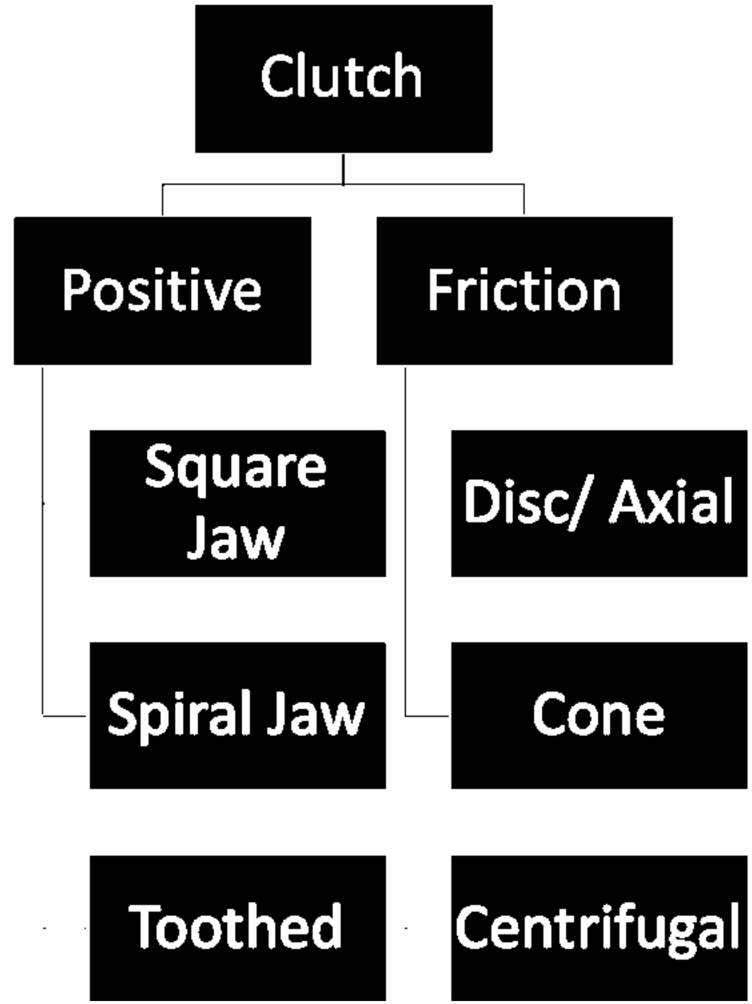
Machine Design

Course No. MEC3110

Clutch

A Clutch is a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft.



Clutch

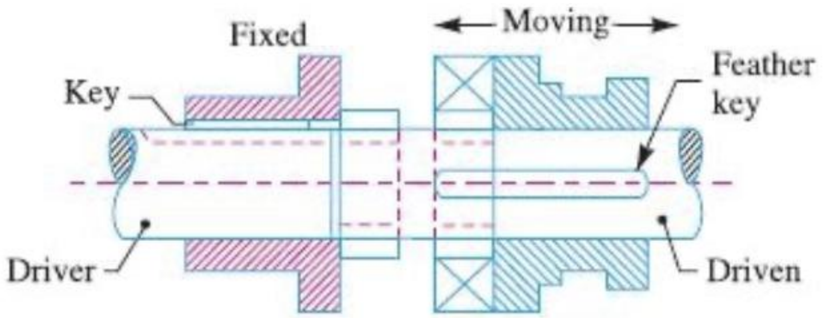
Positive Clutch

Advantages

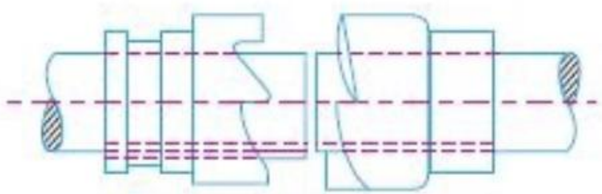
They do not Slip.
They can transmit large Torque.
Develop no heat.

Disadvantages

Engagement of Clutch is not possible at high speed.



(a) Square jaw clutch.



(b) Spiral jaw clutch.

Clutch

Friction Clutch

Advantages

Smooth engagement and minimum shock during the engagement.

