"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
Bachelor of Mechanical Engineering (Automotive)"

Signature: .....

Supervisor: Mr. Fauzi Ahmad

Date: 21st July 2012

SYSTEM IDENTIFICATION OF ELECTRONIC WEDGE BRAKE (EWB)

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This report was submitted in accordance with the partial requirements for honor of Bachelor of Mechanical Engineering (Automotive)

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MAY 2012

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature: .....

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Date: 21st July 2012

For Loving Father and Mother

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ABSTRACT

This study deals with the use of Electronic Wedge Brake (EWB) in improving driving quality and solving common problems in current vehicle braking systems. This new electronic brake concept is based on an electric powered controlled friction brake with high self-reinforcement capability which has performance advantages over conventional brake systems. The main content of this study is the development of System Identification of EWB. Modeling is done to study the brake behavior on a real vehicle through MATLAB SIMULINK software. Detail design of EWB mechanism with CATIA is done followed by test rig which consist of one unit linear variable displacement transducer (LVDT), one unit load cell, one unit rotation encoder, data acquisition (DAQ) and EWB actuator . Experimental result are then used to develop the System Identification of EWB and followed by the EWB modeling. Common problems in hydraulic braking system vary from few sources such as air in the brake line, brake fluid leakage, sticking pistons and more. The ideal solution for these problems is the development and implementation of EWB system in modern vehicles. EWB system are said to be the perfect system to replace existing hydraulic braking system in vehicles because of its dominant advantages. This EWB system results low power consumption, totally silent with no vibration during braking, able to react more quickly and hence shortening the stopping distance. However this EWB system may fail if power supply to be this system is disrupted. To take care of this, EWB is to be connected to a main and a backup power supply. The development of EWB system brings the technology further advance and providing the perfect platform for X-by-wire technologies. In future, brake-by-wire is predicted to be replaced by wireless braking system.

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LIST OF ABBREVIATIONS

EWB	=	Electronic Wedge Brake
DAQ	=	Data Acquisition
EHB	=	Electro-Hydraulic Braking
ESP	=	Electronic Stability Program
EPB	=	Electro-Pneumatic Braking
EMB	=	Electro-Mechanical Braking
LVDT	=	Linear Variable Displacement Transducer
CAD	=	Computer Aided Drawing
DC	=	Direct Current
RPM	=	Rotation per Minute
PID	=	Proportional Integrative Derivative
DOF	=	Degree of Freedom

CHAPTER 1

1 INTRODUCTION

1.1 OVERVIEW

System identification is the art of determining a model of a dynamical process by combining information obtained from experimental data. The purpose of system identification is to determine states or modes needed to construct a model of the system. System identification is to model the dynamic behavior of a physical system by determining the equations of motion.

Automotive brakes provide the means to slow down or stop a vehicle, by using friction to convert the kinetic energy of a moving vehicle into heat. Numerous braking systems are available on modern vehicles but passenger vehicles commonly employ hydraulic braking system. The progress in microelectronics, sensor technology and actuator technology has led to brake-by-wire which replaces mechanical linkage or hydraulic controls in a motor vehicle resulting in a decrease in vehicle weight, improved handling and facilitating the implementation of active safety elements.

Over recent years, studies on electronic wedge brake have been increasingly popular. This modern brake system is a fully controlled electro-mechanical braking system with a high degree of mechanical self-reinforcement. By intelligently controlling the wedge, it becomes possible to convert the kinetic energy of the vehicle into actual braking force. The electronic wedge brake will be far superior to any braking technologies presently being developed or already on the market in terms of energy consumption, efficiency, space consumed, weight and price.

Electronic wedge brake can be considered to bring add-on value both to the car manufacturer as well as to the customer. The car manufacturer will gain not only financial benefit by producing electronic wedge brake but also a reputation of technological leadership. The customer will benefit from improved driving comfort as well as improved driving characteristics and safety.

