# A Review on Design of Hydraulic Disc Braking System and its Calculations for Cycle sports Bicycle.

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**Abstract -** *The design of effective Braking System of your bicycle is the most important safety system in high performance bicycle. Since the stopping distance and speed control during racing or descending hills plays major role in cycle adventure. Fundamental requirement of any braking system is to decelerate a vehicle precisely in variable conditions. The kinetic energy which is proportional to its mass and square of its speed needs to be safely dissipated in form of heat. The braking system must be strong. Any bicycle with highly effective braking system gives confidence to the cyclist. It also increase cycling pleasure. The paper presents the design of effective hydraulic disc braking system and its calculations. It will help to avoid an incident or an accident.*

***Key Words***: Hydraulic disc brake, braking torque, stopping distance, Friction, Rotors, Master cylinder.

## 1. INTRODUCTION

Braking system is back bone of cycle control and safety. A Braking system is designed to slow and halt the motion of vehicle. It converts the moment (Kinetic Energy) to friction energy interns heat energy which is dissipated to atmosphere. This is done by providing friction at the wheels. Brake is the device which brings the moving vehicle into rest or stop the vehicle in the shortest possible time to obtain an excellent control.

There are various types of braking systems available such as Mechanical Disc Braking System and Hydraulic Disc Braking System based on components involved. These brake actuation systems convert kinetic energy (Driving force) into friction force at the friction surface.

In Mechanical disc braking system a cable pull mechanism is used. In this braking system cable pull the caliper down and this forces the pad against the rotor and brings the cycle to stop.

Hydraulic disc braking system use fluid transfer mechanism. In this braking system fluid is used to push the braking pad against the rotor and brings the cycle to stop.

The main objective of any braking system is to maintain reduction in speed of vehicle. Hence we need to calculate the braking torque, stopping distance etc.

### 1.1. Design of Braking System Components-

Let's take a look at the different parts which make the hydraulic braking system. The entire braking system can be divided into the following main parts:

**Master Cylinder (Lever)**
**Brake Lines**
**Brake Fluid**
**Slave Cylinder (Caliper)**
**Brake Pads**
**Rotor**

**Master Cylinder (Lever) -**
The master cylinder, mounted to the handlebar houses the brake level and together they produce the input force. This force needed to push hydraulic brake fluid to the slave cylinder (caliper) and cause the brake pads to fix the rotor and to stop the bicycle.

Master cylinder systems can be categorized into two different groups:

- Open System -

An open system includes a reservoir and bladder which allow fluid to be added or removed from the braking system automatically during use.

- Close System –

A closed system includes a reservoir and bladder which allow fluid to be added or removed from the braking system manually during use.

**Brake Lines (Hose) -**

Hydraulic brake lines (Hoses) play the important role in connecting the master cylinder and slave cylinder (caliper). Hydraulic hoses have multi-layered in their construction and usually consists of 3 layers:

- Inner Tube -

This layer of hose made to hold the fluid. Teflon is used as the material because it does not react with brake fluid.

- Aramid (Kevlar) Layer -

Provides the strength and structure of the hose. This layer is flexible and control the high pressure of the hydraulic system. It can be cut easily and reused using standard hose fitting.

- Outer Casing -

Serves as a protection layer for both the Kevlar layer and inner layer to reduce corrosion.

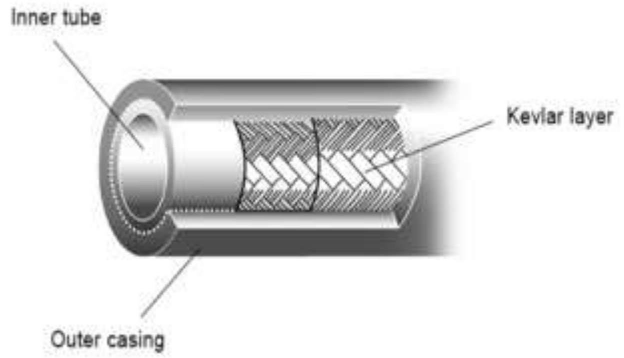


**Fig 1.** Multi-layered construction of hose

**Brake Fluid -**

Brake fluid is type of hydraulic fluid used in hydraulic brake and hydraulic clutch applications. It is used to transfer force into pressure and to increase braking force. When you apply force to the brake lever, brake fluid transfer this force into pressure to the front and rear brakes and stop the bicycle. It works because liquid has incompressible.

Hydraulic braking system generally used two types of brake fluid such as DOT fluid or Mineral oil.