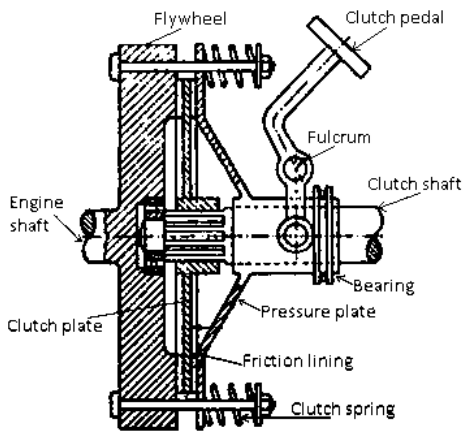
Friction clutch can be engaged and disengaged when the machine is running since they have no jaw or teeth.

Easy to operate.

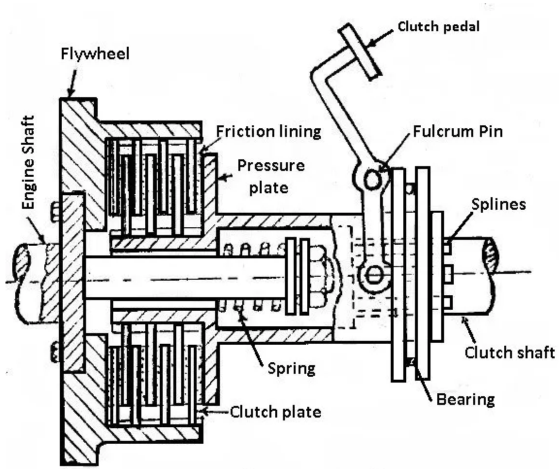
They are capable of transmitting partial power.

Friction clutch can act as a safety device. They slip when the torque exceeds a safe value, thus safeguards the machine.

Frequent engagement and disengagement is possible.



(*a*) Single plate clutch



(*b*) Multi plate clutch

Clutch

Friction Clutch

Requirement of good friction clutch

1. The following are considered during the design of the friction clutch.
2. The coefficient of friction of contact surface should be high enough to hold the load with a minimum amount of axial force. It should not require an external force to carry the burden.
3. The moving parts of the clutch should be lightweight to minimize the inertia load at high speed.
4. Heat generated at contacting surface should dissipate rapidly.
5. It should have provision for taking up the wear of contact.
6. Guard the projecting parts by covering and provide a provision for easy repair.

Clutch

Friction Clutch

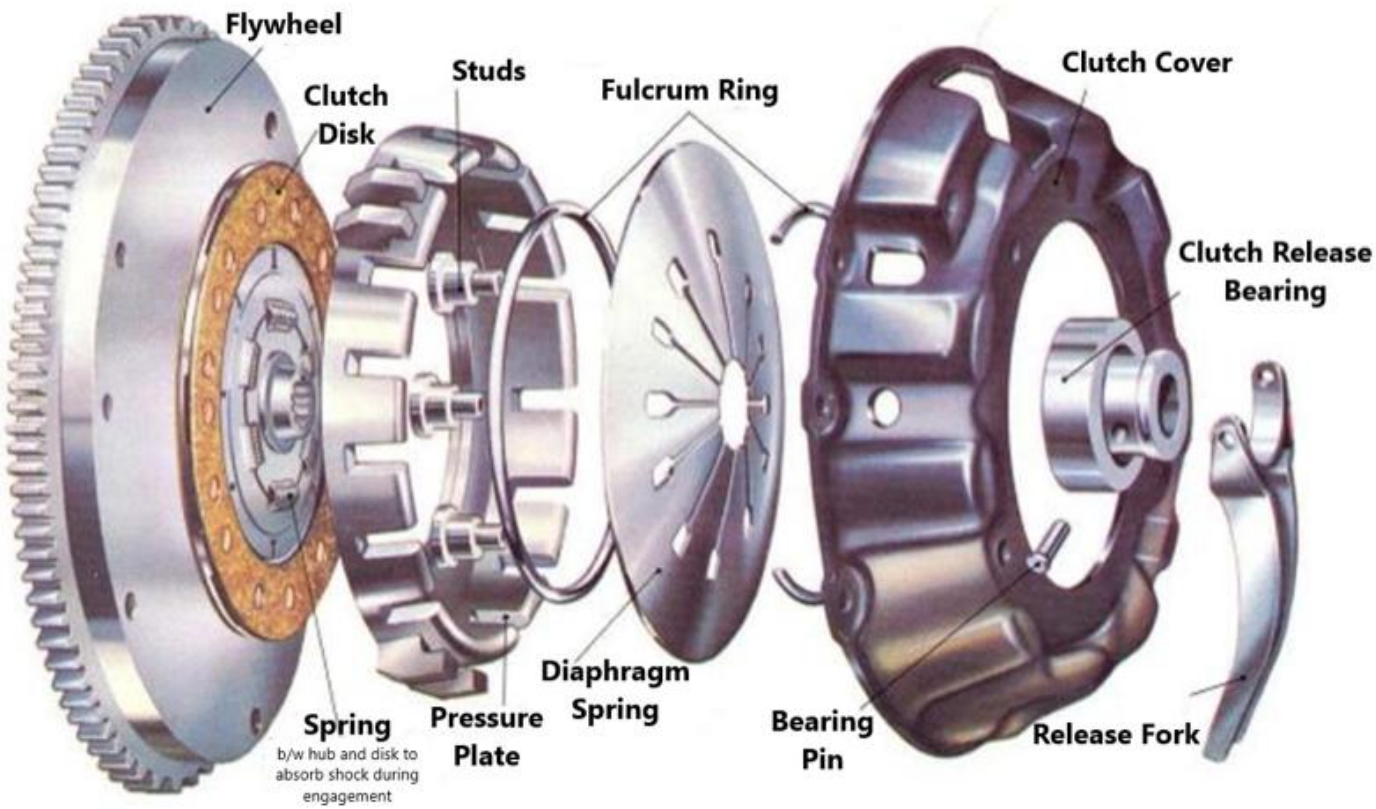
Requirements of material used for friction clutch