The goal of this study is to explore the possibility of improving braking system on passenger vehicles by the use of electronic wedge brake. This is the call for ever more sophisticated and complex braking and driver assistance systems. Brake-by-wire allows for branding by tailoring the overall feel of a vehicle through software changes rather than changing hardware on a vehicle. The main task of this study is to design the system identification of electronic wedge brake (EWB) and to study the behavior of EWB. The research begins with the studies on classification in the type of brakes existing in current market. The electronic wedge brake (EWB) then is designed using CATIA V5R16 software. The study then continued with the development of EWB test rig, sensor installation, experiment and finally system identification of EWB.

1.2 PROBLEM STATEMENT

This research is ignited by the problems that frequently occur in modern hydraulic braking system in current vehicles. There are several problems that commonly occur in commercial braking system. Air in the system is the most common of them all. This is caused by the brake not being bleed properly after rebuild, or lose connection on the hose lines or bleed nipple allowing air into the system. Next are the sticking pistons in the brake caliper allowing the pad to constantly run on the disc, causing friction and heating the fluid. The fluid boils and generates air bubbles so leading to spongy soft brakes. Leaking fluid from the master cylinder seals could allow air into the system too. Worn out or tired brake hose on the other hand could degrade over a period of time so leading to greater expansion of the hydraulic fluid and loss of performance.

The ideal solution for all the above problems is by eliminating mechanical parts and linkage including brake fluid in the braking system. Since EWB system fulfill the criteria needed, hence it is the perfect replacement for current conventional braking system. Developing and integrating EWB system in modern vehicles would be the perfect solution for the technical problems. However, EWB may fail on road if the power supply to the system turns flat since the system uses vehicle battery power. This situation could be avoided if the EWB system is powered by a main vehicle battery and a secondary backup battery in case the main battery fails.

1.3 BACKGROUND OF STUDY

The electronic wedge brake (EWB) is a new electro-mechanical braking system with a high self-reinforcement factor. This results in low power consumption, providing the perfect platform for X-by-wire technologies. In the automotive industry today, there is a strong tend towards 'power-by-wire technologies', aimed at replacing hydraulic or pneumatic systems. EWB differs from the conventional braking system that transmits braking power through hydraulic system such as brake cylinders, hydraulic lines and brake fluid. EWB also has less mechanical parts and hence totally silent with no vibration felt through the brake pedal. Its main benefit is that it is able to react more quickly, resulting in shorter stopping distances and increased safety. Yet another reason for its increasing number of studies is that it takes up much less physical space, which is an important factor considering how tight engine compartments have become.

Currently hydraulic, pneumatic, electro-hydraulic, electro-pneumatic and electro-mechanical braking systems are available in market. Although these braking systems have been researched and developed extensively, EWB is still an interesting subject to be studied. In this research, hydraulic connection between brake pedal and individual brake actuators are eliminated and replaced with electronic system. Caliper, wedge mechanism, brake pad and brake disc is used as an actuator for EWB to improve the braking system of vehicles. The effectiveness of this EWB depends on the accuracy of force sensor, the electronic system and the design of actuator.

In theory, the faster the vehicle travelling when the brakes are applied, the more powerful they become. When the pad is applied to the disc, the momentum of the rotating disc draws the pad farther up an interlocking series of wedges, applying greater braking pressure and increasing stopping efficiency. A series of electric motors push in and pull out at an extremely high frequency, while a torque sensor controls the braking force and keeps the wheels from locking up. The distance required to stop the vehicle is less than half compared to other conventional brakes.

1.4 OBJECTIVES

The primary objective of this study is to identify the system of electronic wedge brake (EWB). EWB actuator mechanism is designed in detail using CATIA V5R16 Software. Then, the model was fabricated according to the design and used for the experimentation purpose. Test rig are also fabricated to test the EWB prototype. Sensors together with the EWB prototype are fixed on the test rig for experimentation evaluation. Data of motor input angle, brake piston displacement and clamping force on disc are obtained from Data Acquisition (DAQ).

