# DEVELOPMENT OF BRAKE SYSTEM MODEL FOR EDUCATIONAL PURPOSE

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## ABSTRACT

The process of braking system is actually simple but yet, the public still do not understand how it works. There are many available braking systems for educational purpose in the market but it is quite expensive. So, a low cost braking system model is needed for the learning process.

The objective of the project is to build the car brakes structure and assembly system for educational, analysis the structure of the brakes and determine the design properties of the brakes. Fabrication work is to design a stand for car brake system model. The structure analysis is carried out using Algor software and the design properties are determined using theoretical calculation.

From the structure analysis, it is shows that the structure is safe and did not exceed the yield strength when the parts are connected to the stand. In design properties analysis, it is calculated that the maximum force that should give to the pedal is 377.46 N as the maximum static coefficient of friction is 0.7. If the tire is locked and car is slide, the kinetic coefficient is used instead of static coefficient.

# ABSTRAK

Proses sistem brek sebenarnya mudah tetapi orang ramai masih belum faham bagaimana ia berfungsi. Terdapat banyak model sistem brek untuk tujuan pendidikan dalam pasaran tetapi agak mahal. Jadi, model sistem brek yang kosnya rendah diperlukan untuk proses pembelajaran.

Objektif projek ini ialah untuk mencipta struktur brek kereta dan sistem pemasangan untuk pendidikan, analisis struktur brek dan menjangka kriteria rekaan sesuatu brek. Kerja kerja pembuatan struktur ialah mereka tempat peletakan brek untuk model sistem brek kereta. Analisis struktur dilakukan menggunakan program Algor dan kriteria rekaan dijangka menggunakan pengiraan teori.

Tempat peletakan struktur brek berjaya dibuat seperti rekaan yang awal. Walaubagaimanpun, model brek hanya akan lengkap dengan penambahan sistem pam vakum dan motor untuk mewujudkan bebanan tayar. Dari analisis struktur, ia menunjukkan struktur itu selamat dan tidak melebihi nilai tekanan yang maksimum. Analisis kriteria rekaan menunjukkan bahawa daya maksimum yang perlu dikenakan pada pedal brek ialah 377.46 N apabila nilai maksimum bilangan pokok geseran statik ialah 0.7. Jika tayar terkunci dan kereta tergelongsor, bilangan pokok geseran kinetik digunakan sebagai gantik statik.

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| | | |
|---|---|---|
| $a$ | - | *Acceleration* |
| $A$ | - | Area |
| $D, d$ | - | diameter |
| $F$ | - | Force |
| $G$ | - | Gravity = 9.81 m/s |
| $m$ | - | Mass |
| $P$ | - | Pressure |
| $r$ | - | Radius |
| s | - | Distance |
| v | - | Velocity |
| $\tau$ | - | Torque |
| $\mu$ | - | Coefficient of friction |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

The braking system is the most important system in your car. If your brakes fail, the result can be disastrous. Brakes are actually energy conversion devices, which converts the kinetic energy (momentum) of your vehicle into thermal energy (heat). When you step on the brakes, you command a stopping force ten times as powerful as the force that puts the car in motion. The braking system can exert thousands of pounds of pressure on each of the four brakes. In modern systems, the master cylinder is power-assisted by the engine. All newer cars have dual systems, with two wheels' brakes operated by each subsystem. That way, if one subsystem fails, the other can provide reasonably adequate braking power. Safety systems like this make modern brakes more complex, but also much safer than earlier braking systems. [1]

In the world of today, many people do not know how brakes works, exactly what parts are involved in stopping a car, or how these parts can deteriorate and cause failure. The user should know and develop an understanding of the principles involved in stopping a car, how these principles can make stopping difficult, the interrelationship among braking components, and the things that can occur to reduce the performance.

## 1.2 Problem Statement

The process of braking system is actually simple but yet, the public still do not understand how it works. There are many available braking systems for educational purpose in the market but it is quite expensive. So, a low cost braking system model is needed for the learning process.

The whole procedure for this project is actually depending on the design of stand for braking structure and arrangement of the braking system. This project also important for those who want to learn a lot of car braking system functioning.

