FRICTION Clutches

CLUTCHES

The clutch is a mechanical device, which is used to connect or disconnect the source of power from the remaining parts of the power transmission system at the will of the operator.

Three terms are used together

- ***Couplings :*** *(* Permanent connection) The driving and driven shafts are permanently attached by means of coupling and it is not possible to disconnect the shafts, unless the coupling is dismantled.
- ***Clutches :***

In the operation of clutch, the conditions are as follows:

(i) Initial Condition The driving member is rotating and the driven member is at rest.

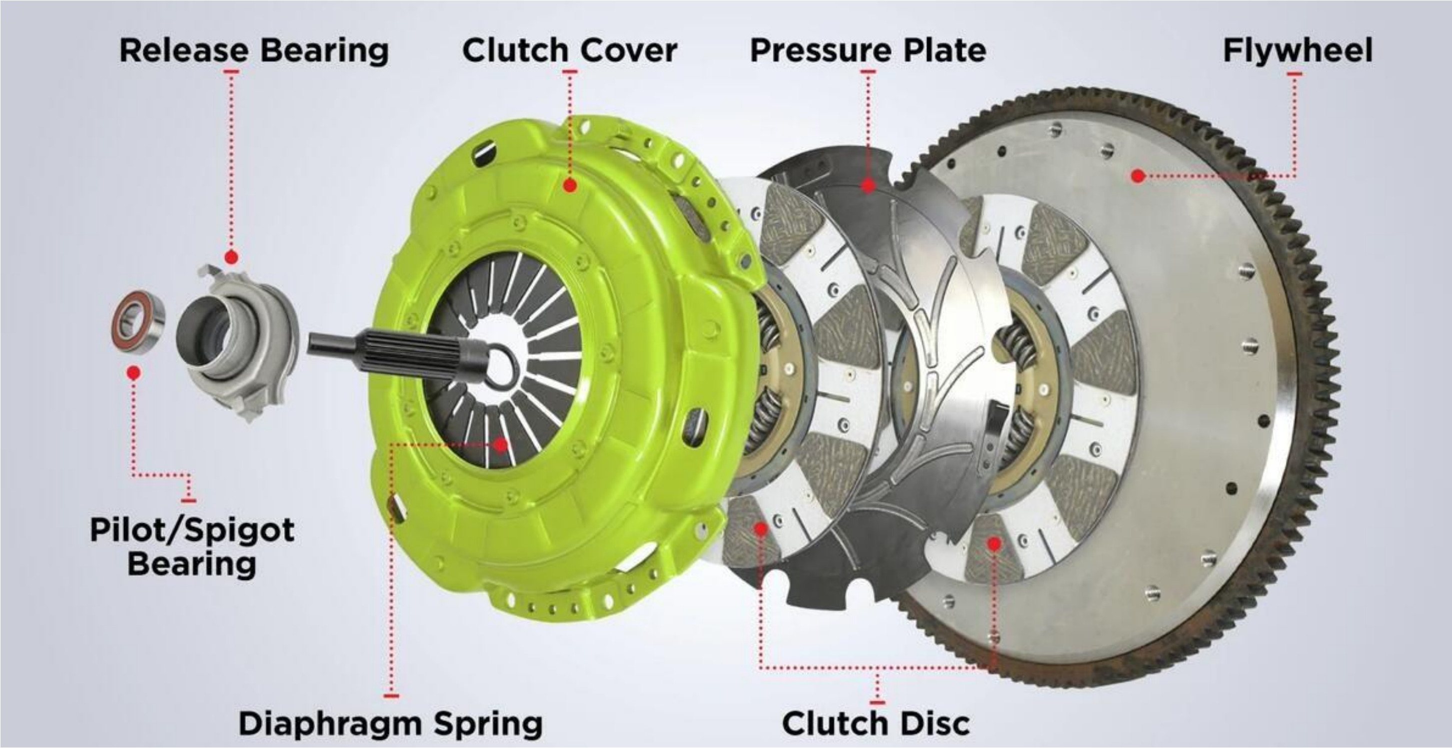
(ii) Final Condition Both members rotate at the same speed and have no relative motion.