The experimental data are processed to two different parts. The first part is the data during braking and the next is the data during releasing the brake. Next, system identification and modeling of EWB are done. The simulation is then used to study the performance of EWB in passenger vehicles. Finally it is also targeted to provide recommendations to automotive designers and manufacturers on the potential benefits in the use of the EWB system in improving the braking system performances of the vehicle. Besides that, EWB are also environmental friendly as there is no oil spillage that damages the environment and wildlife habitat.

1.5 SCOPES

1) Designing the EWB mechanism using CATIA V5R16 software.
2) Fabricating the electronic wedge brake (EWB) test rig for system identification purpose.
3) Sensor installation for experimentation evaluation.
4) System identification of EWB mechanism using MATLAB SIMULINK Software by Math Works Inc.

1.6 SIGNIFICANCE OF THE STUDY

The significance of this EWB study is to improve the safety of vehicle in terms of its braking capabilities by reducing the stopping distance and the reaction time with appropriate control strategy. Drivers are given more control of their vehicles especially in case of emergency. The stopping time needed to stop a vehicle with EWB are just 100 milliseconds compare to conventional brake that takes 140 to 170 milliseconds to generate full braking power at a speed of 100 kilometers per hour. The additional benefit of the study is to develop automotive industries with innovation. EWB is the answer to future vehicle chassis safety, weight, reliability and space requirements. Continued developments in the auto industry made it possible for drivers to have more and more features in their vehicles which make driving a new experience. Thus it is predicted that this study can reduce the number of accidents on road as well as improving the ride of a vehicle without sacrificing the comfort level of the passenger in the compartment.

CHAPTER 2

2 LITERATURE REVIEW

2.1 HYDRAULIC BRAKING SYSTEM

A simple hydraulic system has liquid, a pump, and lines to carry the liquid, control valves and an output device. The liquid must be available from a continuous source such as the brake fluid reservoir or a sump.

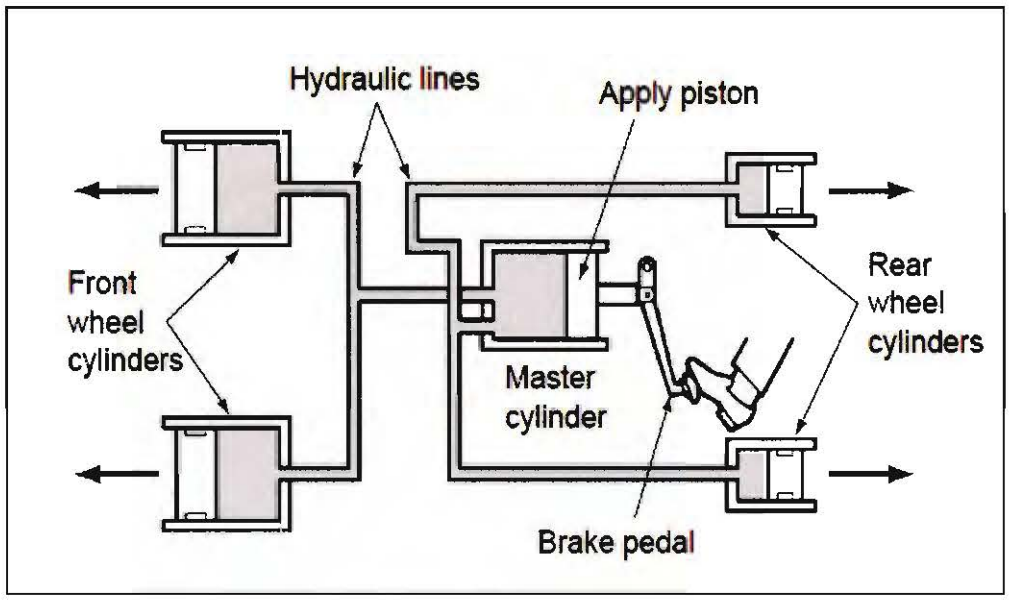

Figure 1: Schematic Diagram of Hydraulic Braking System

Hydraulic brakes use a special liquid called brake fluid to apply brake pressure to pad or shoes. The main parts of this system are a chamber called a master cylinder, which is located near the brake pedal, at least one wheel cylinder at each wheel and tubes called brake pipes which connect the master cylinder to the wheel cylinders. The cylinders and brake pipes are filled with brake fluid (James W *et al*, 1999). Inside the master cylinder is a piston which can slide back and forth. The brake pedal controls piston by means of rod or a mechanical link.