1. The actual contact surface of the friction clutch is the friction lining. Linings are subjected to severe rubbing during a machine run. There are many factors that decide the material for lining is viable or not. However, the lining material should have certain qualities.
2. It should have a relatively high and uniform coefficient of friction under all service conditions.
3. High resistance to wear.
4. It should withstand a high compressive load.
5. It should be chemically inert, oil and moisture have no effect on them.
6. High heat conductivity. It should rapidly dissipate the heat generated.
7. It should have excellent compactibility with cast iron facing.

Clutch

Parts of Friction Clutch

1. **Lever/ Pedal**
2. **Clutch Release Bearing**
3. **Diaphragm Spring**
4. **Pressure Plate Friction Plate**



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Parts of Friction Clutch

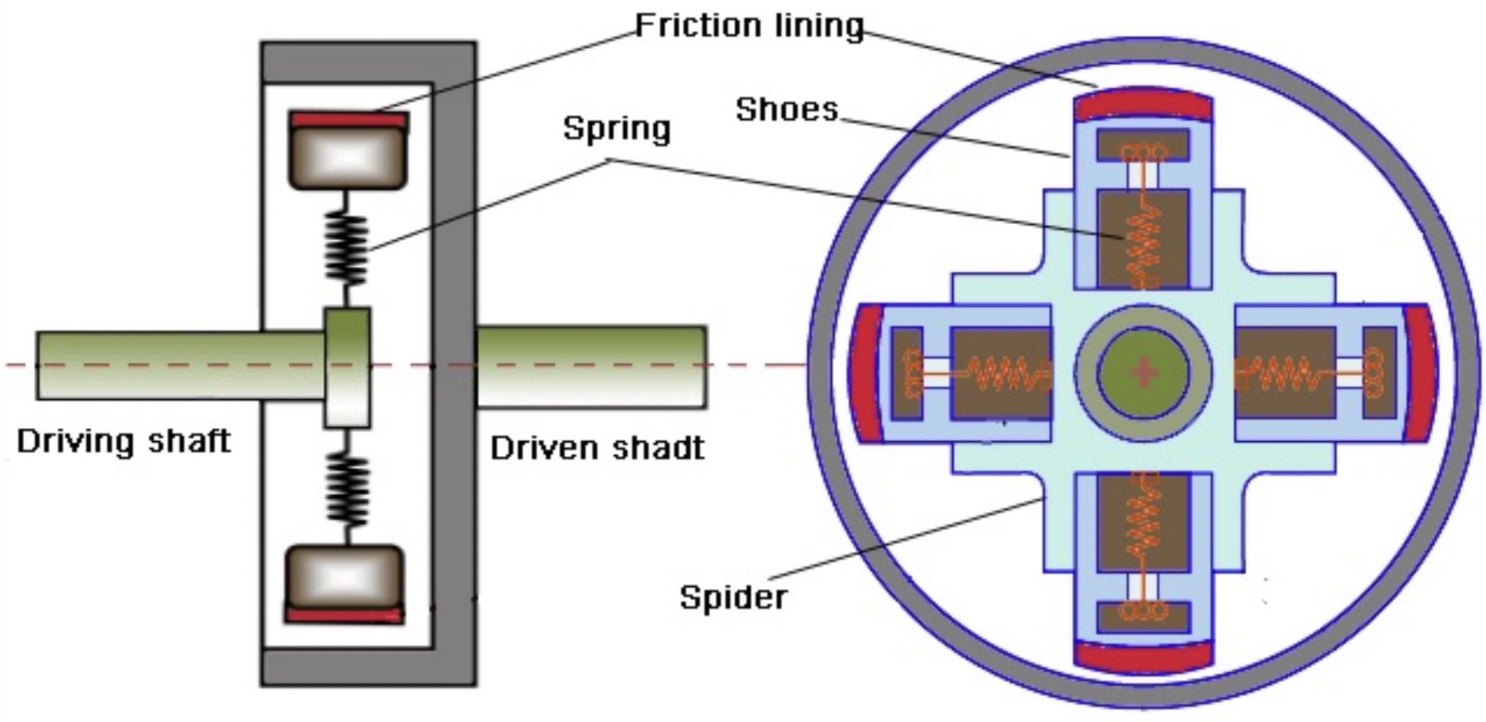
Clutch

Parts of Friction Clutch

Clutch Plate

