20/06/22
Monday.

MODULE : 04

(No theory in this module)

DESIGN OF CLUTCHES AND GEAR.

CLUTCHES :- It is a mechanical device which is used to connect are discont the source of power from remaining parts of power transmission system @ the will of the operated.

clutches are classified into 3 types :-

- ✶ (+ve) clutches
- ✶ Frictional clutches
- ✶ Electromagnetic clutches

1 **(+ve) clutches :-** In these clutches power transmission is achieved by means of interlocking of Jaws (or) teeth. They main advantages is (+ve) engagement they can transmit large torque with no slip.

2. **Friction clutches :-** The friction type of clutches work on the basis of frictional forces developed b/w the surface of contact.

The type of Frictional clutch are :-

1 Single / multiplate clutch
2. Cone clutch
3. Centrifugal clutch.

Electromagnetic clutches :- In these clutches the power transmission is achieved by means of magnetic field they include magnetic particle clutches and eddy current clutches

1 **Single plate / disc clutch :-**

a. A single plate clutch consist of two flanges, one is rigidly keyed to the driving shaft while the other is connected to the driven shaft by means of splint

b. The spline prevents free moment of the driven flange w.r.t the driven shaft.

c. The face of driven flange is lined with frictional material asbestos (or) Leather.

d. The actuating force is provided by the spring which force driven flange to move towards the driving flange.

e. The Torque is transmitted b/w the driving flange and driven flanges.

Applications :-

heavy motor vehicles like trucks, buses etc.

Design procedure for single and multiplate clutches :-

STEP 1 :- Torque to be transmitted

$$M_t = \frac{9.55 \times 10^6 \times P}{n} \longrightarrow \text{(eq 3.3(a) pg 50)}$$

Diameter of shaft

$$d = \sqrt[3]{\frac{16T}{\pi \tau}} \longrightarrow \text{(eq 1.1(d) pg 2)}$$

where τ = allowable shear stress

Assume material C40 steel and FOS of 3. if its not given.

STEP 2 :- Mean Diameter (D_m) :-

Assume always UWT if they not given

* **Uniform pressure theory**

$$D_{mp} = \frac{2}{3}\left[\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right] \longrightarrow \text{(eq 13.9(c) pg 258)}$$

* **Uniform wear theory**

$$D_{mw} = \frac{1}{2}(D_o + D_i) \longrightarrow \text{(eq 13.9(c) pg 258)}$$

STEP 3 :- Axial force (F_a) :-

* **Uniform pressure theory**

$$F_{ap} = \frac{1}{4}\pi p\left(D_o^2 - D_i^2\right) \longrightarrow \text{(eq 13.9(a) pg 258)}$$

* Uniform wear Theory

$$Fa = \frac{1}{2} \pi P \times Di(Do - Di) \longrightarrow$$ (eq 13.9 (d) Pg 258)

STEP 4 :- Dimension of clutches:

$$T = \frac{1}{2} \mu\, Fa\, Dm\, n' \longrightarrow$$ (eq 13.9 (c) Pg 258) This is both for P & W Theory

where,

d_i = Inside diameter of friction surfaces

d_o = outside diameter of friction surfaces.

d_m = mean diameter of friction surfaces.

Fa = axial force

μ = Co-efficient of friction → | If they not given μ. Always assume (from table 13.4) this table.

n' = number of effective surfaces.

P = Pressure.

Problems :-

1. A Car Engine develops maximum power of 15KW @ 1000rpm. The clutch used is a single plate type of both side effective having external diameter 1.25 times of internal diameter $\mu = 0.3$ and maximum axial pressure is not to exceed $0.085 \, N/mm^2$. Determine the dimension of the friction surface and the force necessary to engage the plates. Assume uniform pressure conditions.

Given data :-

$P_{max} = 15 KW$

$n = 1000 rpm$

$D_o = 1.25 D_i$

$\mu = 0.3$

$P = 0.085 \, N/mm^2$

$n' = 2.$

STEP1 :- Torque to be transmitted

$$M_t = \frac{9.55 \times 10^6 \times P}{N}$$

$$= \frac{9.55 \times 10^6 \times 15}{1000}$$

$$\boxed{M_t = 143.25 \times 10^3 \, N\text{-}mm}$$

STEP2 :- Mean Diameter (D_m) :-

$$D_m = \frac{2}{3}\left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right) \longrightarrow (\text{eq } 13.9(c) \text{ Pg } 258)$$

