Friction Devices

Q. 5.1. (a) Define brake.

Ans. A brake is a device used for retarding or stopping the motion of a body. When we apply brakes a frictional resistance acts on the body the kinetic energy of the body is dissipated in the form of heat.

Q. 5.1. (b) Define dynamometer.

Ans. A dynamometer is a device for measuring the mechanical power developed by a machine. Dynamometer applies the frictional resistance and has an arrangement to measure the resistance applied. By knowing the resistance applied the power can be calculated.

Q. 5.1. (c) Classify mechanical brakes.

Ans.

Q. 5.1 (d) What is self-energizing brake?

Ans. A brake in which the force of friction assists the applied force in applying the brakes is called self energizing brake.

Q. 5.1 (e) What is self locking brake?

Ans. If after once applying brake no force is required to keep the brake in applied condition, the brake is called self-locking brake.
Q. 5.2 (a) Differentiate between absorption dynamometer and transmission dynamometer.

Ans. In absorption dynamometer, the power to be measured is absorbed in doing work against the frictional resistance applied and is dissipated in the form of heat.
A transmission dynamometer measures the power which is being transmitted. The power being measured is not dissipated in the form of heat; the power while being transmitted from steam turbine to the ship impeller can be measured by transmission dynamometer.

Q. 5.2. (b) Explain Prony brake dynamometer with the help of a sketch.

Ans.

![Prony Brake Dynamometer Diagram](image)

Prony brake dynamometer consists of two wooden blocks which can be clamped with the help of nuts.
One block has arm L to the end of which a dead-weight W is suspended. The balancing weight B can be slid on arm A in balance, the brake when unloaded.
For counter-clockwise rotation of the drum, the arm L will float between the stops s1 & s2 with a weight W suspended from it.
The torque on the brake drum is Wl and, knowing the speed of rotation of the drum, the power can be calculated.

Q. 5.3. Explain belt transmission dynamometer with the help of a sketch.

Ans.
In this dynamometer a endless belt passes from the driving pulley A over the intermediate pulleys C & C1 to the driven pulley D. The pulleys C & C1 are free to rotate on the pins fixed to the lever L, which, in turn, pivots about the fulcrum E on the fixed frame. The total downward forces on the pins of pulleys C & C1 are 2T1 & 2T2 respectively. They apply a moment (2T1-2T2) x a on the lever L in the counter clockwise direction. This moment is balanced by suspending a dead weight W from the lever.

At equilibrium, \(2(T_1-T_2) a = Wl\)

or \[T_1-T_2 = \frac{Wl}{2a}\]

If \(v\) is belt speed, the power \(P\) can be calculated as

\[P = (T_1-T_2) v\]

Q. 5.4. In a belt transmission dynamometer the diameter of driving pulley is 750 mm and that of driven pulley is 250 mm. The driving pulley rotates at 400 rpm. The dead weight suspended is 318 N at 800 mm from the fulcrum of the lever. Calculate the power being transmitted.

Ans. Refer to Fig. 5.12
Q. 5.5. Write the principle of the torsion dynamometer.

Ans When a shaft transmits power it gets slightly twisted By measuring the angle of twist and applying the torsion equation, the torque transmitted by shaft is calculated Torque multiplied by angular speed of shaft is equal to the power transmitted.

Q. 5.6 If the angle of twist measured is 1.5° over the 15m length of propeller shaft whose internal and external diameters are 200mm & 300mm respectively: Calculate the torque being transmitted if the modulus of rigidity of shaft material is 80 GPa.
Ans. Length of Shaft, \( l = 15 \text{ m} \)

\[
\text{Angle of twist, } \theta = 1.5^\circ = \frac{1.5 \times \pi}{180} = 0.0262 \text{ radian.}
\]

Modulus of rigidity, \( C = 80 \text{ GPa} \)

\[
= 80 \times 10^9 \text{ N/m}^2
\]

Polar moment of inertia = \[
\frac{\pi}{2} (R^4 - r^4)
\]

\[
= \frac{\pi}{2} (0.15^4 - 0.1^4)
\]

\[
= 6.38 \times 10^{-4} \text{ m}^4
\]