Clutch

Centrifugal Clutch



Centrifugal Clutch

Clutch

Centrifugal Clutch

Clutch

Centrifugal Clutch

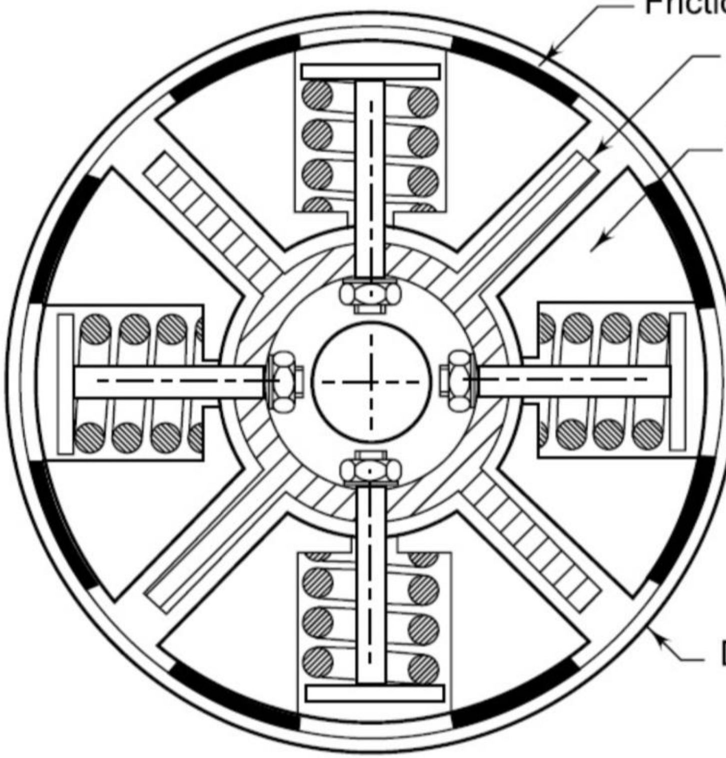
There are two distinct applications of centrifugal clutch, namely, light-duty applications and heavy-duty applications. They are as follows:

(i) In centrifugal clutch, the engagement is very smooth because the electric motor has a chance to accelerate and reach the operating speed, before it has to take up the load. Chain saws, lawnmowers, golf carts and small recreational vehicles use centrifugal clutch on this account.

(ii) The centrifugal clutch is also useful in heavy-duty applications, where a high inertia load is to be brought up to the operating speed. By providing a '*time delay*' that is sufficient to permit the prime mover to gain momentum before taking over the load, centrifugal clutches provide smooth engagement. Heavy mobile equipment such as cranes, cement mills, and ball mills use centrifugal clutches on this account.

