B.Tech.

Fifth Semester Examination

Mechanical Machine Design-I (ME-303-F)

Note : Attempt any *five* questions. All questions carry equal marks.

Q. 1. (a) Explain the following with examples :

(i) Manufacturing process considerations

(ii) Standardization.

Ans. (i) Manufacturing Process Considerations :

It consists of following elements :

Step 1 : Specification function of element

Step 2 : Determination of forces

Step 3 : Selection of material

Step 4 : Failure criterion

Step 5 : Determination of dimension

Step 6 : Design modifications

Step 7 : Working drawing.

(ii) Standardization : Standardization is defined as obligatory norms, to which various characteristic of a product should conform. The characteristic include materials, dimension and shape of the component, method of testing and method of making, packing and storing of the product.

Following standards are used in mechanical engineering design :

(i) Standards for materials, their chemical compositions. mechanical properties and heat treatment.

(ii) Standards for shapes and dimensions of commonly used machine elements. The machine elements include bolts, screws & nuts.
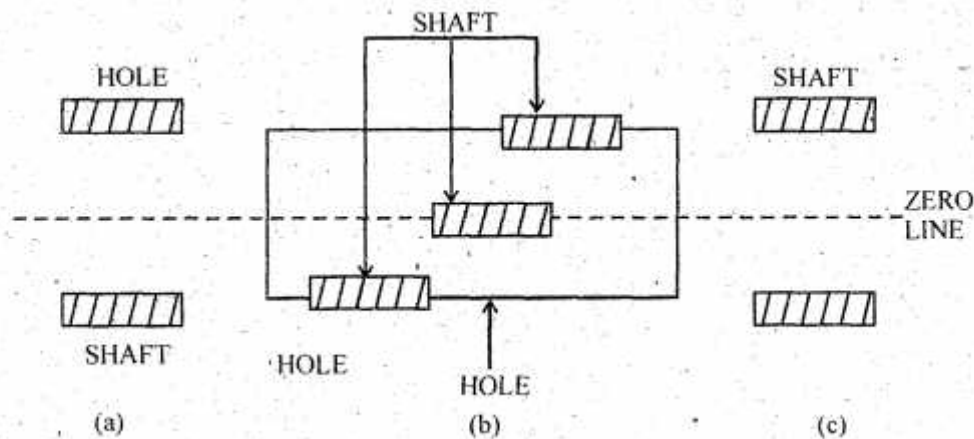
(iii) Standards for fits, tolerances and surface finish of component.

(iv) Standards for testing of products.

(v). Standards for engineering drawing of components.

Q. 1. (b) Graphically represent the clearance, transition and interference fits for hole and shaft base systems. What do you understand by allowance?

Ans.

(a)   (b)   (c)

Type of Fit : (a) Clearance fit (b) Transition fit (c) Interference fit

Clearance Fit : Clearance fit is a fit, which always provides a +ve clearance between the hole and shaft over the entire range of tolerances. In this case, the tolerance zone of the hole is entirely above that of the shaft.

Interference Fit : It is a fit, which always provides a +ve interference over the whole range of tolerances.

Transition Fit : It is a fit, which may provide either a clearance or interference depending upon the actual values of the individual tolerances of the mating components.

Allowance : It is defined as permissible variation in the dimensions of the component.

Q. 2. (a) Explain the importance of material selection decision for machine elements.

Ans. Importance of Material Selection : The four basic factors, which are considered in selecting the material are availability, cost, mechanical properties and manufacturing consideration.

Example : Flywheel, housing of gearbox or engine block have complex shapes. These components are made of cast iron because casting process produces complicated shapes without involving machining operation.

Q. 2. (b) Give a generalized definition of Factor of Safety. Explain the factors responsible for uncertainties in design necessitating a suitable factor of safety.

Ans. Factor of Safety : While designing a component, it is necessary to provide sufficient reserve strength in case of an accident.

$$f_s = \frac{\text{Failure stress}}{\text{Allowable stress}}$$

Or

$$f_s = \frac{\text{Failure load}}{\text{Working load}}$$

Necessity a Suitable FOS :

(i) Uncertainty in the magnitude of external force acting on the component.

