THERMAL STRESS ANALYSIS FOR BRAKE PAD

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

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DECLARATION

"I'm hereby declare that the work in this thesis is my own except for quotations and summaries which have been sources acknowledgement"

Signature : .....

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Date : 13/12/05

DEDICATION

Dedicated to my beloved family. Special thank you to Nur Hazree bt. Surian because always with me to give support and attention.

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To my family and my entire friend, thank you for their understanding and support which inspired me to complete this thesis successfully. Lastly, to the entire person whom I have involved thank you for the knowledge and support.

Thank you.

ABSTRACT

This project is carried out with the purpose to analyze the thermal stress on brake pad. The scopes of project chose a study principle of thermal stress. Braking system include from disc or drum brake, it is usually created to allow the driver to stop the vehicle. Thermal stress produced from the frictional of clamping force at brake pad, against a rotating rotor or drum. Brake pad is a flat block and built with plate steel. The plate steel is adhering with pad, riveting or binds to pad. The brake pad is use to press disc. The material of brake pad is made from non asbestos, semi metallic, low metallic and ceramic. In this project, the material use to analysis is non asbestos and semi metallic. The comparison of temperature will do to both of material with transformation temperature. Pressure will change to heat flux and applied to brake pad surface. After that, the temperature will use to find a friction. Stress occur because have a difference temperature at two things when it frictional. To find the thermal stress analysis, the Finite Element Analysis (FEA) use to solve it. The software use is MSCNastran and in the software uses a finite element analysis (FEA) principle.

ABSTRAK

Projek ini dijalankan dengan tujuan membuat analisis terhadap tegasan haba pada brek pad. Skop projek ini memilih untuk mempelajari prinsip tegasan haba. Sistem brek terdiri daripada brek disk dan brek gelendong, ia direka untuk membenarkan pemandu memberhentikan kenderaan. Tegasan haba terhasil daripada geseran dari cengkaman daya daripada pelapik brek yang menentang arah daya pusingan brek disk dan brek gelendong. Pelapik brek (pad) ialah satu blok rata yang dibina dengan keluli kasut yang dilekatkan dengan lapikan, dirivet atau diikat ke kekasut. Pelapik brek digunakan untuk menekan cakera pada brek disk. Bahan pelapik brek diperbuat dariada non asbestos, semi metallic, low metallic dan seramic. Di dalam projek ini, bahan yang digunakan untuk dianalisa ialah non asbestos dan semi metallic. Perbandingan suhu akan dijalankan terhadap kedua-dua bahan ini dengan perubahan masa. Tekanan akan ditukarkan kepada haba fluks dan dikenakan pada permukaan pelapik brek (pad). Selepas itu, suhu yang diperoleh akan digunakan untuk mendapatkan tegasan. Tegasan berlaku disebabkan terjadinya perubahan suhu pada kedua-dua benda yang bergeser. Analisis ini menggunakan kaedah simulasi untuk mendapatkan keputusan tegasan haba pada pelapik brek. Perisian yang digunakan ialah MSC.Nastran dan di dalam perisian ini, menggunakan prinsip analisa unsur terhingga (FEA).

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NOMENCLATURE

F	Frictional force
$\{F\}$	Applied force vector
$\{k\}$	Stiffness matrix
$\{x\}$	Displacement vector
Q	Heat flux
P	Power
r	partition ratio
T	Time
ΔT	Temperature difference
C	Constant
V	Velocity
x	Thickness
A	Cross-sectional area
E	Modulus elasticity
h	Convection
q	Thermal conductivity
C_p	Specific heat Rake angle
m	mass
μ	Coefficient of friction

CHAPTER 1

INTRODUCTION

1.1 General

An automobile's brake system must be able to slow or stop the vehicle when in motion and it must be able to hold the car in position when stopped on an incline. The force input by the driver is multiplied by the actuation system and enables the energy of the vehicle's motion to be transferred to the brake drums or rotors where friction converts it into heat energy and stops the vehicle.

The purpose of friction brakes or brake pad is to decelerate a vehicle by transforming the kinetic energy of the vehicle to heat, friction, and dissipating that heat to the surroundings. As a part of a commercial automobile, brake materials have additional requirements, like resistance to corrosion, light weight, long life, low noise, stable friction, low wear rate, and acceptable cost versus performance. There are two common types of friction brakes drum/brake shoe and disc/brake pad. The design of the brakes affects heat flow, reliability, noise characteristics, and ease of maintenance.

