Question paper solutions for first IAT, 2017-18 (even sem)

Sem : VI Subject : Design of Machine Elements - II

Sec : A & B Subject code : 15ME64 Staff : RPR.

1(a) Determine the magnitude and location of max. tensile stress of the machine part loaded as shown in fig. 1(a).

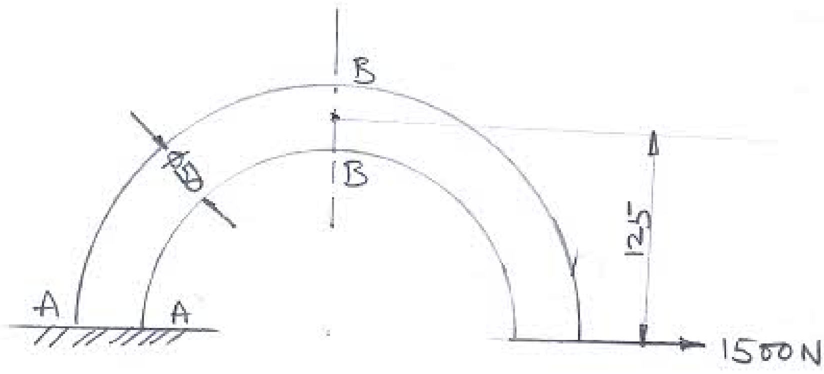
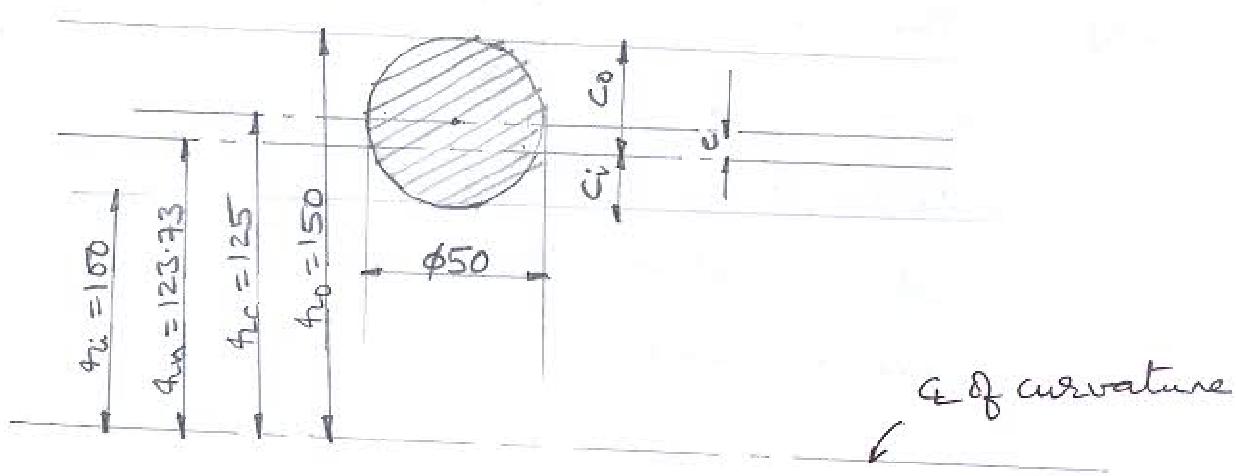


Fig. 1(a)

Ans: Here B-B is the critical section and is subjected to eccentric loading. Its innermost fibre is subjected to max. tensile stress.



$$\text{Max. Tensile Stress} = \frac{F}{A} + \frac{M_b c_i}{A e r_i} \quad \text{—— (1)}$$

$$r_n = \frac{\left(\sqrt{r_i} + \sqrt{r_o}\right)^2}{4} = 123.73\,\text{mm}$$

$$c_i = r_n - r_i = 23.73\,\text{mm}$$

$$e = r_c - r_n$$
$$= 1.27 \text{ mm}$$

$$A = \frac{\pi \times 50^2}{4}$$
$$= 1963.49 \text{ mm}^2$$

$$M_b = 1500 \times 125$$
$$= 187.5 \times 10^3 \text{ N-mm}$$

$(M_b)_B$ is negative as radius of curvature increases at B-B.

$$\therefore (M_b)_B = -187.5 \times 10^3 \text{ N-mm}$$

Sub. in (1)

$$\sigma_{ri} = \frac{1500}{1963.5} + \frac{(-187.5 \times 10^3)(-23.73)}{1963.5 \times 1.27 \times 100}$$

$$= 18.6 \text{ MPa (tensile)}.$$

$\therefore$ Max. tensile stress = 18.6 MPa (At the inner most fibre of sec B-B).