## 1.3 Project Objectives

Main objective

i. To build the car brakes structure and assembly system for educational

ii. To analysis the structure of the brakes

iii. To determine the design properties of the brakes

## 1.4 Project Scopes

i. Using Algor software to analyze the stand structure.

ii. Fabrication work to design a stand for car brake system model.

iii. Theoretical calculation to determine the design properties of the brakes

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

A lot of people are familiar with the parts of a braking system. To give us a common ground for discussion of the principle and to help understand their interrelationship, we will briefly describe them here. Each part is related to the others, and proper operation of each part is necessary for correct operation of the whole system.

So, this chapter will explain about the principles or theory of the car brakes system. It is also gives information and knowledge about the process inside the car brakes system.

## 2.2 History

A major test of brake systems took place in 1902 on an unpaved road in New York City called Riverside Drive. Ransom E. Olds had arranged to test a new brake system against the tire brake of a four-horse coach and the internal drum brake of a

Victoria horseless carriage. His *Oldsmobile* sported a single flexible stainless-steel band, wrapped around a drum on the rear axle. When the brake pedal was applied, the band contracted to grip the drum [6].

## 2.3 Brake system process

When you step on the brake pedal, you are actually pushing against a plunger in the master cylinder which forces hydraulic oil (brake fluid) through a series of tubes and hoses to the braking unit at each wheel. Refer to Figure 2.1.

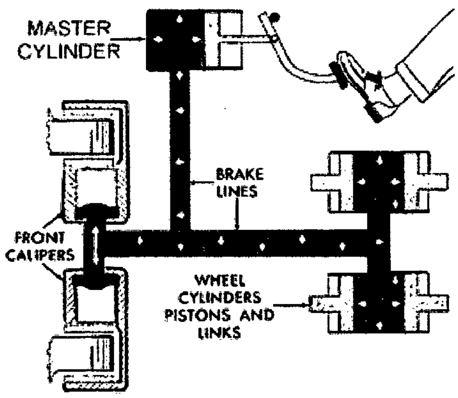


**Figure 2.1**: Hydraulic system [5]

In a normal brake system, the whole system is interconnected and filled with fluid up to the upper part of the master cylinder reservoir. Refer to Figure 2.2. The reservoir is vented to the atmosphere so fluid can expand and contract and still stay at atmospheric pressure. When the fluid in the wheel cylinders and calipers gets hot, it can expand and move through the open compensating port to the reservoir. When it cools and contract, it can move the other way, cylinders use a rubber diaphragm over the reservoirs to separate the fluid from air and to help reduce fluid contamination.

When sufficient force is placed on the brake pedal to overcome the piston return spring, the master cylinder piston will move inward. Fluid from the bore will be displaced to the reservoir until the lip of the primary cup moves past and closes the compensating port.

From this point further force and movement of the brake pedal will displace fluid to the system and move the brake shoes into contact with the rotors. Lining contact will stop further movement of the shoes and wheel cylinder or caliper pistons. From this point, system pressure will increase. Any increases in pedal force will cause a corresponding increase in wheel cylinder and lining pressure [3].

