

# REPORT OF BRAKING SYSTEM

## **Objective:**

The brakes are one of the most important control components of vehicle. They are required to stop the vehicle within the smallest possible distance and this is done by converting the kinetic energy of the vehicle into the heat energy which is dissipated into the atmosphere.

In our vehicle, two disc brakes are used on the front axle to be more effective and drum brake on rear axle assisting to slow or stop the vehicle instantly after applying the brakes. Tandem master cylinder is used as a master cylinder in our vehicle because the tandem master cylinder transforms applied brake force into hydraulic pressure which is transferred to the wheel units through two separate circuits. This provides residual braking in the event of fluid loss.

## **Selection of disc brakes on front:**

- Heating of the Brake rotor increases its thickness thereby causing no loss in brake fluid volume.
- Better stability than Drum Brake.
- Increase in temperature does not affect the disc pads.
- The braking design is simple.
- Maintenance and repairs of disc brakes is easy.

- Disc brakes weight less than drum brakes.
- It has better anti fade properties than drum brakes.
- The major advantage of the disc brake is its ability to operate with little fade at high temperatures of up to 1073 to 1173 K, while drum brakes are highly temperature sensitive. A maximum temperature of 673 to 700 K should not be exceeded.
- Water and dirt resistant.
- Better cooling, Friction surfaces are directly exposed to air in disc brake while in drum the friction surfaces are not directly exposed to air.
- Total frictional area of pads in disc brakes is very less as compared with the conventional drum type brakes, the approximate ratio being 1:4. This means that in disc brakes, the pressure intensity must be considerably greater than in the drum type. This implies that frequent relining would be necessary, due to increased rate of wear.

## **DISC BRAKES:**

Disc brakes are fairly simple to work with, once you know the parts and their functions.

The main components of a disc brake are:

- Rotor
- Caliper, which contains a piston
- Brake pads

In a disc brake, the brake pads squeeze the rotor instead of the wheel, and the force is transmitted hydraulically instead of through a cable. Friction between the pads and disc slows the disc down.

### **Rotor:**

Brake rotors are metal discs. It is an important component in the braking system. The caliper clamp on to them to slow their rotation, and then slow or stop the car.

The discs of the brake have been conventionally made of pearlitic gray cast iron. It is cheap and has good anti wear properties, cast steel discs also used but drawback in their cases are less uniform friction behavior. Recently ceramics and carbon fiber also used.

Two types of discs have been employed in various makes of disc brakes,

- I. Solid type
- II. Ventilated type

### **Caliper:**

Calipers are the housing that contains the pistons and the brake pads. The Calipers are connected to the Hydraulic system, and hold the brake pads to the Rotor.

There are two main types of calipers:

1. Floating (or sliding) calipers
2. Fixed calipers

### **Pistons:**

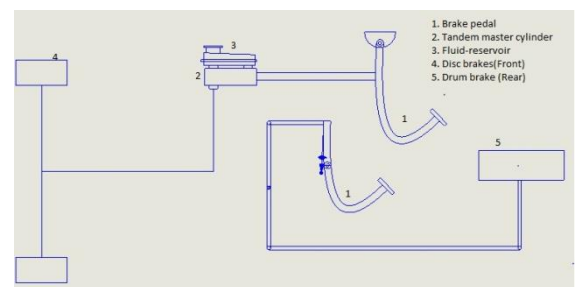
The most common brakes use a single hydraulic-actuated piston within a cylinder in the caliper. Pistons are made up of aluminum or chrome-plated iron.

### **Brake Pads:**

Brake pads are a key brake part because they are the component that contacts and applies pressure and friction to a vehicles brake rotors. Brake pads are designed for high friction.

### **BRAKE CIRCUIT:**

In our Brake circuit, the two independent line from the tandem master cylinder is actuated by single pedal for locking the two wheels on front effectively. And also provide another one pedal for locking the rear wheel with drum brake.



### **Elements used in our vehicle:**

- ❖ Tandem master cylinder: Maruthi Omni
- ❖ Disc (or) Rotor : Pulsar 150
- ❖ Caliper : Pulsar 150
- ❖ Actuation pedal : Maruthi Omni  
actuation pedal

❖ Brake Lining : Maruthi  
Omni brake Hoses

❖ Brake Fluid : Dot 3

### Reasons for choosing:

- ✓ Pulsar 150 disc brakes is selected because of its Low ground clearance.
- ✓ Thickness of Pulsar 150 disc is low so it can be easily turned which is required for our design.
- ✓ Outer diameter of the Pulsar 150 disc is low and which is required as per our design.
- ✓ In Pulsar 150, the Piston diameter in caliper is smaller than other bikes piston diameter, so it can easily mounted.
- ✓ We have chosen Dot 3 as brake fluid as it is inexpensive and easily available.

