Hydraulic Rear Drum Brake System in Two Wheeler

C. Thamotharan, S. Prabhakar, S. Vanangamudi, R. Anbazhagan and C. Coomarasamy

Department of Automobile Engineering, BIST, Bharath University, Selaiyur, Chennai, Tamilnadu, India

Abstract: The function of the braking system is to retard the speed of the moving vehicle or bring it to rest in a shortest possible distance whenever required. The vehicle can be held on an inclined surface against the pull of gravity by the application of brake. The effectiveness of the brake has been increased with the introduction of hydraulic brake system. With this system the stopping distance and the braking force required is considerably less, smooth and easy to operate also less maintenance compared to mechanical braking system. Normally in motor cycle of the current trend employ mechanical braking system with drum brakes. We hope to increase the effectiveness of the braking system in motorcycle with the application of hydraulic drum brakes at rear of the motorcycle.

Key words: INTRODUCTION

In the present day scenario of Indian roads, the number of road accidents is increasing due to increase in the population of road vehicles rather than road network, loss of control in adverse conditions, improper or inadequate braking, etc., This condition is more seen in two-wheelers rather than four wheelers due to the reason that there are features like Anti-lock Brake System (ABS), Electronic Brake Distribution (EBD), Anti-Spin Regulation (ASR), etc., come to rescue incase of any emergency or sudden braking in four wheelers whereas in two wheelers such features are not implemented due to constraints like space, cost and other complications. In order to increase the effectiveness of the braking system in two-wheelers, we have implemented hydraulic system in replacement of the existing mechanical system so as to increase the response of the braking system and to ease the operation or application of brakes also taking care of stability of the rider and pillion especially in motorcycles [1].

Fluid Characteristics: If a liquid is confined and a force is applied, pressure is produced. In order to pressurize a liquid, the liquid must be in a sealed container. Any leak in the container will decrease the pressure. The basic principle of hydraulics is based on certain characteristics of liquids. Liquids have no shape of their own; they acquire the shape of the container they are put in. In addition they always seek a common level. Therefore, oil in a hydraulic system will flow in any direction and through any passage, regardless of size or shape [2].

Liquids are basically incompressible, which gives them the ability to transmit force. The pressure applied to a liquid in sealed container transmits equally in all directions and to all areas of the system and acts with equal force on all areas. As a result, liquids can provide great increase in the force available to do work. A liquid under pressure may also change from a liquid to a gas in response to temperature changes. Liquids can be used to transmit movement. Consider two cylinders of the same diameter are filled with a liquid and connected by a pipe. If you force piston A downward, the liquid will push piston B upward. Because piston A starts the movement, it is called the apply piston. Piston B is called the output piston. If the apply piston moves 10 inches, the output piston will move 10 inches. This principle works not only for one output piston, but for any number of output pistons. The principle that motion can be transmitted by a liquid is used in hydraulic brake systems. A master cylinder piston is pushed when the driver applies the
brakes. The master cylinder piston is the apply piston. The brake fluid in the master cylinder is connected by pipes to pistons in rear wheel brake units. The wheel brake piston is an output piston. They move whenever the master cylinder input piston moves [3].

Mechanical advantage with hydraulics is used to do work in the same way as a lever or gear does work. All of these systems transmit energy or force. Because energy cannot be created or destroyed, these systems only redirect energy to perform work and do not create more energy. Work is the amount of force applied and the distance over which it is applied. Force is power working against resistance; it is the amount of push or pull exerted on an object needed to cause motion. We usually measure force in the same units that we use to measure weight pounds or kilograms. Pressure is the amount of force exerted onto a given surface area. Therefore, pressure equals the applied force (measured in pounds or kilograms) divided by the surface area (measured in square inches or square centimeters) that is receiving the force [4]. In customary English units, pressure is measured in pounds per square inch (psi). In the metric system it can be measured in kilograms per square centimeter, but the preferred metric pressure measurement unit is the Pascal. The pressure of a liquid in a closed system such as a brake hydraulic system is the force exerted against the inner surface of its container, which is the surface of all the lines, hoses, valves and pistons in the system. Pressure applied to a liquid exerts force equally in all directions. If the hydraulic pump provides 100 psi, there will be 100 pounds of force on every square inch of the system. When pressure is applied to a movable output piston, it creates output force. If the system included a piston with an area of 30 square inches, each square inch would receive 100 pounds of force. This means there would be 3,000 pounds of force applied to that piston. The use of the larger piston would give the system a mechanical advantage or increase hydraulic system mechanical advantage with hydraulics [5].

