UNIT-5 DESIGN OF CAM, CLUTCHES AND BRAKES

DESIGN OF CLUTCHES:

A clutch consists principally of two main sections that are engaged or disengaged on an intermittent basis either by manually or by some power driven devices. In clutches power transmission is achieved through (a) inter locking (b) friction (c) wedging (d) magnetic field.

According to the power transmitting method, clutches are categorized into

1. Positive clutches
2. Friction clutches
3. Cone clutches
4. Magnetic clutches

MECHANICALLY OPERATED CLUTCHES:

1. FRICTION CLUTCHES
   a. Disc or plate clutches
      1. Single plate clutches
      2. Multi plate clutches
   b. Cone clutches
   c. Centrifugal clutches
2. POSSITIVE CLUTCHES
   Jaw or claw clutches
   i. Square clutches
   ii. Spiral clutches

SINGLE PLATE CLUTCHES:

DESIGN OF CLUTCHES BASED ON UNIFORM WEAR CONDITION:

Torque to be transmitted $T = \mu . F_a . r_m$

F_a = Actuating torque required $= 2\pi p_{max} r_i (r_o - r_i)$

μ = Coefficient of friction

r_m = Mean radius $= \frac{r_o + r_i}{2}$

For multiple clutches

$$T = n . \mu . F_a . r_m$$

Note:- If there are 'n_1' number of discs on the driving shaft and 'n_2' number of discs on the driven shaft.

Then the number of pairs in contact surfaces

$n = n_1 + n_2 - 1$

DESIGN OF CLUTCH BASED ON UNIFORM PRESSURE CONDITION:

Torque to be transmitted $T = \mu . F_a . r_m$

F_a = Actuating torque required $= \pi p_{max} (r_0^2 - r_i^2)$

μ = Coefficient of friction

r_m = Mean radius $= \frac{2}{3} \left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2} \right]$

Example.5.1. A single plate clutch, effective on both sides, is required to transmit 25 KW at 1500 rpm. Determine the inner and outer diameter of the friction surfaces, if the coefficient of friction is 0.25, ratio of diameters is 1.5 and maximum pressure is not to exceed 0.2 N/mm^2. Also determine the axial thrust to be provided by the springs, assume theory of uniform wear.

Given:

P= 25 KW =25x10^3 W

N=1500 rpm

μ = 0.25

P_{max}=0.2 N/mm^2

Solution:

Let

d_i ,d_o inner and outer diameter of disc

r_o=1.5r_i ; d_o = 1.5 d_i

Torque to be transmitted $T = \frac{60P}{2\pi N} = \frac{60x25000}{2\pi x1500} = 160\ N - m = 160x10^3 N - mm$

Torque to be transmitted $T = n.\mu.F_a.r_m$

n = number of pairs of friction surfaces =2(both sides of the plate are effective)

F_a = Actuating torque required =$2\pi p_{max} r_i(r_o - r_i)$ =2πx0.2x$r_i(1.5r_i - r_i)$=0.63r_i^2N

μ = Coefficient of friction = 0.25

r_m = Mean radius $= \frac{r_o+r_i}{2} = \frac{r_i+1.5r_i}{2} = 1.25r_i$

$160x10^3 = 2x0.25x.0.63r_i^2 1.25r_i$; $r_i = 73.6\ mm \approx 75mm$ $d_i = 150mm$

$r_o = 75x1.5 = 112.5mm$ $d_o = 225mm$

$Axial\ thrust = 0.63r_i^2 = 0.63x75^2 = 3545N$

Example.5.2. A single dry plate clutch is to be designed to transmit 10 hp at 800 rpm, find (i) diameter of the shaft (ii) mean radius and face width of friction lining assuming the ratio of the mean radius to the face width as 5 (iii) outer and inner radii of the clutch plate.

Given:

P=10 hp

N=800rpm

$$T = \frac{4500xP}{2\pi N} = \frac{4500X10}{2\pi X800} = 8.95\ kgf - m = 8.95x10^3 kgf - mm$$

DIAMETER OF THE SHAFT:

$$d \geq \left\{\frac{16xT}{\pi x\tau}\right\}^{\frac{1}{3}} \geq \left\{\frac{16x8.95x10^3}{\pi x4}\right\}^{\frac{1}{3}} \geq 22.5 \quad \approx 25mm \qquad \tau = 4\, {}^{kgf}/_{mm^2}$$

MEAN RADIUS AND FACE WIDTH:

Let r_m = mean radius of the friction lining= $\frac{r_o+r_i}{2}$

$$\frac{r_m}{b} = 5 \quad ; \; r_m = 5b$$

Torque to be transmitted $T = n.\mu.F_a.r_m$

n = number of pairs of friction surfaces =2(assume)

F_a = actuating axial force=average pressure intensity on the friction lining area at which it is applied

=Px2π.r_m.b=0.01x2πxr_mb (assume p=0.01 kgf/mm^2)

μ = Coefficient of friction = 0.3 (assume)

T = 2X0.3X2Πx5bxbx0.01x5b=0.94b^3

8.95x10^3=0.94b^3 ; b=21.2 mm ; take b=22mm

R_m =5b = 5x22 = 110 mm

OUTER AND INNER RADII:

$$r_m = \frac{r_o + r_i}{2} \; ; \; r_o + r_i = 2r_m = 220 --- (A)$$

$b = r_o - r_i \;\; ; r_o - r_i = 22 --- (B)$

From A and B

2r_o=242 mm ; r_o=121 mm ;r_i=99 mm

Example.5.3. A multi plate clutch is to be designed to transmit a power of 50 KW at 500 rpm. Assuming suitable materials and data, determine the main dimensions of the friction lining used in that clutch.

