16 ME 43

Q1

During braking the K.E of the car is into thermal energy through friction in the brakes. The heat from rotors can have determined effect on the performance of the brake and other components of car.

The heating of capillar will also come the temp of brake rise. If the brake fluid starts to boil, air bubbles will form creating a spongy. The mall depends on the diameter and thickness of rotor. The mass depends on the diameter and thickness of rotor. Generally the large the mass the more heat can be absorbed.

Q A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brakes provides a braking torque of 225 N-m. One end of the band is attached to a fulcrum pin of the lever and other end to the pin of 100 mm from the fulcrum. If the operating force applied at 500 mm from the fulcrum and the co-efficient of friction is 0.25. Find the operating force when the drum rotates in the anticlockwise direction.

If the brake lever and pins are to be made of mild steel having permissible stresses for tension and crushing as 70 MPa and for shear 56 MPa, design the shaft, key, lever and pins. The bearing pressure between the pin and lever may be taken as 8 N/mm².

8 <u>Data</u>

$d = 450$ mm $\qquad r = 225$ mm

$T_B = 225$ N-m $\rightarrow 225 \times 10^3$ N-mm

$OB = 100$ mm

$l = 500$ mm

$\mu = 0.25$

$\sigma_t = \sigma_c = 70$ MPa

$\tau = 56$ N/mm^2

$P_b = 8$ N/mm^2.

Sol:

P = operating force

$\theta = \frac{3}{4}$th of circumference $= \frac{3}{4} \times 360 = 270°$

$= 270 \times \frac{\pi}{180} = 4.713$ rad.

and $2.3 \log\left(\frac{T_1}{T_2}\right) = \mu \cdot \theta = 0.25 \times 4.713 = 1.178$

$\log(T_1/T_2) = \frac{1.178}{2.3} = 0.5123$

$\frac{T_1}{T_2} = 3.25$

we know that braking torque (T_B)

$225 \times 10^3 = (T_1 - T_2) r$

$225 \times 10^3 / 225 = T_1 - T_2$

$T_1 - T_2 = 1000N \longrightarrow (ii)$

From eq (i) & (ii)

$T_1 = 1444N$ and $T_2 = 444N$

16 ME 73

Design of shaft

d_s = dia: of shaft

$225 \times 10^3 = \frac{\pi}{16} \times \tau \times (d_s)^3$

$225 \times 10^3 = \frac{\pi}{16} \times 56 \times (d_s)^3$

$d_s = 27.3 \simeq 30\,mm$ Ans.

Design of key

standards
$w = 10\,mm$ Ans
$t = 8\,mm$ Ans.

l = length of key

$225 \times 10^3 = l \times w \times \tau \times \frac{d_s}{2}$

$225 \times 10^3 = l \times 10 \times 56 \times \frac{30}{2}$

$l = 27\,mm$

Now in crushing.

$225 \times 10^3 = l \times t/2 \times \sigma_c \times d_s/2$

$225 \times 10^3 = l \times 8/2 \times 70 \times 30/2$

$l = 54\,mm$

Design of lever

t_1 = Thickness
B = width

$M = P \times l$
$= 88.8 \times 500$
$= 44400$ N-m

Section modulus.

$Z = \frac{1}{6} t_1 . B^2$

$Z = \frac{1}{6} \times t_1 (2t_1)^2$

$Z = 0.67 (t_1)^3$ mm^3

We know that bending stress (σ_t)

$70 = M/Z = \frac{44400}{0.67 (t_1)^3}$

$t_1 = 9.82$ say 10mm Ans

$B = 2t_1 = 2 \times 10 = 20$mm Ans.

Design of Pins

d_1 = Dia of pins at O and B
l_1 = length of the pins = 1.25

maximum tension in band ($T_1 = 1444N$)

$1444 = d_1 \times l_1 \times P_b$

$1444 = d_1 \times 1.25 d_1 \times 8 = 10(d_1)^2$

$(d_1)^2 = 1444/10 = d_1 = 12$ mm Ans

$l_1 = 1.25 d_1$

$= 1.25 \times 12$

$l_1 = 15$ mm Ans

For induced

$1444 = 2 \times \frac{\pi}{4} (d_1)^2 \tau$

$1444 = 2 \times \frac{\pi}{4} (12)^2 \tau$

$1444 = 226 \tau$

$\tau = 6.4$ N/mm^2.

Max Bending moment.