1(b) The section of the frame of a punch press is as shown in fig. 1(b). It is subjected to pure bending in its plane of symmetry. Determine the value of 't' so that the extreme fibre stresses in pure bending are numerically equal.

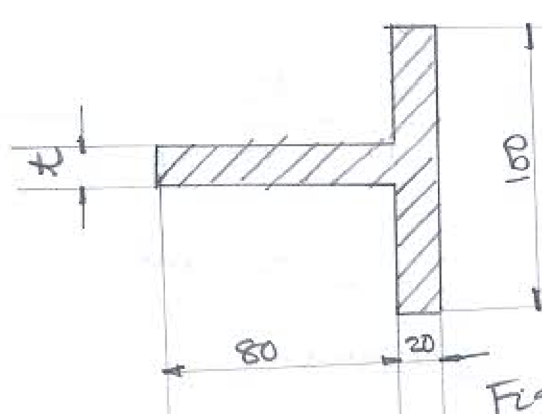
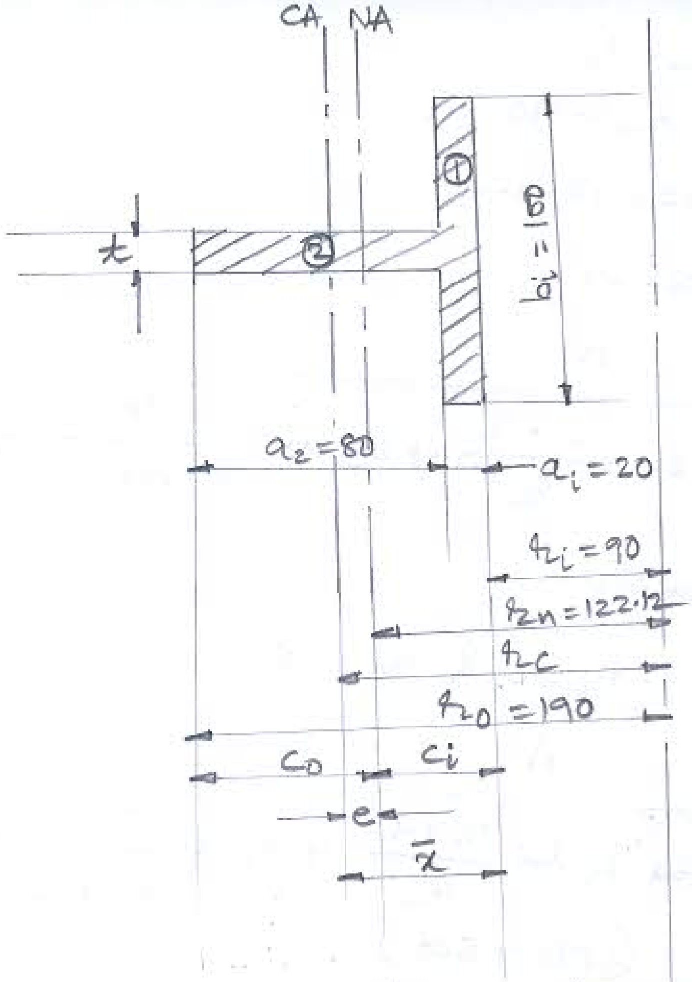


Fig. 1(b)

Ans:



Since the extreme fibre stresses are numerically equal in pure bending,

$$\sigma_{bi} = \sigma_{bo}$$

$$\frac{M_b c_i}{A e r_i} = \frac{M_b c_o}{A e r_o}$$

$$\frac{c_i}{r_i} = \frac{c_o}{r_o}$$

$$\frac{c_i}{90} = \frac{c_o}{190}$$

$$\Rightarrow c_i = 0.473 c_o \quad \text{— (i)}$$

Also from the figure,

$$c_i + c_o = 100.$$

$$\therefore \quad c_o = 67.88 \text{ mm}$$

$$\& \quad c_i = 32.12 \text{ mm}$$

$$A = (100 \times 20) + (80 \times t)$$
$$= (2000 + 80t) \text{ mm}^2.$$

$$c_i = r_n - r_i$$

$$32.12 = r_n - 90$$

$$\Rightarrow r_n = 122.12 \text{ mm}.$$

For an I-section,

$$r_n = \frac{A}{b_i \ln \frac{r_i + a_i}{r_i} + b_2 \ln \frac{r_o - a_o}{r_i + a_i} + b_o \ln \frac{r_o}{r_o - a_o}}.$$