Given:

P=50KW =50000W

N=500 rpm

Design power P_d = rated power x service factor =50,000,1.25=62500W

Design torque to be transmitted

$$T = \frac{60xP_d}{2\pi N} = \frac{60X62500}{2\pi X500} = 1194N - m = 1194x10^3N - mm$$

Let

d= diameter of the clutch shaft

τ = permissible shear stress for that material =50 N/mm^2 (assumed)

$$d \geq \left\{\frac{16xT}{\pi x\tau}\right\}^{\frac{1}{3}} \geq \left\{\frac{16x1194x10^3}{\pi x50}\right\}^{\frac{1}{3}} \geq 50$$

Let

r_i = inner radius of friction lining in mm = 100 mm

r_o = outer radius of friction lining in mm= 1.5x100 = 150mm

n_1= number of driving plates=5(assumed)

n_2 = number of driven plates=4(assumed)

then number of friction pairs $n=n_1+n_2-1=5+4-1=8$

μ = 0.35 (assumed for asbestos)

Allowable pressure (0.21 to 0.56 N/mm^2)

$$T = n.\mu.F_a.r_m$$

r_m = Mean radius $= \frac{r_o+r_i}{2} = \frac{100+150}{2} = 125\ mm$

Example.5.4. A plate clutch has 3 discs on the driving shaft and 2 discs on the driven shaft, providing 4 pairs of contact surfaces. The outside diameter of the contact surfaces is 240 mm and inside diameter 120 mm. Assuming uniform pressure and μ =0.2. Find the total spring load for pressing the plates together to transmit 25 KW at 1575 rpm. If there are 6 springs each of stiffness 13

KN/m and each contact surfaces have worn away by 1.25 mm, find the maximum power that can be transmitted, assuming uniform wear.

Given:

$n_1 = 3$

$n_2 = 2$

$n=4$

$d_o = 240$ mm $r_o = 120$mm

$d_i = 120$mm $r_i = 60$ mm

p=25 kw

N=1575 rpm

No of springs =6

Stiffness =13 KN/m

Torque transmitted $T = \frac{Px60}{2\pi N} = \frac{25x10^3x60}{2\pi x1575} = 151.58\ Nm$

For uniform pressure condition

Torque to be transmitted $T = \mu . F_a . r_m$

r_m = Mean radius $= \frac{2}{3}\left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right] = \frac{2}{3}\left[\frac{120^3 - 60^3}{120^2 - 60^2}\right] = 140mm = 0.14m$

$157.58 = 0.2 x F_a x 0.14$;$F_a = 5627.85$ N

Pressing force required $F_a = 5627.85$ N

Ex.5.1.A multi plate clutch has three pairs of contact surfaces. The outer and inner radii of the contact surfaces are 100 mm and 50 mm respectively. The axial spring force is limited to 1 KN. assuming uniform wear, find the power transmitted at 1500 rpm, take μ = 0.35

Ex.5.2. A multi plate clutch consisting of 6 plates, each plate of external diameter 150 mm and internal diameter 100 mm is to transmit 7.5 KW at 900 rpm. Assuming μ =0.1, determine the pressure on each effective pair of surface in contact .

DESIGN OF CONE CLUTCH:

CONSIDERIG UNIFORM PRESSURE:

Torque transmitted $T = \mu . W_N . r_m . cosec\alpha$

$$r_m = \frac{2}{3}\left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right]$$

$$W_N = \pi P_n (r_o^2 - r_i^2)$$

CONSIDERING UNIFROM WEAR

Torque transmitted $T = \mu . W_N . r_m . cosec\alpha$

$$r_m = \frac{r_o + r_i}{2}$$

AXIAL FORCE REQUIRED AT THE ENGAGEMENT OF CLUTCH

$$W_e = W_n (sin\alpha + \mu . cos\alpha)$$

AXIAL FORCE REQUIRED AT THE DISENGAGEMENT OF CLUTCH

$$W_e = W_n (sin\alpha - \mu . cos\alpha)$$

Example.5.5.The following data relate to a cone clutch: minimum and maximum surface contact radii are 125 mm and 150 mm respectively. Semi cone angle 20˚. Allowable normal pressure is 14×10^4 N/m^2, μ=0.25. Find (a) the axial load (b) power transmitted if the speed is 700 rpm.