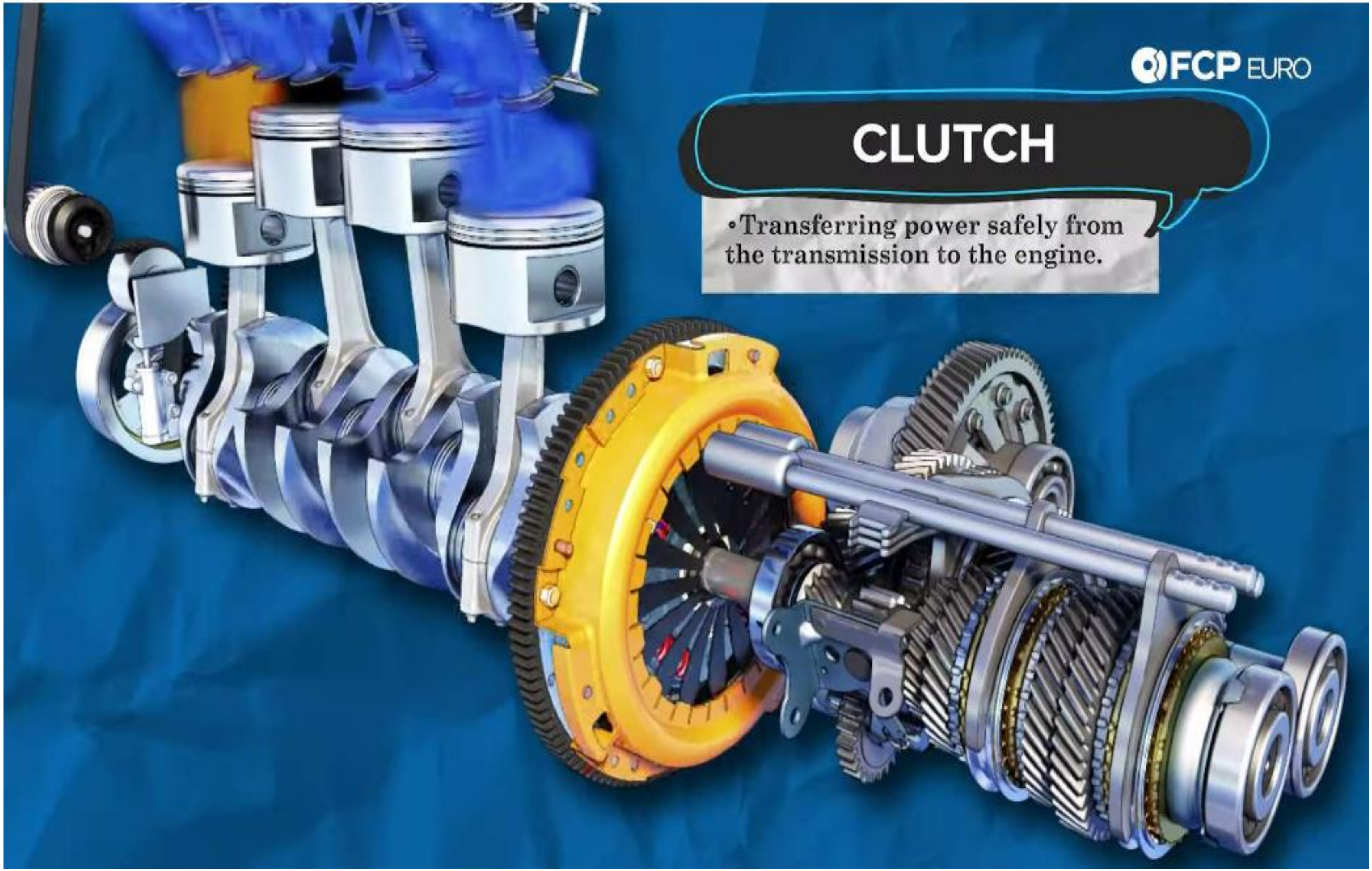
- ***Brakes :***

A brake is a device used to bring a moving system to rest, to slow its speed, or to control its speed to a certain value. The function of the brake is to turn mechanical energy into heat.

