B.E.

Sixth Semester Examination, 2010

Machine Design-II (ME-304-E)

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

Q. 1. (i) Discuss the role of value engineering in design.

Ans. For design engineer it is necessary to provide optimum design parameter w.r.t. performance and cost. Value engineering helps a meeting this objective. In this the cost effective material are selected. Then the satisfactory of the desired values like :

(i) Cost value (ii) Use value

(iii) Steam value

(iv) Exchange value are achieved

Approaches to value engineering consist of :

(i) Team (ii) Individual

(iii) Modified team, tools like brainstorming are the use for the of success of value engineering.

Q. 1. (ii) List the fundamental requirements for machine members for their efficient working.

Ans. Fundamental requirement for machine member for their efficient working are :

(i) Cost (ii) High output and efficiency

(iii) Strength (iv) Reliability

(v) Durability (vi) Wear resistance

(vii) Compliance with state standards

(viii) Economy of performance.

Q 1. (iii) How is factor of safety evaluated for different types of loading?

Ans.
$$\text{Factor of safety} = \frac{\text{Yield stress}}{\text{Design stress}} \text{ (In case of ductile material)}$$

$$\text{FOS} = \frac{\text{Ultimate stress}}{\text{Design stress}} \text{ (For brittle material)}$$

$$\text{FOS} = \frac{\text{Endurance limit}}{\text{Design stress}} \text{ (In case of completely reversed stress cycle)}$$

Evaluation of FOS :

(i) In Static Loading : The factor of safety may be taken as the product of two factors a and R,

$$\text{FOS} = a \times R$$

Where, a = Elastic ratio

R = Reliability factor

(ii) Impact or Shock Loading :

$$FOS = a \times R \times K_i \times K$$

Where, K_i = Shock factor

(iii) Fatigue Loading : $FOS = a \times K_i \times R \times K_f$

Where, K_f = Fatigue stress concentration factor.

Q. 2. A helical spring whose mean diameter of coils is 8 times that of the wire is to absorb 500Nm of energy. The initial compression of the spring is 50mm and the additional compression is 100mm while absorbing the shock. The maximum permissible stress is 450N/mm^2 and modulus of rigidity is 0.83×10^5 N/mm^2. Design the spring completely.

Ans. $\boxed{D = 2d}$

Given : $U = 500\text{N-m}$,

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

$$\delta_i = 50\,\text{mm},\ \delta_f = 100,\ \tau = 450\,\text{N/mm}^2$$

$$G = 0.83 \times 10^5\ \text{N/mm}^2$$

Spring index $(C) = \frac{D}{d} = \frac{2d}{d} = 2$

Wahls stress factor, $K = \frac{4C-1}{4C-4} + \frac{0.65}{C}$

$$= \frac{4 \times 8 - 1}{4 \times 8 - 4} + \frac{0.65}{8}$$

$$= \frac{32-1}{32-4} + \frac{0.65}{8} = 1.107 + 0.08125$$

$$\boxed{K = 1.19}$$

$$C = K \times \frac{8P \times C}{\pi d^2}$$

$$\boxed{d^2 = \frac{K \times 8 \times P \times C}{\pi \times \tau}}$$

P_1 (initial spring force) $= k\delta_1 = 50\text{K}$

P_2 (final spring force) $= k(\delta_1 + \delta_2) = k \times 150$

Average force during compression $= \frac{50K + 150K}{2} = 100K$

$$U = 100K \times 100$$

$$500 \times 10^3 = 100K \times 100$$

$$K = \frac{500 \times 10^3}{10^4} = 50\,\text{N/mm}$$

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$$P_2 = 50 \times 150 = 7500\,\text{N}$$

$$d^2 = \frac{1.19 \times 8 \times 7500 \times 2}{\pi \times 450}$$

$$d = 10.05\,\text{mm}$$

& $$D = 2 \times 10.05 = 20.10\,\text{mm}$$

Number of active coil $$k = \frac{Gd^4}{8D^3 N}$$

$$N = \frac{Gd^4}{8D^3 \times K}$$

$$= \frac{0.83 \times 10^5 \times d^4}{8 \times (2d)^3 \times 50} = \frac{0.83 \times 10^5 \times 10.05}{8 \times 8 \times 50}$$

