 \times 10^3}{(109.533)} = 570.604\ mm^2$

From table 9.10 Pg 149

standard core area = $616\ mm^2$

$p = 6$ mm

$d = 34$ mm

$d_1 = 28$ mm

$D_{Nut} = 34.5$ mm

$d_2 = d - p/2 = 34 - 6/2 = 31$ mm

Check for stress

$\sigma_{max} = \frac{1}{2}\left[\sigma_c + \sqrt{(\sigma_c^2) + 4\tau^2}\right]$,

where $\sigma_c = \frac{W}{A_c} = \frac{50\times10^3}{616} = 81.1688\ N/mm^2$

Shear stress, $\tau = \frac{16T}{\pi d_1^3}$

$T = \frac{W}{2}\left[d_2\left[\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right]\right]$

$T = \frac{50\times10^3}{2}\left[31\left[\frac{0.0616 + 0.14}{1 - 0.14\times0.0616}\right]\right]$

$T = 157.5991\times10^3\ N\text{-}mm$

$\tau = \frac{16\times157.5991\times10^3}{\pi\times(28^3)}$

$\tau = 36.5636\ N/mm^2$

$\tan\alpha = \frac{l}{\pi d_2}$

lead = no of starts × Pitch

= 1×6

lead, l = 6 mm

$\tan\alpha = \frac{6}{\pi\times31}$

$\tan\alpha = 0.0616$

From Table 9.3., Pg 136

Assume Heavy M/C oil

$\mu = 0.14$

~~$\sigma_{max} = \frac{1}{2}\left[81.1688 + \sqrt{(81.1688)^2 + 4(36.5636)^2}\right]$~~

~~$\therefore \sigma_{max} = 95.2103\ MPa < (\sigma_{all})_{screw}\ (109.533\ MPa)$~~

~~$\tau_{max} = \frac{1}{2}\left[\sqrt{(81.1688)^2 + 4(36.5636)^2}\right]$~~

~~$\therefore \tau_{max} = 54.6259\ N/mm^2$~~

$\sigma_{max} = \frac{1}{2}\left[81.1688 + \sqrt{(81.1688)^2 + 4(36.5636)^2}\right]$

$\sigma_{max} = 95.2103\ MPa < (\sigma_{all})_{screw}\ (109.533\ MPa)$

The design of screw rod is safe.

Design for screw head (or) collar:-

(1) Height of collar, $H_1 = 1.5 \times d = 1.5 \times 34 = 51mm$

(2) outside dia of collar, $d_{co} = 2d = 2 \times 34 = 68mm$

(3) Dia of pin head, $D = d_{ci} = 0.5 \times d = 0.5 \times 34 = 17mm$

(4) mea dia of collar, $d_c = \frac{d_{co} + d_{ci}}{2} = \frac{68 + 17}{2} = 42.5\ mm$

Design of nut

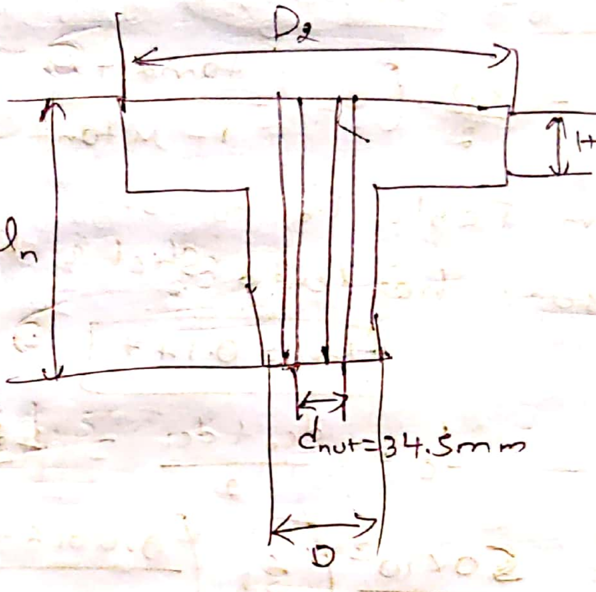
(1) length of nut

$$l_n = \frac{4 \times W \times P}{P_b \pi (d^2 - d_1^2)}$$

assuming $P_b = 15MPa$ (phosphorous)

$$l_n = \frac{4 \times 50 \times 10^3 \times 6}{15 \times \pi \times (34^2 - 28^2)}$$