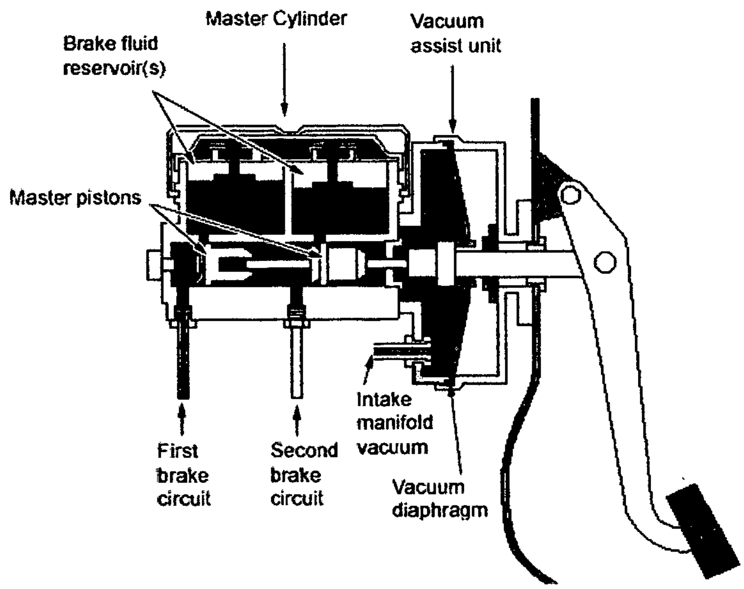


**Figure 2.2**: Master cylinder system [5]

When the brake pedal is released, the piston return spring will move the piston very rapidly back to its stop at the retaining ring, much faster than the fluid will return from the wheel cylinder or calipers. During the motion, the primary cup will collapse or relax its wall pressure slightly and moves through the fluid. There will be a flow or fluid past the edges of the primary cup. Some pistons have a series of holes in the primary cup face to improve this flow.

On a disk brake, the fluid from the master cylinder is forced into a caliper where it presses against a piston. The piston, in-turn, squeezes two brake pads against the disk (rotor) which is attached to the wheel, forcing it to slow down or stop.

## 2.4 Braking Parts

There are four main parts that involves in car disc brake system. All this part is important to make the car stop. The main parts are master cylinder, power booster, disc brake, and steel lines. The other parts are caliper, brake pads, and rotor. To make the function of this parts works, the brake fluid also included in this braking system.

### 2.4.1 Master Cylinder

The master cylinder is located in the engine compartment on the firewall, directly in front of the driver's seat. The master cylinder transmits the pressure on the brake pedal to each of the wheels to stop the vehicle. The master cylinder changes the driver's mechanical pressure on the brake pedal to hydraulic force. The master cylinder uses the fact that fluids are not compressible to transmit the pedal movement to the wheel brakes unit [1]. Refer to Figure 2.3.

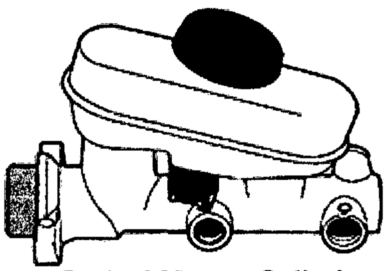


**Figure 2.3**: Typical master cylinder [5]

### 2.4.2 Brake Lines

The brake fluid travels from the master cylinder to the wheels through a series of steel tubes and reinforced rubber hoses. Rubber hoses are only used in places that require flexibility, such as at the front wheels, which move up and down as well as steer. The rest of the system uses non-corrosive seamless steel tubing with special fittings at all attachment points [5].

### 2.4.3 Brake Fluid

Brake fluid is a special oil that has specific properties. It is designed to withstand cold temperatures without thickening as well as very high temperatures without boiling. (If the brake fluid should boil, it will cause you to have a spongy pedal and the car will be hard to stop.) Brake fluid must meet standards that are set by the Department of Transportation (DOT). The current standard is DOT-3 which has a boiling point of 460Â°F [5].

### 2.4.4 Disc Brakes

The disk brake is the best brake that have found in this century. Refer to figure 2.4. Disk brakes are used to stop everything from cars to locomotives and jumbo jets. Disk brakes wear longer, are less affected by water, are self adjusting, self cleaning, less prone to grabbing or pulling and stop better than any other system around. The main components of a disk brake are the Brake Pads, Rotor, Caliper and Caliper Support [5].

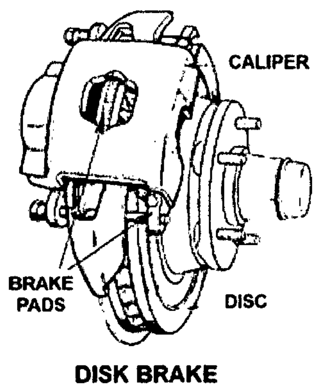


**Figure 2.4**: Disc brake [5]

### 2.4.5 Brake Pads

There are two brake pads on each caliper. Refer to Figure 2.5. They are constructed of a metal "shoe" with the lining riveted or bonded to it. The pads are mounted in the caliper, one on each side of the rotor. Brake linings used to be made primarily of asbestos because of its heat absorbing properties and quiet operation; however, due to health risks, asbestos has been outlawed, so new materials are now being used. [2].