In a hydraulic brake system, the master cylinder serves as the main fluid pump and moves the liquid through the system. The lines which used to carry the liquid throughout the system maybe pipes, hoses, or a network of internal bores or passages in a single housing. Valves are used to regulate hydraulic pressure and direct the flow of the liquid. The output device is the unit that uses the pressurized liquid to do work. In this case, the output devices are brake drum wheel cylinders and disc brake calipers.

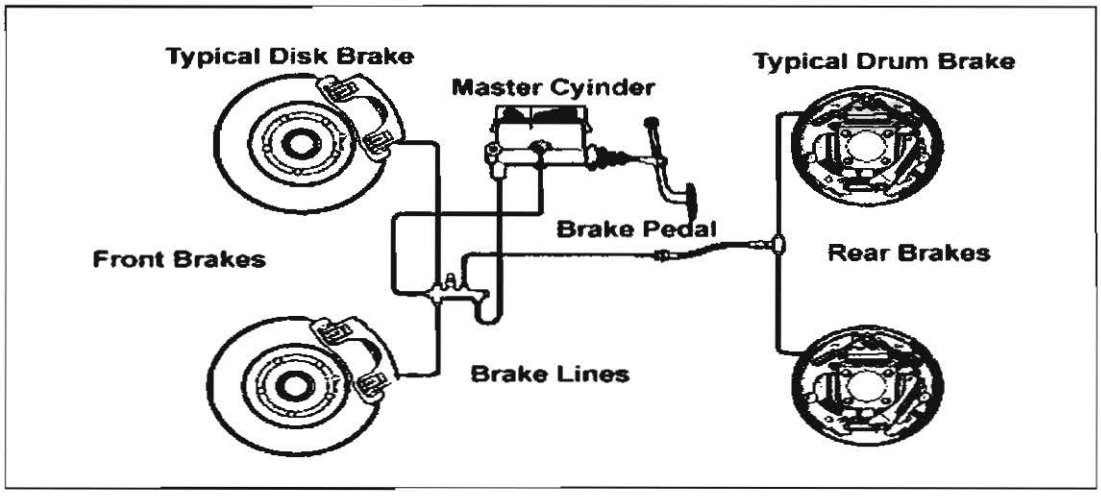

Figure 2 : Typical Automotive Braking System

When the brake pedal is depressed, the pressure on the brake pedal moves the piston within the master cylinder, forcing the brake fluid from the master cylinder through the lines to the wheel cylinder. The wheel cylinders contain two opposed, each

of which is attached to a brake shoe fitted inside the brake drum. Each output piston pushes the attached brake shoe against the wall of brake drum, thus retarding the rotation of wheel (Okwuchi E, 2005). When the pressure on the pedal is released, the springs on the brake shoes return the wheel cylinder pistons to their released positions. This action forces the displaced brake fluid back through the flexible hose and tubing the master cylinder. The force applied to the brake pedal produces a proportional force on each of the output pistons, which in turn apply the brake shoes frictionally to the turning wheels to retard rotation.

2.2 PNEUMATIC BRAKING SYSTEM

Pneumatic brakes are simply the wheel brakes on the vehicle, but they are powered by compressed air. Pneumatic brakes use a compressor which is powered by the engine of the vehicle to compress air, which is stored in tanks, and then used to apply the braking system and stop the vehicle. Compressor is the pump which draws air from atmosphere and compresses it for use in brake system. Main reservoir is the storage tank for braking and other pneumatic systems. The feed valve ensures that brake pipe pressure remains at required level, a feed valve connected between main reservoir and brake pipe.

Pneumatic brakes are operated by number of important components such as the air compressor, governor, air filter drier, alcohol evaporator, air reservoir, protection and control valves, gauges, brake champers, slack adjusters, brake drums, glad hands, and warning devices. Below are components in pneumatic braking system with their respective function.