$l_n = 68.4537mm$



(2) Tearing strength of nut

$$W = \frac{\pi}{4}(D^2 - d_{nut}^2)\sigma_{tnut}$$

$$50 \times 10^3 = \frac{\pi}{4}(D^2 - (34.5)^2)\ 46$$

$D = 50.7366 \approx 51mm$

(3) Crushing strength of collar

$$W = \frac{\pi}{4}(D_2^2 - D^2) \times \sigma_{cnut}$$

$$50 \times 10^3 = \frac{\pi}{4}(D_2^2 - 51^2) \times 57.5MPa$$

$\therefore D_2 = 60.8947mm \approx 61mm$

→ length of screw rod = length of nut + lift + margin

length of screw rod = 68.4537 + 300 + 20

length of screw rod = 388.45 mm.

(4) ~~[struck out]~~

$W = (\pi D) H \times \tau_{nut}$

$50 \times 10^3 = (\pi \times 51) H\, 23$

$H = 13.5681\ mm \approx 14\ mm$

Frictional torque.

$$T = \frac{W}{2}\left[d_2 \left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right) + \mu_c d_c\right]$$

From Table 9.6 pg 137.

Assume hardened steel & starting friction.

$\mu_c = 0.147$

$d_c = \frac{d_{co} + d_{ci}}{2} = 42.5\ mm$

$$T = \frac{50 \times 10^3}{2}\left[31 \left(\frac{0.0616 + 0.14}{1 - (0.14 \times 0.0616)}\right) + 0.147 \times 42.5\right]$$

$T = 313.7866 \times 10^3\ N\text{-}mm$

Design of Handle

(1) Length of hand, $l_h = \frac{T}{F} = \frac{313.7866 \times 10^3}{300} = 1045.955\ mm$

$F = 300N$ (assumed)

To find Dia of handle

(2) $\frac{M}{I} = \frac{\sigma_b}{y}$

$M = F \times l_h = T = 313.7866 \times 10^3\ N\text{-}mm$

$I = \frac{\pi d_h^4}{64}$; $y = \frac{d_h}{2}$

$\sigma_y = 328.6\ N/mm^2$

$n = 3$

$\sigma_b = \frac{\sigma_y}{n} = \frac{328.6}{3} = 109.533\ MPa$

$$\frac{M}{I} = \frac{\sigma_y}{y}$$

$$\frac{313.7866 \times 10^3 \times 64}{\pi d_h^4} = \frac{109.533 \times 2}{d_h}$$

$$\frac{6.392408 \times 10^6}{d_h^4} = \frac{219.066}{d_h}$$

$$\frac{6.392408 \times 10^6}{219.066} = d_h^3$$

$$\therefore \boxed{d_h = 30.7867 mm} \approx \underline{31 mm}$$

Design of Cup

- Bottom dia of cup, $D_3 = dc_o = 68 mm$
- Top dia of cup, $D_4 = 2 dc_o = 2 \times 68 = 136 mm$
- Heigh of cup, $H_2 = 62.5 mm$ (assumed)
- Thickness of cup $t = 12.5 mm$ (assummed)

Efficiency of the Screw

$$\eta = \frac{d_2 \tan\alpha}{d_2\left(\frac{\tan\alpha + \mu}{1 - \mu \tan\alpha}\right) + \mu_c d_c}$$

$$\eta = \frac{31 \times 0.0616}{31\left(\frac{0.0616 + 0.14}{1 - 0.14 \times 0.0616}\right) + 0.147 \times 42.5}$$

$$\eta = 0.1521$$

$$\therefore \boxed{\eta = 15.21\%}$$

Check for over Hauling:-

$$\tan\alpha \geq \frac{\mu d_2 + \mu_c d_c}{d_2 + \mu \mu_c d_c}$$

$$0.0616 \geq \frac{0.14 \times 31 + 0.147 \times 42.5}{31 + 0.14 \times 0.147 \times 42.5}$$

$$0.0616 \geq 0.3514$$

LHS is not greater than RHS so, the screw is not overhauling, then it is a self locking screw.