Hydraulics is used to do work in the same way as a lever or gear does work. All of these systems transmit energy or force. Because energy cannot be created or destroyed, these systems only redirect energy to perform work and do not create more energy. The multiplication of force through a hydraulic system is directly proportional to the difference in the piston sizes throughout the system. By changing the sizes of the pistons in a hydraulic system, force is multiplied and as a result, low amounts of force are needed to move heavy objects.

The mechanical advantage of a hydraulic system can be further increased by the use of levers to increase the force applied to a piston [6]. A is smaller than output piston B. Piston A has an area of 20 square inches; in the example, we are applying 200 pounds of force. Therefore, 200 pounds (F) = 10 psi (P) × 20 square inches (A) where F is force, A is area and P is pressure. If that same 200 pounds of force is applied to a piston of 10 square inches, system pressure is 20 psi because 200 pounds (F) = 20 psi (P) × 10 square inches (A). Therefore, pressure is inversely related to piston area. The smaller the piston, the greater the pressure that is developed. Let us apply the 10 psi of pressure in the first example to an output piston with an area of 50 square inches. In this case, output force equals pressure times the surface area:

\[ P \times A = F \]

Therefore, 10 psi of pressure on a 50-square-inch piston develops 500 pounds of output force:

\[ 10 \times 50 = 500 \]

Brake systems use hydraulics to increase force for brake application. Piston of 10 square inches. A force of 500 pounds is pushing on the piston. The pressure throughout the system is 50 psi: 500 (F) ÷ 10 (A) = 50 (P).

A pressure gauge in the system shows the 50 psi pressure. There are two output pistons in the system. One has 100 square inches of area. The 50 psi pressure in the system is transmitted equally everywhere in the system. This means that the large output piston has 50 psi applied to 100 square inches to deliver an output force of 5000 pounds: 100 square-inches × 50 psi = 5000 pounds. The other output piston is smaller than the input piston with a 5-square-inch area. The 5-square-inch area of this piston has 50-psi pressure acting on it to develop an output force of 250 pounds: 5 square inches × 50 psi = 250 pounds. In a brake system, a small master cylinder piston is used to apply pressure to larger pistons at the wheel brake units to increase braking force. Importantly, the pistons in the front brakes have a larger surface area than the pistons in the rear brakes. This creates greater braking force at the front and exerts more force but travels a shorter distance. The opposite also is true. If the output piston is smaller than the input piston, it exerts less force but travels a longer distance. Apply the equation to the 5 square inch output piston. square inches (input piston) 5 square inches (output piston) = 21 × 2 inches (input stroke) = 4.0 inches output motion. In this case, the smaller
output piston applies only half the force of the input piston, but its stroke (motion) is twice as long. These relationships of force, pressure and motion in a brake system are easily observed when you consider the force applied to the master cylinder’s pistons and the resulting brake force and piston movement at the wheels [7].