By torsion equation:

\[
\frac{T}{J} = \frac{C\theta}{l}
\]

\[
\therefore T = \frac{80 \times 10^9 \times 0.0262 \times 6.38 \times 10^{-4}}{15}
\]

\[
= 89095 \text{ Nm Ans.}
\]

SECTION—C

Q. 5.7 Derive an expression for the braking torque applied by a single block or shoe brake.
Ans.

Fig. 5.3

\[ r = \text{radius of drum} \]
\[ \mu = \text{coeff. of friction between drum of block} \]
\[ P = \text{force applied at the end of lever} \]
\[ R = \text{normal reaction by drum on block} \]
\[ F = \text{frictional force by shoe on drum & vice-versa. It is equal to } \mu R \]
\[ O = \text{fulcrum of the lever} \]
\[ s = \text{distance of shoe from fulcrum.} \]
\[ l = \text{distance of } P \text{ from fulcrum.} \]

The force of friction on drum will be opposite to the motion & therefore the force of friction on shoe is in direction of motion of drum.

Fig. 5.4

Taking moments about \( O \):
\[ P \times l + F \times a = Rs \] \hfill (i)
\[ \text{or} \]
\[ P \times l + \mu R \times a = Rs \] \hfill (ii)

\[ R = \frac{P \times l}{s - \mu a} \]

\[ F = \mu R = \frac{\mu Pl}{s - \mu a} \]

Brake torque \( F \times r = \frac{\mu Pr}{s - \mu a} \)
Note (a): From equation (i), we see that moment $F_a$ gets added to moment $P_x$ of the applied force. Thus the frictional force helps the applied force in applying the brake. Such type of brake is called self energizing brake.

Note (b): From equation (ii), $P = R(s - \sin \theta)$, therefore if $s$ ha, no force will be required to keep the brake applied. This type of brake is called self locking brake.

Note (c): In the above equations $t'$ will have to be used in place of $j.t$ if the angle $2\theta$ subtended by the shoe is $> 400$.

$$\mu' = 4\mu \left[ \frac{\sin \theta}{20 + \sin 2\theta} \right]$$

Q. 5.8. For the block brake shown in fig. 5.3, find the brake torque if $r = 125$ mm, $2\theta = 90^\circ$, $P = 350$ N, $\mu = 0.35$, $l = 450$ mm, $s = 200$ mm, $a = 50$ mm.

Ans.

$$\mu' = 4 \times 0.35 \left[ \frac{\sin 45^\circ}{\frac{\pi}{2} + \sin 90^\circ} \right] = 0.385$$

Taking moments about O:

$$350 \times 450 + F \times 50 = R \times 200 = \frac{F}{0.385} \times 200 = 520 F$$

$$\therefore \quad F = \frac{350 \times 450}{470} = 335 \text{ N}$$

But Brake torque $= F \times r$

$$\therefore \quad T = 335 \times 0.125$$

$$= 41.875 \text{ Nm Ans.}$$

Q. 5.9 A bicycle and rider travelling at 12 knVhr on a level ground have a mass of 105 kg. A brake is applied to the rear wheel which is 800 mm in diameter. The pressure applied on the brake is 80 N and the coefficient of friction 0.06. Find the distance covered by the bicycle and the number of turns of its wheel before the cycle comes to rest

Ans. Normal reaction, $R = 80$ N

$p = 0.06$
Q. 5.10. Derive an expression for the brake torque in case of simple band brake.

Ans. A band brake has a leather band, or steel band lined with friction material. The band embraces a part of the circumference of the brake drum. In simple band brake, one end of the band is attached to the fulcrum of the lever and the other end is attached to lever.

Frictional force, \( F = \mu R \)
\[ = 0.06 \times 80 \]
\[ = 4.8 \text{ N} \]

Initial velocity \( u = 12 \times \frac{1000}{3600} = \frac{10}{3} \text{ m/s} \)

Let \( S \) is the distance covered.