(ii) Variation in the properties of material like yield strength or ultimate strength.

(iii) Variation in the dimensions of the components due to imperfect workmanship.

Q. 3. A bracket is supported by means of 4 rivets of same size, as shown in figure. Determine the diameter of the rivet if the maximum allowable shear stress is 100MN/mm^2.
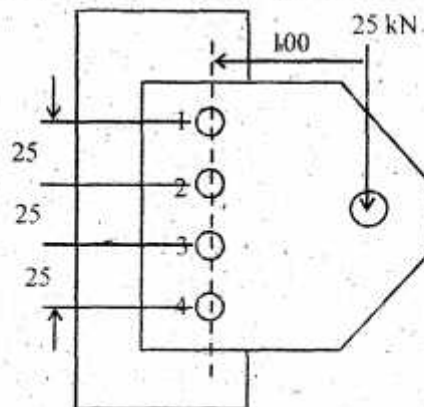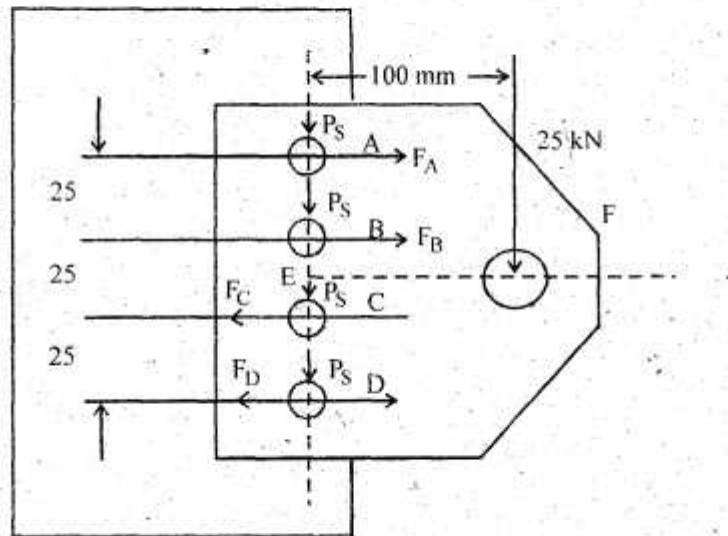
Ans. Given :

$$n = 4$$

$$\tau_y = 100 \, MN/m^2$$

$$AB = BC = CD = 25 \, mm$$

$$P = 25 \, kN$$

$$EF = 100 \, mm$$

Diameter of Rivets :

Let d = diameter of rivets.

$$P_s = \frac{P}{n} = \frac{25 \times 10^3}{4} = 6250 \, N$$

Turning moment produced by the load P due to eccentricity

$$= P.e. = 25 \times 10^3 \times 100$$

$$= 2500 \times 10^3 \, N - mm$$

This turning moment is resisted by four bolts. Let F_A, F_B, F_C and F_D be the secondary shear load on rivets, A, B, C and D placed at distance L_A, L_B, L_C & L_D respectively from the centre of gravity of rivet system

$$l_A = l_D = 25 + \frac{25}{2} = 37.5 \, mm$$

$$l_B = l_C = \frac{25}{2} \, mm = 12.5 \, mm$$

$$P \times e = \frac{F_A}{L_A}\left[(l_A)^2 + (l_B)^2 + (l_C)^2 + (l_D)^2\right]$$

$$= \frac{F_A}{L_A}\left[2(l_A)^2 + 2(l_B)^2\right]$$

$$2500 \times 10^3 = \frac{F_A}{37.5}\left[2 \times (37.5)^2 + 2(12.5)^2\right]$$