**Figure 2.5**: Brake Pads [5]

### 2.4.6 Rotor

The disk rotor is made of iron with highly machined surfaces where the brake pads contact it. Refer to figure 2.6. Just as the brake pads wear out over time, the rotor also undergoes some wear, usually in the form of ridges and groves where the brake pad rubs against it. This wear pattern exactly matches the wear pattern of the pads as they seat themselves to the rotor [5].

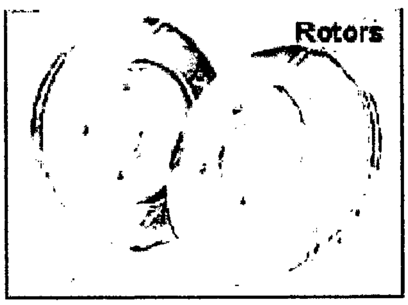


**Figure 2.6**: The rotor [5]

### 2.4.7 Caliper

The caliper is the casting that is mounted over the rotor. Refer to figure 2.7. It contains the brake pads and the hydraulic pistons that apply the pads. It must be strong enough to transmit the high clamping forces needed and also transmit the braking torque from the pads to the steering knuckle. The pressure between brake pads and each side of the rotor should be equal to prevent flexing and bind at the wheel bearings and flexing or distortion of the rotor or caliper [3].

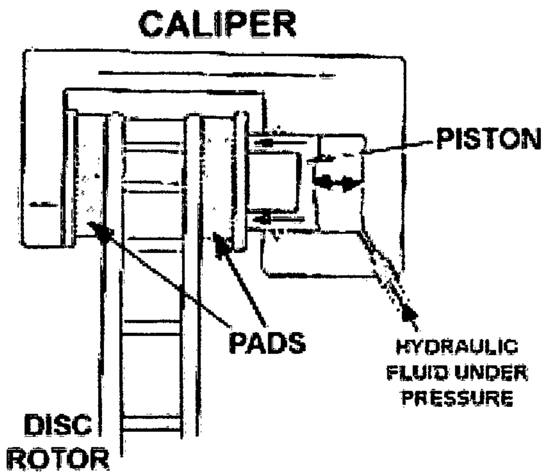


**Figure 2.7**: The caliper [5]

### 2.4.8 Power Brake Booster

The power brake booster is mounted on the firewall directly behind the master cylinder and, along with the master cylinder, is directly connected with the brake pedal. Its purpose is to amplify the available foot pressure applied to the brake pedal so that the amount of foot pressure required to stop even the largest vehicle is minimal. Power for the booster comes from engine vacuum. In order to have power assist, the engine must be running. If the engine stalls or shuts off while you are driving, you will have a small reserve of power assist for two or three pedal applications but, after that, the brakes will be extremely hard to apply and you must put as much pressure as you can to bring the vehicle to a stop [1]. Refer to figure 2.8.

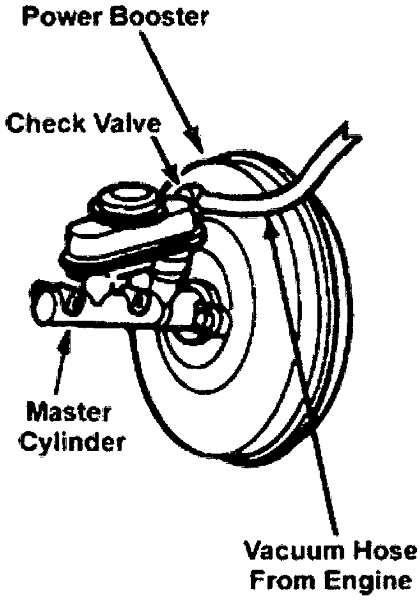


**Figure 2.8**: Power booster [5]

## 2.5 Braking Theory

The braking system is the most important system in your car. If your brakes fail, the result can be disastrous. Brakes are actually energy conversion devices, which converts the kinetic energy (momentum) of your vehicle into thermal energy (heat). The system of car braking actually started at brake pedal and lastly at the tire or wheel. But in this car braking system model calculation, it only finishes at the rotor.