But work done against frictional force = decrease in K.E

\[
F \times S = \frac{1}{2} m(u^2 - 0^2)
\]

\[
S = \frac{1}{2} \times \frac{105}{4.8} \left( \frac{10}{3} \right)^2 = 121.5 \text{ m Ans.}
\]

But

\[
S = 2\pi r \times \text{no. of revolution.}
\]

\[
\therefore \quad n = \frac{121.5}{2\pi \times 0.4} = 48.3 \text{ rev. Ans.}
\]
Let $T_1$ & $T_2$ = tensions in band
0 = angle of lap
$\mu$ = coeff. of friction
$r$ = radius of brake drum
$P$ = force applied on the lever end to apply brakes.
$l$ = distance of $F$ from the fulcrum of the lever = OF
$B$ = pin on lever to which one end of band is attached

$\therefore \frac{T_1}{T_2} = e^{\mu \theta}$

Now taking the moments about O of the forces acting on the lever.
$T_2 \times b = P \times l$
$T_2 = \frac{P l}{b}$

Brake torque = $(T_1 - T_2) \times r$
$= T_2 \left( e^{\mu \theta} - 1 \right) \times r$

Brake torque $= \frac{P l}{b} \left( e^{\mu \theta} - 1 \right) \times r$

If the direction of rotation is clockwise, the right hand side of the band becomes tight side i.e. $T_2 \geq T_1$.

$\therefore \frac{T_2}{T_1} = e^{\mu \theta}$

Brake torque $= (T_2 - T_1) \times r$
$= T_2 \left( 1 - \frac{T_1}{T_2} \right) \times r$

Brake torque $= \frac{P l}{b} \left( 1 - \frac{1}{e^{\mu \theta}} \right) \times r$

Simple band brake can neither be a self-energising brake nor be self-locking brake.
Q. 5.11. A simple band brake is operated by a lever of length 500 mm. The brake drum has a diameter of 500 mm and the brake band embraces of the circumference. One end of the band is attached to the fulcrum of the lever while the other end is attached to a pin on the lever 100 mm from the fulcrum. If the effort is applied to the end of the lever is 2000 N and the coefficient of friction is 0.25, find the maximum braking torque on the drum.

**Ans.** Refer to Fig. 5.3
Considering the forces on the lever and taking their moment about O.

\[ T_2 \times b = F \times l \]

\[ \therefore \quad T_2 = \frac{F \times l}{b} = \frac{2000 \times 500}{100} = 10,000 \text{ N} \]

Now,

\[ \frac{T_1}{T_2} = \omega^2 \text{ where } \omega = \frac{5}{8} \times 2\pi \]

\[ \therefore \quad \frac{T_1}{T_2} = \varphi^{0.25 \times 1.25\pi} = 2.67 \]

\[ T_1 = 2.67 \times 10,000 = 26700 \text{ N} \]

Brake torque = \((T_1 - T_2) r = (26700 - 10000) \times 250 \text{ Nmm} = 4175 \text{ Nm} \textbf{Ans.} \]

Q. 5.12. With the help of diagram explain differential band brake and derive an expression for brake torque.

**Ans.** In differential band brake the two ends of the band are attached to the two pins A & B, one on either side of the fulcrum 0 of the lever as shown in the Fig. 5.4
The brake is self-energising because the moment of 12 helps the moment of applied force F as is clear from equation (i).

Q. 5.13. Differentiate between a simple band brake and differential band brake.

Ans. (i) In simple band brake the fulcrum is at one end of lever.
In differential band brake the fulcrum is between the two ends of the lever.
(ii) Simple band brake is not self-energising but differential band brake always is.
(iii) Simple band brake is not self-locking where as the differential band brake can
Q. 5.14 (a) If for the band brake shown in fig. 5.5, \(a = 25\) mm, \(b = 100\) mm, \(l = 1\) m, \(F = 500\) N acting upward, \(\mu = 0.25\), \(\theta = 240^\circ\), drum diameter 0.75m. Calculate the brake torque for (i) anticlockwise direction (ii) clockwise rotation of the drum.

