(4) A friction clutch is used to rotate a machine from a shaft rotating at a uniform speed of 250 rpm. The disc type clutch has both of its sides effective, the co-efficient of friction being 0.3. The outer and inner diameters of the friction plate are 200 and 120 mm respectively. Assuming uniform wear of the clutch, the intensity of pressure is not to exceed 100 kN/m². If the Moment of Inertia of the rotating parts of the machine is 6.5 kg-m², determine the time to attain the full speed by the Machine and the energy lost in slipping of the clutch.

What will be the intensity of Pressure, If the condition of uniform pressure of the clutch is considered? Also determine the ratio of power transmitted with uniform wear to that with uniform pressure? [Single Plate clutch Problem].

Given Data:-

$N = 250$ rpm, $n = 2$, $\mu = 0.3$, $d_1 = 200$ mm, $r_1 = 100$ mm (or) 0.1 m.

$d_2 = 120$ mm $r_2 = 60$ mm.

$P_{max} = 100$ kN/m² $I = 6.5$ kg-m²

Solution:-

i) The Time to attain the full speed by the Machine (with uniform wear):-

$P_{max} \cdot r_2 = C$ (or) $C = 100 \times 10^3 \times 60 \times 10^{-3}$

6000 N/m

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

$W = 2\pi \times 6000 (100 \times 10^{-3} - 60 \times 10^{-3})$

$\Rightarrow 1507.96$ N.

$T \Rightarrow n \cdot \mu \cdot W \left(\frac{r_1 + r_2}{2}\right)$

$\Rightarrow 2 \times 0.3 \times 1507.96 \times \left(\frac{100 \times 10^{-3} + 60 \times 10^{-3}}{2}\right)$

$\Rightarrow 72.38$ N-m.

Power Transmitted $P = \frac{2\pi N T}{60} \Rightarrow 1895$ W.

$T = I\alpha$, $\alpha \rightarrow$ is angular Acceleration

$72.38 = 6.5 \times \alpha$ (or) $\alpha = 11.135$ rad/sec^2.

$\alpha = \frac{\omega}{t} = 11.135$.

$\left(\frac{2\pi N}{60}\right) \times \frac{1}{t} = 11.135$

$t = 2.35$ sec

ii) The Energy lost in slipping of the clutch :-

Angle turned by the driving shaft, $\theta_1 = \omega t = \frac{2\pi N}{60} \times t$

$\Rightarrow \frac{2\pi \times 250}{60} \times 2.35$

$\Rightarrow 61.52$ rad.

$\theta_2 = \omega_0 t + \frac{1}{2} \alpha t^2$

$\Rightarrow 0 + \frac{1}{2} \times 11.135 \times (2.35)^2 = 30.75$ rad

Energy lost in friction $= T(\theta_1 - \theta_2)$

$\Rightarrow 72.38 \times (61.52 - 30.75)$

$\Rightarrow 2226$ N-m.

iii)

Intensity of Pressure, $P = \frac{W}{\pi(r_1^2 - r_2^2)}$

$\Rightarrow \frac{1507.96}{\pi\left[(100 \times 10^{-3})^2 - (60 \times 10^{-3})^2\right]}$

$\Rightarrow 75000$ N/m^2 (or) 75 kN/m^2

iv) Ratio of Power Transmitted with uniform wear to that with uniform Pressure:

Power Transmitted with uniform wear } = 1895 W.

Torque Transmitted with uniform pressure } $= n \cdot \mu \cdot W \cdot \frac{2}{3}\left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$

$$\boxed{T \Rightarrow 73.89\ N\text{-}m.}$$

$$P = \frac{2\pi NT}{60}$$

$$\Rightarrow \frac{2\pi \times 250 \times 73.89}{60}$$

$$\boxed{\Rightarrow 1934\ W}$$

$$\frac{\text{Power Transmitted with uniform wear}}{\text{Power Transmitted with uniform pressure}} = \frac{1895}{1934}$$

$$\boxed{\Rightarrow 0.98}$$

Multiplate clutch Problem :-

A Multiplate disc clutch transmits 55 kW of power at 1800 rpm. coefficient of friction surfaces is 0.1. Axial intensity at Pressure is not to exceed $160\ kN/m^2$. The internal radius is 80mm and is 0.7 times the external radius. Find the no. of plates needed to transmit the required Torque.

Given Data:

$P = 55\ kW = 55 \times 10^3\ W$, $N = 1800$ rpm, $\mu = 0.1$

$P_{max} = 160\ kN/m^2$

$r_2 = 80\ mm = 80 \times 10^{-3}\ m$. $r_2 = 0.7 r_1$

To find:

Number of Plates needed to transmit the required torque

Solution:

$$r_2 = 0.7 r_1 \quad (\text{or}) \quad \frac{r_2}{r_1} = 0.7$$

$$r_1 = \frac{r_2}{0.7} = \frac{80 \times 10^{-3}}{0.7} = 0.1143 \text{ m.}$$

Assuming uniform wear, axial force exerted is given by,

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

$$P_{max} \cdot r_2 = C \quad (\text{or})$$

$$C = 160 \times 10^3 \times 80 \times 10^{-3}$$

$$\Rightarrow 12800 \text{ N/m.}$$

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

$$\Rightarrow 2\pi \times 12800 (0.1143 - 0.08) = 2758.57 \text{ N.}$$

$$T = \mu \cdot W \cdot \frac{(r_1 + r_2)}{2}$$

$$\Rightarrow 0.1 \times 2758.57 \times \frac{(0.1143 + 0.08)}{2}$$

Torque required per surface $T = 26.8$ N-m.

$$\text{Power, } P = \frac{2\pi N T}{60}$$

$$55 \times 10^3 = \frac{2\pi \times 1800 \times T}{60}$$

$$\boxed{T \Rightarrow 291.78 \text{ N-m.}}$$

Number of friction surfaces required $\Rightarrow \dfrac{\text{Total Torque required}}{\text{Total required per surface}}$

$$\Rightarrow \frac{291.78}{26.8} \Rightarrow 10.887$$

$$\boxed{\Rightarrow 11}$$

Total no. of plates $\Rightarrow$ Number of contact surface + 1

$$\Rightarrow 11 + 1 \boxed{\Rightarrow 12 \text{ surfaces}}$$

Hence, there will be 12 total plates, in which driving and driven shafts having six plates each