Wheel cylinder pistons move only a fraction of an inch to apply hundreds of pounds of force to the brake shoes; the wheel cylinder piston travel is quite a bit less than the movement of the master cylinder piston. Disc brake caliper pistons move only a few thousands of an inch but apply great force to the brake rotors. This demonstrates how the use of hydraulics provides mechanical advantage similar to that provided by the use of levers or gears. Although hydraulic systems, gears and levers can accomplish the same results, hydraulics is preferred when the size and shape of the system are of concern. In hydraulics, the force applied to one piston will transmit through the fluid and the opposite piston will have the same force on it. The distance between the two pistons in hydraulic system does not affect the force in a static system. Therefore, the force applied to one piston can be transmitted without change to another piston located somewhere else. A hydraulic system responds to the pressure or force applied to it. The mere presence of different sized pistons does not always result in fluid power [8].

The force or pressure applied to the pistons must be different in order to cause fluid power. If an equal amount of pressure is exerted onto both pistons in a system and both pistons are the same size, neither piston will move; the system is balanced or is at equilibrium. The pressure inside the hydraulic system is called static pressure because there is no fluid motion. When an unequal amount of pressure is exerted on the pistons, the piston receiving the least amount of pressure will move in response to the difference between the two pressures. Likewise, the fluid will move if the size of the two pistons is different and an equal amount of pressure is exerted on the pistons. The pressure of the fluid while it is in motion is called dynamic pressure.

Hydraulic Brake Systems: Engineers must consider these principles of force, pressure and motion when designing a brake system for any vehicle. If an engineer chooses a master cylinder with relatively small piston areas, the brake system can develop very high hydraulic pressure, but the pedal travel will be extremely long. Moreover, if the master cylinder piston travel is not long enough, this high-pressure system will not move enough fluid to apply the large area caliper pistons regardless of pressure. If, on the other hand, the engineer selects a large area master cylinder piston, it can move a large volume of fluid but may not develop enough pressure to exert adequate braking force at the wheels. The overall size relationships of master cylinder pistons, caliper pistons and wheel cylinder pistons are balanced to achieve maximum braking force without grabbing or fading. Most brake systems with front discs and rear drums have large diameter master cylinders (a large piston area) and a power booster to increase the input force [9].

Braking Requirements
Kinetic Energy: Kinetic energy is the force that tends to keep the vehicle moving. Kinetic energy must be dissipated as heat by the brakes during operation. The kinetic energy doubles as the weight doubles, but it increases four times as speed doubles. The kinetic energy of a vehicle is given by

\[ W = (u^2 - v^2) \]

where \( W \) = vehicle gross weight
\( u \) = initial velocity
\( v \) = final velocity

Co-Efficient Of Friction: Frictional force opposes the motion of the vehicle consuming power and producing heat. Frictional force occurs between the sliding tyre and the road surface when brakes lock wheel rotation. Vehicle’s kinetic energy and its ability to stop is related to the coefficient of friction between the rubbing surfaces. Maximum usable coefficient of friction occurs between the tyre and road surface, rather than in the brakes. Two - wheeler brakes have coefficient of friction 0.3 to 0.5.

The Amount of Energy: The amount of energy the brakes can absorb is dependent upon the coefficient of friction of the brake materials, their diameter, their surface area, shoe geometry and the pressure used to actuate them. Stopping a car quickly means total friction must be greater, resulting in high brake temperature [1].

Brake Balance: The stopping distance is same with the same tyre and road conditions, when the wheels are locked and skidding, regardless of the weight, number of wheels or vehicle load. Maximum braking power occurs
when the wheels are braked just before the locking point or point of impending skid. Non-skid brake systems are designed to operate at or below this point. Changes in load on a wheel will change the point of impending skid [2].

The effective braking force of a vehicle occurs at ground level. Vehicle weight and kinetic energy of the vehicle act through center of gravity which is above ground level. This causes the vehicle to tend to pitch forward as the brakes are applied. Pitching forward effectively transfers some of the vehicle weight from the rear wheels to the front wheels. The front brakes therefore, must absorb more kinetic energy than the rear brakes. The maximum amount of weight transfer is given by

\[ W_t = \mu h W/b \]

where, \( W_t \) = weight transferred, N
\( \mu \) = coefficient of friction
\( h \) = height of C.G from the ground, m
\( W \) = vehicle gross weight, N
\( b \) = wheel base, m

This weight is added to the static weight on the front wheels and subtracted from the static weight on the rear wheels. The front wheel static weight is normally 55% of the vehicle weight.