(b) Calculate the brake torque for both directions of rotation if \(F\) is applied in downward direction.

**Ans. (a)**

\[
\begin{align*}
& r = \frac{0.75}{2} = 0.375\ m \\
& \mu\theta = 0.25 \times \frac{\pi}{180} \times 240 = \frac{\pi}{3}\ radians.
\end{align*}
\]

for the design to be on safer side.

Fig. 5.7

\[
\frac{\text{Tension in tight side}}{\text{Tension in slack side}} = e^{\mu\theta} = e^{\frac{\pi}{3}} = 2.85
\]
Taking moments about O:
\[ T_2 \times b = T_1 \times a + F \times l \]  
(i) Anticlockwise rotation: \( T_2 < T_1 \)
\[ \frac{T_1}{T_2} = e^{\theta} = 2.85 \]

Putting in (i):
\[ T_2 \times 100 = 2.85 \times T_2 \times 25 + 500 \times 1000 \]
\[ T_2 = \frac{500 \times 1000}{100 - 2.85 \times 25} = 17376 \text{ N.} \]
\[ T_1 = 49504 \text{ N. i.e. } 17376 \times 2.85 \]
Brake torque = \((49504 - 17376) \times 0.375 \)
\[ = 12408 \text{ Nm} \]

(ii) Clockwise rotation of brake drum: \( T_2 > T_1 \)
\[ \frac{T_2}{T_1} = e^{\theta} = 2.85 \]
Putting in (i):
\[ 2.85 \times T_1 \times 100 = T_1 \times 25 + 500 \times 1000 \]
\[ T_1 = \frac{20 \times 1000}{2.85 \times 4 - 1} = \frac{20000}{11.4 - 1} \]
\[ = 1923.1 \text{ N} \]

Brake torque, \((T_2 - T_1) r = (2.85 - 1) \times 1923.1 \times 0.375 \)
\[ = 1334 \text{ Nm. Ans.} \]

(b) If \( F \) is applied downward at end C of the lever, the downward movement of pin B will be greater than the upward moment of pin A, therefore the band will move away from the drum and thus no brake torque will act on the drum.

Q. 5.15. What is the difference between a brake and a dynamometer?

**Ans.** A dynamometer is used for measuring the power developed by a machine and therefore has the arrangement to measure the resistant applied to the motion of the machine. It is not used to slow down or stop the machine.

A brake is used to slow down or stop the motion of a body. It need not have any measuring arrangement to know the resistance applied to the motion of the body.

Q.5.16 Derive an expression for the retardation produced when the brakes are applied to the rear wheels of a vehicle going up inclined road.
Ans.

Let

\( W \) = weight of the vehicle

\( = mg \), where \( m \) is vehicle mass.

\( \alpha \) = Angle of inclination of road with horizontal.

\( G \) = centre of gravity of the vehicle.

\( f \) = longitudinal distance of \( G \) from front axle.

\( r \) = longitudinal distance of \( G \) from rear axle.

\( l \) = wheel base = \( r + f \)

\( h \) = height of \( G \) from road.

\( a \) = retardation produced due to brakes.

\( ma \) = inertia force, it acts in forward direction.
Q. 5.17. Derive an expression for the retardation produced when the brakes are applied to the front wheels of a vehicle moving up an inclined road.
The various terms are same as in the preceding question.

\( F = \) Friction force on front wheels when the brakes are applied to front wheels.

\[
= \mu \times R_f
\]

Considering the forces parallel to the road:

\[
ma = W \sin \alpha + F_f = W \sin \alpha + \mu \times R_f
\]

... (i)

Taking moments about the line of contact of rear wheels with road:

\[
R_f \times l = (ma - W \sin \alpha) h + W \cos \alpha \times r
\]

... (ii)

