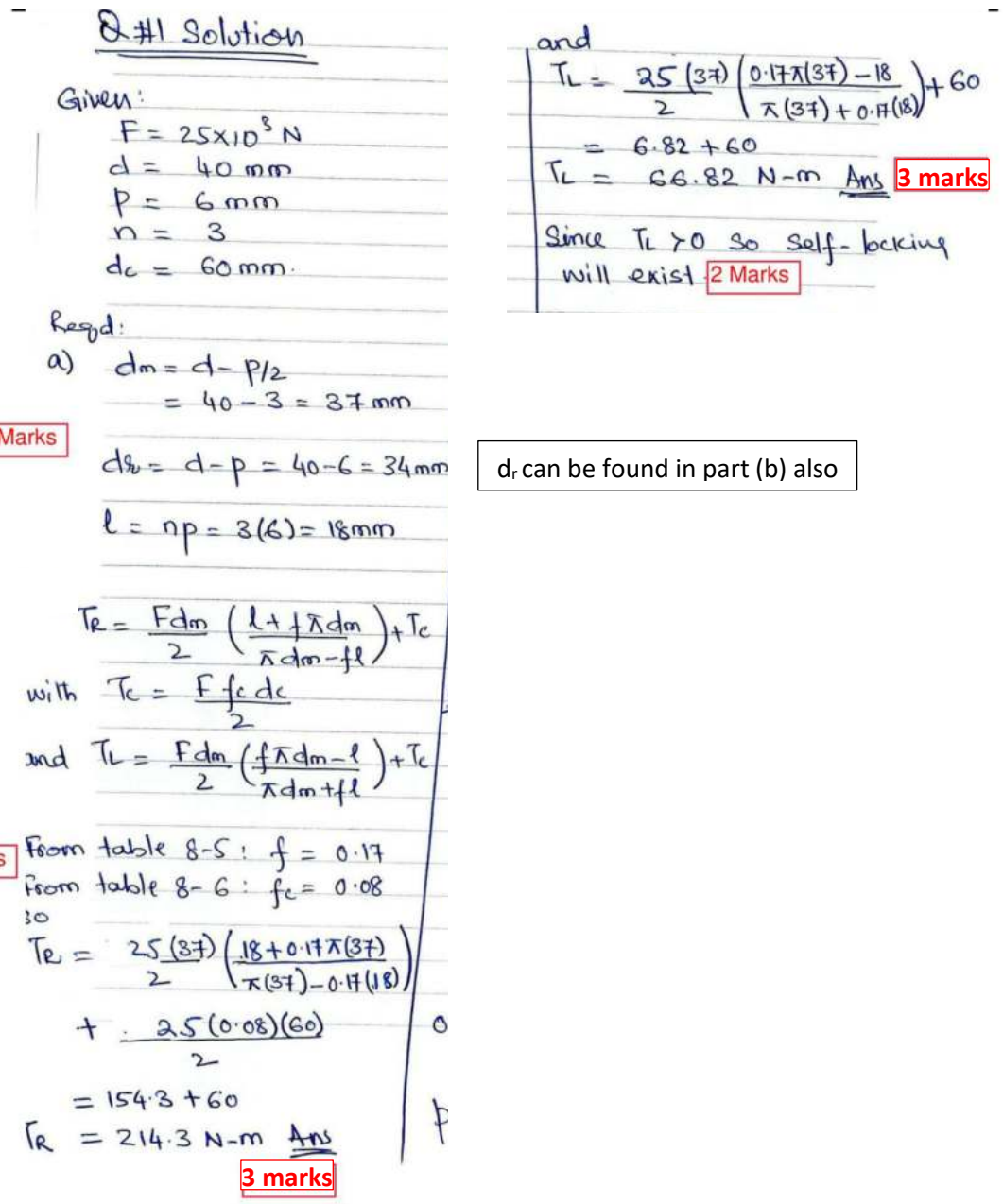
HW5-1 Solutions

Problem 1 (25 Marks)

Design a hard steel (screw and nut) lubricated power screw for raising and lowering a load of 25 kN using a square – thread with major diameter of 40 mm, pitch of 6 mm with triple threads and a plain bronze thrust collar of 60 mm (f_c=0.08) (Assume maximum friction).

(a) Find the torque for raising and lowering the load. Is the design self-locking? If not, please change the design accordingly
(b) Find the largest axial and shear body stresses. Also find the bending stresses
(c) With a safety factor of 2, a designer has chosen the DE approach to design the power screw with Sy = 260 MPa. Is this a suitable option?



