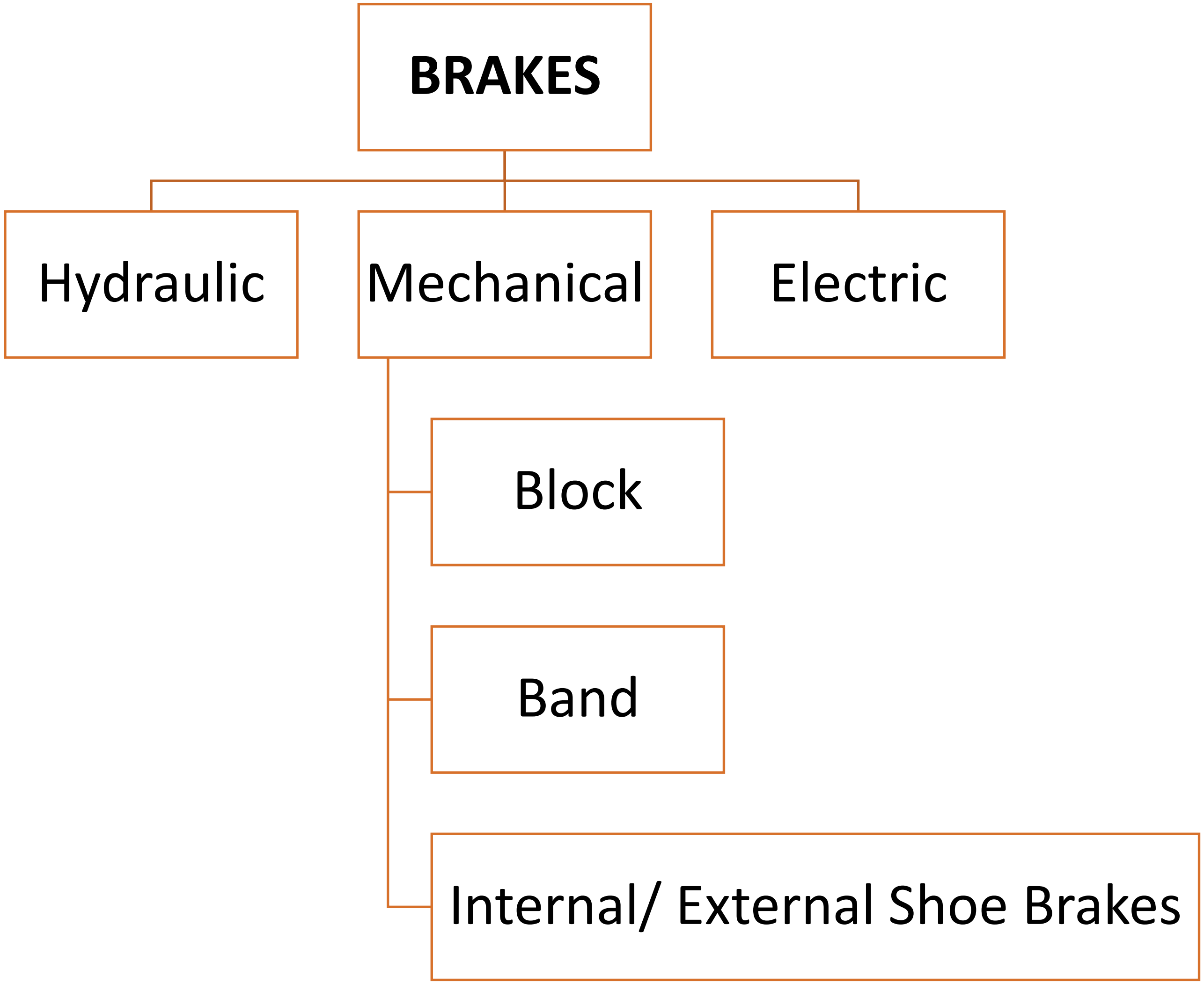
Machine Design

Course No. MEC3110

Brakes

A brake is a mechanical device, which is used to absorb the energy possessed by a moving system or mechanism by means of friction.

Its primary purpose is to slow down or completely stop the motion of a moving body.