Clutch

Analysis of Centrifugal Clutch



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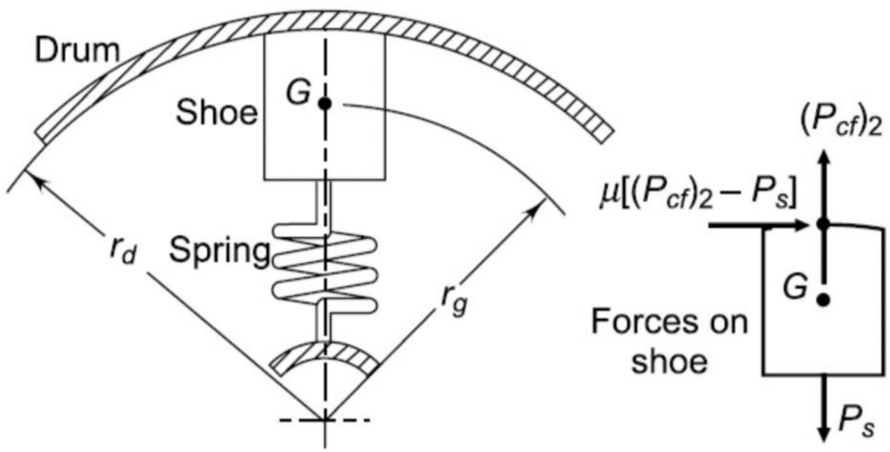
Analysis of Centrifugal Clutch



r_d = radius of the drum (mm)

r_g = radius of the centre of gravity of the shoe in engaged position (mm)

m = mass of each shoe (kg)

P_{cf} = centrifugal force (N)

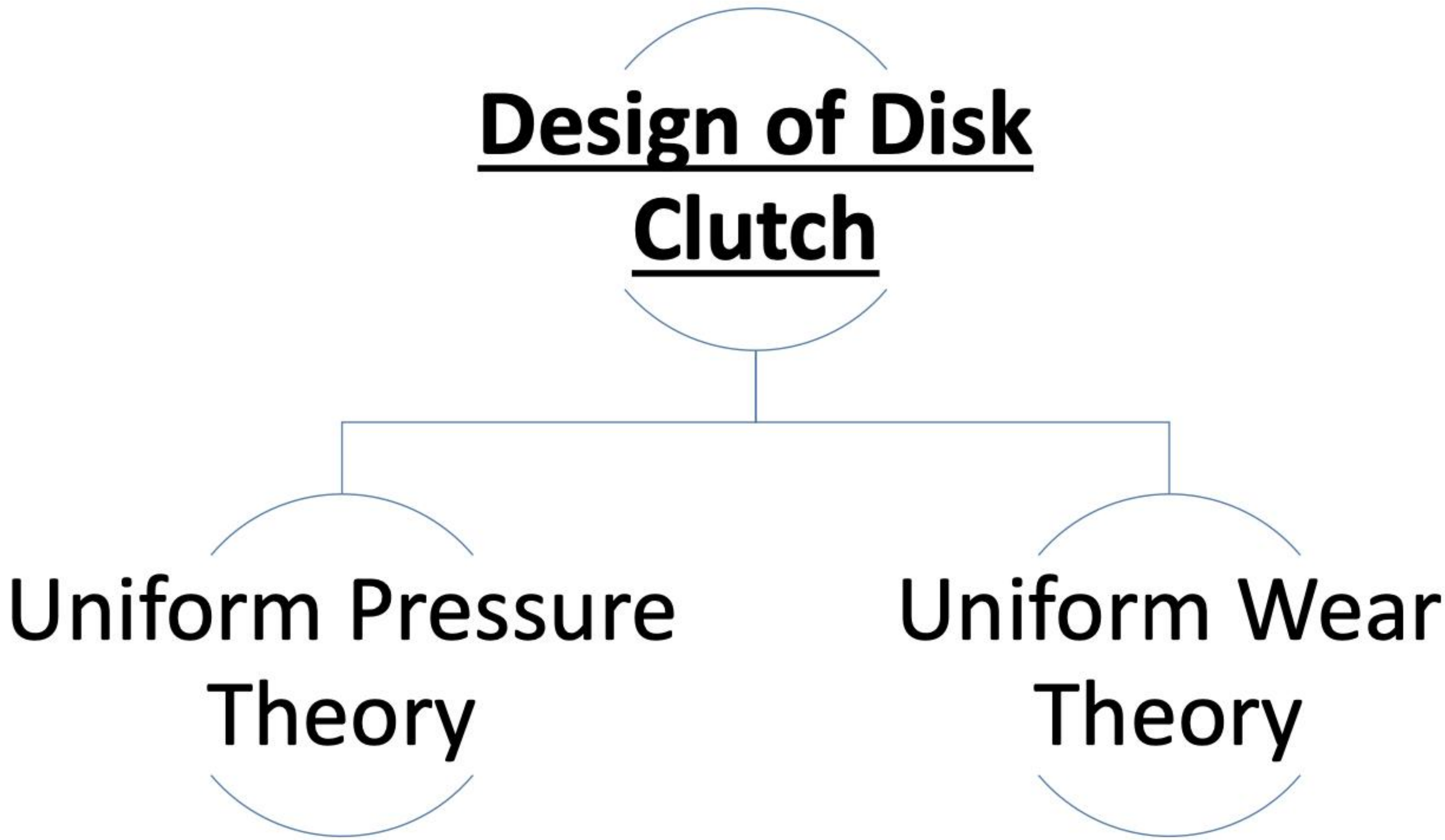
P_s = spring force (N)