Design of body

1) Height of body = length of screw + clearance (50)

$= 388.45 + 50$

$= 438.45\,mm$

2) Body dia. at Top $D_5 = 1.5 \times D_2 = 1.5 \times 61 = 91.5\,mm$

3) Inside Body dia, $D_6 = 2.25 \times D_2 = 2.25 \times 61 = 137.25\,mm$

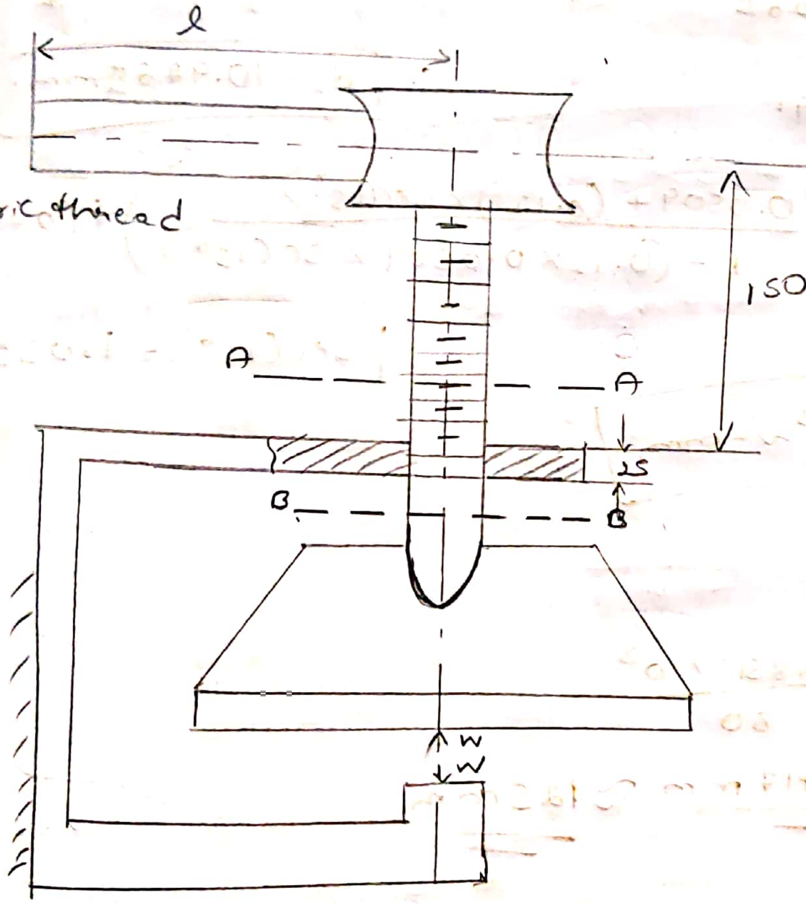
4) outside Body dia, at bottom, $D_7 = 1.5 \times D_6 = 1.5 \times 137.25$

$D_7 = 205.875\,mm$

5) Thickness of base $t_1 = 2H = 2 \times 14 = 28\,mm$

6) Thickness of body $t_2 = 0.25d = 0.25 \times 34 = 8.5\,mm$

3) The following data refers to the C-clamp show in the figure pitch $P = 1.75mm$ outside diameter 12mm, root dia 9.853mm root area $76.25 mm^2$. Co-efficient of thread friction 0.12. coefficient of collar friction 0.25 mean collar radius 6mm load $W = 4000N$, operator comfortabally exert a force of 80N at the end of the angle. determine what is length of handle, what is the maximum shear stress in the body of the screw, where does it excist, what is the bearing pressure on the thread.



* Isometric thread

Sol^n :-

$P = 1.75mm$

$d = 12mm$

$d_1 = 9.853mm$

$A_c = 76.25mm^2$

$\mu = 0.12$

$\mu_c = 0.25$

$r_c = 6mm$, $d_c = 12mm$

$W = 4000N$

$F = 80N$

i) $l = ?$

ii) stresses

iii) $P_b / \sigma_b' = ?$

For Isometric thread

$2\theta = 30°$

$\theta = 15°$

For Isometric thread including collar friction

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu\sec\theta}{1-\mu\tan\alpha\sec\theta}\right) + \mu_c d_c\right] \rightarrow [\text{eqn } 9.10(a), \text{ Pg } 134]$$

where

$$\tan\alpha = \frac{l}{\pi d_2}$$

lead, l = no of starts × pitch = $1 \times 1.75 = 1.75\,mm$

assume the no of starts = 1

$$\tan\alpha = \frac{1.75}{\pi \times 10.9265}$$

$$d_2 = \frac{d_1 + d}{2} = \frac{12 + 9.853}{2}$$

$\therefore$ $d_2 = 10.9265\,mm$

$\tan\alpha = 0.0509$

$$T = \frac{4000}{2}\left[10.9265\left(\frac{0.0509 + (0.12)\times\sec(15^\circ)}{1-(0.12\times 0.0509\times\sec(15^\circ))}\right) + (0.25\times 12)\right]$$

$\sec(15^\circ) = 1.0352$

$\therefore$ $T = 9.8513 \times 10^3\ N\text{-}mm$

Torque, $T = F \times l$

$$l = \frac{T}{F} = \frac{9.8513 \times 10^3}{80}$$

i) Length of lever arm, $\therefore l = 123.1417\,mm \approx 125\,mm$

ii)

Consider the shear stress at section A-A just above the nut.