$$= \frac{2}{3}\left(\frac{(1.25 d_i)^3 - D_i^3}{(1.25 d_i)^2 - D_i^2}\right)$$

$$= \frac{2}{3} \frac{D_i^3}{D_i^2}\left(\frac{1.25^3 - 1}{1.25^2 - 1}\right)$$

$$\boxed{D_m = 1.129 D_i}$$

STEP 3 :- Axial force (Fa) :-

$$Fa = \frac{1}{4}\pi P\left(Do^2 - Di^2\right) \longrightarrow \text{(eq 13.9 (a) Pg 258)}$$

$$= \frac{1}{4} \times \pi \times 0.085\left(1.25^2 di^2 - Di^2\right)$$

$$= \frac{1}{4} \times \pi \times 0.085 \times Di^2\left(1.25^2 - 1\right)$$

$$\boxed{Fa = 0.037\ Di^2}$$

STEP4 :- Dimensions of clutches.

$$T = \frac{1}{2}\mu\ Fa\ Dm\ n' \longrightarrow \text{(eq 13.9 (c) Pg 258)}$$

$$143.25 \times 10^3 = \frac{1}{2} \times 0.3 \times 0.037 Di^2 \times 1.129 Di \times 2$$

$$\boxed{Di = 2.25mm}$$

Outside diameter $Do = 1.25Di = 1.25 \times 2.25 \Rightarrow \boxed{Do = 2.80mm}$

Mean diameter $Dm = 1.129Di = 1.129 \times 2.25 \Rightarrow \boxed{Di = 2.54mm}$

Axial force $Fa = 0.037Di^2 \Rightarrow 0.037 \times (2.25)^2 \Rightarrow \boxed{Fa = 1873.12mm}$

2. A Single plate friction clutch with outside diameter of the plate are 360mm and Inside diameter of the plate are 240mm rotates @ 900rpm. The Co-efficient of friction is 0.3 and allowable pressure on the friction surface is 0.21 mPa. find the safe power that can be transmitted by clutch Assuming uniform pressure theory. & unifor wear theory.

Given data :-
$d_o = 360mm$
$d_i = 240mm$
$N = 900 rpm$
$\mu = 0.3$
$P = 0.21 MPa$
Power = ?
$n' = 2$
If they mention single plate friction considering both side surface.

STEP 1 :- Torque to be transmitted :-

$$M_t = \frac{9.55 \times 10^6 \times P}{n} \Rightarrow 1.08 \times 10^6 = \frac{9.55 \times 10^6 \times P}{900}$$

$$\boxed{P = 101.78 KW}$$

STEP 2 :- Mean Diameter (D_m)

$$D_m = \frac{2}{3}\left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right)$$

$$= \frac{2}{3}\left(\frac{(360)^3 - (240)^3}{(360)^2 - (240)^2}\right)$$

$$\boxed{D_m = 304 mm}$$

STEP 3 :- Axial force (F_a)

$$F_a = \frac{1}{4}\pi P \left(D_o^2 - D_i^2\right)$$

$$= \frac{1}{4} \times \pi \times 0.21 \times \left((360)^2 - (240)^2\right)$$

$$\boxed{F_a = 11.87 \times 10^3 N}$$

STEP 4 :- Dimensions of clutches :-

$$T = \frac{1}{2} \mu \times F_a \times D_m \times n'$$

$$= \frac{1}{2} \times 0.3 \times 11.87 \times 10^3 \times 304 \times 2$$

$$\boxed{T = 1.08 \times 10^6 N\text{-}mm}$$

Uniform wear Theory:

STEP 1:- Torque to be transmitted

$$M_t = \frac{9.55 \times 10^6 \times P}{n} \Rightarrow 855 \times 10^6 = \frac{9.55 \times 10^6 \times P}{900} \Rightarrow \boxed{P = 80.57 \text{ kW}}$$

STEP 2:- Mean Diameter (D_m):

$$D_m = \frac{1}{2}(D_o + D_i) \Rightarrow \frac{1}{2}(360 + 240) \Rightarrow \boxed{D_m = 300 \text{mm}}$$

STEP 3:- Axial force (F_a)

$$F_a = \frac{1}{2} \times \pi \times 0.21 \times 240 \, (360 - 240) \Rightarrow \boxed{F_a = 9.50 \times 10^3 N}$$

STEP 4: Dimension of clutches:-

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$$

$$= \frac{1}{2} \times 0.3 \times 9.50 \times 10^3 \times 300 \times 2$$

$$\boxed{T = 855 \times 10^3 \text{ N-mm}}$$

3. Determine the power transmitted by a single pair plate clutch. Assuming uniform pressure conditions. distribution the friction surface have outer diameter of 350mm and inside diameter of 280mm. The Co-efficient friction is 0.25 and the maximum all pressure is 0.85MPa.