$$F_A = \frac{2500 \times 10^3 \times 37.5}{2\left[(37.5)^2 + (12.5)^2\right]}$$

$$= 30 \times 10^3 \, N$$

$$F_B = F_A \times \frac{l_B}{l_A}$$

$$= 30 \times 10^3 \times \frac{12.5}{37.5} = 10 \times 10^3 \, N$$

$$F_C = F_A \frac{l_C}{l_A} = 30 \times 10^3 \times \frac{12.5}{37.5} = 10 \times 10^3 \, N$$

$$F_D = F_A \frac{l_D}{l_A} = 30 \times 10^3 \, N$$

Resultant

$$R_D = R_A = \sqrt{(P_S)^2 + (F_A)^2}$$

$$= \sqrt{(6250)^2 + (30 \times 10^3)^2}$$

$$= 30.644 \times 10^3 \, N$$

$$R_C = R_B = \sqrt{(P_S)^2 + (F_B)^2}$$

$$= \sqrt{(6250)^2 + (10 \times 10^3)^2}$$

$$= 11.792 \times 10^3 \, N$$

Now maximum shear load is on rivet A and D.

Let $\qquad F_S = 1$

$$30.644 \times 10^3 = \frac{\pi}{4} \times d^2 \times \tau$$

$$= \frac{\pi}{4} \times d^2 \times 100$$

$$d^2 = \frac{30644 \times 4}{\pi \times 100}$$

$$d = 19.75 \, mm \approx 20 \, mm \qquad \text{Ans.}$$

Q. 4. Design and draw a cotter joint subjected to slow reversal of 30 kN load. Clearly state the design decisions taken.

Ans. Given load $\qquad P = 30 \, kN = 30 \times 10^3 \, N$

Step 1 : Calculate the diameter of rod.

$$d = \sqrt{\frac{4P}{\pi \sigma_t}}$$

Let FOS for rod $\qquad = 6$

FOS for cottor $\qquad = 4$

The material of two rods and cottor is selected as plain carbon steel of grade $30 \, C8 \left(S_{yt} = 400 \, N/mm^2 \right)$.

Then, $\qquad \sigma_t = \dfrac{400}{6} = 66.67 \, N/mm^2$

$$\sigma_c = \frac{S_{yc}}{f_s} = \frac{2S_{yt}}{6} = \frac{2(400)}{6} = 133.33 \, N/m$$

$$\tau = \frac{S_{fy}}{f_o} = \frac{0.5 S_{yt}}{f_s} = \frac{0.5(400)}{6} = 33.33 \, N/m^2$$

Permissible stress for cotter are

$$\sigma_t = \frac{S_{yt}}{f_s} = \frac{400}{4} = 100 \, N/mm^2$$

$$\tau = \frac{0.0 S_{yt}}{4} = 50 \, N/mm^2$$

$$d = \sqrt{\frac{4P}{\pi \sigma_t}}$$

/

$$= \sqrt{\frac{4 \times \left(30 \times 10^3\right)}{\pi 66.67}}$$

$$= 23.93 \approx 24 \, mm$$

Step 2:
$$r = 0.31d$$
$$= 0.31 \times 24$$
$$= 7.44 \approx 8 \, mm$$

Step 3:
$$P = \left[\frac{\pi}{4}d_2^2 - d_2t\right]\sigma_t$$

$$30 \times 10^3 = \left[\frac{\pi}{4}d_2^2 - d_2 \times 8\right](66.67)$$

$$52.36d_2^2 - 533.36d_2 - 30 \times 10^3 = 0$$

$$d_2 = 29.56 \, mm \approx 30 \, mm$$

Step 4:
$$P = \left[\frac{\pi}{4}\left(d_1^2 - d_2^2\right) - (d_1 - d_2)t\right]\sigma_t$$

$$30 \times 10^3 = \left[\frac{\pi}{4}\left(d_1^2 - 30^2\right) - (d_1 - 30)8\right]66.67$$

$$= \left[\frac{\pi}{4}\left[d_1^2 - 900\right] - 8d_1 + 240\right] \times 66.67$$

$$= \left(0.785d_1^2 - 706.85 - 8d_1 + 240\right)66.67$$

$$= 52.33d_1^2 - 533.36d_1 - 466.85$$

$$52.33d_1^2 - 533.36d_1 - 30466.85 = 0$$

$$d_1 = 29.75 \approx 30 \, mm$$

Step 5:
$$d_3 = 1.5d$$
$$= 1.5 \times 24 = 36 \, mm$$
$$d_4 = 2.4 \times 24 = 57.6 \, mm$$