$M = \frac{5}{24} \times W \cdot l_1 = \frac{5}{24} \times 1444 \times 15$

$M = 4513$ N-mm

section modulus.

$$Z = \frac{\pi}{32}(d_1)^3$$

$$Z = \frac{\pi}{32}(12)^3 = 170\,mm^3$$

Bending stress induced

$$= \frac{M}{Z} = \frac{4513}{170} = 26.5\ N\text{-}mm^2.$$

safe limits of 70 MPa

thickness

$$t_2 = \frac{d_1}{2} = \frac{15}{2} = 7.5\,mm.$$

Outer diameter.

$$D = 2d_1$$
$$= 2 \times 12 = 24\,mm.$$

Diameter of hole in the lever

$$= d_1 + 2 \times 3 = 18\,mm$$

Outer diameter of boss.

$$= 2d_1$$
$$= 2 \times 12$$
$$= 24\,mm.$$

length of boss $= l_1 = 15\,mm.$

$M = P \cdot l$

$= 88.8 \times 500$

$= 44400$ N-mm

section modulus

$$Z = \frac{\frac{1}{12} \times 15 \left[(24)^3 - (18)^3\right]}{24/2}$$

$= 833 \; mm^3$

∴ Bending stress induced

$$= \frac{M}{Z} = \frac{44400}{833} = 53.3 \; N/mm^2$$

Ans.

safe limits is 70 MPa.

Q2 (A)

A single plate clutch effective on both sides, is required to transmit 25 kW at 3000 rpm. Determine the outer and inner diameters of frictional surface if the coefficient of friction is 0.255, ratio of diameter is 1.25 and the maximum pressure is not exceed 0.1 N/mm². Also determine the axial thrust to be provided by springs. Assume the theory of uniform wear.

Data

$n = 2$; $P = 25$ kW, $N = 3000$ rpm

$\mu = 0.225$; $\frac{d_1}{d_2} = 1.25$ or $\frac{r_1}{r_2} = 1.25$.

$P_{max} = 0.1$ N/mm².

Soln:

Outer & inner diameters of frictional surface.

$$T = \frac{P \times 60}{2\pi N}$$

$$= \frac{25 \times 10^3 \times 60}{2\pi \times 3000} = 79.57 \text{ N-mm}$$

$P_{max} \times r_2 = C$

$C = 0.1\ r_2$. N/mm.

Axial load.

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

$= 2 \times \pi \times 0.1 r_2 (1.25 r_2 - r_2)$

$W = 0.157 (r_2)^2$

Mean radius of frictional surface.

$R = r_1 + r_2 / 2$

$R = 1.25 r_2 + r_2 / 2 = 1.125 r_2$.

Torque

$79600 = n . \mu . W . R$

$79600 = 2 \times 0.255 \times 0.157 (r_2)^2 \; 1.125 r_2$

$79600 = 0.09 (r_2)^2$

$r_2 = 96$ mm

$r_1 = 120$ mm

∴ Outer diameter of frictional

$d_1 = 2r_1 = 2 \times 120 = 240$ mm Ans

$d_2 = 2r_2 = 2 \times 96 = 192$ mm Ans

Axial thrust to be provided by springs

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

$= 2\pi \times 0.1 r_2 (1.25 r_2 - r_2)$

$= 0.157 (r_2)^2$

$W = 1447$ N Ans.

Q2(B)

A dry single plate clutch is to be designed for an automatic vehicle whose is rated to give 100 kW at 2400 rpm and maximum torque 500 N-m. The outer radius of the friction plate is 25% more than the inner radius. The intensity of pressure between the plate is not to exceed 0.07 N/mm^2. The co-efficient of friction may be assumed equal to 0.3. The helical springs required by this clutch to provide axial force necessary to engage the clutch are eight. If each spring has stiffness equal to 40 N/mm, determine the dimensions of the friction plate and initial compression in springs.

Data

$P = 100$ kW

$N = 2400$ rpm

$T = 500$ N-m

$p = 0.07 \, N/mm^2$

$\mu = 0.3$

No. of springs = 8

stiffness/spring = 40 N/mm

Dimensions of friction plate

$r_1 = 1.25\, r_2$

$p \cdot r_2 = C$ or $C = 0.07\, r_2$ N/mm

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

$= 2\pi \times 0.07\, r_2 (1.25 r_2 - r_2)$

$= 0.11 (r_2)^2$ N $\longrightarrow$ (i)

$R = \frac{r_1 + r_2}{2} = \frac{1.25 r_2 + r_2}{2}$

$R = 1.125\, r_2$

$500 \times 10^3 = n \cdot \mu \cdot W \cdot R$

$500 \times 10^3 = 2 \times 0.3 \times 0.11 (r_2)^2\, 1.125 r_2$

$500 \times 10^3 = 0.074 (r_2)^3$

$r_1 = 1.25 \times 190$

$r_1 = 237.5$ mm Ans.