For a T-section,

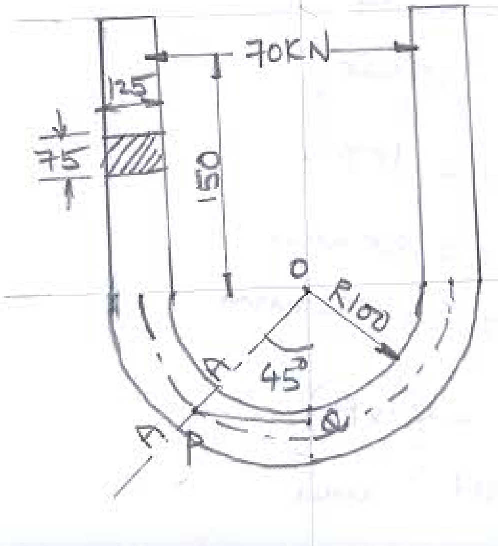
$$b_o = 0 \ \& \ a_o = 0.$$

$$\therefore r_n = \frac{A}{b_i \ln \frac{r_i + a_i}{r_i} + b_2 \ln \frac{r_o}{r_i + a_i} + 0}.$$

$$122.12 = \frac{(2000 + 80t)}{100 \ln \left(\frac{90+20}{90}\right) + t \ln \frac{190}{90+20}}$$

$$\Rightarrow t = 33.73 \text{ mm}.$$

2(a) A portable hydraulic riveter has a maximum riveting force of 70 KN. The U-frame is made of cast steel with $\sigma_u = 480$ MPa and $\sigma_y = 240$ MPa. Referring to the figure 2(a) and considering sec A-A, determine the following.



(i) BM
(ii) Dist from CA to NA
(iii) Direct tensile force
(iv) Max. tensile stress & location
(v) Max. shear stress & location.

Ans: (i) BM $(M_b)_A$

$(M_b)_A$ = B.M about CG

$= 70\times10^3\,(150 + OQ)$

where $OQ = OP\cos 45^\circ$

$= \left(100 + \frac{125}{2}\right)\cos 45^\circ$

$= 114.9\,mm$

$\therefore (M_b)_A = 70\times10^3\,(150 + 114.9)$.

$= 18.54\times10^6$ N-mm (-ve).

(ii) Dist b/w CA & NA (e)

$$r_n = \frac{h}{\ln\left(\frac{r_o}{r_i}\right)}$$

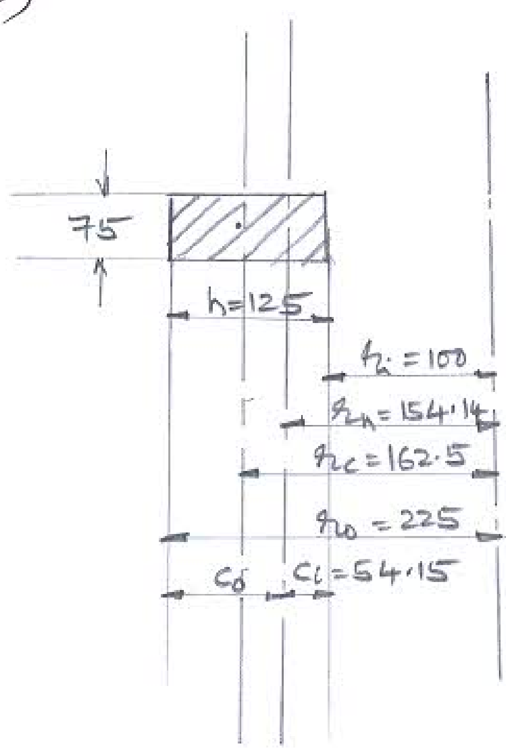
$$= \frac{125}{\ln\left(\frac{225}{100}\right)}.$$

$= 154.14\,mm$.

$e = r_c - r_n$

$= 162.5 - 154.14$

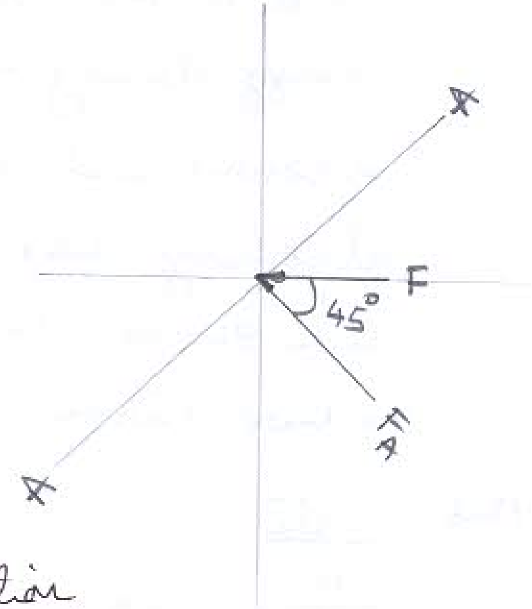
$= 8.35\,mm$.