Front brakes are designed to absorb this extra brake effort by selecting shoe-drum or shoe-disc combination type, brake size, lining coefficient of friction, wheel cylinder size and differential hydraulic actuating pressures [3]. With full braking it is desirable to have the front brakes lock up slightly ahead of the rear brakes. This causes the car to go straight forward and not to spin out.

**Stopping Distance:** Stopping distance is extremely important for emergency braking. The stopping distance is based on the deceleration rate. Also it is affected by the tyre deflection, air resistance, engine braking efforts and the inertia of the drive line.

**Brake Fade:** Since brake lining material is a poor conductors of heat, most of the heat goes into the brake drum or disc during braking. Under severe use, brake drums may reach 590k. The coefficient of friction between the drum and the lining is much lower at these high temperatures and hence additional pedal pressure is required. After a number of severe stops or after holding the brakes on a long downhill grade, a point is eventually reached when the coefficient of friction drops so low that little braking effect is available. This is called brake fade [4].

In drum brakes, the lining covers a large portion of the internal drum surface allowing little cooling space. Therefore, drum brakes are more susceptible to fade than disc brakes. As the vehicle moves, cooling air is directed around the drum and disc to remove brake heat.

The drum and disc expansion due to brake temperature is another factor for fade. The diameter of the drum increases as it gets hot. The shoe arc no longer will match the drum and hence lining-to-drum contact surface becomes smaller. The same stopping force requires higher pedal pressure and this in turn increases the temperature on the smaller contact surface. Continued braking increases the problem until the braking becomes ineffective, regardless of the pedal force. On the other hand, expansion of disc has little effect on braking because the pads apply braking force on the side of the disc and hence braking surface area remains constant. Leading shoes are more susceptible to fade than trailing shoes [5].

Fade-resistant drum brakes must limit brake shoe arc to 110 degree and power absorption to 28370kW/m² of lining. The horsepower absorbed by the brakes during a stop can be calculated as

\[ P = KE/1000t, \text{ kW} \]

where, \( KE \) = Kinetic energy, N
\( t \) = time, s

**Braking Torque:** The braking torque is the twisting action caused by the drum or disc on the shoes or caliper anchors during the application of brakes. The amount of torque is determined by the effective axle height and stopping force between the tyre and the road surface [6].

Brake torque on the front wheels is absorbed by the knuckle and suspension control arms. In rear, it is absorbed by the axle housing and the leaf spring or control arm. Braking torque during an emergency stop is much higher than accelerating torque at full throttle. Brake supporting and anchoring members must therefore, have sufficient strength to withstand and these high braking loads.
Brake Safety: All automobiles are equipped with an emergency brake that would operate independently from the service brakes. Safety standards require the emergency brake to hold the automobile on a 30% slope indefinitely after the brake has been applied until the operator releases it [7].

Braking System: The brakes are classified according to the application of brake shoe to the revolving brake drum as the internal-expanding or external-contracting type. They are also classified as mechanical or hydraulic, depending upon the way of transferring braking force from hand lever or foot pedal to brake shoes, either by means of mechanical linkage or by hydraulic pressure. In modern vehicles the service brakes are generally hydraulically operated, internal-expanding type and the hand brakes are mechanically operated internal-expanding and external-contracting type [8].