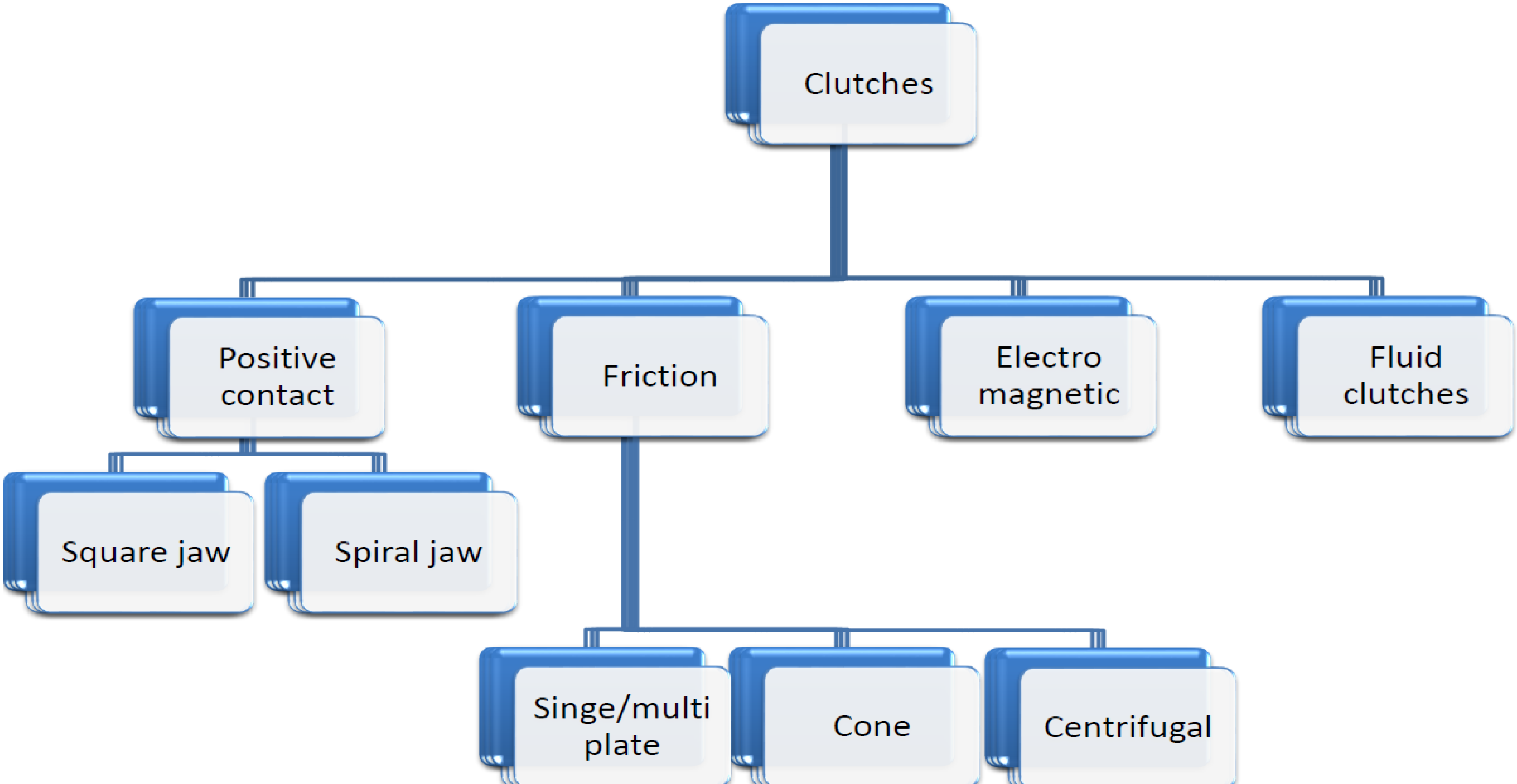
i) Initial Condition One member such as the brake drum is rotating and the braking member such as the brake shoe is at rest.

(ii) Final Condition Both members are at rest and have no relative motion.


Release Bearing
Clutch Cover
Pressure Plate
Flywheel
Pilot/Spigot Bearing
Diaphragm Spring
Clutch Disc


FCP EURO
CLUTCH
•Transferring power safely from the transmission to the engine.

Classifications of Clutch



Positive contact Clutches : square jaw clutches; spiral jaw clutches and toothed clutches. Power transmission is achieved by means of interlocking of jaws or teeth. Their main advantage is positive engagement and once coupled, they can transmit large torque with no slip.

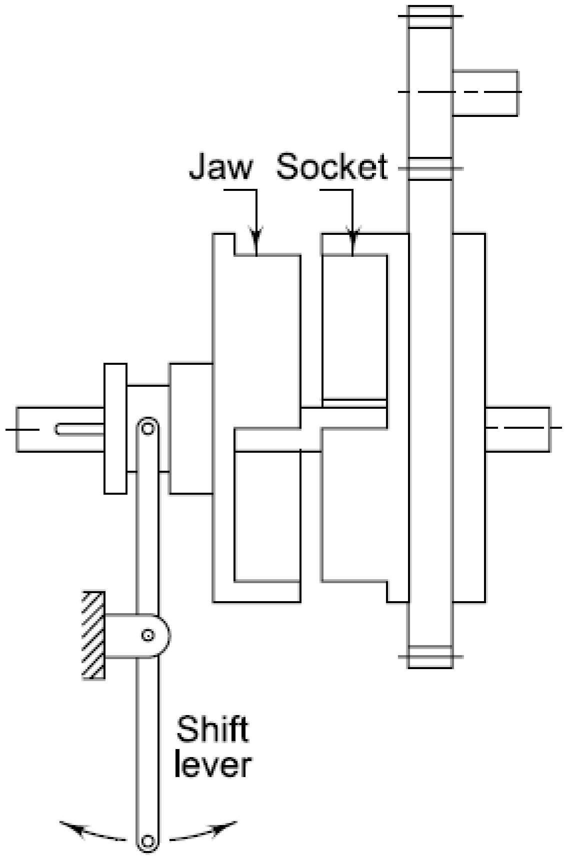
Friction Clutches Single and multi-plate clutches, cone clutches and centrifugal clutches.

Power transmission is achieved by means of friction between contacting surfaces.

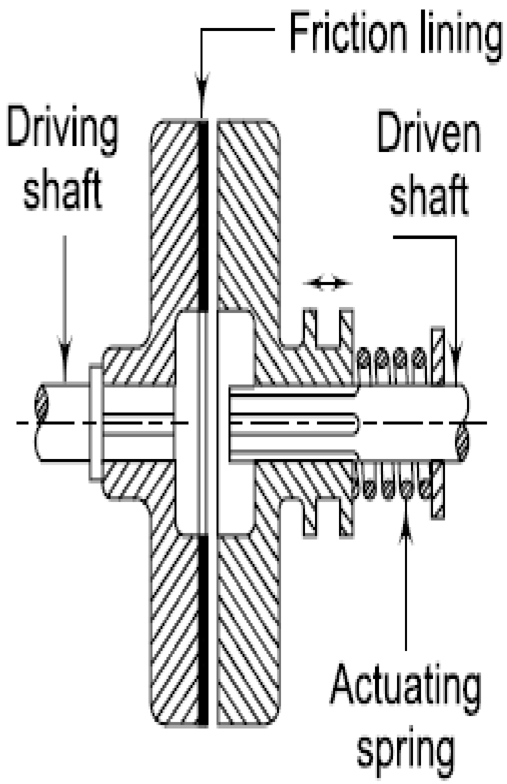
Electromagnetic Clutches Magnetic particle clutches, magnetic hysteresis clutches and eddy current clutches.