Given data :-

$P = ?$

$n' = 1 \rightarrow$ (for single pair plate)

$d_o = 350mm$

$D_i = 280mm$

$\mu = 0.25$

$P = 0.85 MPa$

$N = 1000 rpm$ - (Assume)

$$D_m = \frac{2}{3}\left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right)$$

$$= \frac{2}{3}\left(\frac{(350)^3 - (280)^3}{(350)^2 - (280)^2}\right)$$

$$\boxed{D_m = 316.29 mm}$$

$$F_a = \frac{1}{4}\pi P\left(D_o^2 - D_i^2\right)$$

$$= \frac{1}{4} \times \pi \times 0.85 \times \left(350^2 - 280^2\right)$$

$$\boxed{F_a = 29440.65 N}$$

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n' \Rightarrow \frac{1}{2} \times 0.25 \times 29.44 \times 10^3 \times 316.29 \times 1$$

$$\boxed{T = 1.163 \times 10^6 N-mm}$$

$$M_t = \frac{9.55 \times 10^6 \times P}{n} = 1.163 \times 10^6 = \frac{9.55 \times 10^6 \times P}{1000} \Rightarrow \boxed{P = 121.78 KW}$$

4 Design a single plate clutch to transmitted a torque of 300N-m. The maximum friction lining is 300mm. and allowable pressure = 0.18 MPa both sides of the plate are effective.

Given data :-

$n' = 2$

$T = 300 N-m$

$= 300 \times 10^3 N-mm$

$d_o = 300mm$

$P = 0.18 MPa$

$N = 1000 rpm$.

$$D_m = \frac{1}{2}(D_o + D_i) \Longrightarrow \boxed{D_m = \frac{1}{2}(300 + D_i)}$$

$$F_a = \frac{1}{2} \times \pi \times p \times D_i (D_o - D_i)$$

$$= \frac{1}{2} \times \pi \times 0.18 \times D_i (300 - D_i)$$

$$\boxed{F_a = 0.282 \times D_i (300 - D_i)}$$

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$$

$$a^2 - b^2 = a+b \times a-b$$

$$300 \times 10^3 = \frac{1}{2} \times 0.3 \times 0.282 \times D_i (300 - D_i) \frac{1}{2}(300 + D_i) \times 2.$$

$$0.3 \times 0.28 \times \frac{1}{2}$$

$$300 \times 10^3 = 0.0423 \times D_i (300^2 - D_i^2)$$

$$300^2 \times 0.423.$$

$$300 \times 10^3 = 3807 D_i - 0.0423 D_i^3$$

On rearranging

$$0.0423 D_i^3 - 3807 D_i + 300 \times 10^3 = 0$$

$$ax^3 + bx^2 + cx + d = 0$$

On solving.

$$D_i = -333.55, \; 247.73, \; \boxed{85.82}$$

$$D_m = \frac{1}{2}(D_o + D_i) \Rightarrow \frac{1}{2}(300 - 85.82) \Rightarrow \boxed{D_m = 192.91 \text{ mm}}$$

$$F_a = 0.282 \times 85.82 \times (300 - 85.82)$$

$$\boxed{F_a = 5183.42 \text{ N}}$$

5. Design a single plate clutch with both side effective to transmit 22KW @ 2800rpm. The pressure intensity is not to exceed 0.08MPa. and surface of mean @ mean radius is not to exceed 2000 rpm. take $\mu = 0.35$ and the ratio of $\frac{d_o}{d_i} = 1.5$.

Given data :-

$n' = 2$

$P = 22KW$

$N = 2800rpm$

$P = 0.08MPa$

$n_{mean} = 2000rpm$ → (Torque should be maximum consider this only)