$$N \approx 264 \text{ turns}$$

Free Length : It is assumed that the spring has square and ground ends

$$N_t = N + 2 = 266$$

Solid length $$= N_t \times d = 266 \times 10.05 = 2673.3\,\text{mm}$$

Axial gap $$= (266 - 1) \times 2 = 530\,\text{mm}$$

$$\delta_{max} = \frac{8PD^3 N}{Gd^4} = 151.9\,\text{mm}$$

Free length = Solid length + Axial gap + δ_{max}

$$= 2673.3 + 530 + 151.9 = 3355.2\,\text{mm} \quad \text{Ans.}$$

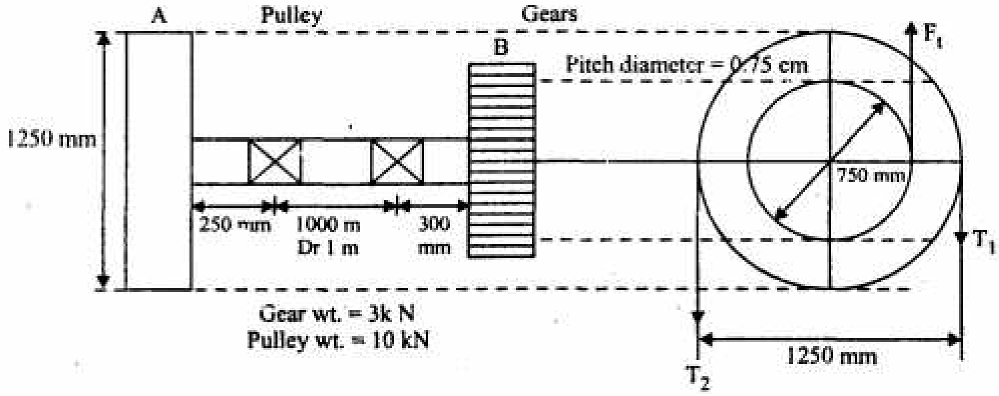
Q. 3. A horizontal power transmission shaft is supported by two bearings 1.0m apart. The shaft overhangs the right hand bearing and supports a 0.75m pitch diameter straight tooth spur gear 0.30m from the bearing. It supports a 1.25m flat belt pulley 0.25m to the left of the left hand bearing. The gear weights 3kN and the pulley weighs 10kN. The gear is driven by pinion such that the tangential turning force acts upwards. The pulley that delivers the power vertically downwards has a belt tension ratio of 2.5 : 1. The shaft must transmit 20kW at 150 rpm. Assume transmission efficiency as 100%. Determine the shaft diameter based on maximum normal stress theory. Assume suitable other data.

Ans. $$T = \frac{P \times 60}{2\pi \times N} = \frac{20 \times 10^3 \times 60}{2 \times \pi \times 150}$$

$$T = 1273.24\,\text{N-m} = 1273.24 \times 10^3\,\text{N-mm}$$

$$R_A = \frac{1250}{2} = 625\,\text{mm}$$

$$R_B = \frac{750}{2} = 375\,\text{mm}$$



$$(T_1 - T_2) \times R_A = 1273.24 \times 10^3$$

$$T_1 - T_2 = 2037.18 \qquad \text{..... (i)}$$

$$\frac{T_1}{T_2} = 2.5 \text{ (given)}$$

$$T_1 = 2.5 T_2$$

From equation (i) $\qquad 1.5 T_2 = 2037.18$

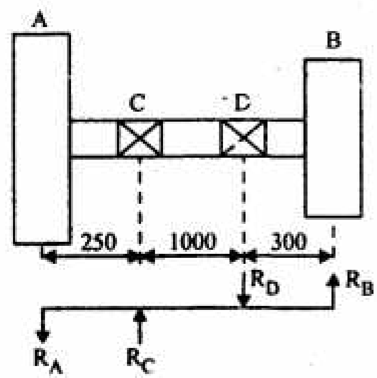
$$T_2 = 1358.12 \text{ N}$$

$$T_1 = 3395.31 \text{ N}$$

Total downward load at A, $\qquad = T_1 + T_2 + W_A = 14753.43 \text{ N}$

Tangential force on gear B $\qquad F_t = \dfrac{T}{R_B} = 3395.31 \text{ N}$

Total vertical load at B, $\qquad = F_t - W_B = 3395.31 - 3000 = 395.31 \text{ N}$



$$R_A = 14753.43 \text{ N}$$

$$R_B = 395.31 \text{ N}$$

Taking moment about D

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$-R_C \times 1000 + R_B \times 300 + R_A \times 1250 = 0$