Power transmission is achieved by means of the magnetic field. These clutches have many advantages, such as rapid response time, ease of control, and smooth starts and stops.

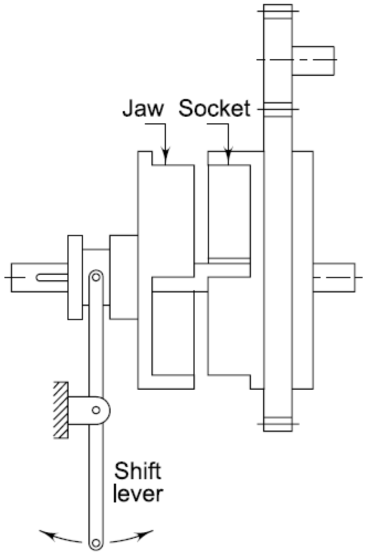
Fluid Clutches and Couplings In these clutches, power transmission is achieved by means of hydraulic pressure. A fluid coupling provides extremely smooth starts and absorbs shock.



Square Jaw Clutch



Single Plate Clutch



Square Jaw Clutch

Advantages of jaw clutches

(a) They do not slip and engagement is positive.

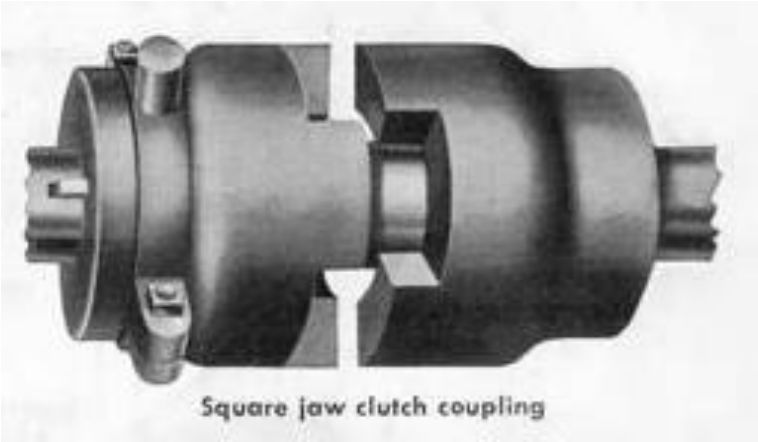
(b) No heat is generated during engagement or disengagement

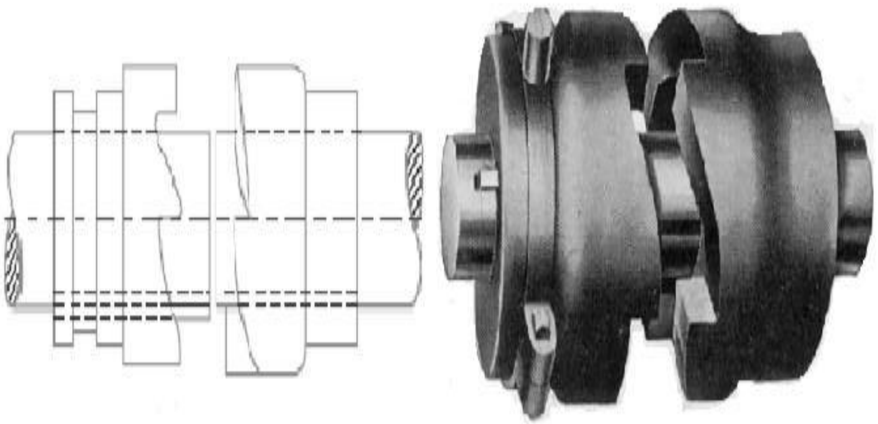
Drawbacks:

(a) Jaw clutches can be engaged only when both shafts are stationary or rotate with very small speed difference.