Air compressor is a machine that pumps the air into a smaller space to produce compressed air powered by the engine and could be mounted to the engine. Governor is a controller that limits the air compressor to produce amount of air required. It controls the compressor cut-in (on) and cut-out (off) to make sure the compressor produces enough air but not too much air. Governor is normally located on the compressor. Air dryer removes moisture and vaporized oil from the compressed air before it enters the air supply tank. Air dryer is normally located on the air compressor Alcohol evaporator prevents any moisture in the air brake system to freeze. Air reservoir system stores compressed air before it's released to the brakes.

Safety valve protects the air tank to over pressure or release access of air in case the governor fails. Warning devices detects low air pressure and warns the driver when the air pressure drops below 60 psi. A light and buzzer goes off to warn the driver in the case of low air pressure. Air pressure gauges located on the dashboard indicates amount of air pressure in the air tank. Some trucks are equipped with two air pressure gauges, one for each tank. Brake champers consists of diaphragm, air inlet, push rod, return springs, and clamp. Air enters the brake champers through the air inlet and pushes against diaphragm which also pushes the push rod. The push rod is connected to the slack adjuster. Return spring returns the diaphragm to its original position.

Slack Adjuster is a lever arm attached to the push rod. Glad hands are coupling devices at the end of the air lines where tractor connects with the trailer. Glad hands are color coded, service line is normally blue and supply line is red. Service line supplies air from the brake pedal to the trailer service brakes and supply line supplies air to the trailer air tank and controls trailer brake.

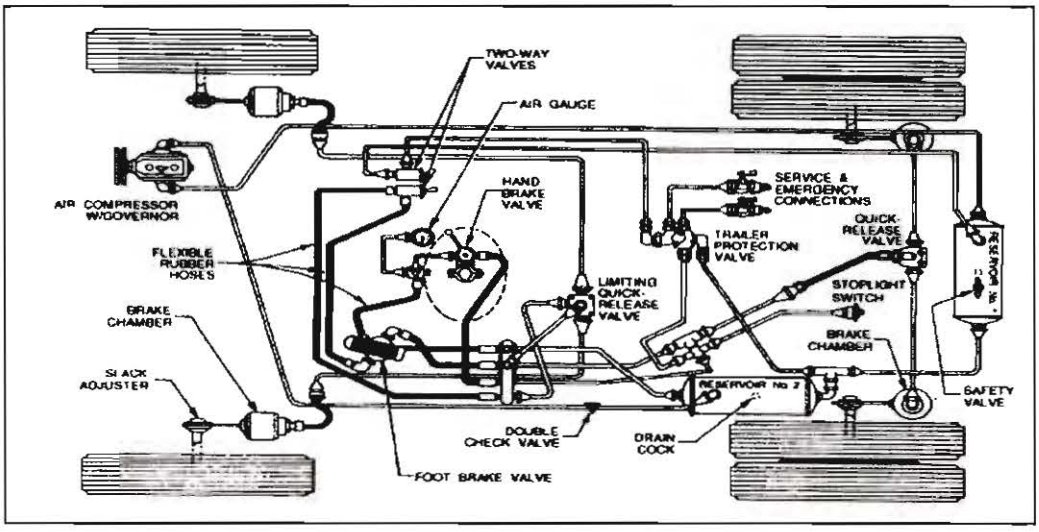

Figure 3 : Typical Pneumatic Brake System

When the driver presses the brake pedal, they operate a valve which controls the air pressure release into the brake lines. The harder the brake pedal is pressed, the more air the tanks release, and the harder the brakes are applied to the disc or drum. There are two types of air brakes. First type which use pressure to apply the brakes, and the second that use pressure to hold the brakes open. The main braking system in commercial vehicles uses air to apply the brakes, and has a secondary system which called emergency or parking brake that uses springs to apply the brake, and a small air canister to hold the brakes open. Pneumatic brake system is undoubtedly one of the most enduring features in commercial vehicles.