Q#1 Solution

Given:

$F = 25 \times 10^3$ N
$d = 40$ mm
$p = 6$ mm
$n = 3$
$d_c = 60$ mm.

Reqd:

a) $d_m = d - p/2$
$= 40 - 3 = 37$ mm

3 Marks

$d_r = d - p = 40 - 6 = 34$ mm

d_r can be found in part (b) also

$l = np = 3(6) = 18$ mm

$$T_R = \frac{F d_m}{2}\left(\frac{l + f\pi d_m}{\pi d_m - f l}\right) + T_c$$

with $T_c = \frac{F f_c d_c}{2}$

and $$T_L = \frac{F d_m}{2}\left(\frac{f\pi d_m - l}{\pi d_m + f l}\right) + T_c$$

2 Marks

From table 8-5: $f = 0.17$
From table 8-6: $f_c = 0.08$
so

$$T_R = \frac{25(37)}{2}\left(\frac{18 + 0.17\pi(37)}{\pi(37) - 0.17(18)}\right) + \frac{2.5(0.08)(60)}{2}$$

$= 154.3 + 60$
$T_R = 214.3$ N-m Ans

3 marks

and

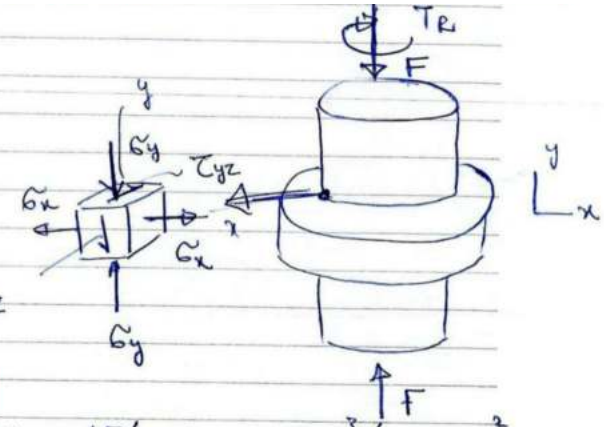
$$T_L = \frac{25(37)}{2}\left(\frac{0.17\pi(37) - 18}{\pi(37) + 0.17(18)}\right) + 60$$

$= 6.82 + 60$
$T_L = 66.82$ N-m Ans 3 marks

Since $T_L > 0$ so self-locking will exist 2 Marks

(b)

Torsional stress



$$\tau_{yz} = \frac{16 T_R}{\pi d_r^3}$$

$$= \frac{16(214.3)}{\pi (0.034)^3}$$

$\tau_{yz} = 27.7$ MPa 2 Marks

Body Compressive Stress $\sigma_y = 4F/\pi d_r^2 = 4 \times 25 \times 10^3 / \pi (0.034)^2$

$\sigma_y = -27.5$ MPa 2 Marks

Bending Stress $\Rightarrow \sigma_x = \frac{6(0.38F)}{\pi d r P} = \frac{6(0.38)(25 \times 10^3)}{\pi (34)(18) \times 10^{-6}} = 88.94$ MPa 2 Marks

(c)

Using DE Theory (i.e. Non-Conservative)

$$\sigma' = \frac{1}{\sqrt{2}} \left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2) \right]^{1/2}$$

$$= 1/\sqrt{2} \left[(88.94 + 27.5)^2 + (27.5)^2 + 6(27.7)^2 + (88.94)^2 \right]^{1/2}$$

$= 115.9$ MPa 4 marks

Using DE theory

$$n = \frac{S_y}{\sigma'} \Rightarrow S_y = n\sigma' = 2(115.9) = 231.7 \text{ MPa}$$ 2 Marks

Problem 2 (20 Marks)

A single square-thread power screw has an input power of 3 kW at a speed of 1 rev/s. The screw has a diameter of 40 mm and a pitch of 8 mm. The frictional coefficients are 0.14 for the threads and 0.09 for the collar, with a collar friction radius of 50 mm. Find the axial resisting load *F* and the combined efficiency of the screw and collar.