z = number of shoes

ω_2 = running speed (rad/s)

ω_1 = speed at which engagement starts (rad/s)

Clutch



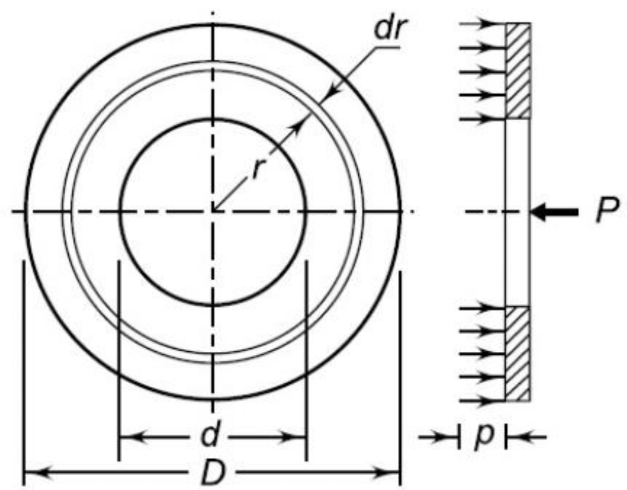
Design of Disk Clutch
Uniform Pressure Theory
Uniform Wear Theory

Clutch

TORQUE TRANSMITTING CAPACITY

A friction disk of a single plate clutch is shown in figure:

D = outer diameter of friction disk (mm)
d = inner diameter of friction disk (mm)
p = intensity of pressure at radius r (N/mm^2)
P = total operating force (N)
M_t = torque transmitted by the clutch (N-mm)



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Consider an elemental ring of radius r and radial thickness dr as shown in Fig. For this ring,

$$\text{elemental area} = (2\pi r\, dr)$$

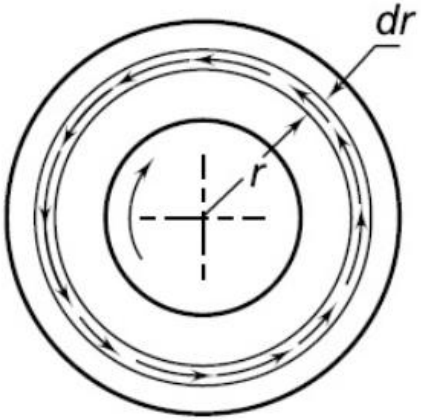
$$\text{elemental axial force} = p(2\pi r\, dr)$$

$$= 2\pi(pr\, dr) \qquad \text{(a)}$$

$$\text{elemental friction force} = \mu p(2\pi r\, dr)$$

$$\text{elemental friction torque} = \mu p(2\pi r\, dr)\, r$$

$$= 2\pi\mu\,(pr^2\, dr) \qquad \text{(b)}$$



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Integrating the expression (a),