From (i) & (ii),

\[
R_f \times l = (\mu R_f) \times l + W \cos \alpha \times r
\]

\[
R_f = \frac{mg \cos \alpha \times \left[ \frac{r}{l - \mu h} \right]}{l - \mu h}
\]

\[
R_f = \frac{mg \cos \alpha \times \left[ \frac{f - \mu h}{l - \mu h} \right]}{l - \mu h}
\]

Putting the value in (i):

\[
ma : mg \sin \alpha + \mu mg \cos \alpha \times \left[ \frac{r}{l - \mu h} \right]
\]

\[
a = g \sin \alpha + \mu g \cos \alpha \times \frac{r}{l - \mu h}
\]
Q.5.18 Derive an expression for the retardation produced when brakes are applied to all the four wheels of a vehicle moving up an inclined plane.

Ans.

The various terms are same as in the preceding two questions. Considering the forces normal to the road:

\[ R_y + R_r = W \cos \alpha = mg \cos \alpha \]  
\[ \ldots(i) \]

Considering the forces parallel to the road:

\[ ma = W \sin \alpha + F_f + F_r = mg \sin \alpha + \mu x R_f + \mu x R_r \]  
\[ \ldots(ii) \]

From (i) & (ii)

\[ ma = mg \sin \alpha + \mu (mg \cos \alpha) \]

\[ a = g \sin \alpha + \mu g \cos \alpha \]

To find \( R_f \) we take the moments about the line of contact of the rear wheels:

\[ R_f x l = W \cos \alpha x r + (ma - W \sin \alpha) x h \]  
\[ \ldots(iii) \]

From (ii) & (iii)

\[ R_f x l = mg \cos \alpha x r + \mu (R_f + R_r) x h \]

But

\[ R_y + R_r = mg \cos \alpha \]

\[ \therefore \]

\[ R_f x l = mg \cos \alpha x r + \mu (mg \cos \alpha) x h \]

\[ \frac{R_f}{l} = mg \cos \alpha \left( \frac{r + \mu h}{l} \right) \]

and \[ \therefore \]

\[ R_r = mg \cos \alpha \left( \frac{f - \mu h}{l} \right) \]

Q.5.19 A vehicle moving on a rough plane inclined at 100 with the horizontal at a speed of 36 kn/h has a wheel base 1.8 m. The centre of gravity of the vehicle is 0.8 m from the rear axle and 0.9 m above the inclined, plane. Find the distance travelled by
the vehicle before connected to rest and the time taken to do so then the vehicle moves up the plane.
The brakes are applied to all the four wheels and the coefficient of friction is 0.5.

**Ans.**

\[ u = \frac{36 \times 1000}{3600} = 10 \text{ m/s} \]

\[ \alpha = 10^\circ \]

\[ \mu = 0.5 \]

When the vehicle is moving up the plane, and the brakes are applied to all the four wheels:

\[ ma = mg \sin \alpha + \mu mg \cos \alpha \]

\[ n = g (\sin \alpha + \mu \cos \alpha) = 9.81 (\sin 10 + 0.5 \cos 10) \]

\[ = 6.53 \text{ m/s}^2 \text{ retardation} \]

\[ v^2 - u^2 = 2aS \]

\[ 0^2 - 10^2 = 2 (-6.53) \times S \]

\[ \therefore \]

\[ S = \frac{100}{2 \times 6.53} = 7.66 \text{ m} \text{ Ans.} \]

Also

\[ v = u + at \]

\[ 0 = 10 + (-6.53) \times t \]

\[ \therefore \]

\[ t = \frac{10}{6.53} = 1.53 \text{ s} \text{ Ans.} \]

Q. 5.20. Derive an expression for tension ratio in band & block brake.

**Ans.**

Fig 5.11 should the bind and block brake which consists of a number of wooden blocks fixed to the inside surface of the band. When the force F is applied downward at the end of lever the blocks get pressed against the rotating drum.