$d_m = 40 - 4 = 36$ mm, $l = p = 8$ mm 4 marks

From Eqs. (8-1) and (8-6)

$$T = \frac{36F}{2}\left[\frac{8 + \pi(0.14)(36)}{\pi(36) - 0.14(8)}\right] + \frac{0.09(100)F}{2}$$

$$= (3.831 + 4.5)F = 8.33F \quad \text{N} \cdot \text{m} \quad (F \text{ in kN})$$ 4 marks

$$\omega = 2\pi n = 2\pi(1) = 2\pi \text{ rad/s}$$

$$H = T\omega$$

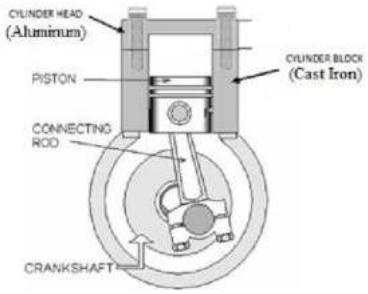
$$T = \frac{H}{\omega} = \frac{3000}{2\pi} = 477 \text{ N} \cdot \text{m}$$ 4 marks

$$F = \frac{477}{8.33} = 57.3 \text{ kN} \quad Ans.$$ 4 marks

$$e = \frac{Fl}{2\pi T} = \frac{57.3(8)}{2\pi(477)} = 0.153 \quad Ans.$$ 4 marks

Q3. (30 marks)

A single cylinder air compressor head sees forces that range from 0 to 18.5 kN at each cycle. The cylinder head is 6 mm thick aluminum (E = 71.7 GPa), and the cylinder block is cast iron (E = 100 GPa). To fix the compressor head on the block it is proposed to use fully threaded M6 x 1 cap screws of rolled threads, class 5.8 with a fully corrected endurance limit of 127 MPa and E=207 GPa. Assume an effective length of 160 mm with a permanent connection. 2 marks



(a) Find k_b, k_m and C – assume a fully threaded screw
(b) Calculate the number of screws (N) needed for a load safety factor of 1.2
(c) Find fatigue factor of safety using Goodman criteria. Based on these results, the danger of failure is by static or fatigue loading ?

Q#2 Solution

Given M6×1 class 5.8
$\ell' = 160$ mm
$P_{min} = 0$; $P_{max} = 18.5$ kN
$n_L = 1.2$
$S_e = 127$ MPa
$H = 100$ mm

Find K_b, K_m & C
$N_{screw} = ?$ for $n_L = 1.2$

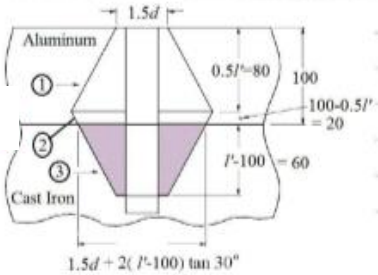
Sol
First we find K_b & K_m for fully threaded screw. 2 marks

$K_b = \frac{A_t E}{\ell'}$ with $A_t = 20.1$ (From Table 8-1)

$= \frac{20.1 \times 207}{160} = 26.004$ GN/mm 3 Marks

For K_m we would have 3 frustum 2 marks

From Table A-5
$E = 71.7$ GPa for Al.
$E = 100$ GPa for gray Cast Iron



for K_1
$D_1 = 1.5d = 1.5(6) = 9$ mm 2 marks
$d = 6$ mm, $t = \ell'/2 = 80$ mm

$$K = \frac{0.5774\pi E d}{\ln \frac{(1.15t+D-d)(D+d)}{(1.15t+D+d)(D-d)}}$$

with $E = 71.7$ GPa gives

$K_1 = 523$ GN/mm 2 Marks

for K_3
$D_3 = D_1 = 9$ mm, $d = 6$ mm
$t_3 = \ell' - 100 = 60$ mm
$E = 100$ GPa

$K_3 = 748$ GN/mm 2 Marks

for K_2
$D_2 = D_3 + 2t_2 \tan 30$
$= 9 + 2(60)\tan 30$
$= 78.38$ mm
$t_2 = 100 - 80 = 20$ mm
$E = 71.7$ GPa
So
$K_2 = 22313$ GN/mm 3 Marks

So
$\frac{1}{K_m} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3}$ gives

$K_m = 303.77$ GN/mm 1 Mark

now $C = \frac{K_b}{K_b + K_m} = \frac{26.004}{26+303.77 \cdot 1}$

$= 0.08$ 2 marks

C.

Now

c) $n_L = \dfrac{S_p A_t - F_i}{C(P/N)}$ for N bolts.

For class 5.8 bolts $S_p = 380$ MPa (Table 8-10)

For permanent joint $F_i = 0.9 S_p A_t$.