Step 6:
$$a = c = 0.75 \times d = 18 \, mm$$

Step 7:
$$b = \frac{P}{2\tau t} = \frac{30 \times 10^3}{2 \times 50 \times 8}$$

$= 37.5 \, mm$

Step 8 : Stresses in spigot end,

$$\sigma_c = \frac{P}{t d_2} = \frac{30 \times 10^3}{8 \times 30}$$

$$= 125 \, N/mm^2$$

$$\tau = \frac{P}{2 a d_2} = \frac{30 \times 10^3}{2 \times 18 \times 30}$$

$$= 27.37 \, N/mm^2$$

$$\sigma_c < 133.33 \, N/mm^2 \; \& \; \tau < 33.33 \, N/m^2$$

Step 9 : Stresses in socket end :

$$\sigma_c = \frac{P}{(d_y - d_2) t} = \frac{30 \times 10^3}{(57.6 - 30) \times 8}$$

$$= 132 \, N/mm^2$$

$$\tau = \frac{P}{2(d_y - d_2) c} = \frac{30 \times 10^3}{2(57.6 - 30) 18}$$

$$= 30.19 \, N/mm^2$$

The stresses induced in the spigot and socket ends are within limit.

Step 10 : $t_1 = 0.45 d = 0.45 \times 24$

$$= 10.8 = 11 \, mm$$

Q. 5. A V-belt drive is to transmit 15 kW to a compressor. The motor speed is 750 rpm and the compressor pulley runs at 250 rpm. Give complete design of the drive.

Ans. Given $P = 15 \, kW = 15 \times 10^3 \, W$

$$N_2 = 250 \, rpm$$

$$N_1 = 750 \, rpm$$

$$\frac{N_1}{N_2} = \frac{d_2}{d_1}$$

Let $d_2 = 1 m$

$$d_1 = 0.33 m$$

Let centre distance between the pulleys is 1.75

$$\sin\alpha = \frac{r_2 - r_1}{x} = 0.1914$$

$$\alpha = 11.04°$$

Angle of lap on smaller pulley

$$\theta = 180° - 2\alpha = 157.92°$$

$$= 2.76 \text{ rad}$$

Neglect centrifugal tension :

Maximum tension in belt,

$$T_1 = \sigma \times a$$

Let

$$\sigma = 2.5 \text{ N/mm}^2$$

$$a = 375 \text{ mm}^2$$

$$T_1 = 937.5 \text{ N}$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta \cos ec\beta$$

$$= 0.25 \times 2.76 \times \cos ec\, 17.5°$$

$$T_2 = 67.4 \text{ N}$$

Number of V belts :

$$= \frac{\text{Total power transmitted}}{\text{Power transmitted / belt}}$$

$$= \frac{15}{(T_1 - T_2)v} \quad (\text{Let } V = 26.67)$$

$$\frac{15}{16.085} \approx 1 \qquad\qquad \text{Ans.}$$

$$r_1 = \frac{d_1}{2} = \frac{0.33}{2} = 0.165 \text{ m}$$

$$r_2 = \frac{d_2}{2} = 0.5$$

$$L = \pi(r_2 + r_1) + 2x + \frac{(r_2 - r_1)^2}{x}$$

$$= 5.654 \text{ m} \qquad\qquad \text{Ans.}$$

Q. 6. Design a pin type flexible coupling to connect two shafts of 50 mm diameter transmitting 45 kW at 1200 rpm. The bearing pressure between rubber bush and cast iron flange is 0.5N/mm² and the allowable

shear stress for the pin is 30 N/mm². Thicknesses of input and output flanges are taken as diameter of bush and half of shaft diameter respectively. Assume that there are six pins used in the coupling and the diameter of each pin is 20 mm.