Let, T0 tension in the slack side of band
T tension in the tight side of band
T1 tension in the band after first block
coefficient of friction.
R normal reaction on the block by the drum.
θ angle subtended by a block at the centre of the drum.
i = number of blocks.
The forces on block first are as shown in (h). For equilibrium:

\[
\begin{align*}
T_1 \cos \theta &= T_0 \cos \theta + \mu R \\
(T_1 - T_0) \cos \theta &= \mu R \\
T_1 \sin \theta + T_0 \sin \theta &= R \\
\frac{T_1 - T_0}{T_1 + T_0} &= \frac{\mu \tan \theta}{1} \\
\frac{2T_1}{2T_0} &= \frac{1 + \mu \tan \theta}{1 - \mu \tan \theta} \\
\frac{T_1}{T_0} &= \frac{1 + \mu \tan \theta}{1 - \mu \tan \theta} \\
\text{Similarly} \quad \frac{T_2}{T_1} &= \frac{1 + \mu \tan \theta}{1 - \mu \tan \theta} \\
\text{But,} \quad \frac{T_2}{T_0} &= \frac{T_1 \times T_2}{T_0 \times T_1} \\
&= \left( \frac{1 + \mu \tan \theta}{1 - \mu \tan \theta} \right)^2 \\
\text{Similarly} \quad \frac{T_{ii}}{T_0} &= \left( \frac{1 + \mu \tan \theta}{1 - \mu \tan \theta} \right)\omega
\end{align*}
\]

Q. 5.21 Derive an expression for the friction moment of a collar thrust bearing.

Ans.
Let

\[ r = \text{internal radius of collar} \]
\[ R = \text{external radius of collar} \]
\[ p = \text{pressure intensity at radius } y \]
\[ W = \text{axial load} \]

Consider an elemental ring of radius \( y \) and width \( \delta y \). Area of ring = \( 2\pi y \delta y \)

Normal reaction on ring = \( p \cdot 2\pi y \delta y \)

Total normal force = \( W = \int_r^b p2\pi y \delta y \) \( \quad \ldots(i) \)

\[ \delta F = \text{Frictional force on ring} = \mu \times p \cdot 2\pi y \delta y \]

\[ \delta T = \text{Moment of friction ring} = \mu p 2\pi y \delta y \times y \ i.e. \ \delta F \times y \]

\( T = \text{Total friction moment on the whole collar} \)
Q. 5.22. Which of the two assumptions—uniform intensity of pressure or uniform rate of wear—would you make of in designing friction Dutch and why?

\[ \mu \cdot 2 \pi \int_{r}^{R} y^2 \, dy = \frac{\mu}{2^2} \pi \left( R^3 - r^3 \right) \quad \text{...(ii)} \]

(a) Assuming uniform pressure i.e. \( p = \text{constant} \):

\[ W = p \cdot 2\pi \left[ \frac{y^2}{2} \right]_{r}^{R} \quad \text{... from (i)} \]

\[ W = p \cdot \pi \left( R^2 - r^2 \right) \quad \text{... (iii)} \]

\[ T = \mu \cdot 2\pi \cdot \left[ \frac{y^2}{3} \right]_{r}^{R} \quad \text{... from (ii)} \]

\[ T = \frac{2}{3} \mu \pi \cdot p \cdot \left( R^3 - r^3 \right) \quad \text{... (iv)} \]

From (iii) & (iv):

\[ T = \mu \cdot W \cdot \frac{2}{3} \left( \frac{R^3 - r^3}{R^2 - r^2} \right) \]

From (i),

\[ W = 2\pi k \left[ y^2 \right]_{r}^{R} \]

\[ = 2\pi k \left( R^2 - r^2 \right) \quad \text{...(v)} \]

From (ii),

\[ T = \mu \cdot 2\pi k \cdot \left[ \frac{y^2}{2} \right]_{r}^{R} \]

\[ = \mu k \pi \left( R^2 - r^2 \right) \quad \text{... (vi)} \]

From (v) & (vi),

\[ \frac{T}{W} = \frac{\mu (R^2 - r^2)}{2(R - r)} \]

\[ T = \mu \cdot W \left( \frac{R + r}{2} \right) \]
Ans I. designing a friction clutch, the assumption of uniform use of Because if clutch is designed by ass uniform the clutch will able to transmitter ujavke been designed even if the intensity of pressure is uniform. In this way the design is on safe side.’