### 2.5.1 The Brake Pedal

The sole function of the brake pedal assembly is to harness and multiply the force exerted by the driver's foot. Refer to figure 2.9. This concept is known as "leverage" [7]. See Equation 2.1.

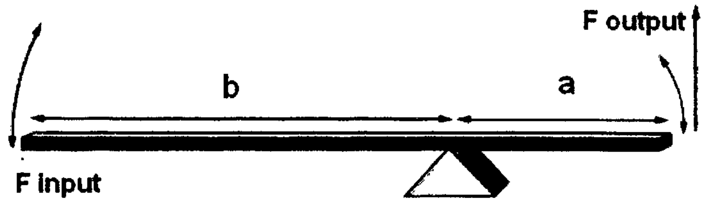


Figure 2.9: Leverage concept [7]

$$\frac{Foutput}{Finput} = \frac{b}{a} \tag{2.1}$$

### 2.5.2 The Master Cylinder

The master cylinder, consisting of a piston in a sealed bore with the brake pedal output rod on the one side and brake fluid on the other, performs this task. As the pedal assembly output rod pushes on the piston, the piston moves within the cylinder and pushes against the fluid, creating hydraulic pressure. The pressure generated at the master cylinder is equal to the amount of force from the brake pedal output rod divided by the area of the master cylinder piston [4]. See Equation 2.2.

$$P = \frac{F_{PEDAL\ OUTPUT}}{A} \tag{2.2}$$

Where F pedal output = Output force of brake pedal (N)

$A$ = Area of the master cylinder piston ($m^2$)

### 2.5.3 The Brake Tubes and Hoses

The function of the brake tubes and hoses is to transporting the pressurized brake fluid away from the master cylinder to the corners of the car.

### 2.5.4 The Caliper

Like the master cylinder, the caliper is just a piston within a bore with pressurized fluid on one side. While the master cylinder used mechanical force on the input side to create hydraulic force on the output side, the caliper does the opposite by using hydraulic force on the input side to create mechanical force on the output side [4].

In order to calculate the amount of clamping force generated in the caliper, the incoming pressure is multiplied by the area of the caliper piston. See Equation 2.3.

$$F = P\,A \tag{2.3}$$

where $P$ = pressure generated at the master cylinder (Nm$^2$)

$A$ = Effective area of the caliper (m$^2$)

The 'effective area' of the caliper will be equal to two times the area of a single 1.5" piston. See equation 2.4.

$$A = \frac{\pi d^2}{4} \tag{2.4}$$

Where $d$ = diameter of caliper (m)

### 2.5.5 The Brake Pads

The brake pads have the responsibility of squeezing on the rotor (a big steel disc which is mechanically attached to the road wheel) with the clamping force generated by the caliper. By knowing the clamp load generated by the caliper and the coefficient of friction between the pad and rotor, one can calculate the force acting upon the rotor. Assume the brake pads have a coefficient of friction of 0.45 when pressed against the rotor face. The rotor output force is equal to the clamp force multiplied by the coefficient of friction (which is then doubled because of the 'floating' design of the caliper) [4]. See Equation 2.5.

$$Fr = F \mu 2 \tag{2.5}$$

where $Fr$ = Rotor output force (Nm)

$F$ = Clamp force (N)

$\mu$=coefficient of friction

### 2.5.6 The Rotor

Unlike the other braking system components, the rotor serves two purposes. In order of appearance, they are:

i. The rotor acts as the frictional interface for the brake pads. But because it is a spinning object, it reacts to the output force by absorbing the torque created (any time a force is applied to a spinning object, a torque is generated). See Equation 2.6.

ii. The rotor must also absorb the heat generated by the rubbing of the brake pads against the rotor face [4].

$$\tau = Fr \tag{2.6}$$

Where $\tau$ = Torque (Nm)

$F$= clamp force (Nm)

$r$= radius (m)

### 2.5.7 The Wheels and Tires

It is the interface between the tire and the road that reacts to this torque, generating a force between the tire and the road that will oppose the motion of the vehicle [4]. See Equation 2.7.

$$F = \frac{\tau}{r} \tag{2.7}$$

Where $F$ = Force generated between tire and road (N)

$\tau$ = Torque (Nm)

$r$ = Rolling radius (m)