(b) They cannot be engaged at high speeds because engagement of jaws and sockets results in shock.

positive contact clutches are rarely used

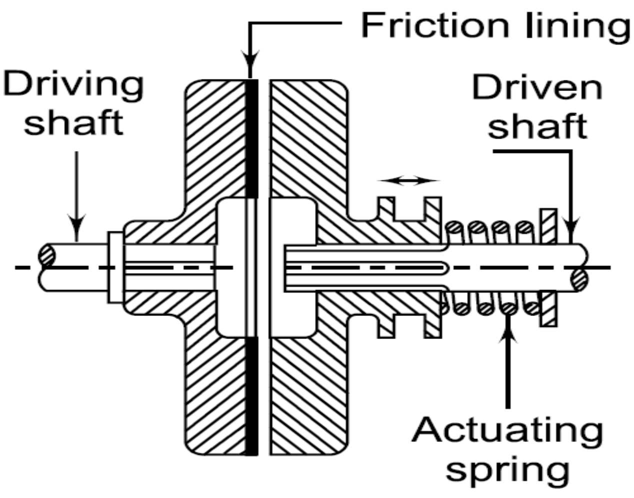




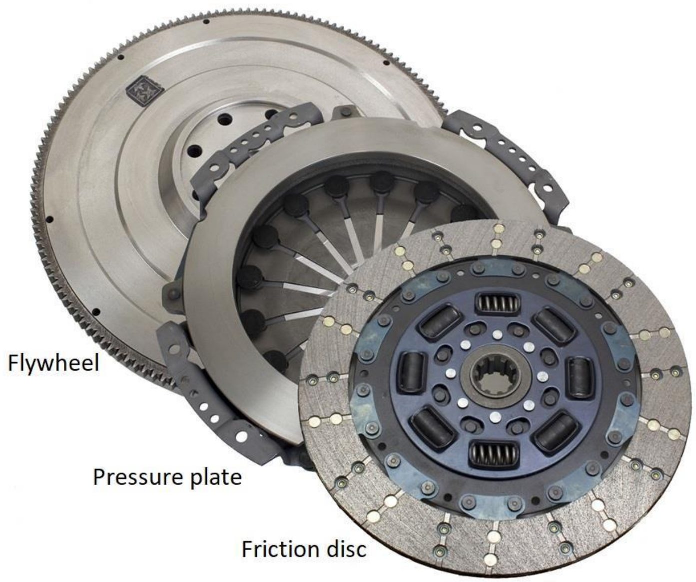
Spiral Jaw Clutch

Friction Clutch

Friction Clutches work on the basis of the frictional forces developed between the two or more surfaces in contact.



Single Plate Clutch



- Consists of two flanges, one rigidly keyed to driving shaft and one connected to driven shaft with splines
- Actuating force is given by spring
- Power transmission between driving and driven flange is through friction
- Fork inserted on the collar of the driven flange for axial movement of driven flange

Advantages

- Smooth engagement
- Slip only during engagement
- Acts as safety device

Design Considerations

(i) Selection of a proper type of clutch that is suitable for the given application

(ii) Selection of suitable friction material at the contacting surfaces

(iii) Designing the clutch for sufficient torque capacity

(iv) Engagement and disengagement should be without shock or jerk

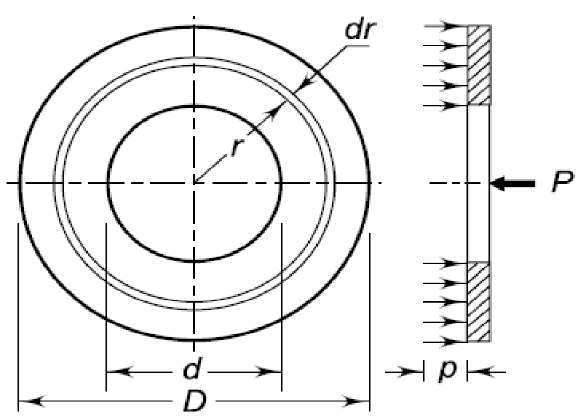
(v) Provision for holding the contacting surfaces together by the clutch itself and without any external assistance

(vi) Low weight for rotating parts to reduce inertia forces, particularly in high-speed applications

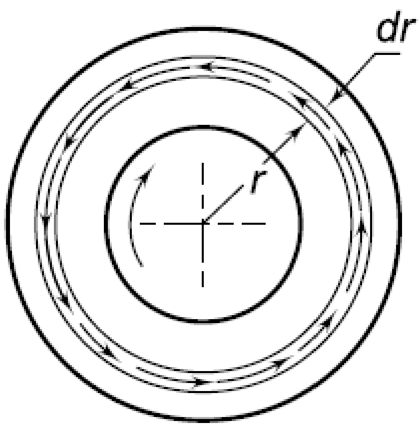
(vii) Provision for taking or compensating wear of rubbing surfaces

(viii) Provision for carrying away the heat generated at the rubbing surfaces

Torque transmitting capacity : *Single plate clutch*



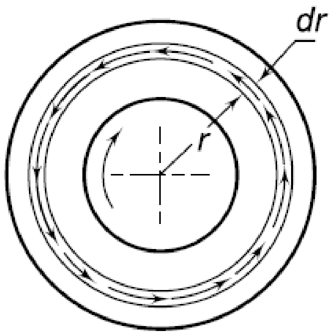
Friction Disk



Friction Force on Elemental Ring

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)

The intensity of pressure p at radius r may be constant or may be variable. Consider an elemental ring of radius r and radial thickness dr as shown in Fig.