BRAKES
Hydraulic
Mechanical
Electric
Block
Band
Internal/ External Shoe Brakes

Classification of Brakes

By method of power:

According to the means used for transferring the energy by the braking element is classified as

a) Mechanical brakes
b) Hydraulic brakes
c) Air brakes
d) Vacuum brakes
e) Power assisted hydraulic brakes
f) Magnetic brakes
g) Electrical brakes

By method of application:

a) Service or foot brakes
b) Parking or hand brakes

By method of operation

a) Manual
b) Servo
c) Power operation

By method of Braking contact

a) Internal Expanding Brakes
b) External Contracting Brakes

By method of application

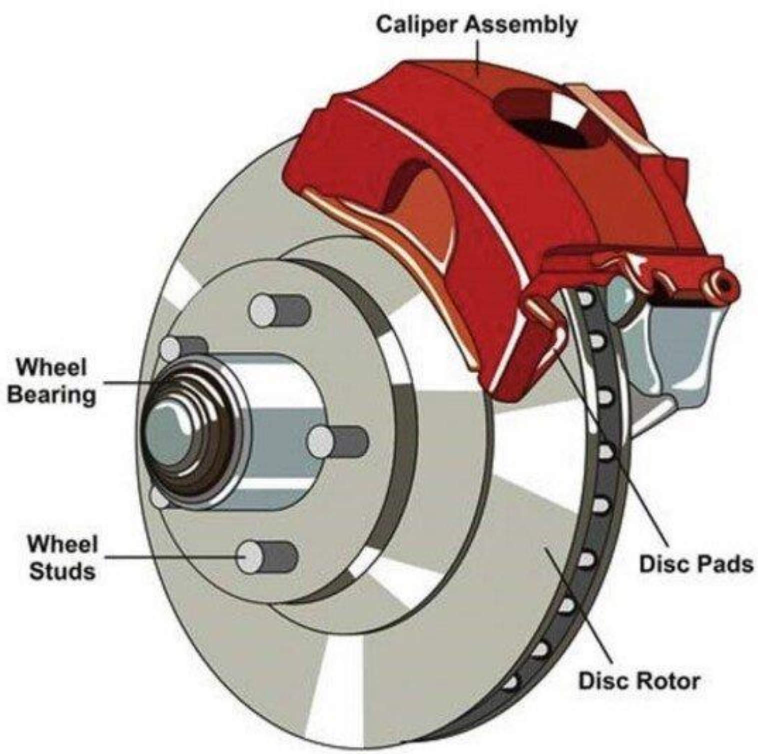
a) Service or foot brakes
b) Parking or hand brakes

By Method of Applying Brake force

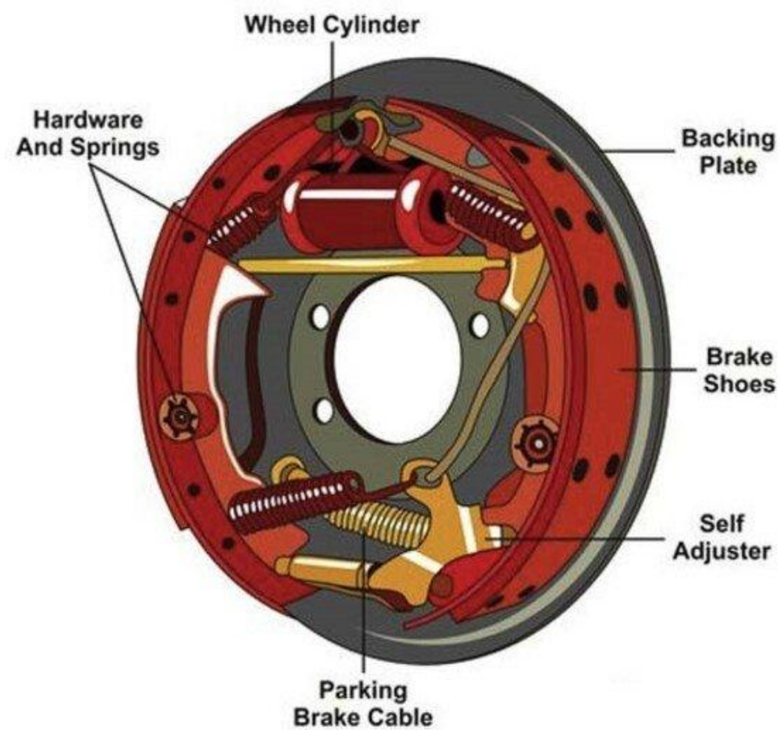
a) Single Acting Brakes.
b) Double Acting Brakes.