Main Components: The main components of the braking system are the brake assembly at the wheel and the mechanism which applies them. The brake assembly at the wheel comprises of the following main components. Braking plates are pressed-steel discs placed on the axle ends on which the brake shoes are mounted. Brake shoes are the curved members, usually two numbers for a wheel and are mounted on the braking plates so as to be concentric with the wheels. They are pivoted at one end and are moved outward at the other end (in case of internal expanding) when brakes are applied. Brake lining of special asbestos compound is either riveted or bonded to the faces of these shoes. This lining comes in contact with the metal brake drum when brakes are applied. Friction between the lining and the drum resists the turning of the wheels. The lining withstands high heat and the dragging force that develops when the brake shoes are pressed against the drum. A force of 640 Pa and a temperature of 480 K is not uncommon under extreme brake applications. Cooling fins attached to outside of the drum help in dissipating this heat to atmosphere. The brake drums or hubs are made up of aluminum casting and rotate with the wheels. In internal expanding shoes, the brake lining comes in contact at the inside surface of the drum and in external-contacting type the lining contacts on the outside surface of the drum. The pivot pins at the ends of the shoes outward against the drum by hydraulic pressure. Whereas actuating cams spread the shoes in mechanical operation. When the pressure on the brake pedal is released, the brake retracting springs return the shoes to their ‘off’ position [9].

The brake application mechanism consists of brake pedal where force is applied by operator’s foot. Linkage transmits the applied by operator’s foot. Linkage transmits the applied force on brake pedal to brake shoes in mechanical system. It consists of rods and levers connected so as to apply the brake. In hydraulic system the master cylinder operates the brake shoes by transmitting the pressure through brake fluid when the pedal is depressed.

Hydraulic Brakes: The hydraulic brake system consists of essentially of a master cylinder with piston and the wheel cylinder with piston a in the rear wheel. The master cylinder is connected to the wheel cylinder by rubber tubing.

The depression of the brake pedal moves the piston in the master cylinder which displaces the brake fluid (usually a glycerine compound) forcing it through the tubing to the rear wheel. The wheel cylinder consists of a piston and the brake fluid is forced in between them, separating them apart. The outer end of the piston presses the cam lever which in turn operates the cam inside the drum causing the brake linings to come in contact with the drum. When the brake pedal is released the hydraulic pressure drops and the return spring in the in the brake shoe pushes the piston to its original position. At the same time retracting springs on the wheel brakes pull the shoes back to their position, bringing drums out of contact. This also forces the pistons at the wheel cylinder inward causing the flow of braking fluid back to the master cylinder.

The hydraulic brake has the following advantages over the mechanical brakes

- Application of equal pressure.
- Minimum moving parts and less complicated linkage.
- Application of brake is smooth and easy.
- Maintenance of brake is easy.

Brake Fluid: Brake fluid is specifically designed to be compatible with its environment of high heat, high pressure and moving parts. Standards for brake fluid have been established by the society of automobiles engineers (SAE) and the Department of Transportation (DOT).

Requirements of a fluid used in automotive brake applications must include the following:

- Remain viscous.
- Have a high boiling point
- Act as lubrication for moving parts.
The Federal Motor Vehicle Safety Standard (FMVSS) states that by law, brake fluid must be compatible regardless of manufacturer. Fluids are not necessarily identical however, any DOT approved brake fluid can be mixed with any other approved brake fluid without damaging chemical reactions. Although the fluid may not affect the properties of liquid under pressure.

Two types of brake fluid are used in automotive brake application, each having specific attributes and drawbacks. Polyglycol is clear to amber in color and is the most common brake fluid used in the industry. One of the negative characteristics of polyglycol is that it is hygroscopic, that is, it has a propensity to attract water. Water can be absorbed through rubber hoses and past seals and past vent in the master cylinder reservoir cap. Moisture in the hydraulic circuit reduces the boiling point of the fluid and causes it to vaporize. In addition, moisture causes metal parts to parts to corrode resulting in leakage and / or frozen wheel cylinder pistons.

Extra caution should be taken with containers of brake fluid because it absorbs moisture from the air when the container is opened. Do not leave the container uncapped and closed it tightly. Silicone is purple in colour. It is not hygroscopic and therefore has virtually no rust corrosion problems. It has a high boiling point and can be used in higher heat applications. It will not harm paint when it comes in contact with it. Silicone has greater affinity for air than polyglycol. Because the air remains suspended in the fluid it is more difficult to bleed air from the hydraulic system.