### WEIGHT TRANSFER:

Front Weight (Rest): 1079.1 N

Rear Weight (Rest): 882.9 N

Total Weight: 1962 N

% Front Weight (Static): 55 %

CG Height in Inches: 0.254 m

Wheelbase: 1.8 m

Dynamic Front Weight: 1096 N

Dynamic Rear Weight: 866 N

% Front Weight (Dynamic): 55.86%

### Braking Calculations:

#### The Conservation of Energy:

The braking system exists to convert the energy of a vehicle in motion into thermal Energy, more commonly referred to as heat.

From basic physics, the kinetic energy of anybody in motion is defined as:

$$\text{Kinetic Energy} = \frac{1}{2} Mv * Vv^2$$

$$Mv = 200 \text{ Kg}$$

$$Vv = 35 \text{ Km/hr}$$

$$= (35 * 1000) / 3600$$

$$= 9.72 \text{ m/s}$$

$$\text{K.E} = \frac{1}{2} (200 * 9.72^2)$$

$$= 9.45 \text{ KJ.}$$

Where,

**Mv** = the mass (commonly thought of as weight) of the vehicle in motion.

**Vv** = the velocity (commonly known as speed) of the vehicle in motion.

In most single-stop events, the rotors serve as the primary energy absorbing components.

In practical application, tire rolling resistance, aerodynamic drag, grade resistance, and other mechanical losses will also play an energy-absorbing role, but value is still placed

In establishing this fundamental relationship as a limiting condition.

### Force applied on brake:

$$\begin{aligned} F_d &= 70 \text{ lb.} \\ &= (70 * 0.445) * 9.81 \\ &= 305.58 \text{ N} \end{aligned}$$

### The Brake Pedal:

The brake pedal exists to multiply the force exerted by the driver's foot. From elementary statics, the force increase will be equal to the driver's applied force multiplied by the lever ratio of the brake pedal assembly:

$$F_{bp} = F_d * (L_2 / L_1)$$

$$F_d = 305.58 \text{ N}$$

$$L_2 = 6 \text{ m}$$

$$L_1 = 1 \text{ m}$$

$$\begin{aligned} F_{bp} &= 305.58 * (6/1) \\ &= 1833.48 \text{ N} \end{aligned}$$

Where,  $F_{bp}$  = the force output of the brake pedal assembly

$F_d$  = the force applied to the pedal pad by the driver

$L_1$  = the distance from the brake pedal arm pivot to the output rod clevis attachment.

$L_2$  = the distance from the brake pedal arm pivot to the brake pedal pad

### PRESSURE IN MASTER CYLINDER:

It is the functional responsibility of the master cylinder to translate the force from the brake pedal assembly into hydraulic fluid pressure. Assuming incompressible liquids and infinitely rigid hydraulic vessels, the pressure generated by the master cylinder will be equal to:

$$\begin{aligned} P_{mc} &= F_{bp} / A_{mc} \quad (d=21\text{mm}) \\ &= F_{bp} / (\pi/4 * d^2) \end{aligned}$$

$$A_{mc} = 3.46 * 10^{-4} \text{ m}^2$$

$$\begin{aligned} P_{mc} &= 1833.48 / (3.46 * 10^{-4}) \\ &= 5.29 * 10^6 \text{ N/m}^2 \end{aligned}$$

Where,  $A_{mc}$  = Area of the master cylinder.

$P_{mc}$  = the hydraulic pressure generated by the master cylinder

$d$  = diameter of the master cylinder piston

### BRAKE FLUID, BRAKE PIPES AND HOSES:

It is the functional responsibility of the brake fluid, brake pipes, and hoses to transmit the hydraulic fluid pressure from the master cylinder to the caliper located at the wheel ends. However, again assuming incompressible liquids and infinitely rigid hydraulic vessels, the pressure transmitted to the calipers will be equal to:

$$P_{cal} = P_{mc}$$

Where,  $P_{cal}$  = the hydraulic pressure transmitted to the caliper

### THE CALIPER, PART I:

It is the first functional responsibility of the caliper to transfer the hydraulic fluid pressure from the pipes and hoses into a linear mechanical force. Once again assuming incompressible liquids and infinitely rigid hydraulic vessels, the one-

sided linear mechanical force generated

by the caliper will be equal to:

Measured value of caliper diameter = 34mm

$$F_{cal} = P_{cal} \times A_{cal}$$

$$\begin{aligned} A_{cal} &= 3.14/4 * d^2 \\ &= 3.14/4 * (34*10^{-3})^2 \\ &= 9.08 * 10^{-4} \text{ m}^2 \end{aligned}$$

$$\begin{aligned} F_{cal} &= 5.29 * 10^6 * (9.08*10^{-4}) \\ &= 4803.32 \text{ N} \end{aligned}$$

Where,

$F_{cal}$  = the one-sided linear mechanical force generated by the caliper.

$A_{cal}$  = the effective area of the caliper hydraulic piston(s) found on One half of the caliper body.

## THE CALIPER, PART II:

The amount of force it can apply to the surface of a rotor, is known as Clamping force. It is the second functional responsibility of the caliper to react the one-sided linear mechanical force in such a way that a clamping force is generated between the two halves of the caliper body. Regardless of caliper design (fixed body or floating body), the clamping force will be equal to, in theory, twice the linear mechanical force as follows:

$$\begin{aligned} F_{clamp} &= F_{cal} * 2 \\ &= 4803.32 * 2 \\ &= 9606.64 \text{ N} \end{aligned}$$

Where,  $F_{clamp}$  = the clamp force generated by the caliper.