Mechanical Brakes

1. Disc Brakes
2. Drum Brakes (Internal Expanding or External Contracting)



Disk Brake



Drum Brake

Disc Brakes

The development of disc brake begin in England in the 1890.

The Jaguar racing team won the Le Mans auto race in 1953, using disc brake equipped car.

Mass production quickly followed with the 1955 Citroen DS.

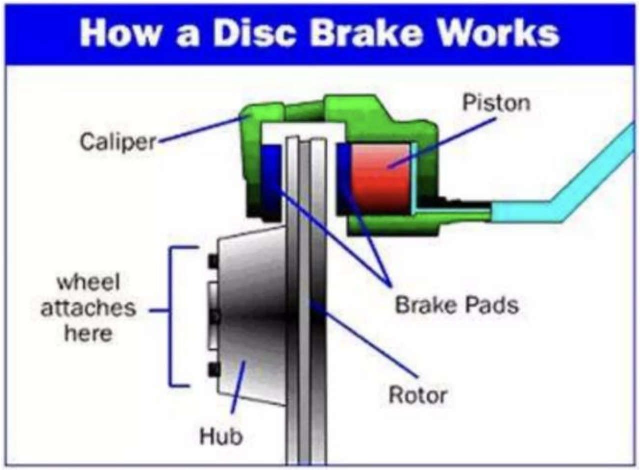
It makes use of fluid pressure to squeeze the disc brakes on to the disc in order to create friction which retards motion.

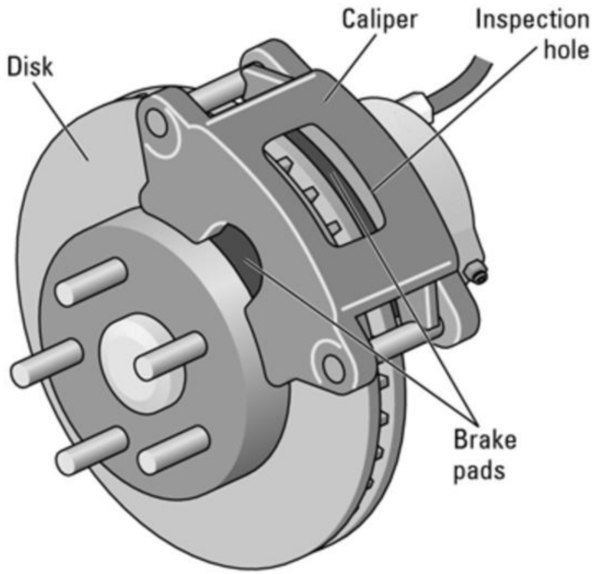
It uses calipers which has piston inside it.

Compared to drum brakes they have better braking efficiency.

Drum brakes are prone to bell mouthing.

Usually made of cast iron but in some cases they are made of carbon-carbon or carbon ceramic matrix composites.

