DESIGN OF CLUTCHES, BRAKES AND CAMS

(A) PLATE CLUTCHES
   (a) Single plate
   (b) Multi plate

(b) CONICAL CLUTCH

I) DESIGN OF BRAKES
   (a) Differential band brake
   (b) Double block brake

II) DESIGN OF CAMS
    (a) Cycloidal cam
(D) **Design of Clutches**

(A) **Plate Clutches**

(i) **Single plate clutch**

(ii) A dry single plate clutch is to be designed for an automatic vehicle whose engine is rated to give 100 kW at 2400 rpm and max. torque of 500 Nm. The outer radius of friction plate is 250 mm, more than inner radius. Pressure = 0.07 MPa, $\mu = 0.3$. 10 no. helical springs = 8. Stiffness of each spring = 40 N/mm. Design the clutch spring system.

**Solution**

**Step 2**

$P_{max} \cdot R = C$

$0.07 \times R = C$

**Step 3**

$W = \frac{2 \pi}{C} \left( R_2 - R_1 \right)$
\[
\begin{align*}
W &= 0.109 M_2^2 \\
\text{Step II} \\
[M_2] &= n \sqrt{W R} \\
R &= \frac{M_1 + M_2}{2} \\
500 \times 10^3 &= 2 \times 0.3 \times 0.109 M_2^2 \times 1.129 M_2 \\
M_2 &= 189.41 \text{ mm} \\
M_1 &= 286.76 \text{ mm} \\
W &= 3910.68 \text{ N}
\end{align*}
\]

\[
\begin{align*}
\text{Step IV} \\
M_T &= \frac{(M_2)}{L_5} \\
M_T &= 500 \times 10^3 \text{ Nmm} \\
L_5 &= \text{Stiffness of Total Spans} \\
&= 407 \delta = 320 \text{ N/mm} \\
\delta_s &= 320 \frac{N}{mm} = \frac{3910.68}{8} \delta_i = 2.22 \text{ mm}
\end{align*}
\]
Q: A multi-disc clutch consists of 5 steel plates and 4 bronze plates. The inner and outer diameters of friction disc are 75 mm and 150 mm. \( \mu = 0.1 \) pressure = 0.3 N/mm². \( N = 750 \) rpm. Design the clutch.

Solution:

Step 1:
\[ P_{max} = \mu \frac{N}{d} \]
\[ C = 0.3 \times 37.5 \]
\[ C = 11.25 \text{ N/mm} \]

Step 2:
\[ W = 251 C \left( R_2 - R_1 \right) \]
\[ W = 25 \times 11.25 \times (75 - 37.5) \]
\[ W = 2650.718 \text{ N} \]

Step 3:
\[ \text{C.L} = \frac{n \times W \times R}{2} \]
\[ R = \frac{R_1 + R_2}{2} = \frac{75 + 37.5}{2} = 56.25 \text{ mm} \]
\[ n = 8 \]

\[ M_L = 8 \times 0.1 \times 26500 \times 118 \times 52.5 \]

\[ [M_L] = 11,928.2 \text{ Nmm} \]

\[ [M_L] = 11,928.2 \text{ Nmm} \]

\[ M_L = M_t \times k \]

\[ M_t = \frac{[M_L]}{k} \]

\[ M_t = 119.2 \times 10^3 \text{ Nmm} \]

\[ M_L = \frac{60P}{2\pi W} \]

\[ P = \frac{2\pi W M_L}{60} \]

\[ P = \frac{2\pi \times 750 \times 119.2}{60} \]

\[ P = 9.368 \text{ kw} \]

\[ \text{Power} = 9.368 \text{ kw} \]
(B) Clutch

3. A weather felled conical friction clutch has a cone angle of 30°. The intensity of pressure between the contact surface is not to exceed \(6 \times 10^3 \, N/m^2\), and the breadth of the conical surface is \(\frac{1}{3}\) of mean radius. \(\mu = 0.2\). Power = 57 kW. \(N = 2000 \, \text{rpm}\). Design the clutch.

Solution

Step I

\[
\frac{g_1 - g_2}{b} = \sin \alpha
\]

\[b = \frac{1}{3} R
\]

\[g_1 - g_2 = \sin 150^\circ \left( \frac{1}{3} R \right)
\]

\[g_1 - g_2 = 0.086 \, R
\]

Step II

\[R = \frac{g_1 + g_2}{2}
\]

\[g_1 + g_2 > 2 \, R
\]
\[ W_n = \frac{p_n \times n^{0.5}}{2 \times 10^{-5}} \]

\[ W_n = 0.06 \times 2\pi \times 10^{-3} \times \frac{1}{3} R \]

\[ W_n = 0.125 \times R^2 \]

\[ [MT] = \mu W_n R^2 = \frac{60 P}{10} \times \frac{1000}{125} \times 2.5 = 0.2 \times 10^{-5} n^2 R \]

\[ R = 260.54 \text{ mm} \]

\[ g_1 - g_2 = 22.39 \]

\[ g_1 + g_2 = 520.88 \]

\[ g_1 = 271.65 \text{ mm} \]

\[ g_2 = 249.25 \text{ mm} \]
\[ b = \frac{1}{3} \times R \]
\[ b = 86.81 \text{ mm} \]