Initial compression in the springs

$S = 40 \times 8 = 320$ N/mm

$W = 0.11 (r_2)^2$

$= 0.11 (190)^2$

$= 3970$ N

∴ Initial compression in springs

$= \frac{W}{S} = 12.4\text{ mm}$ Ans

Q3 A punching press pierces 35 holes per minute in a plane using 10 kN-m of energy per hole during each revolution. Each piercing takes 40 % of the time needed to make one revolution. The punch receives power through a gear reduction unit which in turn is fed by a motor driven belt pulley 800 mm diameter and turning at 210 rpm. Find power of the electric motor if overall efficiency of the transmission unit is 80 %. Design a cast iron flywheel to be used with punchin machine for a coefficient of steadiness of 5, if the space consideration limit the max: diameter to 1.3 m.

Allowable shear stress = 50 MPa

Allowable tensile stress = 4 MPa

Density of cast iron = 7200 kg/m³

Data

No. of holes = 35 per min

Energy per hole = 10 kN-m

$d = 800$ mm

$N = 210$ rpm

$\eta = 80\% = 0.8$

$1/C_s = 5$

$C_s = 1/5 = 0.2$

$D_{max} = 1.3$ m

$\tau = 50$ MPa.

$\sigma_t = 4$ MPa.

$\rho = 7200$ kg/m^3.

Sol.

Power of electric motor

= No. of holes × Energy used

= 35 × 10,000

= 350000 N-m/min.

$$P = \frac{\text{Energy used per min}}{60 \times \eta}$$

= 350000 / 60 × 0.8

= 7.29 kW.

Design of cast iron flywheel

$$E_T = \frac{10,000}{0.8} = 12500 \text{ N-m}$$

$$V = \pi d N = \pi \times 0.8 \times 210 = 528 \text{ m/min}$$

$$Pull = \frac{P \times 60}{v} = \frac{7292 \times 60}{528} = 828.6$$

40% time needed

$$= 0.4/35 = 0.0114 \text{ min}$$

distance moved = velocity × time

$$= 528 \times 0.0114$$
$$= 6.03 \text{ m}$$

$$E_B = \text{Net tension} \times \text{Distance travelled}$$
$$= 828.6 \times 6.03$$
$$= 4996 \text{ N-m}$$

$$\Delta E = E_T - E_B$$
$$= 12500 - 4996 = 7504 \text{ N-m}$$

Mass of the flywheel

$D = 1.2m$ or $R = 0.6m$

$\omega = \frac{2\pi \times N}{60} = \frac{2\pi \times 210}{60} = 22$ rad/s.

$7504 = m \cdot R^2 \cdot \omega^2 \cdot C_s$

$7504 = m (0.6)^2 \cdot (22)^2 \cdot 0.2$

$m = 7504 / 34.85$

$m = 215.3$ kg

Cross-sectional dimensions.

$A = b \times t$

$= 2t \times t = 2t^2$

$m = A \times \pi D \times \rho$

$215.3 = 2t^2 \times \pi \times 1.2 \times 7200$

$t^2 = 215.3 / 54.3 \times 10^3$

$t = 0.063$

$b = 2t = 2 \times 65 = 130$ mm

Diameter and length of hub.

$$T_{mean} = \frac{P \times 60}{2\pi N} = \frac{7292 \times 60}{2\pi \times 210}$$

$$= 331.5 \text{ N-m}$$

$$T_{max} = 2 \times T_{mean} = 2 \times 331.5 = 663 \text{ N-m}$$

$$T_{max} = \frac{\pi}{16} \times \tau (d_1)^3$$

$$663 \times 10^3 = \frac{\pi}{16} \times 50 \times (d_1)^3$$

$$d_1 = 40.7 \text{ mm}$$

$$d = 2d_1$$

$$d = 2 \times 45 = 90 \text{ mm}$$

$$l = b = 130 \text{ mm}$$

Cross-sectional dimensions of elliptical cast iron

$$M = \frac{T}{R \cdot n}(R - r) = \frac{T}{D \cdot n}(D - d)$$

$$= \frac{663}{1.2 \times 6}(1.2 - 0.09)$$

$= 102200$ N-mm.

$$Z = \frac{\pi}{32} \times b_1 (a_1)^2$$

$$= \frac{\pi}{32} \times 0.5 a_1 (a_1)^2 = 0.05 (a_1)^3.$$

$$4 = \frac{M}{Z} = \frac{102200}{0.05 (a_1)^3} = \frac{2044 \times 10^3}{(a_1)^3}$$

$$(a_1)^3 = 2044 \times 10^3 / 4$$

$(a_1) = 80$ mm Ans

$b_1 = 0.5 a_1$

$= 0.5 \times 80$

$= 40$ mm Ans

Dimensions of key.