$\frac{d_o}{d_i} = 1.5$

$\mu = 0.35$

$$M_t = \frac{9.55 \times 10^6 \times P}{N}$$

$$= \frac{9.55 \times 10^6 \times 22}{2000}$$

$$M_t = 105.05 \times 10^3 \, N\text{-}mm$$

$$D_m = \frac{1}{2}(D_o + D_i)$$

$$= \frac{1}{2} D_i \left(\frac{D_o}{D_i} + 1\right)$$

$$= \frac{1}{2} D_i (1.5 + 1)$$

$$D_m = 1.25 D_i$$

$$F_a = \frac{1}{2} \times \pi \times P \times D_i (D_o - D_i) \Rightarrow \frac{1}{2} \pi \times P \times D_i \times D_i \left(\frac{D_o}{D_i} - 1\right)$$

$$= \frac{1}{2} \times \pi \times 0.08 \times D_i^2 (1.5 - 1)$$

$$F_a = 0.0628 D_i^2$$

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$$

$$105.05 \times 10^3 = \frac{1}{2} \times 0.35 \times 0.0628 D_i^2 \times 1.25 D_i \times 2$$

$$105.05 \times 10^3 = 0.0275 D_i^3$$

On solving inside dia of friction surface

$D_i = 15.703 mm$

$D_m = 1.25 \times 15.703 \Rightarrow D_m = 19.62 mm$

$F_a = 0.0628 \times 15.703^2 \Rightarrow F_a = 15.48 N$

$d_o = 1.5 \times 15.703 \Rightarrow d_o = 23.55 mm$

6. A single plate clutch used in automobile transmission for the following specification. power is transmitted 20KW 1500rpm to 2500rpm. friction surface is moulded asbestos on steel.

Given data :-

$n' = 2$ → Assume both effective surface

$P = 20KW$

$n_1 = 1500 rpm$ - always consider minimum speed.

$n_2 = 2500 rpm$

Friction material (moulded asbestos on steel).

(from table 13.4 pg 283)

$\mu = 0.3 \Rightarrow (0.2 - 0.5)$

Maximum pressure. always consider dry friction

$(0.34 - 0.98)$

$P = 0.5 MPa$

(Assume C40 steel for shaft material and take FOS = 3)

(Table 18 pg 464)

$\tau_y = 324$ — always do this in all problems

WKT.

$FOS = \frac{\tau_y}{\tau_{all}} \Rightarrow \tau_{all} = \frac{324}{3} \Rightarrow \tau_{all} = 108 N/mm^2$

shear stress (τ)

$$\tau = \frac{\tau_{all}}{2} \Rightarrow \frac{108}{2} \Rightarrow \boxed{\tau = 54 \text{ MPa}}$$

STEP1 : Torque to be transmitted

$$M_t = \frac{9.55 \times 10^6 \times P}{n} \Rightarrow \frac{9.55 \times 10^6 \times 20}{1500} \Rightarrow \boxed{M_t = 127.33 \times 10^3 \text{ N-mm}}$$

STEP2 :- Diameter of the shaft (d)

$$d = \sqrt[3]{\frac{16T}{\pi \tau}}$$

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

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

$$d = \sqrt[3]{\frac{16T}{\pi \tau}}$$

$$d = \sqrt[3]{\frac{16 \times 127.33 \times 10^3}{\pi \times 54}}$$

$$\boxed{d = 22.9 \text{ mm}}$$

(from table 3.5 (a) standard size in mm)

standard dia $\boxed{d = 25 \text{ mm}}$.

STEP3 : Considering uniform wear condition.

$$D_m = \frac{1}{2}(D_o + D_i)$$ inside dia of friction surface

$$D_i = 4d = 4 \times 25 \Rightarrow \boxed{D_i = 100 \text{ mm}}$$

$$\boxed{D_m = \frac{1}{2}(D_o + 100)}$$

STEP4 : Axial force (F_a) :

$$F_a = \frac{1}{2} \pi P D_i (D_o - D_i)$$

$$= \frac{1}{2} \times \pi \times 0.5 \times 100 (D_o - 100)$$

$$\boxed{F_a = 78.53 (D_o - 100)}$$

STEP 5 :- Also T in general.

$$T = \frac{1}{2} \mu F_a D_m n'$$

$$127.33 \times 10^3 = \frac{1}{2} \times 0.3 \times 78.58 (D_0 - 100) \frac{1}{2} (D_0 + 600) \times 2$$

$$127.33 \times 10^3 = 11.77 (D_0^2 - 100^2)$$

$$\boxed{D_0 = 144.28 mm}$$

STEP 6 :- Dimensions :

$$D_m = \frac{1}{2} (D_0 + 100) = \frac{1}{2} (144.28 + 100) \Rightarrow \boxed{D_m = 122.14 mm}$$

$$F_a = 78.58 (D_0 - 100) \Rightarrow \boxed{F_a = 3.477 \times 10^3 N}$$

Multi plate Clutch.