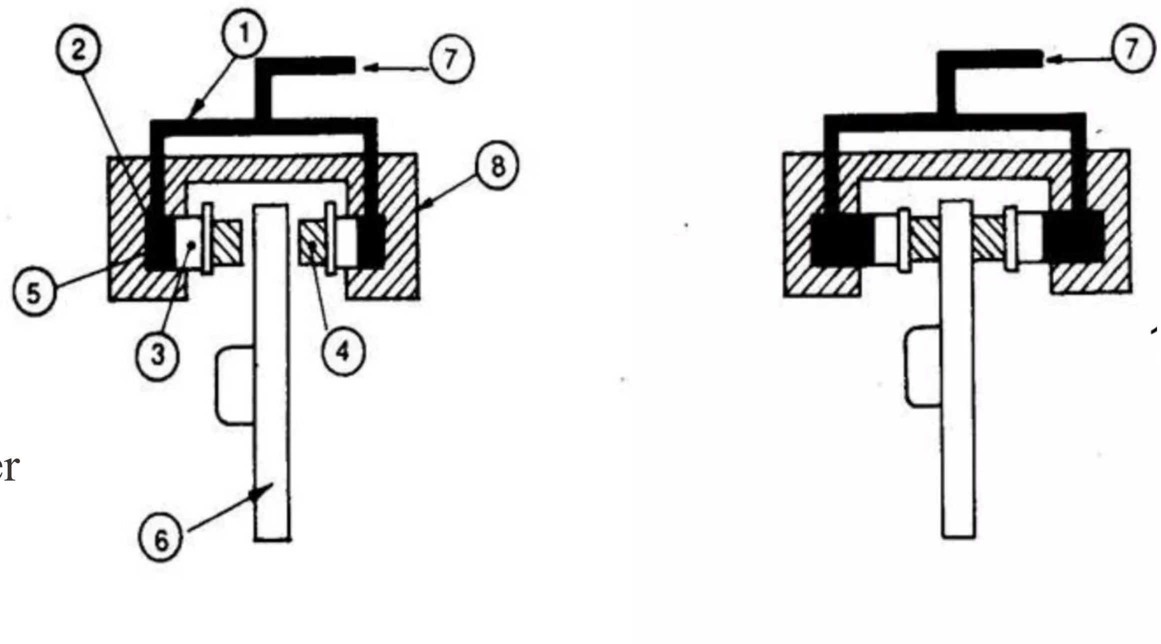




Disc Brakes (Construction)

Disc Brakes

1. Connecting tube
2. Cylinder
3. Piston
4. Friction pad
5. Hydraulic fluid
6. Brake disc
7. From master cylinder
8. Calliper



(a) RELEASED

(b) APPLIED

Disc Brakes

Disc

- It is made of high-grade of gray cast iron having pearlitic structure to give better wear resistance property.
- This disc, which rotates with the car wheel, is efficiently cooled as most of its area lies exposed.

Calipers

- These are of V-shaped type and are in two halves. Each half has a pad bonded to a steel plate, a steel piston and a brake cylindrical housing bolted together.
- Both these halves are hydraulically linked so that equal pressure may be applied on the pad through floating pistons.
- Hydraulic pressure is applied only on one side of the piston.

Disc Brakes

Friction Pads

- These are made of asbestos, fiber and metal oxide fillers bonded with organic compounds.
- Each pad is fixed to a steel plate that has to take torque during braking on to the calliper.
- The pads may be of square, rectangular, oval or segmental in shape.
- The size of the piston is made the same as that of pads to avoid noise during braking.
- Rubber sealing rings prevent dust and moisture to enter the piston housings.