(iii) Direct tensile force (F_A)

From figure,

$$F_A = F\cos 45^\circ$$
$$= 49.49\ \text{KN}.$$



(iv) Max. tensile stress & location

Max. tensile stress occurs at the innermost fibre of sec A–A.

$$(\sigma_{ri})_A = \frac{F_A}{A} + \frac{(M_b)_A\, c_i}{A e r_i}.$$

$$A = 125 \times 75$$
$$= 9375\ \text{mm}^2.$$

$$c_i = r_n - r_i$$
$$= 154.14 - 100$$
$$= 54.14\ \text{mm}\ (-ve).$$

$$(\sigma_{ri})_A = \frac{49.49 \times 10^3}{9375} + \frac{(-18.54 \times 10^6)(-54.14)}{9375 \times 8.35 \times 100}$$

$$= 133.52\ \text{MPa}$$ (at the innermost fibre of sec A–A).

(v) Max. shear stress & location (τ_{max})

$$\tau_{max} = \frac{(\sigma_{ri})_A}{2} = 66.76\ \text{MPa}$$ (at the innermost fibre of sec A–A).

2(b) A helical spring whose mean diameter of coils is 8 times that of wire is to absorb 400 N-m of energy during a shock. The initial compression of spring is 50 mm and compresses by an additional 70 mm while absorbing shock. The max. allow. stress is 400 MPa and $G = 84$ GPa. Determine the dia. of wire and no. of active turns. (7)

Ans:- data

$$\frac{D}{d} = C = 8.$$

$U = 400$ N-M
$= 400 \times 10^3$ N-mm.

$y_1 = 50$ mm

$y' = 70$ mm

$y_2 = y_1 + y'$
$= 120$ mm.

$\tau = 400\ N/mm^2$

$G = 84 \times 10^3\ N/mm^2$.

to find

1) d

2) i

1) d

Energy absorbed (U) = Mean load x deflection.

$$400 \times 10^3 = \left(\frac{F_1 + F_2}{2}\right) \times y'$$

$$= \left(\frac{F_1 + F_2}{2}\right) \times 70$$

$$\Rightarrow F_1 + F_2 = 11{,}428.57\ N$$

Also $\dfrac{F_1}{y_1} = \dfrac{F_2}{y_2}$

$$\frac{F_1}{50} = \frac{F_2}{120}$$

$\Rightarrow F_1 = 0.417 F_2$.

$\therefore$ Max. load on spring (F_2) = 8.067 KN

Hence, design the spring for a max. load of F = 8.067 KN & max. deflection of y = 120 mm.

i) dia. of spring wire (d)

$$\tau = \frac{8FCK}{\pi d^2}$$

where $K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$.

$= 1.18$

$$\therefore 400 = \frac{8 \times 8067 \times 10^3 \times 8 \times 1.18}{\pi d^2}.$$

$\Rightarrow d = 22 mm \quad \Rightarrow D = C \times d$

$= 176 mm$.

ii) no. of active turns (i)

$$y = \frac{8FD^3 i}{Gd^4}.$$

$$120 = \frac{8 \times 8.067 \times 10^3 \times 176^3 \times i}{84 \times 10^3 \times 22^4}$$

$\Rightarrow i = 6.71$ say 7.

3(a) A helical compression spring is made of 6mm stainless steel wire and carries a fluctuating load. The spring index is 6 and F.S is 1.5. If the average load on spring is 500N, find the permissible value for max. and min. loads. The tensile strength σ_u of the wire is 1350 MN/m². Take shear yield as 0.5σ_u and shear endurance as 0.22σ_u. (9)