$w = 16$ mm Ans.

$= 10$ mm Ans

$$663 \times 10^3 = L \times w \times \tau \times d_1 / 2$$

$$663 \times 10^3 = 18 \times 10^3 L$$

$L = 36.8$ mm Ans

$$v = \frac{\pi D N}{60}$$

$$= \frac{\pi \times 1.2 \times 210}{60} = 13.2 \text{ m/s}$$

Total Stress

$$\sigma = \rho . v^2 \left(0.75 + \frac{4.935 R}{n^2 . t} \right)$$

$$= 7200 (13.2)^2 \left[0.75 + \frac{4.935 \times 0.6}{6^2 \times 0.065} \right]$$

$$= 1.25 \times 10^6 (0.75 + 1.26)$$

$$= 2.5 \times 10^6 \text{ N/m}^2$$

Design is safe.

Q4 A single cylinder double acting steam engine delivers 185 kW at 100 rpm The maximum fluctuation of energy per revolution is 15% of the energy developed per revolution. The speed variation is limited to 1 percent either way from the mean. The mean diameter of rim is 2.4 m. Design.

Sol

$P = 185\ kW$

$N = 100\ rpm$

$\Delta E = 15\%$

$E = 0.15E$

$D = 2.4m$

1. Mass of flywheel rim

$$E = \frac{P \times 60}{N} = \frac{185 \times 10^3 \times 60}{100} = 111000\ N\text{-}m$$

$$\Delta E = 0.15E = 0.15 \times 111000 = 16650\ N\text{-}m$$

$N_1 - N_2 = 2\%$ of mean speed $= 0.02N$.

$$C_s = \frac{N_1 - N_2}{N} = 0.02$$

$$V = \frac{\pi D N}{60} = \frac{\pi \times 2.4 \times 100}{60} = 12.57\ m/s$$

$16,650 = m \cdot v^2 \cdot C_s$

$16650 = m\,(12.57)^2\,0.02 = 3.16\,m$

$m = 5270$ kg.

2. Cross - sectional dimensions.

$A = b \times t \Rightarrow 2t \times t$

$= 2t^2$

$m = A \times \pi D \times \rho$

$= 2t^2 \times \pi \times 2.4 \times 7200$

$5270 = 108588\,t^2$

$t = 0.0485$ or $t = 0.22$ m

$b = 2t = 2 \times 220 = 440$ m

3. Diameter & length of hub

$T_{mean} = \dfrac{P \times 60}{2\pi N} = \dfrac{185 \times 10^3 \times 60}{2\pi \times 100}$

$= 17664$ N-m

$T_{max} = 2 \times T_{mean}$

$= 2 \times 17664$

$= 35328$ N-m

$$T_{max} = \frac{\pi}{16} \times \tau \times d_1^3$$

$$35.328 = \frac{\pi}{16} \times 40 \times (d_1)^3$$

$$d_1 = 165 \text{ mm} \quad Ans$$

$$d = 2d_1$$
$$= 2(165) = 330 \text{mm}$$

$$l = b = 440 \text{ mm}$$

3. Cross-sectional dimension of elliptical arms

$$M = \frac{T}{R.n}(R-r) = \frac{T}{D.n}(D-d)$$

$$= \frac{35328}{2.4 \times 6}(2.4 - 0.33)$$

$$M = 5078 \text{ N-m}$$

$$Z = \frac{\pi}{32} b_1 (a_1)^2$$

$$= \frac{\pi}{32}(0.5)a_1 (a_1)^2$$

$$= 0.05 (a_1)^3$$

$\sigma_b = \frac{M}{Z}$

$14 = \frac{5078 \times 10^3}{0.05 (a_1)^3}$

$a_1 = 200$ mm

$b_1 = 0.5\, a_1$

$= 0.5 \times 200$

$b_1 = 100$ mm

5. Dimensions of key

$w = 45$ mm

$t = 25$ mm

$T_{max} = L \times w \times \tau \times \frac{d_1}{2}$

$35.328 \times 10^6 = L \times 45 \times 40 \times 165/2$

$35.328 \times 10^6 = 148500\, L$

$L = 238$ mm

$\text{stress} = \rho \cdot v^2 \left(0.75 + \frac{4.935\, R}{n^2 \cdot t}\right)$

$= 7200\, (12.57)^2 \left[0.75 + \frac{4.935 \times 1.2}{6^2 \times 0.22}\right]$

$= 1.7?$ MPa

Design is safe