The screw is subjected to torque & bending. Therefore,

At section A-A

i) ~~Bending stress of~~ Because of Torque.

Shear stress $\tau = \frac{16T}{\pi d_1^3} = \frac{16 \times (9.85 \times 10^3)}{\pi \times (9.853)^3}$

$\tau = 52.45\ N/mm^2$

ii) Bending stress because of force applied.

Bending moment equation.

$$\frac{\sigma_b}{y} = \frac{M}{I}$$

$$\sigma_b = \frac{M \times y}{I}$$

where

$M = F \times l = (80 \times 150) = 12 \times 10^3$ N-mm

$$y = \frac{d_1}{2} = \frac{9.853}{2} = 4.9265 \text{ mm}$$

$$I = \frac{\pi d_1^4}{64} = \frac{\pi \times (9.853)^4}{64} = 462.6406 \text{ mm}^4$$

$$\sigma_b = \frac{12 \times 10^3 \times 4.9265}{462.6406}$$

$$\boxed{\sigma_b = 127.783 \text{ N/mm}^2}$$

max. shear stress $\tau_{max} = \frac{1}{2}\left[\sqrt{\sigma^2 + 4\tau^2}\right]$

$$\tau_{max} = \frac{1}{2}\left[\sqrt{(127.783)^2 + 4(52.45)^2}\right]$$

$$\therefore \boxed{(\tau_{max})_{A-A} = 82.6627 \text{ N/mm}^2}$$

At section B-B

The section below the nut is subjected to torque & direct compressive load. The Torque is only frictional torque of the collar since it is beyond screw & nut portion.

Because of Torque at section B-B

$$T = \frac{W}{2}\left[d_2\left(\frac{\tan\alpha + \mu\sec\theta}{1 - \mu\tan\alpha\sec\theta}\right) + \mu_c d_c\right] \to 0$$

$$T = \frac{W}{2}[\mu_c d_c] = \frac{4000}{2}[0.25 \times 12]$$

$T = 6000$ N-mm

$$\therefore \boxed{T = 6 \times 10^3 \text{ N-mm}}$$

Shear stress $\tau = \frac{16T}{\pi d_1^3} = \frac{16 \times 6 \times 10^3}{\pi \times (9.853)^3} = 31.9459\ N/mm^2$

Direct compressive stress, $\sigma_c = \frac{W}{A_c} = \frac{4000}{76.25}$

$\therefore \boxed{\sigma_c = 52.459\ N/mm^2}$

max. shear stress at section B-B

$(\tau_{max})_{B-B} = \frac{1}{2}\left[\sqrt{\sigma_c^2 + 4\tau^2}\right] = \frac{1}{2}\sqrt{(52.459)^2 + 4(31.9459)^2}$

$\therefore \boxed{(\tau_{max})_{B-B} = 41.3343\ N/mm^2}$

The shear stress is maximum at section A-A (or) above the nut.

iii) Bearing pressure (σ_b' / P_b):-

WKT $l_n = \frac{4 \times W \times P}{\pi \sigma_b' (d^2 - d_1^2)}$

From figure the length of nut $l_n = 25mm$.

$25 = \frac{4 \times 400 \times 1.75}{\pi \times \sigma_b' (12^2 - 9.853^2)}$

$\sigma_b' = \frac{4 \times 400 \times 1.75}{\pi \times (12^2 - 9.853^2) \times 25}$

$\boxed{\sigma_b' = 7.5984\ N/mm^2}$

4) Design a screw jack for a capacity of 10kN, to lift 200mm height select suitable material & factor of safety. (~~[illegible]~~)

~~[illegible]~~

Solⁿ:- $W = 10 \times 10^3 N$

lift = 200mm

For screw rod

Assume Carbon steel as the screw rod material & FOS 3

$\sigma_y = 324 MPa$ $FOS(n) = \frac{\sigma_y}{\sigma_{all}}$

$(\sigma_{all})_{screw} = \frac{\sigma_y}{n} = \frac{324}{3}$

$(\sigma_{all})_{screw} = 108 N/mm^2$