Q. 5.23. Differentiate between theory of uniform pressure and theory of uniform wear.

Ans. The assumption of uniform hold good-with newly fitted leaning surfaces where the surfaces is assumed to be perfect. But as the wear depends upon the velocity and r intensity therefore the wear will not be uniform, therefore, as the slfit Is run or sometime the pressure distribution will remain uniform According to the assumption of uniform-pressure goes on decreasing radically outward because velocity goes on ndecreasing.

Q. 5.24. In collar thrust bearing the external and internal radii are 250 mm and 150mm respectively. The total axial load is 50 kN and the shaft rotates at 150 r.p.m. The coefficient of friction is 0.05. Find the power lost in friction assuming (a) uniform wear (b) uniform pressure.

Ans. External radius, \( R = 250 \text{ mm} = 0.25 \text{ m} \)

Internal radius, \( r = 150 \text{ mm} = 0.15 \text{ m} \)

Axial load, \( W = 50 \text{ kN} = 50 \times 10^3 \text{ N} \)

Speed \( N = 150 \text{ r.p.m.} \)

\( \mu = 0.05 \)

(a) Assuming uniform wear,

\[
T = \mu W \left( \frac{R + r}{2} \right)
\]

\[
= 0.05 \times 50 \times 10^3 \left[ \frac{0.25 + 0.15}{2} \right]
\]

\[
= 500 \text{ Nm}
\]

\[
P = \frac{2\pi rT}{60 \times 1000} = \frac{2\pi \times 150 \times 500}{60 \times 1000} = 7.85 \text{ kW Ans.}
\]

(b) Assuming pressure to be uniform

\[
T = \mu W \frac{2}{3} \left( \frac{R^3 - r^3}{R^2 - r^2} \right)
\]
Note: From the question 5.24, it is clear that friction torque is less if wear is assumed to be constant. Therefore, in design of clutch the wear is assumed to be uniform.

Q. 5.25. Determine the external and internal radii of the friction plate of a single plate clutch to transmit 90 Nm torque. The both sides of the plate are effective and the outer radius is 1.5 times the inner radius. Assume uniform wear and take $\mu = 0.3$. The pressure is not to exceed 0.8 bar.

**Ans.**

- $R = 1.5r$
- $\mu = 0.3$
- $T = 90 \text{ Nm}$
- $p_{\text{max}} = 0.8 \times 10^5 \text{ N/m}^2$

For uniform wear, $p \times \text{radius} = \text{constant}$

\[ 0.8 \times 10^5 \times r = k \]

Also

\[ W = 2\pi \times k \text{ (R-r)} \]

\[ W = 2\pi \times 0.8 \times 10^5 \times r \times (1.5-1) \times r \]

\[ = 251327 \times r^2 \]

Friction torque for both sides effective is given as

\[ T = \mu W \left( \frac{R+r}{2} \right) \times 2 \]

\[ 90 = 0.3 \times 251327 \times r^2 \left( \frac{1.5+1}{2} \right) \times 2 \]

\[ r^3 \times 6.75 \times 251327 = 90 \]

\[ r^3 \times 6.75 = 90 \]

\[ r = 0.0782 \text{ m} \]

\[ = 78.2 \text{ mm Ans.} \]

And

- $R = 1.5 \times r$
- $R = 117.3 \text{ mm Ans.}$

Ans.

\[ T = \frac{F \cdot S}{2} \]