$$R_C = \frac{395.31 \times 300 + 14753.43 \times 1250}{1000}$$

$$R_C = 18560.38 \text{ N}$$

$$R_D = 3806.95 \text{ N}$$

Bending moment at A & $B = 0$

Bending moment at $C = 18560.38 \times 250 = 4640.09 \times 10^3$ N-mm

B.M at $D = 3806.95 \times 300 = 1142.09 \times 10^3$ N-mm

From above bending moment at C is maximum

$$M_C = 4640.09 \times 10^3 \text{ N-mm}$$

$$T_e = \sqrt{M^2 + T^2}$$

$$= 4811.61 \times 10^3 \text{ N-mm}$$

$$T_e = \frac{\pi}{16} \times \tau \times d^3$$

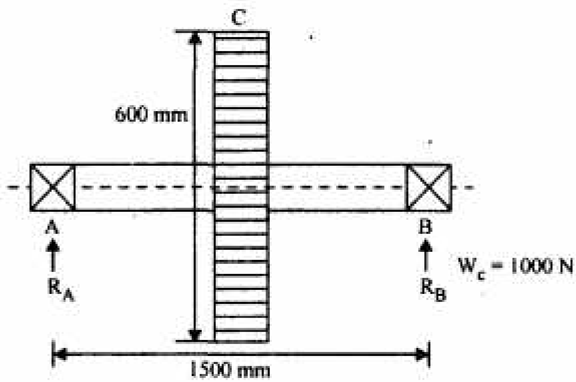
$\Rightarrow$ $$d^3 = \frac{T_e \times 16}{\pi \times \tau} = \frac{4811.61 \times 10^3 \times 16}{\pi \times 64}$$

Assume $\tau = 64$ Mpa

$\boxed{d = 72.62 \text{ mm}}$ **Ans.**

Q. 4. A steel shaft 1.5m long between bearings carries 1000N pulley at its mid point. The pulley is keyed to the shaft and receives 20kW at 200 rpm. The belt drive is horizontal and the ratio of the belt tensions is 3:1. The diameter of the pulley is 600 mm. The load is applied with moderate shocks. Calculate the necessary diameter of the shaft.

Ans.



$$\frac{T_1}{T_2} = 3 \qquad P = 20\text{kW}$$

$$N = 200 \text{rpm}$$

$$T = \frac{P \times 60}{2\pi N} = 954.93 \text{ N-m}$$

$$= 954.93 \times 10^3 \text{ N-mm}$$

$$T = (T_1 - T_2)R$$

$\Rightarrow$ $$T_1 - T_2 = \frac{954.93 \times 10^3}{300}$$

$$T_1 - T_2 = 3183.09 \text{ N}$$

$$T_1 = 3T_2$$

$$2T_2 = 3183.09$$

$$T_2 = 1591.55 \text{ N}$$

$$T_1 = 4774.65 \text{ N}$$

$$R_A + R_B = 1000$$

Taking moment about A, $$= -750 \times 1000 + R_B \times 1500$$

$$R_B = 500 \text{ N}$$

$$R_A = 500 \text{ N}$$

Maximum bending moment $$M = 500 \times 750$$

$$= 375 \times 10^3 \text{ N-mm}$$

$$T_e = \sqrt{M^2 + T^2}$$

$$= \sqrt{(375 \times 10^3)^2 + (954.93 \times 10^3)^2}$$

$$= 1025.922 \times 10^3 \text{ N-mm}$$

$$T_e = \frac{\pi}{16} \tau \times d^3$$

Assume $$\tau = 64 \text{ N/mm}^2$$

$$d^3 = \frac{1025.922 \times 10^3 \times 16}{\pi \times 64}$$

$\boxed{d \approx 43.38 \text{ mm}}$ **Ans.**

Q. 5. Determine the dimensions of a bearing and journal to support a load of 5500N as 800 rpm using hardened steel journal and bronze-backed bearing. An abundance of oil is provided which has a specific gravity of 0.9 at 15.5°C and a viscosity of 10.2 centistockes at 82°C that may be taken to the limiting temperature for oil. Assume a clearance of 0.0025 cm per cm of diameter. Calculate also the rate of heat generated in the bearing.

Ans. Given : $W = 5500 \text{ N}, \; N = 800 \text{ rpm}$

Specific gravity of oil $= 0.9$ at, $t_a = 15.5°C$

Viscosity $= 10.2$ centistroke, $t_o = 82°C$

Clearance $= 0.0025$ cm/cm of diameter

$$Z = \text{Sp. gr of oil}\left[0.000225 - \frac{0.18}{5}\right] \text{ kg/m-sec}$$

$$= 0.9\left[0.22\times 5 - \frac{180}{5}\right]\times 10^{-6} \text{ N-sm}^2$$

$$= 13.88\times 10^{-6} \text{ N-sm}^2$$

Let us take $\frac{l}{d} = 1.5$

& $d = 100\,\text{mm}$

Bearing pressure $(P) = \frac{w}{ld} = \frac{5500}{1.5\times d^2} = 0.367\,\text{N/mm}^2$