Friction Force on Elemental Ring

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

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

$= 2\pi\,(pr\, dr)$ (a)

elemental friction force = $\mu p\,(2pr\, dr)$ ....

elemental friction torque = $\mu p(2pr\, dr)\, r$

$= 2p\mu\,(pr^2\, dr)$ ...... (b)

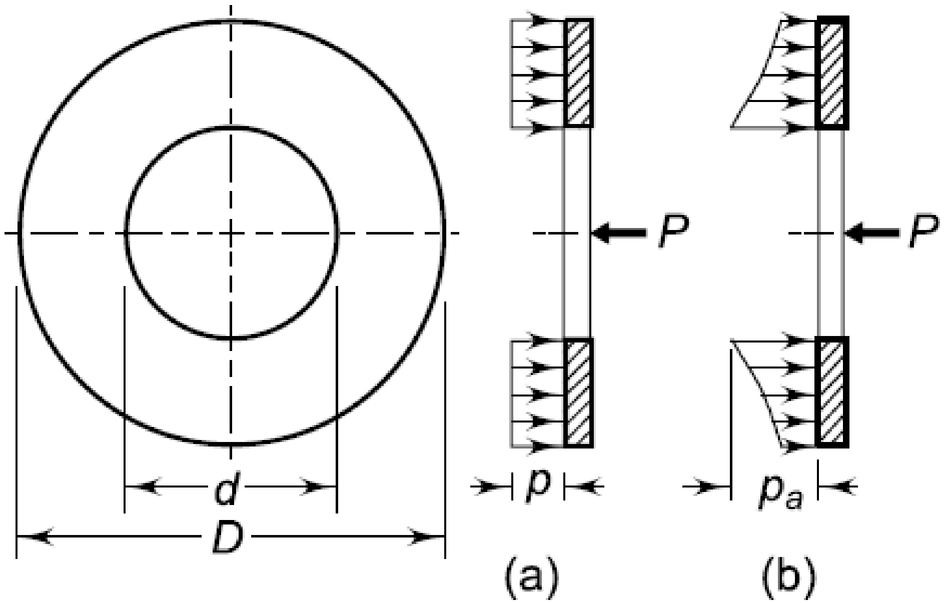
$P = \int 2\pi(pr\, dr) = 2\pi \int_{d/2}^{D/2} pr\,dr$ *Operating force*

$M_t = \int 2\pi\mu(pr^2\, dr) = 2\pi\mu \int_{d/2}^{D/2} pr^2\, dr$ torque transmitted by the clutch

Two theories are used
Uniform pressure theory and Uniform wear theory

(i) Uniform Pressure Theory In case of new clutches employing a number of springs, the pressure remains constant over the entire surface area of the friction disk.

With this assumption, *p* is assumed to be constant. This constant pressure distribution is illustrated in Fig



Pressure Distribution

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

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

From Eq.

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

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

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

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

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 wornout 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 (μ *p*) and rubbing velocity
(2 π *r n*) where *n* is speed in rev/min.

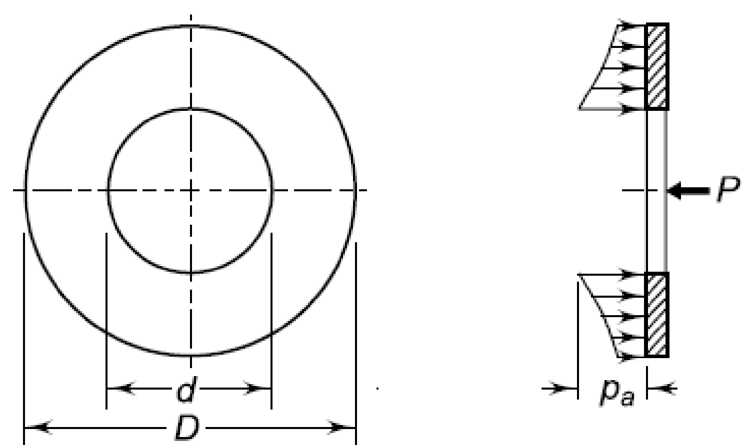
$$\therefore \qquad \text{wear} \propto (\mu p)(2\pi rn)$$

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

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

When the wear is uniform,

$$pr = \text{constant}$$



The pressure distribution according to uniform wear theory is illustrated in Fig. 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 *pr* is constant,

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

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

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

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

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

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

(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 wornout 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.

$$M_t = \mu P R_f$$

where R_f is called the *friction radius*.

For uniform wear theory or worn-out clutches,

$$R_f = \frac{1}{4}(D + d)$$

For uniform pressure theory or new clutches

$$M_t = \mu P R_f$$

$$R_f = \frac{1}{3}\frac{(D^3 - d^3)}{(D^2 - d^2)}$$

Torque transmitting capacity

$$M_t = \frac{\mu P}{4}(D+d) = \mu P \frac{1}{2}\left(\frac{D}{2}+\frac{d}{2}\right) = \mu P r_m$$

the torque transmitting capacity can be increased by three methods:

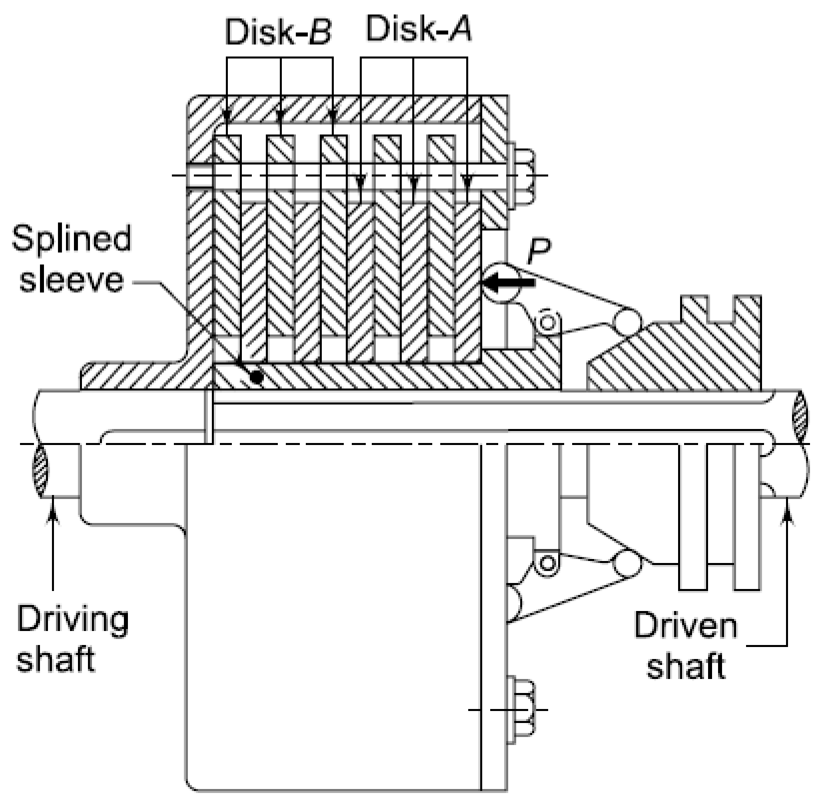
(i) Use friction material with a higher coefficient of friction (m)

(ii) Increase the plate pressure (P)

(iii) Increase the mean radius of the friction disk

MULTI-DISK CLUTCHE

consists
of two sets of disks—*A* and *B*. Disks of Set *A* are usually made of hardened steel, while those of Set *B* are made of bronze. Disks of Set *A* are connected to the driven shaft by means of splines. Because of splines, they are free to move in an axial direction on the splined sleeve



For the uniform-pressure criterion,

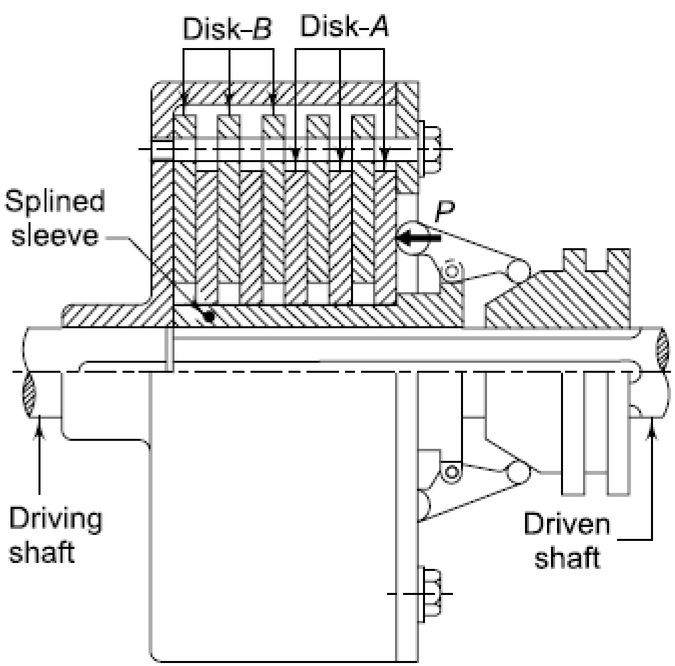
$$M_t = \frac{\mu P z}{3} \frac{(D^3 - d^3)}{(D^2 - d^3)}$$

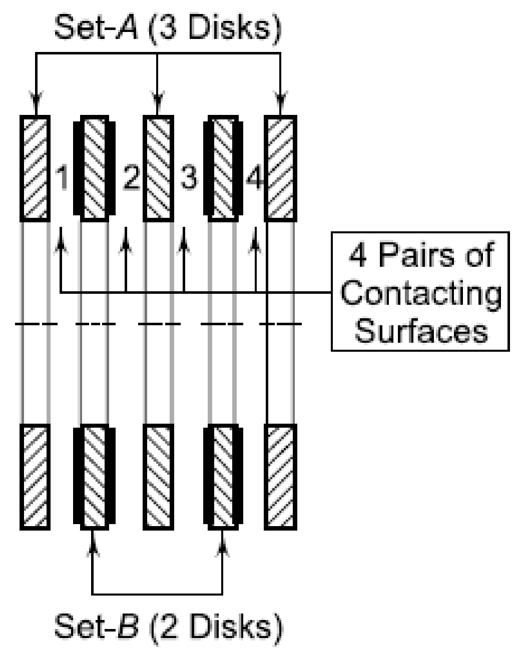
For the uniform-wear criterion,

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

where z is the number of pairs of contacting surfaces.