Ans.

$D = 50$ mm $\qquad t = 30 \, \text{N/mm}^2$

$L = 45$ kW

$N = 1200$ rpm

$t_i = $ diameter of bush

$t_o = $ Diameter of shaft $= D = 50$ mm

$d_1 = 20$ mm

$$M_t = \frac{45 \times 60 \times 10^6}{2 \times \pi \times 1200} = 358098.62 \, \text{N-mm}$$

$$\tau = \frac{8 M_t}{\pi d_i^2 DN} = \frac{8 \times 358098.62}{\pi \times d_i^2 \times 50 \times 6}$$

$$d_i^2 = \frac{8 \times 358,098.62}{\pi \times 30 \times 50 \times 6}$$

$$d_1 = 10.06 \text{mm} \approx 11$$

The force acting on each bush (P) and torque M_t are related

$$M_t = P \times \frac{P}{2} \times N$$

$$P = \frac{2 \times M_t}{DN} = 2387.324 \, \text{N}$$

It is assumed that P is uniformly distributed over the bush length of 50 mm

$$\left[\frac{l_b}{P_b} = 1 \quad l_b = 50 \text{mm} \right]$$

$$M_b = p \left[5 + \frac{50}{2} \right] = 2387.32 \times 30$$

$$\approx 71619.72 \, \text{N-mm}$$

$$\sigma_b = \frac{32 M_b}{\pi d_i^3} = \frac{32 \times 71619.72}{\pi d_i^3}$$

$$\sigma_b = \frac{32 \times 71619.72}{\pi \times (11)^3}$$

$$= 548.99 \, \text{N/mm}^2 \quad \textbf{Ans.}$$

Q. 7. (a) Distinguish between Uniform pressure theory and Uniform wear theory.

Ans. Difference between Uniform Pressure and Uniform Wear Theory :

Uniform Pressure	Uniform Wear
(i) When the pressure uniformly distributed over the entire area of the friction face.	The basic principle in designing machine parts that are subjected to wear due to sliding friction is that the wear is proportional to the work of friction.
Pressure intensity for plate clutch	Normal wear α work of friction
$$P = \frac{W}{\pi\left(r_1^2 - r_2^2\right)}$$	$$\alpha P.V$$
(ii) Mean radius for plate clutch,	(ii) Mean radius for plate clutch
$$R = \frac{2}{3}\left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$$	$$R = \frac{r_1 + r_2}{2}$$

Q. 7. (b) A multiple disk wet clutch is to be designed for transmitting a torque of 85 Nm. Space restriction limit the outside disk diameter to 100 mm. Design values of molded friction material and steel disks to be used are $\mu = 0.06$, $P_{max} = 1.4$ MPa. Determine appropriate values for the disk inside diameter and the total number of disks.

Ans. Given :

$$T = 85\,N-m$$

$$r_1 = \frac{100}{2}\,mm = 50\,mm$$

$$\mu = 0.06$$

$$P_{max} = 1.4\,MPa = 1.4\,N/mm^2$$

For uniform wear P_r = constant

Pressure is maximum at inner surface

$$P_{max} \times r_2 = C$$

$$C = 1.4\,r_2$$

Axial Force :