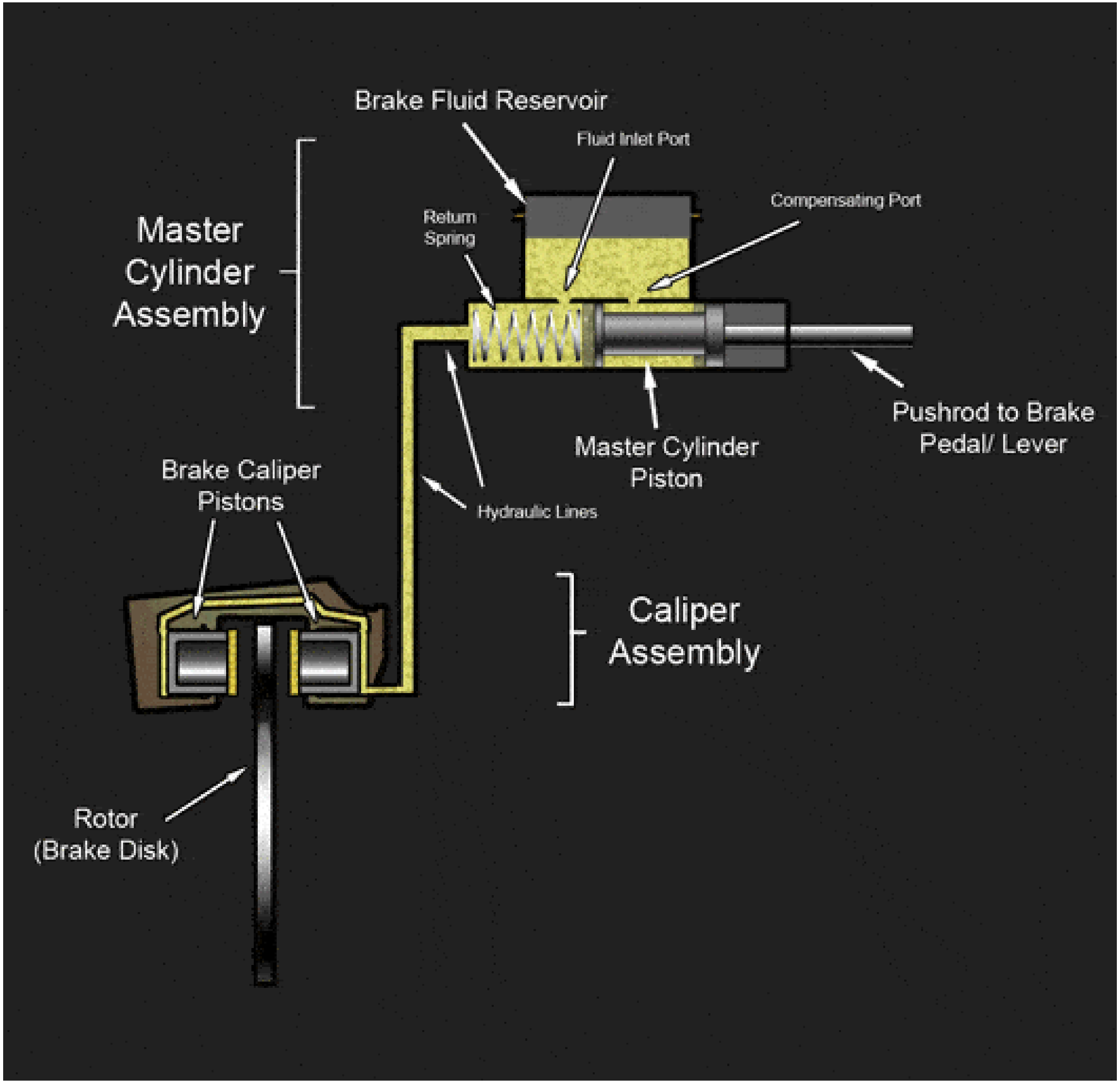
Disc Brakes (Working)

- When the driver applies pressure on the brake pedal, hydraulic pressure pushes the pistons out from their housing.

- The pistons, in turn, press the brake pads against the moving disc faces, causing friction and hence slowing it down.

- Hydraulic pressure is equally applied by the hydraulic fluid to the floating pistons on either side.

- When the driver takes his foot off the brake pedal, hydraulic pressure on the friction pads is released; the pistons move inwards and break their contact with the disc.


Brake Fluid Reservoir
Fluid Inlet Port
Compensating Port
Return Spring
Master Cylinder Assembly
Pushrod to Brake Pedal/ Lever
Master Cylinder Piston
Brake Caliper Pistons
Hydraulic Lines
Caliper Assembly
Rotor (Brake Disk)

Disc Brakes

Advantages

- **Less Effort:** Due to hydraulics as a standard on all disc brake systems, engaging a disc brake requires less effort and produces greater braking force.
- **Heat Dissipation:** Due to the large surface area of discs any heat produced by friction of the brake pads on the disc dissipates into the atmosphere. This prevents overheating of the disc and improves braking even in frequent hard braking situations.
- **Standard Performance In Any Weather:** Disc brakes perform well even in wet conditions and don’t slip or grab like their drum counterparts.
- **Easy Installation:** A disc brake has a few components and hence very easy to install, even you can learn how to change the brake pads on your discs.