## THE BRAKE PADS:

The brake pads will generate a frictional force which opposes the rotation of the spinning rotor assembly. This frictional force is related to the caliper clamp force as follows:

$$\begin{aligned} F_{friction} &= F_{clamp} * \mu_{bp} \\ &= 9606.64 * 0.5 \\ &= 4803.32 \text{ N} \end{aligned}$$

Where,

$F_{friction}$  = the frictional force generated by the brake pads opposing the Rotation of the rotor.

$\mu_{bp}$  = the coefficient of friction between the brake pad and the rotor. (According to the material used)

## TORQUE PRODUCED IN ROTOR:

Generally rotors are vented to aid in cooling and keep braking consistent and overheating. It is the functional responsibility of the rotor to generate a retarding torque as a function of the brake pad frictional force. This torque is related to the brake pad frictional force as follows:

$$\begin{aligned} T_{r1} &= F_{friction} \times R_{eff} \\ &(\text{Rear effective radius} = 90*(10)^{-3} \text{ m}) \end{aligned}$$

$$= 4803.32 * 90*(10)^{-3}$$

$$= 432.3 \text{ N-m}$$

$$\begin{aligned} T_{r2} &= F_{friction} \times R_{eff} \\ &(\text{Rear effective radius} = 90*(10)^{-3}) \end{aligned}$$

$$= 4803.32 * 90*(10)^{-3}$$

$$= 432.3 \text{ N-m}$$

Where,

$T_{r1}, T_{r2}$  = the torque generated by the rotor

$R_{eff}$  = the effective radius (effective moment arm) of the rotor (measured from the rotor centre of rotation to the centre of pressure of the caliper pistons).

Because the rotor is mechanically coupled to the hub and wheel assembly, and because the tire is assumed to be rigidly attached to the wheel, the torque will be constant throughout the entire rotating assembly as follows:

$$T_t = T_w = T_r$$

Where,  $T_t$  = the torque found in the tire

$T_w$  = the torque found in the wheel

### THE TIRE:

$$F_{tire} = T_t / R_t$$

**For front 1,**

$$F_{tire} = 432.3 / (217 * 10^{-3}) \\ = 1992.17 \text{ N}$$

**For front 2,**

$$F_{tire} = T_t / R_t \\ = 432.3 / (217 * 10^{-3}) \\ = 1992.17 \text{ N}$$

Where,

$F_{tire}$  = the force reacted between the tire and the ground (assuming friction exists to support the force)

$R_t$  = the effective rolling radius (moment arm) of the loaded tire

Up to this point our analysis has consisted of a single wheel brake assembly; however, because modern vehicles have one wheel brake assembly at each corner

of the car, there are actually three tire forces being reacted during a typical stopping event. Because of this condition, the total braking force generated is defined as the sum of the three contact patch forces as follows:

$$F_{total} = \Sigma F_{tire} (LF, RF) \\ = 2 * 1992.17 \\ = 3984.34 \text{ N}$$

Where,

$F_{total}$  = the total braking force reacted between the vehicle and the ground (assuming adequate traction exists)

### DECELERATION OF THE VEHICLE:

If a force is exerted on a body it will experience a commensurate acceleration. Convention dictates that accelerations which oppose the direction of travel are called decelerations. In the case of a vehicle experiencing a braking force, the deceleration of the vehicle will be equal to:

$$a_v = F_{total} / M_v \\ = 3984.34 / 200 \\ = 19.92 \text{ m/s}^2$$

Integrating the deceleration of a body in motion with respect to time allows for the determination of speed. Integrating yet again allows for the determination of position. Applying this relationship to a vehicle experiencing a linear deceleration, the theoretical stopping distance of a vehicle in motion can be calculated as follows:

Where,

$a_v$  = the deceleration of the vehicle.

**KINEMATIC RELATIONSHIPS  
OF VEHICLES  
EXPERIENCING  
DECELERATION:**

$$SD_v = v_v^2 / 2 * a_v$$

$$= 9.72^2 / 2 * 19.92$$

$$= 2.37 \text{ m}$$

Where,

$SD_v$  = the stopping distance of the vehicle

Note: In practical application, deceleration cannot be achieved instantaneously, nor can Deceleration be assumed to be constant for the duration of a stopping event.

**STOPPING TIME:**

$$SD_v = V_v * t + \frac{1}{2} a_v t^2$$

$$0 = 9.72 * t + \frac{1}{2} 19.92 t^2$$

$$t = 0.96 \text{ sec}$$

**BRAKING EFFICIENCY:**

$$\eta = (\text{Weight of the vehicle} / \text{Brake effort}) * 100\%$$

$$= (200 / 305.58) * 100\%$$

$$= 65 \% \text{ (Fair)}$$