23/09/22
Thursday

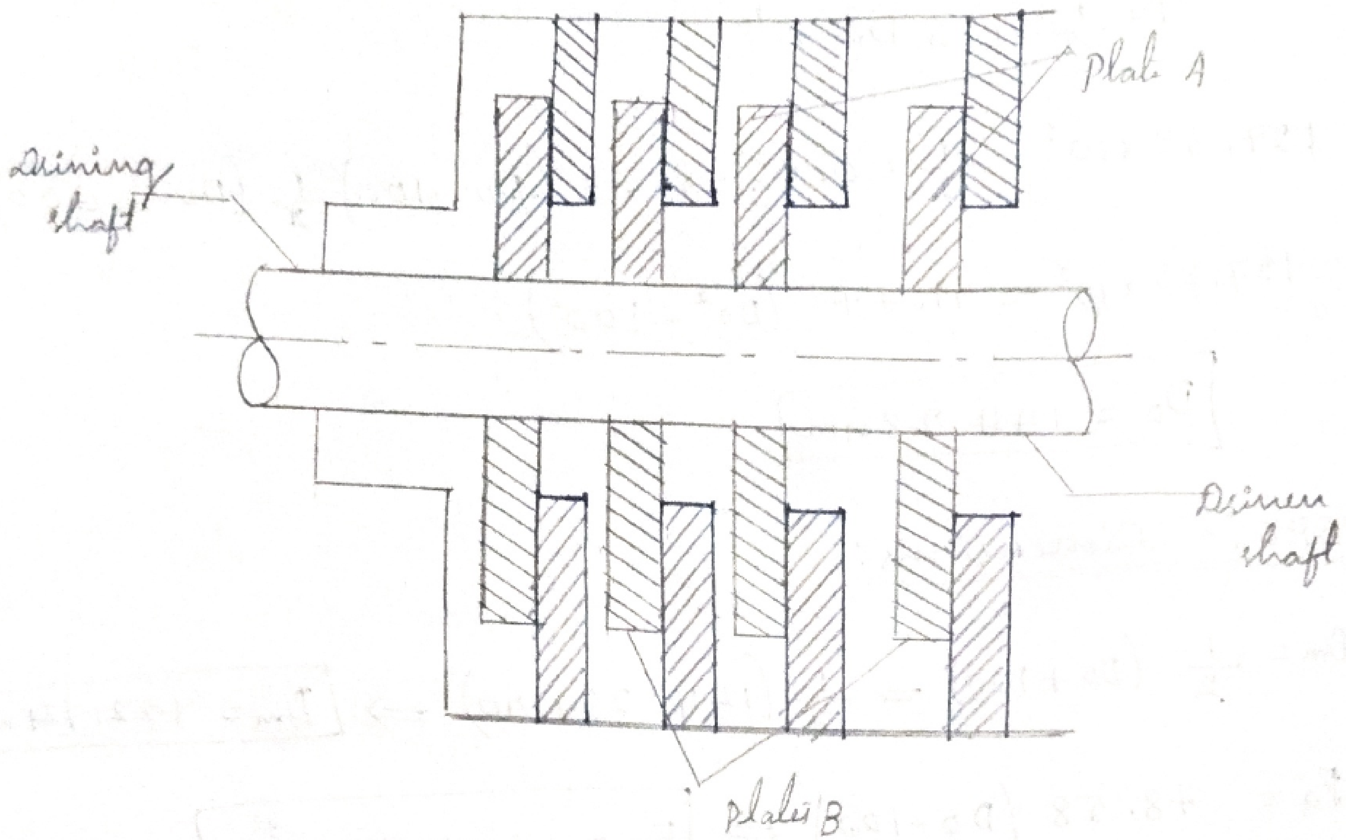

Figure shows the line diagram of multi plate clutch. The plates shown as 'A' are made of steel and are mounted on driven shaft by splines to permit axial motion. Plate B are made of bronze are mounted on the driving shaft. These are used where a large amount of torque has to be transmitted.

Applications :-

* Machine tool and light motor vehicles such as scooters.

NOTE :-

* In multi plate clutch the number of friction surface (n')

$$\boxed{n' = n_1' + n_2' - 1}$$

where, $n_1' =$ No of disc on driving shaft $= \frac{n}{2}$.

$n_2' =$ No of disc on driven shaft $= \frac{n'}{2} + 1$

* $n_2' > n_1'$
* Total Number of disc $= n_1' + n_2' = n' + 1$

Design procedure for multi plate clutches:-

The procedure is same as single plate clutch.