Disc Brakes

Disadvantages

- **Expensive:** Disc brakes are downright expensive and that is the reason why car manufacturers opt for drum brakes on the rear wheels to bring down manufacturing costs.
- **Rotor Warping:** In case of high speed braking there is a chance that the brake rotor might warp. This can happen due to very high temperatures on the discs followed by immediate cooling. Improper installation of the disc brake could also cause it to warp.
- **Brake Pad Wear Out:** Brake pads on disc brakes tend to wear out faster than drum brakes, this happens due to the powerful squeezing motion of the brake piston on the brake pads. This provides better stopping power but reduced brake pad life.
- **Less Effective As Parking Brakes:** The brake pads on discs tend to expand when heated and contract when cold. Since parking does not produce heat, the disc brakes are less likely to hold the wheels for a longer duration. This is the reason why high performance vehicles have an extra drum brake in addition to four wheel discs.

Disc Brakes Design

There are two shapes of disc brake pads *viz.*

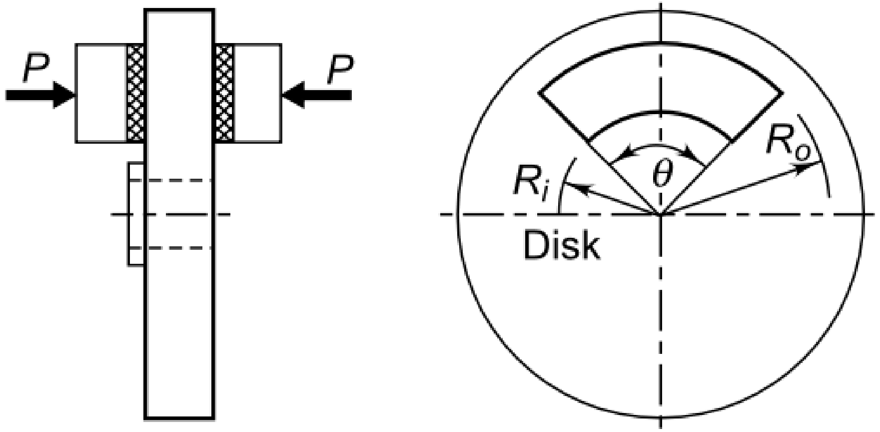
1. Annular
2. Circular

Disc Brakes Design

Annular

The disc brake with an annular pad is illustrated in Fig. below. The dimensions of the annular pad are as follows:

R_o = outer radius of pad (mm)
R_i = inner radius of pad (mm)
θ = angular dimension of pad (radians)



Disc brake with an annular pad

Disc Brakes Design

Annular

Since the area of the pad is comparatively small, it is assumed that pressure on friction lining is uniform. The friction radius (*Rf*) for uniform pressure theory is given by,

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

Substituting,
($D = 2R_o$) and ($d = 2R_i$) in the above expression,

$$R_f = \frac{2}{3}\frac{(R_o^3 - R_i^3)}{(R_o^2 - R_i^2)} \qquad (12.29)$$

Disc Brakes Design

Annular

The torque capacity of the disk brake is given by,

$$M_t = \mu P R_f \qquad (12.30)$$

where,

M_t = torque capacity of pad (N-mm)

μ = coefficient of friction

P = actuating force (N)

R_f = friction radius (mm)

Disc Brakes Design

Annular

The area of the pad is given by,

$$A = \left(\frac{\theta}{2\pi}\right)\pi(R_o^2 - R_i^2)$$

or
$$A = \frac{1}{2}\theta(R_o^2 - R_i^2) \qquad (12.31)$$

where (θ) is in radians.

The actuating force P is given by,

$$P = \text{average pressure} \times \text{area of pad}$$

or
$$P = p_{\text{ave.}}\, A \qquad (12.32)$$

where A is the area of the pad (mm^2)

Disc Brakes Design

Annular

Example 12.12 *Following data is given for a caliper disk brake with annular pad, for the front wheel of the motorcycle:*

torque capacity	=	*1500 N-m*
outer radius of pad	=	*150 mm*
inner radius of pad	=	*100 mm*
coefficient of friction	=	*0.35*
average pressure on pad	=	*2 MPa*
number of pads	=	*2*

Calculate the angular dimension of the pad.

Disc Brakes Design

Annular

Solution

Given $M_t = 1500$ N-m $R_o = 150$ mm
$R_i = 100$ mm $p_a = 2$ MPa $\mu = 0.35$
Number of pads = 2

Step I *Actuating force*

Since there are two pads, the torque capacity of one pad is (1500/2) or 750 N-m.