**Dot Grades:** There are three grades of brake fluid which are determined by Federal Motor Vehicle Safety Standard 116. Fluid grades are rated by the minimum boiling point for both fluid (dry) and water contaminated fluid (wet):

- DOT 3- Polyglycol
- Minimum boiling point - 401°F dry, 284°F wet
- Blends with DOT -4

**Drum Brake Components:** Drum brakes consist of a backing plate, brake shoes, brake drum, wheel cylinder, return springs and an automatic or self-adjusting system. When you apply the brakes, brake fluid is forced, under pressure, into the wheel cylinder which, in turn, pushes the brake shoes into contact with the machined surface on the inside of the drum. When the pressure is released, return springs pull the shoes back to their rest position. As the brake linings wear, the shoes must travel a greater distance to reach the drum. When the distance reaches a certain point, a self-adjusting mechanism automatically reacts by adjusting the rest position of the shoes so that they are closer to the drum.

**Brake Shoes:** Like the disk pads, brake shoes consist of a steel shoe with the friction material or lining riveted or bonded to it. Also like disk pads, the linings eventually wear out and must be replaced. If the linings are allowed to wear through to the bare metal shoe, they will cause severe damage to the brake drum.

**Backing Plates:** The backing plate is what holds everything together. It attaches to the axle and forms a solid surface for the wheel cylinder, brake shoes and assorted hardware. It rarely causes any problems.

**Brake Drum:** Brake drums are made of iron and have a machined surface on the inside where the shoes make contact. Just as with disk rotors, brake drums will show signs of wear as the brake linings seat themselves against the machined surface of the drum. When new shoes are installed, the brake drum should be machined smooth. Brake drums have a maximum diameter specification that is stamped on the outside of the drum. When a drum is machined, it must never exceed that measurement. If the surface cannot be machined within that limit, the drum must be replaced.

**Wheel Cylinder:** The wheel cylinder consists of a cylinder that has a piston, on one side. Each piston has a rubber seal and a shaft that connects the piston with a brake shoe. When brake pressure is applied, the pistons are forced out pushing the shoes into contact with the drum. Wheel cylinders must be rebuilt or replaced if they show signs of leaking.

**Return Springs:** Return springs pull the brake shoes back to their rest position after the pressure is released from the wheel cylinder. If the springs are weak and do not return the shoes all the way, it will cause premature lining wear because the linings will remain in contact with the drum. A technician will examine the springs during a brake job and recommend their replacement if they show signs of fatigue.
Self Adjusting System: The parts of a self adjusting system should be clean and move freely to insure that the brakes maintain their adjustment over the life of the linings. If the self adjusters stop working, you will notice that you will have to step down further and further on the brake pedal before you feel the brakes begin to engage. Disk brakes are self adjusting by nature and do not require any type of mechanism. When a technician performs a brake job, aside from checking the return springs, he will also clean and lubricate the self adjusting parts where necessary.

Tyre Adhesion: The amount of the force applied on a shoe against controls the resistance to rotation of a road wheel. Simultaneously the road surface has to drive the wheel around. This driving force attains its limit when the resistance offered by the brake equals the maximum frictional force generated between the tire and road which is known as the adhesive force. This force can be determined from the expansion

\[
\text{Adhesive Force} = \text{Load on wheel} \times \text{Coefficient of friction}
\]

Road Adhesion: Road adhesion depends on

- Type of roads surface.
- Conditions of surface e.g. wet, dry, icy,
- Design of tire tread, composition of tread material and depth of tread.

The stopping distance of a wheel is greatly affected by the interaction of the rotating tire tread and the road surface. The relationship between the decelerating force and the vertical load on a wheel is known as the adhesion factor. This factor is very similar to the coefficient of friction that occurs when one surface slides over the other. In the ideal situation of braking, the wheel should always rotate right up to the point of stopping to obtain the greatest retarding resistance.