- DOT Brake Fluid -

DOT brake fluid is approved and controlled by the department of transportation. It is classified by its performance property mainly its boiling point.
The table below shows DOT brake fluid with its corresponding boiling temperature.

| DOT Fluid | Dry Boiling Point |
|---|---|
| DOT 3 | 205°C(401°F) |
| DOT 4 | 230°C(446°F) |
| DOT 5 | 260°C(500°F) |
| DOT 5.1 | 270°C(518°F) |

**Table -1:** DOT brake fluid with its boiling temp.

**Slave Cylinder (Caliper) -**

The brake caliper fits over the rotor like a clamp. The brake caliper connects each wheel and respond to the lever input generated by the cyclist. This lever input is converted to clamping forces at the pistons and move the brake pad to contact the rotor. Caliper can be fixed by a rigid mount to the frame or floating. Inside the caliper there is a pair of metal plates bonded with friction materials are called brake pads. Caliper construction can be divided into two categories:

- Mono-block -

A Mono-block caliper is actually a one piece design formed from one piece of material. It is light weight caliper as there is no need of steel bolts for joining both halves. Maintenance of a Mono-block caliper is tricky, but manufacturing and assembly are usually more difficult.

- Two piece -

These two piece calipers are constructed into two separate halves and then combined together with steel bolts, which can provide additional strength as compared to mono-block design. Maintenance, manufacturing and assembly of two piece is simple. Steel bolts are required for joining both the halves.

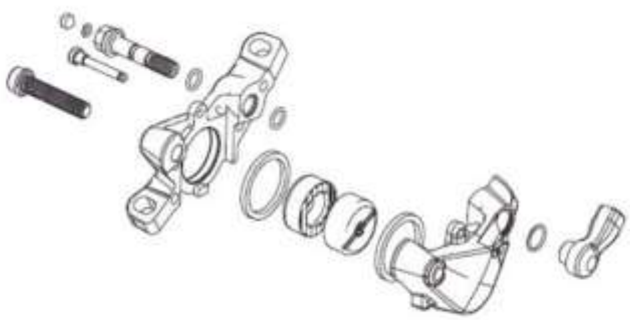

**Fig 2.** Exploded view of two piece caliper design

**Brake Pads -**

Inside of the caliper there is pair of metal plate with friction material bound to the surface that forces the rotor are called brake pads.
Let's look at the different pad materials available:


**Fig 3.** Different brake pad materials

**Rotor -**

The rotor is the rotating part of the braking system assembly, which is held at wheel. Rotor size has a direct effect on braking power. Larger brake rotor had more power produced for any given input.

Mountain bicycles rotors having range in size from 160 mm to 203 mm.

There are two types of rotors in the market today are ISO standard 6-bolt rotors and center lock rotors. Both have their pros and cons.

- 6-bolt rotors -

This is the common rotor fixing system in use today. Installation of six fixing bolts there is always the risk of stripping a thread on fixing bolts and hub mounting points.

- Center-Lock rotors -

The center lock system eliminates the risk of stripping threads as there are no bolts to worry about, just one Centre locking ring. Installation and removal is also simplified. Center lock rotors are also generally slightly heavier and can come at a price premium.

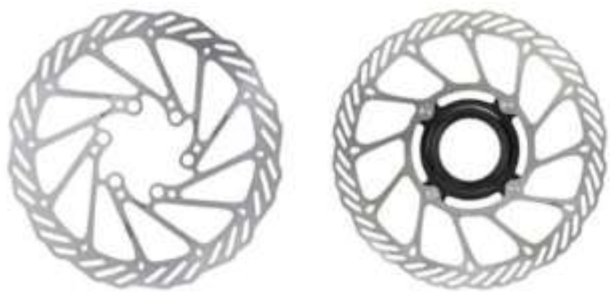

**Fig 4.** Left to right: ISO standard 6-bolt rotor and Center lock rotor

### 1.2 Working of Hydraulic Disc Braking System-

Hydraulic brake works on Pascal's law which states that "pressure acting in an enclosed system is same in all directions". According to this law when the pressure is applied on a fluid it will travel equally in all the directions. Hence the uniform braking action is applied on both wheels. When you press the break lever, the fluid forces the pads against the rotor, and the resistance created between the two objects which stops the bicycle. The hydraulic disc brakes do well than mechanical disc brakes because the fluid in the braking system is not compressible. Due to this the pressure applied to the rotor is much higher than your applied force on the lever. You don't have to push the lever hard. A simple push with the help of two fingers is enough to give you more stopping power.

## 2. CALCULATIONS-

We consider,

1. Rotor diameter = 180mm
2. Brake pad diameter = 12mm
3. Brake line (cable) diameter = 1.6mm
4. Total weight of bicycle with cyclist = 60 kg
5. Bicycle wheel diameter = 24 inch = 0.6096 m
6. Speed of bicycle = 40kmph

- Weight on single wheel = 60/2 kg
  = 30 kg
  = 30 × 9.81
  **= 294.3N**

- Speed (v) = 40 kmph
  = 40 × 5/18
  **= 11.11m/sec**

We know that,

- Kinetic Energy = $1/2 \times mv^2$
  = $1/2 \times 60 \times 11.11^2$
  **= 3702.96 J**……… (For two wheels)
  **= 1851.48 J**……… (For single wheel)