In the design of multi-disk clutches, very often it is required to determine the number of disks rather than the number of pairs of contacting surfaces. In multi-disk clutch, illustrated in Fig. 1, there are two types of disks called disks of Set *A* and disks of Set *B*. We can use steel disks for Set *A* and bronze disks for Set *B*. Or, we can use plane steel disks for Set *A* and Set *B* consisting of steel disks with asbestos lining. Let us consider 5 disks—3 disks of Set *A* and 2 disks of Set *B*. As shown in Fig.2, the number of pairs of contacting surfaces is 4. Therefore,





Number of disks = number of pairs of contacting surfaces + 1 = z +1 (a)

Suppose,

z_1 = number of disks on driving shaft

z_2 = number of disks on driven shaft

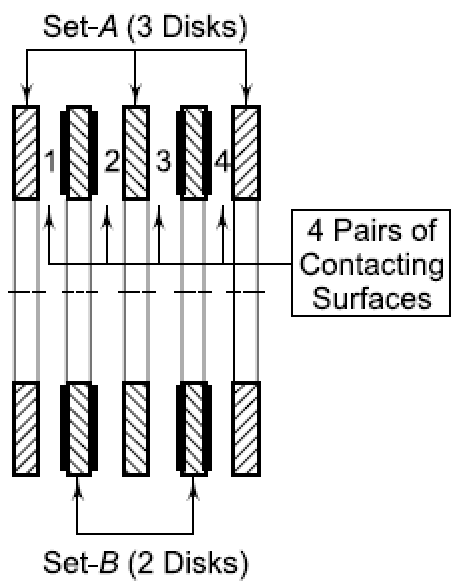
Substituting in (a),

$z_1 + z_2$ = number of pairs of contacting surfaces + 1

or number of pairs of contacting surfaces

= $(z_1 + z_2 - 1)$

It should be noted that the two outer disks have contacting surface on one side only.



Difference between single and multi-plate clutches

(i) The number of pairs of contacting surfaces in the single plate clutch is one or at the most, two. There are more number of contacting surfaces in the multi-disk clutch.
(ii) As the number of contacting surfaces is increased, the torque transmitting capacity is also increased, other conditions being equal. In other words, for a given torque capacity, the size of the multi-plate clutch is smaller than that of the single plate clutch, resulting in compact construction.
(iii) The work done by friction force during engagement is converted into heat. More heat is generated in the multi-plate clutch due to increased number of contacting surfaces. Heat dissipation is a serious problem in the multi-plate clutch. Therefore, multi-plate clutches are wet clutches, while single plate clutches are dry
(iv) The coefficient of friction decreases due to cooling oil, thereby reducing the torque transmitting capacity of the multi-plate clutch. The coeffi cient of friction is high in dry single plate clutches.
(v) Single plate clutches are used in applications where large radial space is available, such as trucks and cars. Multi-disk clutches are used in applications where compact construction is desirable, e.g., scooter and motorcycle.

Difference between dry and wet clutches

(i) A dry clutch has higher coefficient of friction. In wet clutches, the coefficient of friction is reduced due to oil. The coefficient of friction for dry operation is 0.3 or more, while it is 0.1 or less for wet operation.
(ii) The torque capacity of dry clutch is high compared with the torque capacity of wet clutch of the same dimensions.
(iii) For dry clutch, it is necessary to prevent contamination due to moisture or nearby lubricated machinery, by providing seals. Such a problem is not serious in wet clutches.
(iv) Heat dissipation is more difficult in dry clutches. In wet clutches, the lubricating oil carries away the frictional heat.
(v) Rate of wear is far less in wet clutches compared to dry clutches. The wear rate inwet clutches is about 1% of the rate expected in dry clutches.
(vi) The engagement in wet clutch is smoother than in the case of dry clutch.
(vii) In wet clutches, the clutch facings are grooved to provide for passage of lubricant. This reduces the net face area for transmitting torque.

1. A plate clutch consists of one pair of contacting surfaces. The inner and outer diameters of the friction disk are 100 and 200 mm respectively. The coeffi cient of friction is 0.2 and the permissible intensity of pressure is 1 N/mm2. Assuming uniform-wear theory, calculate the power-transmitting capacity of the clutch at 750 rpm.

calculate the power transmitting capacity of the clutch using uniform pressure theory.

2. An oil immersed multi-disk clutch with cork sheet as the friction material is used on a scooter engine. The friction disk of such a clutch is shown in Fig.. The torque transmitted by the clutch is 10 N-m. The coefficient of friction between the cork sheet and the steel plate in the wet condition is 0.2. The permissible pressure on the cork sheet is 0.1 N/mm2. The inner and outer diameters of the friction lining are 65 and 95 mm respectively. There are radial slots, on the friction surface for the circulation of the coolant, which reduces the effective friction area. To account for these slots, the number of contacting surfaces can be increased by 5%. Assuming uniform-wear theory, calculate the required number of contacting surfaces.