It is common thinking that the shortest stopping distance is achieved when the wheel is locked to produce a skid. This idea is incorrect because experiments have confirmed that the force required to unstuck the tire is greater than the force required to skid it over the surface. A wheel held on the verge of skidding not only provides the shortest distance, but also allows the driver to maintain directional control of the vehicle. Typically adhesion factors for various road surfaces are given below.

<table>
<thead>
<tr>
<th>No</th>
<th>Road Surface</th>
<th>Adhesion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Concrete, Coarse asphalt dry</td>
<td>0.8</td>
</tr>
<tr>
<td>2.</td>
<td>Tarmac, gritted bitumen dry</td>
<td>0.6</td>
</tr>
<tr>
<td>3.</td>
<td>Tarmac wet</td>
<td>0.4</td>
</tr>
<tr>
<td>4.</td>
<td>Ice wet</td>
<td>0.1</td>
</tr>
<tr>
<td>5.</td>
<td>Gritted bitumen Tarmac wet</td>
<td>0.3</td>
</tr>
<tr>
<td>6.</td>
<td>Gritted bitumen Tarmac greasy</td>
<td>0.25</td>
</tr>
<tr>
<td>7.</td>
<td>Gritted bitumen, snow compressed dry</td>
<td>0.2</td>
</tr>
<tr>
<td>8.</td>
<td>Gritted bitumen, snow compressed wet</td>
<td>0.15</td>
</tr>
<tr>
<td>9.</td>
<td>Concrete, Coarse asphalt wet</td>
<td>0.5</td>
</tr>
</tbody>
</table>

It is common thinking that the shortest stopping distance is achieved when the wheel is locked to produce a skid. This idea is incorrect because experiments have confirmed that the force required to unstuck the tire is greater than the force required to skid it over the surface. A wheel held on the verge of skidding not only provides the shortest distance, but also allows the driver to maintain directional control of the vehicle. Typically adhesion factors for various road surfaces are given below.

### Common Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Value obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>New wheelbase after the rear wheel lifted</td>
<td>(L_n)</td>
<td>1.1003 m</td>
</tr>
<tr>
<td>Height of CG from the ground</td>
<td>(H)</td>
<td>0.5133 m</td>
</tr>
<tr>
<td>Weight transfer during braking</td>
<td>(w)</td>
<td>42.1774 Kg</td>
</tr>
<tr>
<td>Pedal ratio</td>
<td>(P)</td>
<td>7:1</td>
</tr>
</tbody>
</table>

### Results for the Rear Wheel

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Value obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum retarding force at the rear</td>
<td>(F_r)</td>
<td>384.552 N</td>
</tr>
<tr>
<td>Effective radius of the rear wheel</td>
<td>(R_r)</td>
<td>0.3042 m</td>
</tr>
<tr>
<td>Effective radius of the rear drum</td>
<td>(r)</td>
<td>0.065 m</td>
</tr>
<tr>
<td>Tangential braking force at the rear drum</td>
<td>(B_r)</td>
<td>435.837 N</td>
</tr>
<tr>
<td>Normal force at the rear wheel brake drum</td>
<td>(N_{fb})</td>
<td>871.674 N</td>
</tr>
<tr>
<td>Actual normal force required at each brake shoe</td>
<td></td>
<td>435.837 N</td>
</tr>
</tbody>
</table>

**CONCLUSION**

The design of the braking system for motor cycle is to improve the braking performance and stability at all road conditions. The fabrication of this hydraulic brake system has enabled us to know more about practical working of braking system and its components. While comparing with the existing mechanical drum brake system, hydraulic brake system has more effective braking, lesser stopping distance and smooth operation. Thus by this project we had fabricated the hydraulic braking system, which is more effective than the conventional braking system and in the near future we hope to see this system in reality.
REFERENCES