- Angular velocity (ω) = (velocity)/(radius of wheel)
  = 11.11/0.3048
  **= 36.45rad/sec**

Consider the driver can apply the force on brake of 65N

- Pressure in brake cable,
  $P_{cable}$ = (Applied force)/ (area of wire)
  = $65/ \pi/4 \times (1.6)^2$
  **= 32.32N/mm²**

- Force generated by caliper piston,

$F_{caliper}$ = (Pcable) × (area of brake pad)
= $32.32 \times (\pi/4 \times (12)^2)$
**= 3656.25N**

- Caliper clamp load,

$F_{clamp} = (F_{caliper}) \times 2$
= 3656.25 × 2
**= 7312.5N**

- Force on disc by brake pad (friction force),

$F_{friction}$ = Fclamp × μ ……… (Where μ is coefficient of friction)
= 7312.5 × 0.3
**= 2193.75N**

- Toque on rotor (braking torque),

$\tau_R = F_{friction} \times R_{efficient}$
= 2193.75 × 0.09
**= 197.43Nm**
**∴ Braking torque is equal to 197.43Nm**

- Angle through which disc rotated during brake period(θ),

Braking torque ($\tau_R$) = (K.E.)/θ
197.43 = 1851.48/θ
θ = 1851.48/197.43
**θ = 9.37**
θ = ω/2 × t
t = (θ × 2)/ω
t = (9.37 ×2)/36.45
**t = 0.51 sec**
Now,

- Stopping distance (s) = 1/2 × 11.11 × 0.51
  **= 2.83m**

**∴ stopping distance of bicycle running at a speed of 40kmph is 2.8m**

## 3. BRAKE ASSEMBLY –

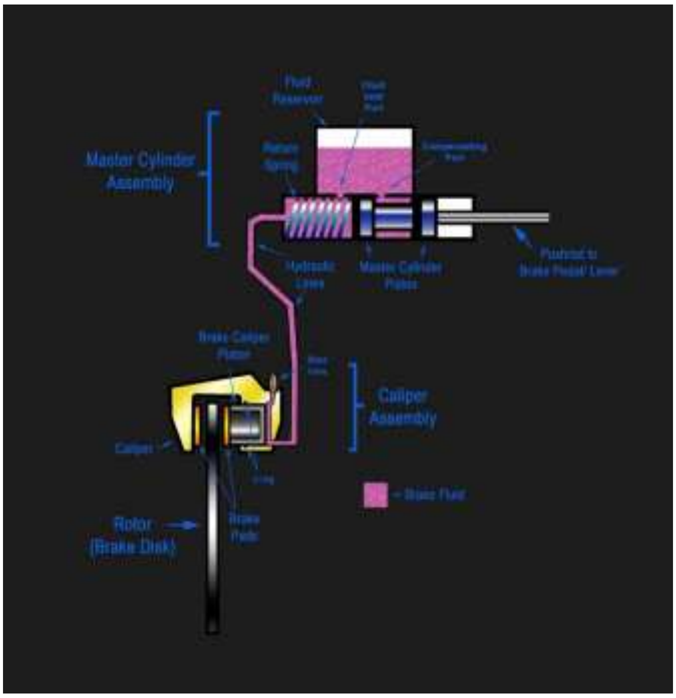


**Fig 5.** Assembly of Hydraulic disc braking system

## 4. WHY BRAKES FAIL?

Hydraulic brakes can fail or stop working for temporary time because of some reasons such as fluid leak or due to air bubble. Hydraulics depends on pressure within the system and brakes depends on friction. Absence of any of this results in failure of the system. A loss of brake fluid will decrease the pressure and a loss of friction will occurs due to the lubricating nature of brake fluid.

## 5. RESULT-

From above design and calculations of hydraulic disc braking system, the system will be able to slow and stop the bicycle from 40kmph to 0kmph within the stopping distance of 2.8m and braking time of 0.5 seconds.

## 6. CONCLUSION-

As discussed in above design and calculations, we conclude that the braking force acting on bicycle and stopping distance of bicycle are depends upon the speed of bicycle, size of rotor, brake cable (hose) diameter, slave cylinder (caliper) and coefficient of friction.

## REFERENCES

1. James Walker, The physics of Braking systems, 2005 StopTech LLC.
2. Paul S Grit, Brakes system, SAE
3. Design of effective Hydraulic Braking System for formula Motorsports Car, Vinaykumar Manjunath Naik, IOP Conf. Series: Material Science and Engineering 376 (2018).
4. Design of brake disc for Hydraulic Brakes, Vivek Singh Negi, IRJET, Volume: 05 Issue: 01, Jan 2018.
5. Rudolf Limpert, Brake design and Safety, Society of Automotive Engineers, 2011.
6. CMTI, Machine Tool Design Handbook, Tata McGraw Hill Education (India) Private Limited.

## BIOGRAPHIES

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