Given:

r_o=150 mm=0.15m

r_i=125 mm=0.125m

α = 20˚

$p_n = 14 \times 10^4$ N/m^2

N=700 rpm

Axial load transmitted by the clutch:

$$W_N = \pi P_n\left(r_o^2 - r_i^2\right) = \pi x 14 x 10^4 (0.15^2 - 0.125^2) = 3023.78N$$

Power transmitted:

Assuming uniform pressure

Torque transmitted $T = \mu . W_N . r_m . cosec\alpha$

$$r_m = \frac{2}{3}\left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right]$$

$$T = \mu . W_N . \frac{2}{3}\left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right] . cosec\alpha = \frac{2}{3} x 0.25 x 3023.78 \left[\frac{0.15^3 - 0.125^3}{0.15^2 - 0.125^2}\right] cosec 20° = 304.73Nm$$

$$P = \frac{2\pi NT}{60} = \frac{2\pi X 700 X 304.73}{60} = 22.34\ KW$$

Cam, clutches and brakes:

May/June 2007

1. Name the profile of the cam that gives no jerk.
2. Give the reason for left and right shoes of the internal expansion brakes having different actuating force.
3. A plate clutch has 3 discs on the driving shaft and 2 discs on the driven shaft, providing 4 pairs of contact surfaces. The outside diameter of the contact surfaces is 240 mm and inside diameter 120 mm assuming uniform pressure and μ=0.3,find the total spring load for pressing the plates together to transmit 25 kw at 1575 rpm. If there are 6 springs each of stiffness 13 KN/m and each of the contact surfaces have worn away by 1.25 mm, find the maximum power that can be transmitted assuming uniform wear.
4. Design a cam for operating the exhaust value of an oil engine. It is required to give equal uniform acceleration and retardation during opening and closing of the valve, each of which corresponding to 60˚ of cam rotation. The valve should remain in the fully open position for 20˚ cam rotation. The lift of the valve is 37.5 mm and the least radius of the cam is 50 mm, the follower is provided with a roller of 50 mm diameter and its line of stroke passes through the axis of the cam.

Nov/December 2007

5. What are the effects of temperature rise in clutches?
6. A cycloidal cam with a central roller follower has a rise of 25 mm in cam angle of 70˚. Base circle radius is 90 mm and the follower roller radius is 20 mm. speed of rotation of the cam is 5000 rpm. Mass of the follower is 0.5 kg. Find the maximum value of the acceleration of the follower, corresponding pressure angle, stiffness of the spring used with the follower and maximum cam force. The friction between the follower and the guide may be ignored.
7. The layout a double block brake is shown in fig. the brake is rated at 250 N-m at 650 rpm. The drum diameter is 250 mm. assuming coefficient of friction to be 0.3 and for conditions of service a pV value of 1000 (kPa) m/s may be assumed.
   Determine:
   (i) Spring force 'S' required to set the brake and
   (ii) Width of shoes.

   Which shoe will have greater rate of wear and what will be the ratio of rates of wear of the two shoes.

   May/ june 2006

8. Why in automobiles, braking action when traveling in reverse is not as effective as when moving forward.
9. If a multidisc clutch has 8 discs in driving shaft and 9 discs in the driven shaft, then how many number of contact surfaces will it have?
10. A power of 20 kw is to be transmitted through a cone clutch at 500 rpm. For uniform wear condition, find the main dimensions of clutch and shaft. Also determine the axial force required to engage the clutch .assumecoeeficient of friction as 0.25 , the maximum normal pressure on the friction surface is not to eceed 0.08 MPa and take the design stress for the shaft material as 40 MPa.
    Nov/dec 2006
11. Name the different types of clutch. Why positive clutch is used?
12. How does the function of brake differ from that of a clutch?
13. A single plate clutch effective on both sides, is required to transmit 25 kw at 3000 rpm. Determine the outer and inner diameter of frictional surface if the coefficient of friction is 0.255, ratio of diameters is 1.25 and the maximum pressure is not to exceed 0.1 N/mm^2. Also determine the axial thrust to be provided by springs. Assume theory of uniform wear.
14. An engine developing 45 kw at 1000 rpm is fitted with a cone clutch built inside the fly wheel. The cone has a face angle of 12.5˚ and a maximum mean diameter of 500 mm. the coefficient of friction is 0.2. the normal pressure on the clutch face is not to exceed 0.1 N/mm^2. Determine (i) the face width required (ii) the axial spring force necessary to engage the clutch.

15. In a single block brake, the diameter of the drum is 250 mm and the angle of contact is 90˚. If the operating force of 700 N is applied at the end of lever which is at 250 mm from the centre of the brake block. The coefficient of friction between the drum and lining is 0.35. Determine the torque that may be transmitted. Fulcrum is at 200 mm from the centre of brake block with an offset 50 mm from the surface of contact.
    April/may 2008
16. State the advantage of cam over reciprocating mechanism.
17. How the uniform rate of wear assumption is valid for clutches.
18. A multi-disk clutch consists of five steel plates and four bronze plates. The inner and outer diameter of friction disks are 75 mm and 150 mm respectively. The coefficient of friction is 0.1 and the intensity of pressure is limited to 0.3 N/mm^2. Assuming uniform wear theories, calculate (i) the required operating force, and (ii) power transmitting capacity at 750 rpm.