\( S_1 = \) During shaft. It is crank-shaft in automobile engine.
\( S_2 = \) Driven shaft. It is shaft going into gear box of an automobile.
\( F = \) Flange of \( S_1 \).
\( F.W = \) Flywheel bolted to \( F \).
\( C.P = \) Clutch plate riveted to Boss \( B' \).
\( B' = \) Boss or hub. It has internal splines corresponding to external splines on \( S_2 \).
\( F_1 \) & \( F_2 = \) Friction linings fixed to \( CP \)
\( PP = \) pressure plate.
\( B_1 \) & \( B_2 = \) Bolts, six in number.
\( SP = \) Springs, six in number, they keep \( PP \) pressed towards \( CP \).
Working: The springs keep the pressure plate pressed towards clutch plate. Due to this the clutch plate remains sandwiched between pressure plate and flywheel. Therefore when the shaft S1 rotates, the clutch plate also rotates with FW & PP. Thus power is transmitted from to S2. When pedal is pressed, the PP moves towards right hand side, the CP becomes free and therefore stops rotating. Thus power is stopped from going to shaft S2. For derivation please see 5.21. The torque will be double of the torque of collar because in single plate clutch there are two pairs of friction surfaces.

Q. 5.27. What are thick & thin film lubrications?

Ans. If lubricant layer is of finite thickness, so that no actual contact takes place between the surfaces, the friction is determined by the viscosity of lubricant. It is thick film lubrication. If the layer is only a few molecules thick, the friction is determined by the oiliness of the lubricant. It is thin film lubrication.

Q. 5.28. A vehicle having a wheel base 2.85 m, has its centre of mass 1.2 from the rear axle and 600 mm above ground. It moves on a level road at a speed of 60 knVhr. Determine the distance moved by the vehicle before coming to rest on applying the brakes (i) to the rear wheels, (ii) to the front wheels (iii) to all the four wheels. Take $\mu = 0.6$.
Q. 5.29. What is the advantage of double shoe brake over single shoe brake?
Ans. Single shoe when pressed against the brake drum, produces side thrust on the bearings of the shaft of the drum.
But in case of double shoe brake, the two shoes press the drum in opposite direction, therefore there is no side thrust.

Find the maximum braking torque and the angular retardation of the brake drum when a band and block having 12 blocks, each of which sust ends an angle of 18 degree at drum centre, is applied to a drum of diameter 0 mm. The blocks are 100 mm thick. The drum and flywheel mounted on the same shaft have a mass of 1600 kg and have a combined radius of gyration of 500 mm, the two ends of the band are attached to the pins on the opposite side of the brake fulcrum at a distance of 35 mm and 140 mm from fulcrum. The co-efficient of friction between the blocks and drum may be taken as 0.3. A force of 150 N is applied at distance of 800 mm from the fulcrum to apply brake.

\[ \text{Ans.} \quad n = 12 \]
\[ \theta = 18 \text{ degree} \]
\[ \theta = 9 \text{ degree} \]
\[ d = 800 \text{ mm} \]
\[ t = 100 \text{ mm} \]
D = 800 + 2 \times 100, \therefore D = d + 2t,
= 1000 \text{ mm} = 1 \text{ m}
I = mk^2, \text{ where } k \text{ is radius of gyration} = 0.5 \text{ m (given)}
= 1600 \times 0.5^2 = 400 \text{ kg m}^2

In a band and block brake:

\[ T_n = \left( \frac{1 + 0.3 \tan \theta}{1 - \mu \tan \theta} \right)^9 \times T_0 = \left( \frac{1 + 0.3 \tan \theta}{1 - 0.3 \tan \theta} \right)^{12} \times T_0 \]

= 3.13 \times T_0

Taking the moments, about fulcrum O, of the forces acting on lever, we get

\[ P \times 800 + T_n \times 35 = T_0 \times 140 \]
\[ 150 \times 800 + 3.13 \times 35 \times T_0 = T_0 \times 140 \]

\[ \frac{150 \times 800}{140 - 35 \times 3.13} = T_0 \]

\[ \therefore T_0 = 3941 \text{ N} \]

and

\[ T_n = 3.13 \times 3941 = 12335 \text{ N} \]

Braking Torque = \((T_n - T_0) \times \frac{D}{2} = (12335 - 3941) \times \frac{1}{2} \]

= 4197 \text{ Nm Ans.}

(ii) Retardation = \(\frac{\text{Brake torque}}{I} = \frac{4197}{400} \]

= 10.4925 \text{ rad/s}^2 \text{ Ans.}