From Eq. (12.29),

$$R_f = \frac{2}{3}\frac{(R_o^3 - R_i^3)}{(R_o^2 - R_i^2)} = \frac{2}{3}\frac{(150^3 - 100^3)}{(150^2 - 100^2)} = 126.67 \text{ mm}$$

From Eq. (12.30),

$$M_t = \mu P R_f$$

$750(10)^3 = 0.35P(126.67)$ or $P = 16\,916.85$ N

Disc Brakes Design

Annular

Step II *Angular dimension of pad*

P = average pressure × area of pad

[2 MPa = 2 N/mm^2]

16 916 .85 = 2 A or A = 8458.42 mm^2

From Eq. (12.31),

$$A = \frac{1}{2}\theta(R_o^2 - R_i^2)$$

or
$$8458.42 = \frac{1}{2}\theta(150^2 - 100^2)$$

$$\theta = 1.3533 \text{ radians}$$

or
$$\theta = 1.3533\left(\frac{180}{\pi}\right) = 77.54°$$

The angular dimension of the pad can be taken as 80°.

Disc Brakes Design

Circular/ Round

The disc brake with a circular pad is illustrated in Fig. below. The dimensions of a circular pad are as follows:

R = radius of pad (mm)
e = distance of pad centre from the axis of disk (mm)

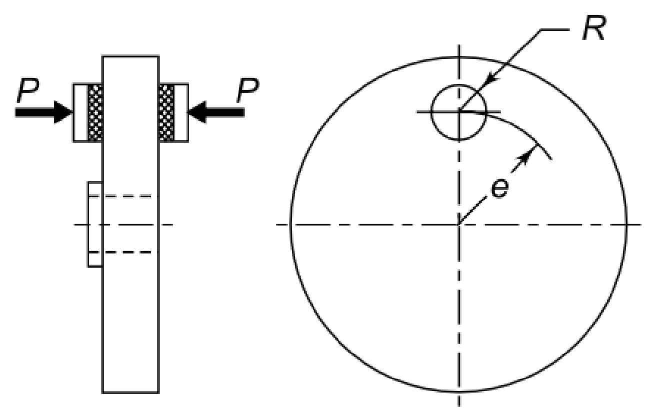


Fig. 12.28 *Disk Brake with Circular Pad*

The friction radius (R_f) of circular pad is given by,

$$R_f = \delta e \qquad (12.33)$$

The values of (δ) are given in Table 12.1.

Disc Brakes Design

Circular/ Round

Values of δ for circular-pad caliper disk brakes

R/e	δ
0.0	1.0000
0.1	0.9833
0.2	0.9693
0.3	0.9572
0.4	0.9467
0.5	0.9375

Disc Brakes Design

Circular/ Round

Example 12.13 The following data is given for a calliper disc brake, with circular pad, for the lightweight two-wheeler,

torque capacity = 1500 N-m
number of caliper brakes on the wheel = 3
number of pads on each caliper brake = 2
coefficient of friction = 0.35
average pressure on pad = 2 MPa

The ratio of pad radius to the distance of the pad center from axis of disk is 0.2. Calculate the radius of the pad.

Disc Brakes Design

Circular/
Round

Solution

Given $M_t = 1500$ N-m $p_a = 2$ MPa $\mu = 0.35$

$(R/e) = 0.2$ Number of brakes = 3

Number of pads on each brake = 2

Step I *Radius of pad*

Since there are three caliper brakes, each with two pads, the torque capacity of one pad is (1500/6) or 250 N-m.

$$\left(\frac{R}{e}\right) = 0.2 \quad \text{from Table 12.1A, } \delta = 0.9693$$

From Eq. (12.33),

$$R_f = \delta e = 0.9693e = 0.9693\left(\frac{R}{0.2}\right)$$
$$= (4.8465)R \text{ mm}$$

Disc Brakes Design

Circular/ Round

P = average pressure × area of pad = $2(\pi R^2)$
[2 MPa = 2 N/mm^2]

From Eq. (12.30),

$$M_t = \mu P R_f$$

$$250(10^3) = 0.35(2\pi R^2)(4.8465\ R)$$

$$R = 28.63 \text{ mm}$$

The radius of the pad can be taken as 30 mm.