$$W = 2\pi C(r_1 - r_2)$$

$$= 2\pi(1.4r_2)\left[50 - r_2\right]$$

$$= 2.8\pi r_2\left[50 - r_2\right]$$

$$T = n\mu WR$$

$$85 \times 10^3 = n\mu\, 2.8\pi r_2(50 - r_2)\left(\frac{r_1 + r_2}{2}\right)$$

$$= 0.5270 r_2 (50 - r_2) \left(\frac{50 + r_2}{2} \right)$$

$$322.09 = r_2 (50 - r_2)(50 + r_2) \times r_2$$

$$\left[(50)^2 - (r_2)^2 \right] r_2 n = 322.09$$

$$n \left(2500 r_2 - r_2^3 \right) = 322.09$$

Let $n = 4$

$$2500 r_2 - r_2^3 = 80.52$$

$$\boxed{r_2 = 28.5 \simeq 29 \text{ mm}} \quad \text{Ans.}$$

Q. 8. A short shoe external drum brake is shown in figure has 40 mm width, coefficient of friction 0.3 and $P_{max} = 600$ kPa. Determine the limiting force that can be applied to the lever, braking torque and radial force on the lever pivot. Also determine whether the brake is self-energizing or de-energizing for the direction of rotation involved.
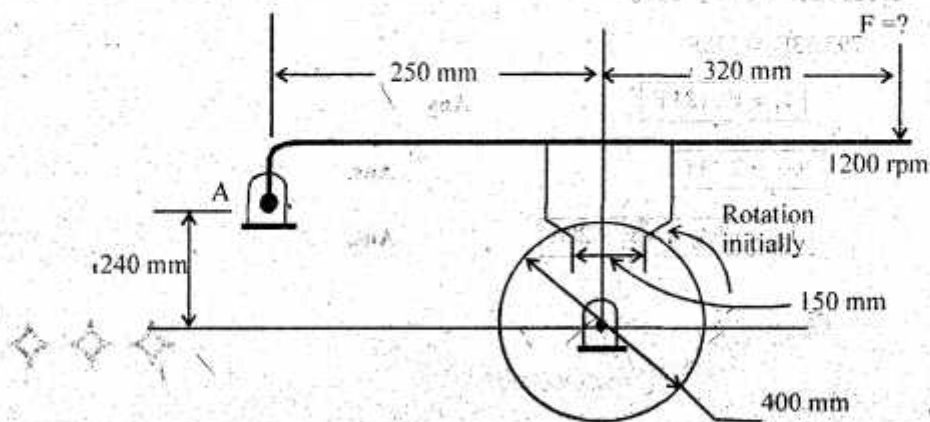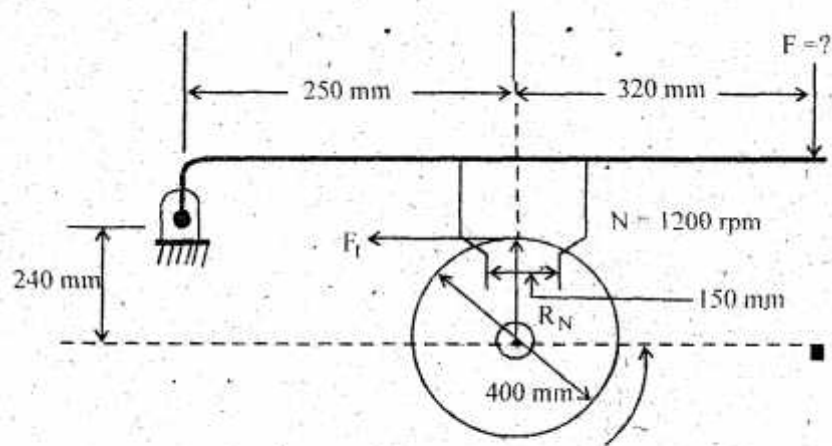

Ans. Given :

$$r = \frac{400}{2} = 0.2 \text{ m}$$

$$\mu = 0.3$$

$$P_{max} = 600 \text{ kPa} = 0.6 \text{ N/mm}^2$$

$$F_t = \mu R_N \qquad R_N = \frac{F_t}{\mu}$$

$$R_N \times 250 = F_t(240 - 200) = F(250 + 320)$$

$$\frac{F_t}{0.3} \times 250 - F_t(0) = F \times 570$$

$$F_t[833.33 - 40] = F \times 570$$

$$793.33 F_t = 570 F$$

$$\boxed{F_t = 0.7184\, F} \qquad \text{Ans.}$$

$$\boxed{R_N = 2.39\, F} \qquad \text{Ans.}$$

$$\boxed{T_B = \mu R_N . r = F_t \times 200} \qquad \text{Ans.}$$