4. **DESIGN OF BRAKES**

A differential band brake is to be designed for a pinch lifting a load of 4.5 kW through a row around a barrel of 500 mm diameter. The brake drum to be mounted on the same shaft is 600 mm in diameter. The angle of lap of the brake band over the drum is 250°. Operating lever is 1800 mm long. Arm of brake are 400 mm x 280 mm. Design the brake.
Step 2: To find Torque

Breaking Torque = Load x Barbel radius

\[ = 45 \times 10^3 \times \frac{500}{2} \]

Breaking Torque \( T = 11.25 \times 10^6 \text{ N/mm} \).

Also

Breaking Torque = \( (T_1 - T_2) \times \text{Radius of shaft} \)

\[ = (T_1 - T_2) \times \frac{600}{2} \]

\[ T = 300 (T_1 - T_2) \]

\[ 11.25 \times 10^6 = 300 (T_1 - T_2) \]

\[ \sqrt{T_1 - T_2} = 37500 \]

But \[ \frac{T_1}{T_2} = e^{-0.3 \times 4.36} \]

\[ T_1 = 3.69T_2 \]

\[ 3.69T_2 - T_2 \geq 37500 \]

\[ T_2 = 13.940 \text{ kN} \]

\[ T_1 \geq 51.4 \text{ kN} \]
Step II: To find Thickness

\[ t = 0.005 \times \text{Diameter of Shaft} \]
\[ t = 0.005 \times 600 \]
\[ t = 3 \text{ mm} \]

Step III: To find breadth

\[ \sigma = \frac{t}{\text{Area}} \]
Assume \[ \sigma = 50 \text{ MPa} \]

\[ 50 = \frac{51.4 \times 10^3}{6 \times t} \]

\[ t \approx 34.2 \text{ mm} \]
A cycloidal cam with a central roller follower has a rise of 25 mm in cam angle of 70°. Base circle radius is 80 mm and the follower roller radius is 70 mm.

\[ N = 6000 \text{ rpm} \quad m = 0.5 \log \text{ design the cam.} \]

\[
\text{Step 1: calculation of displacement} \]

From PB pg 7.110

\[
y = \frac{h}{\pi} \left( \frac{\pi a}{b} - \frac{1}{2} \sin \frac{2h\pi}{b} \right)
\]

for max. acceleration

\[
\alpha = \frac{a^2}{b^2}
\]

\[
\theta = 0.25 \times 1.221
\]

\[
\theta = 0.30 \text{ opening} = 17.5°.
\]
\[ y = \frac{25}{11} \left( \frac{11 \times 0.30r}{1.221} - \frac{1}{2} \sin \left( \frac{2\pi \times 17.5}{70} \right) \right) \]

\[ y = 7.95 \left( 0.784 - 0.012 \right) \]

\[ y = 6.129 \text{ mm} \]

**Step 10:**

**Calculate** \( \tau_0 \) and \( R \)

\[ \tau_0 = \tau_0 + \tau_y = 60 + 20 = 80 \text{ mm} \]

\[ R = 100 \text{ mm} \]

\[ R = \tau_0 + y \]

\[ = 100 + 6.129 \]

\[ R = 106.129 \text{ mm} \]

**Step 11:**

**Calculate** \( \frac{dy}{dx} \) \( \frac{dy}{dx} \)

\[ \frac{dy}{dx} = \frac{b}{\beta} - \frac{25}{1.221} - \frac{25}{2\pi} \cos \left( \frac{25 \times 17.5}{70} \right) \times \frac{2(1)}{1.221} \]

\[ \frac{dy}{dx} = 7.69 \times 10^{-3} \]
Step II: Calculation of position L/R

\[ \tan \alpha = \frac{\frac{dy}{dx}}{R} \]

\[ \tan \alpha = \frac{7.69 \times 10^{-3}}{106.19} \approx 0.0072 \]

\[ \alpha \approx 0.415 \times 10^{-3} \text{ degrees} \]

Step III: Calculation of max. acceleration

From DB pg 7.110.

\[ a = \frac{2 i \pi M \omega^2}{p^2} \]

\[ s = \frac{2.71 \times 10000}{60} = \frac{2.71 \times 10000}{60} = 523.99 \text{ m/s}^2 \]

\[ W = 523.99 \text{ m/s}^2 \]

\[ a = \frac{2 \times 523.99 \times 2.71 \times 17.5}{(1.221)^2} \times \frac{2.71}{70} \approx 7930.07 \text{ mm/s}^2 \]

\[ a = 793.007 \text{ m/s}^2 \]
Steps: Calculation of Inertia Force

\[ F = \frac{1}{2} ma \]
\[ F = 0.5 \times 793.007 \]
\[ F = 396.5 \text{ N} \]