$$P = \int 2\pi (pr\, dr)$$

or

$$P = 2\pi \int_{d/2}^{D/2} pr\, dr$$

Integrating the expression (b),

$$M_t = \int 2\pi\mu (pr^2\, dr)$$

or

$$M_t = 2\pi\mu \int_{d/2}^{D/2} pr^2\, dr$$

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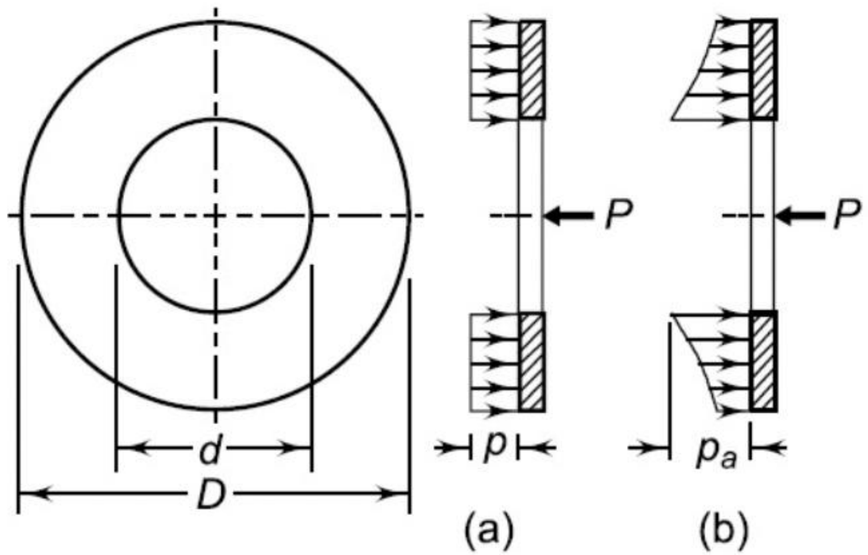
$$P = 2\pi \int_{d/2}^{D/2} pr\, dr = 2\pi p \int_{d/2}^{D/2} r\, dr = 2\pi p \left(\frac{r^2}{2} \right)_{d/2}^{D/2}$$

or $$P = \frac{\pi p}{4} (D^2 - d^2)$$



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$$M_t = 2\pi\mu \int_{d/2}^{D/2} pr^2 \, dr = 2\pi\mu \, p \int_{d/2}^{D/2} r^2 \, dr$$

$$= 2\pi\mu \, p \left(\frac{r^3}{3} \right)_{d/2}^{D/2}$$

or $$M_t = \frac{\pi\mu \, p}{12} (D^3 - d^3)$$

$$M_t = \frac{\mu P}{3} \frac{(D^3 - d^3)}{(D^2 - d^2)}$$

Clutch

(ii) Uniform wear Theory According to the second theory, it is assumed that the wear is uniformly distributed over the entire surface area of the friction disk. This assumption is used for worn-out clutches. The axial wear of the friction disk is proportional to the frictional work. The work done by the friction force at radius r is proportional to the frictional force (μp) and rubbing velocity ($2\pi r\, n$) where n is speed in rev/min.

$$\therefore \quad \text{wear} \propto (\mu\, p)\,(2\pi\, rn)$$

Assuming speed n and the coefficient of friction μ as constant for a given configuration,

$$\text{wear} \propto pr$$

When the wear is uniform,

$$pr = \text{constant}$$

Clutch

In this case, p is inversely proportional to r. Therefore, pressure is maximum at the inner radius and minimum at the outer periphery. The maximum pressure intensity at the inner diameter ($d/2$) is denoted by p_a. It is also the permissible intensity of pressure. Since p_r is constant,

$$pr = p_a (d/2)$$

$$P = 2\pi \int_{d/2}^{D/2} pr\, dr = 2\pi \left(p_a \times \frac{d}{2} \right) \int_{d/2}^{D/2} dr$$

$$P = \frac{\pi p_a d}{2}(D - d)$$

$$M_t = 2\pi\mu \int_{d/2}^{D/2} pr^2 dr = 2\pi\mu \left(p_a \times \frac{d}{2} \right) \int_{d/2}^{D/2} r dr$$

$$M_t = \frac{\pi\mu p_a d}{8}(D^2 - d^2)$$

$$M_t = \frac{\mu P}{4}(D + d)$$

Clutch

Conclusions

(i) The uniform-pressure theory is applicable only when the friction lining is new.

(ii) The uniform-wear theory is applicable when the friction lining gets worn out.

(iii) The friction radius for new clutches is slightly greater than that of worn-out clutches.

(iv) The torque transmitting capacity of new clutches is slightly more than that of worn-out clutches.

(v) A major portion of the life of friction lining comes under the uniform wear criterion.

(vi) It is more logical and safer to use uniform-wear theory in the design of clutches.