So

$$\frac{P}{N} = \frac{380(20.1) - 0.9(380)(20.1)}{0.08\ (1.2)} = 8.1 \text{ kN}$$ 2 marks

The total force i.e. P ... $\Rightarrow N = 18.5/8.1$

$N = 2.29$ i.e. 3 bolts must be used. 2 Marks

d) Using goodman crite 2 marks

$$n_f = \frac{S_e(S_{ut} - \sigma_i)}{\sigma_a(S_{ut} + S_e)}$$

where

$S_e = 127$ MPa (given)

$S_{ut} = 520$ MPa (Table 8-1) 1 Mark

$\sigma_i = \dfrac{F_i}{A_t} = 0.9 S_p = 342$ MPa 1 Mark

$\sigma_a = \dfrac{CP}{2A_t} = \dfrac{0.08\ (6.17 \times 10^3)}{2(20.1)} = 12.09$ MPa 2 Marks

So

$$n_f = \frac{127(520 - 342)}{12.09\ (520 + 127)}$$

$n_f = 2.89$ 1 Mark

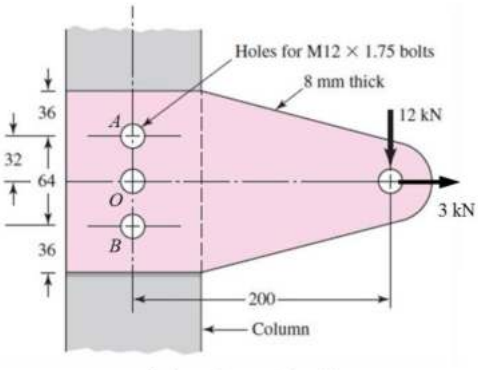
Against fatigue failure

$n_f > n_L$ so will fail by static loading

Problem 4 (25 Marks)

The AISI 1020 hot-rolled steel bracket shown below is bolted to a column with 3 ISO 5.8 bolts with L = 32 mm.

(a) Draw a free body diagram and show all forces acting on each bolt
(b) Determine the most critical bolt
(c) Find factor of safety against shearing of bolt



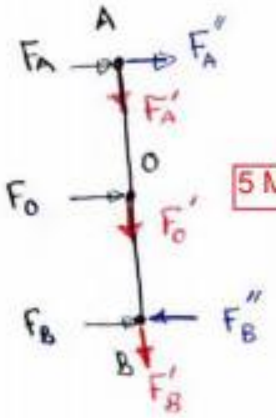
All dimensions are in millimeters

Solution

$F_{AH} = F_A + F_A''$, $F_{AV} = F_A'$

$F_{BH} = F_B - F_B''$, $F_{BV} = F_B'$

$F_{OH} = F_O$, $F_{OV} = F_O'$



5 Marks

$F_A = F_O = F_B = \frac{3}{3} = 1\ kN$

3 Marks $F_A' = F_B' = F_O' = \frac{12}{3} = 4\ kN$

$F_A'' = F_B'' = \frac{M}{2R} = \frac{(12 \times 200)}{64} = 37.5\ kN$

So $F_{AH} = 38.5\ kN$, $F_{BH} = -36.5\ kN$ & $F_{OH} = 1\ kN$

$F_{AV} = F_{BV} = F_{OV} = 4\ kN$ 3 Marks

So $F_A = \sqrt{F_{AH}^2 + F_{AV}^2} = \sqrt{(38.5)^2 + (4)^2} = 38.7\ kN$

$F_B = \sqrt{F_{BH}^2 + F_{BV}^2} = \sqrt{(-36.5)^2 + (4)^2} = 36.7\ kN$

$F_O = F_{OV} = 4\ kN$. 3 Marks

So Point A is Critical 1 Mark

mm. (2)

Now $L_T = 2d + 6$ mm for $L \leq 125$ mm & $d \leq 48$ mm

$L_T = 2(12) + 6$ mm

$L_T = 30$ mm

Therefore the shearing will occur in threaded portion. 3 Marks

Now $A_r = 76.3 \text{ mm}^2$

Also for ISO 5.8 bolts

$S_p = 380$ MPa (Table 8-11) 1 Mark
$S_y = 420$

Therefore

$S_{sy} = 0.577(380) = 219.26$ MPa or

$= 0.577(420) = 242.3$ MPa. 2 Marks

The shear stress at point A will be

$\tau_A = \frac{F_A}{A_r} = \frac{38.7 \times 10^3}{76.3} = 507.2$ MPa. 2 Marks

now

$n = \frac{S_{sy}}{\tau_A} = \frac{219.26}{507.2} = 0.432$

or

$= \frac{242.3}{507.3} = 0.477$ 2 Marks

n <1 – not safe to use this system with these bolts