Problems :-

1. A multi-plate disc clutch has 5 plates having 4 pair of active friction surfaces. If the intensity pressure is not to exceed 0.127 MPa. find the power transmitted. @ 500 rpm. The outer and inner radii of friction surface are 125 mm. and 75 mm. respectively. Assume uniform wear conditions. and take co-eff of friction as 0.3.

Given data :

$n_1' + n_2' = 5$

$n' = 4$ (No of eff surface)

$P = ?$

$N = 500$ rpm

$r_i = 75$ mm

$r_o = 125$ mm

$\mu = 0.3$

$p = 0.127$ MPa

$D_i = 2 \times R_i \Rightarrow 2 \times 75 \Rightarrow \boxed{D_i = 150\text{mm}}$

$D_o = 2 \times R_o \Rightarrow 2 \times 125 \Rightarrow \boxed{D_o = 250\text{mm}}$

$$M_t = \frac{9.55 \times 10^6 \times P}{N}$$

$$\boxed{M_t = \frac{9.55 \times 10^6 \times P}{500}}$$

STEP 2 :- Mean Diameter (D_m) :-

$$D_m = \frac{(D_o + D_i)}{2} = \frac{(250 + 150)}{2} \Rightarrow \boxed{D_m = 200mm}$$

STEP 3: Axial force (F_a) :

$$F_a = \frac{1}{2} \pi \times p \times D_i (D_o - D_i)$$

$$= \frac{1}{2} \times \pi \times 0.127 \times 150 (250 - 150)$$

$$\boxed{F_a = 2992.36N}$$

STEP 4 :- Dimensions :-

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$$

$$= \frac{1}{2} \times 0.3 \times 2992.36 \times 200 \times 4$$

$$\boxed{T = 359.08 \times 10^3 N\text{-}mm}$$

$$M_t = \frac{9.55 \times 10^6 \times P}{N} \Rightarrow 359.08 \times 10^3 = \frac{9.55 \times 10^6 \times P}{500}$$

$$\boxed{P = 18.8kW}$$

2. A multi plate clutches has steel on bronze is to transmit 8KW @ 1440rpm. The Inner diameter of the Contact is 80mm and outer diameter of Contact is 140mm. The clutches operates in oil with expected co-efficient of friction of 0.1. The angular allowable pressure is 0.35mPa. Assume uniform wear theory and determine the following

1. No of steel and bronze plates. $n_1' + n_2'$
2. Axial force required. F_a
3. actual maximum pressure. P_{max}

Given data :-

$P = 8 kW$

$N = 1440 rpm$

$D_i = 80 mm$

$D_o = 140 mm$

$\mu = 0.1$

$P = 0.35 MPa$

$$M_t = \frac{9.55 \times 10^6 \times P}{N}$$

$$= \frac{9.55 \times 10^6 \times 8}{1440}$$

$$\boxed{M_t = 53.05 \times 10^3 N\text{-}mm}$$

$$D_m = \frac{(D_o + D_i)}{2} = \frac{(140+80)}{2} \Rightarrow \boxed{D_m = 110 mm}$$

$$F_a = \frac{1}{2} \pi P D_i (D_o - D_i) \Rightarrow \frac{1}{2} \times \pi \times 0.35 \times 80 (140-80)$$

$$\boxed{F_a = 2638.93 N}$$

$$T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$$

$$53.05 \times 10^3 = \frac{1}{2} \times 0.1 \times 2638.93 \times 110 \times n'$$

$$\boxed{n' = 3.79 \simeq 4}$$ — take next even no

i) No of disc on driving shaft $\frac{n'}{2} = \frac{4}{2} = \frac{2}{1}$

No of disc on driven shaft $\frac{n'}{2} + 1 = \frac{4}{2} + 1 = \frac{3}{1}$.

iii) $T = \frac{1}{2} \times \mu \times F_a \times D_m \times n'$

$$53.05 \times 10^3 = \frac{1}{2} \times 0.1 \times F_a \times 110 \times 4$$

$$\boxed{F_a = 2411.36 N}$$

iii) Pnom :- ?

$$T = \frac{\pi}{8} \times \mu \times n' \times P_{nom} \times D_i \left(D_o^2 - D_i^2\right) \longrightarrow \text{(eq 13.9 (f) pg 259)}$$

$$53.05 \times 10^3 = \frac{\pi}{8} \times 0.1 \times 4 \times P_{nom} \times 80\left(140^2 - 80^2\right)$$

$$\boxed{P_{nom} = 0.3198 \text{ MPa}}$$