Ans: $\left.\begin{array}{l} d = 6\,mm \\ c = 6 \end{array}\right\} D = 36\,mm$

$n = 1.5$

$F_m = 500\,N$

$\sigma_u = 1350\,MPa$

$\tau_y = 0.5\sigma_u$
$= 67.5\,MPa$

$\tau_e = 0.22\sigma_u$
$= 297\,MPa$

<u>to find</u>

F_{max}, F_{min}

From Soderberg's relation

$$\frac{\tau_a}{\tau_e} + \frac{\tau_m}{\tau_y} = \frac{1}{n}$$

where $\tau_m = K_c\left(\frac{8D}{\pi d^3}\right)\left(\frac{F_{max}+F_{min}}{2}\right)$

where $K_c = 1 + \frac{0.5}{c}$
$= 1.083$

$$\therefore \tau_m = 1.083\left(\frac{8 \times 36}{\pi \times 6^3}\right) \times 500$$

$$\Rightarrow \tau_m = 229.81\ N/mm^2$$

$$\tau_a = k_W \left(\frac{8D}{\pi d^3}\right)\left(\frac{F_{max} - F_{min}}{2}\right)$$

where $k_W = k_\tau k_C$.

& $k_c = 1.15$ (T 20.15)

$$\therefore k_W = 1.083 \times 1.15$$
$$= 1.245.$$

$$\therefore \tau_a = 1.245 \left[\frac{8 \times 36}{\pi \times 6^3}\right] F_a$$

$$= (0.528 F_a)\ N/mm^2$$

Now $\frac{\tau_a}{\tau_e} + \frac{\tau_m}{\tau_y} = \frac{1}{n}$

$$\frac{0.528 F_a}{297} + \frac{229.81}{675} = \frac{1}{1.5}$$

$$\Rightarrow F_a = 183.49 N.$$

$$\Rightarrow \begin{array}{l} F_{max} + F_{min} = 1000 \\ F_{max} - F_{min} = 366.98 \\ \hline \end{array}$$

$$\left.\begin{array}{l} F_{max} = 683.49 N \\ \& \ F_{min} = 316.51 N. \end{array}\right\}$$

3(b) Two helical springs, nested one inside the other supports a load of 2KN. Both springs are made of same material and modulus of rigidity is 79.3 GPa. The dimensions of each spring are as follows.

particulars	outer spring	Inner spring
Mean coil diameter	120 mm	75 mm
Wire diameter	18 mm	10 mm
Active turns	20	15
Free length	350 mm	350 mm.

Determine

i) Deflection of the spring system

ii) Load carried by each spring

iii) Max. shear stress in each spring

iv) Energy stored in each spring.

Ans = data

$F_1 + F_2 = 2000N$.

$D_1 = 120$ mm. $D_2 = 75$ mm

$d_1 = 18$ mm $d_2 = 10$ mm.

$i_1 = 20$ $i_2 = 15$

$(l_o)_1 = (l_o)_2 = 350$ mm.

Since the freelengths are same, the deflections will be same.

to find

1) y

2) F_1, F_2

3) τ_1, τ_2

4) U.

2) F_1, F_2

Since both springs have the same free length,

$$\frac{F_1}{F_2} = \left(\frac{D_2}{D_1}\right)^3 \left(\frac{d_1}{d_2}\right)^4 \left(\frac{i_2}{i_1}\right)\left(\frac{G_1}{G_2}\right).$$

Since both springs are made of the same material,

$$G_1 = G_2$$

$$\frac{F_1}{F_2} = \left(\frac{75}{120}\right)^3 \left(\frac{18}{10}\right)^4 \left(\frac{15}{20}\right)(1).$$

$$= 1.922.$$

Also, $F_1 + F_2 = 2000.$

$\therefore F_2 = 684.46 N$

& $F_1 = 1315.53 N.$

1) y

$$y = \frac{8 F_1 D_1^3 i_1}{G_1 d_1^4}$$

$$= \frac{8 \times 1315.53 \times 120^3 \times 20}{79.3 \times 10^3 \times 18^4}$$

$$= 43.69 mm$$

3) $\tau_1 = \frac{8 F_1 D_1 K_1}{\pi d_1^3}$

here $c_1 = \frac{D_1}{d_1} = 6.66$

$$K_1 = \frac{4c_1 - 1}{4c_1 - 4} + \frac{0.615}{c_1}$$

$$= 1.22.$$

$$\therefore \tau_1 = \frac{8 \times 1315.53 \times 120 \times 1.22}{\pi \times 18^3}$$

$= 84.09\ N/mm^2$

Similarly $\tau_2 = \dfrac{8 F_2 D_2 K_2}{\pi d_2^3}$

$c_2 = 7.5$

$\therefore K_2 = 1.197$

$\therefore \tau_2 = 156.4 N/mm^2$.

4) Energy stored (U)

U = Mean load × deflection.

$= \frac{1}{2} F \times y$

$= \frac{1}{2} \times 2 \times 10^3 \times 43.69$

$= 43,690$ N-mm.