Since the given bearing pressure for the pump is 1.5 N/mm^2. then above value of p is safe for the select l and d

$$\frac{ZN}{P} = \frac{0.00138\times 800}{0.367} = 3.008$$

From the data book, $\frac{ZN}{P} = 28$

Hence the minimum value of bearing modulus at which the oil filth will be is given by

$$\frac{ZN}{p} = 3K$$

$\Rightarrow$ $K = \frac{ZN}{P\times 3} = 9.33$

$\frac{ZN}{P} = 3.008$ is less than the value of $\frac{ZN}{P} = 9.33$

So the bearing will operate under hydrostatic condition.

The clearance ratio $= 0.0025\times d$

$$= 0.25$$

$$\mu = \frac{33}{10^8}\times\left(\frac{ZN}{P}\right)\times\left(\frac{d}{c}\right) + k$$

$k = 0.002$ from databook

$$= \frac{33}{10^8}\times 3.008\times\frac{1}{0.25} + 0.002$$

$$= 0.002$$

Heat generated $Q_g = \mu w v = \mu\times w\left(\frac{\pi DN}{60}\right) W$

$$= \frac{0.002 \times 5500 \times \pi \times 0.1 \times 800}{60} = 46.08\text{ W}$$ **Ans.**

Q. 6. Select a roller bearing for a shaft to carry 1800N stationary radial load and 2700 N axial load at a shaft speed of 500 rpm. The rating life required is 6000 hrs. There is no shock loading.

Ans. $F_r = 1800\text{N},\ F_a = 2700\text{N}$

$N = 500\text{ rpm}$

Basic dynamic load rating $C = W \times \left(\frac{L}{10^6}\right)^{1/k}$

$R = \frac{10}{3}$ for roller bearing

$L = 60 \times N \times L_H = 60 \times 500 \times 6000 = 180 \times 10^6$ rev

$W = XVF_R + YF_A$

$\frac{F_A}{C_o} \Rightarrow$ Where C_o (basic load capacity is not known)

Let us take $\frac{F_A}{C_o} = 0.5$ then $e = 0.44$

From data book, $\frac{F_A}{F_R} = \frac{2700}{1800} = 1.5$

$\frac{F_A}{F_R} > e$

$X = 0.56,\quad Y = 1.0,\quad V = 1$ (Rotational factor)

$W = 0.56 \times 1 \times 1800 + 1 \times 2700 = 3708\text{ N}$

For no shock loading $K_s = 1$

$$C = W\left(\frac{L}{10^6}\right)^{1/k} = 3708 \times \left(\frac{180 \times 10^6}{10^6}\right)^{1/3.33}$$

$$= 17608.46\text{ N}$$

Select single row deep groove ball bearing.

Let us select the bearing no. 307 from the data table

$C_o = 17.6\text{ kN} = 17600\text{ kN}$

$C = 26000\text{ N}$

$\frac{F_A}{C_o} = \frac{2700}{17600} = 0.153$

From data book, $X = 0.56,\ Y = 1.4$

$$W = 0.56 \times 1 \times 1800 + 1.4 \times 2700$$

$$= 4788\,\text{N}$$

$$C = 4788 + \left(\frac{180 \times 10^6}{10^6}\right)^{1/10/3}$$

$$= 4788 \times (180)^{0.3}$$

$$= 22.74\ \text{kN}$$

Hence then select bearing no. 309. **Ans.**

Q. 7. Design the teeth for a pair of cast iron spur gears with cast teeth to transmit 26kW. The pinion runs at 50 rpm and the velocity ratio is to be 2.5. Decide upon a suitable grade of cast iron and find the module, face and diameters and centre distance for the gears.

Ans. $P = 26 \times 10^3$ W

$$N = 50\,\text{rpm}$$

$$V.R = 2.5$$

Cast iron grade for the gear, and pinion of bronze.

Allowable static stress $(\sigma_o) = 105\,\text{N/mm}^2$ (gear)

For pinion $= 84\ \text{N/mm}^2$

$$V.R = 2.5 = \frac{N_P}{N_G} = \frac{T_G}{T_P} = \frac{D_G}{D_P}$$

Set the system of gear teeth

20° full depth involve—then $T_P = 18$

$$T_G = 2.5 \times 18 = 45$$

$$m = \text{Module in mm}$$

Pitch velocity $v = \dfrac{\pi m \times T_P \times N_P}{60} = \dfrac{\pi \times m \times 18 \times 50}{60}$

$$v = 47.12\,\text{mm/sec} = 0.047\,\text{m/sec}$$

Assuming steady load condition and 8-10 hrs. service per-day

Then $C_s = 1$

Tangential load, $W_T = \dfrac{P}{v} \times C_s = \dfrac{26 \times 10^3}{0.047 \times m} \times 1 = \dfrac{553.19 \times 10^3}{m}\,N$

$$C_v = \frac{3}{3+V} = \frac{3}{3+0.047\text{m}}$$

Tooth form factor for the pinion

$$y_P = 0.154 - \frac{0.912}{T_P} = 0.1033$$

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$$y_G = 0.154 - \frac{0.912}{T_G} = 0.1337$$

$$\sigma_{0_G} \times y_G = 105 \times 0.1337 = 14.04$$

$$\sigma_{0P} \times y_P = 84 \times 0.1033 = 11.23$$

$\sigma_{0G} \times y_G > \sigma_{0P} \times y_P$ means pinion is weaker.

Now Levis equation for the pinion

$$W_T = \sigma_{wP} \times b \times \pi \times m \times y_P = (\sigma_{0P}) \times C_v \times b \times \pi \times m \times y_P$$

$$\frac{553.19 \times 10^3}{m} = 11.23 \times \frac{3}{3 + 0.047m} \times 14 \times m \times \pi \times m$$

$$553.19 \times 10^3 \times (3 + 0.047m) = 11.23 \times 3 \times \pi \times 14 \times m^3$$

$$373.33 \times (3 + 0.047m) = m^3$$

$$1119.99 + 17.55m = m^3$$

$$m = 9\,\text{mm}$$

Face width $\quad b = 14m = 9 \times 14 = 126\,\text{mm}$

$$D_P = mT_P = 9 \times 18 = 162$$

$$D_G = mT_G = 9 \times 45 = 405$$

Centre distance $\quad = \frac{D_G}{2} + \frac{D_P}{2}$

$$= \frac{405}{2} + \frac{162}{2} = 283.5\,\text{mm} \quad \textbf{Ans.}$$

Q. 8. A pair of helical gears is to transmit 37.5 kW at 1750 rpm of the pinion. The velocity ratio is to be 4.25 and the helix angle is to be 15°. The gears are subjected to a heavy shock load 24 hr per day. The minimum pitch diameter of the pinion is 0.116 m. Determine the module, face, material if the teeth are 20° full depth in the normal plane.

Ans. $\quad P = 37.5\,\text{kW}, \quad N_P = 1750\,\text{rpm}$

$$V_R = 4.25 = \frac{N_P}{N_G} = \frac{T_G}{T_P} = \frac{D_G}{D_P}$$

$$\alpha = 15°$$

$$\phi = 20°, \ T_P = 18, \ T_G = 76.5$$

$$D_P = 116\,\text{mm}, \ N_G = 411.76$$

$$T = \frac{P \times 60}{2\pi N} = 204.63\,\text{N-m} = 204.63 \times 10^3\,\text{N-mm}$$

Equivalent no. of teeth $\quad T_E = \frac{T_G}{\cos^3 \alpha} = \frac{76.5}{\cos^3 15°} = 84.89$

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Tooth factor $y' = 0.154 - \frac{0.912}{T_E} = 0.14326$

$$W_T = \frac{T}{D_G/2} = \frac{2G}{D_G} = \frac{2 \times 204.63 \times 10^3}{m \times T_G} = \frac{2 \times 204.63 \times 10^3}{76.5 \times m}$$

$$W_T = \frac{5349.8}{m} \text{ N}$$

Peripheral velocity $v = \frac{\pi D_G N_G}{60} = \frac{\pi \times m T_G \times N_G}{60} = 1649.3 \text{ m (mm/sec)}$

Assume $\sigma_0 = 56 \text{ N/mm}^2$ (C.I.) ordinary $= 1.649 \text{ m (m/sec)}$

$$C_v = \frac{15}{15+v} = \frac{15}{15+1.65m}$$

$\because$ $b = \frac{2.3 \times \pi \times m}{\tan \alpha} = 26.97 \text{ m}$

$$W_T = (\alpha_0 \times C_v) \times l \times \pi \times m \times y'$$

$$\frac{5349.8}{m} = 56 \times \frac{15}{15+1.65m} \times 26.97 \times m \times \pi \times m \times 0.14326$$

$m \approx 7 \text{ mm}, \ b = 26.97 \times 7 = 188.77 \text{ mm}$ **Ans.**

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