Braking performance of vehicle can be significantly affected by the temperature rise. Therefore it is important to predict the temperature of a given brake pad and access the thermal and stress distribution at the early stage of design. In this thesis, the main focus is to analysis the thermal stress on brake pad using finite element method analysis.

The modeling technique carried out in this thesis is using the finite element software Msc.Nastran. There are two major criteria that has been carry out in order to investigate and analyze the brake pad performance which is due to severe braking is to carry out temperature variation in the brake pad with time and to carry linear elastic of stress distribution and hence thermal loading in the brake pad.

1.2 Objective project

The objective of this project is to analyze thermal stress on surface brake pad, to simulate the distribution and developed of heat in brake pad under a range of deceleration due to several braking and to investigate and analyze the brake pad performance which is due to severe braking is to carry out temperature variation in the brake pad. Beside that, from this thesis it can do the testing of brake capability and the rate of brake wear.

1.3 Scope project

The scope of this project is analysis will be done on local made car brake pad by using finite element analysis software, MSC/NASTRAN. Beside that, use the Finite Element Analysis software MSC/NASTRAN. Meanwhile, the principles using is Thermal Stress concept or principles to do brake pad.

CHAPTER 2

BRAKING SYSTEM

2.1 History of Brake

Brake is a device used to slow and stop a rotating wheel and there by a moving vehicle. Brakes such as those on automotives, trucks, trains, and bicycles use friction between the wheel and another object to slow the motion of the vehicle. The friction created by the rubbing together of two objects generates a large amount of heat. A brake system must be capable of dissipating the heat as rotating wheels slowly, because excess heat can cause the brakes to lose their grip and fail.

In its early days, a battle raged over the need for front brakes. Popular belief had it that a car equipped with front brakes would go end-over-end in a panic stop. But, just having rear wheel brakes often resulted in "side is skidding and weight transfer reduced their effectiveness. The battle continued for several years, and front brakes did not become common on passenger cars until the early 1920s.

Drum brakes with internal expanding shoes were the most common, but the details often varied. Most were mechanically actuated, although the 1906 Northern had service brakes operated by compressed air. The Westinghouse Air Brake Co. discovered that brakes exerted their greatest retarding effect when the wheels did not quite lock, but

continued to revolve. The advantages of anti-locking brakes became known by 1914, but it was implemented only after a few decades.

2.2 Definition of Brake

The automobile's brake system is design to allow the driver to stop and control the speed of the vehicle. The brake system is composed of many parts, including friction pads on each wheel, a master cylinder, wheel cylinders or calipers and a hydraulic control system. At the vehicle, have a one brake system, brake disc at in front and brake drum at rear. The using of brake system also depends on the speed to stop or slow the vehicle, either use both of brake disc at the vehicle or one at in front.

The brake system is based on the principles of hydraulics. Hydraulic action begins when force is applied to brake pedal. This force creates pressure in the master cylinder, either directly or through a power booster. It serves to displace hydraulic fluid stored in the master cylinder. The displaced fluid the wheel cylinder and caliper push the piston that actuate the brake shoe and brake transmits the pressure through the fluid filled brake lines to pads mechanisms forces the linings and pads against the drums (rear wheels) and rotors (front wheel) where friction converts it into heat energy and stops the wheel. Figure 1 Design braking system in a vehicle and figure 2 shows the common brake system using in vehicle.

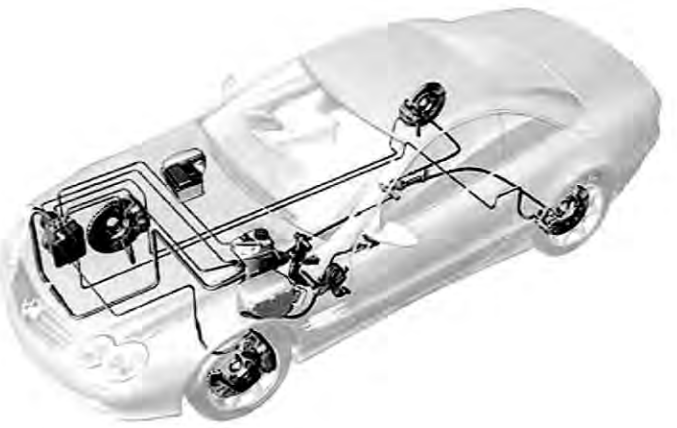

Figure 1 Design braking system in a vehicle

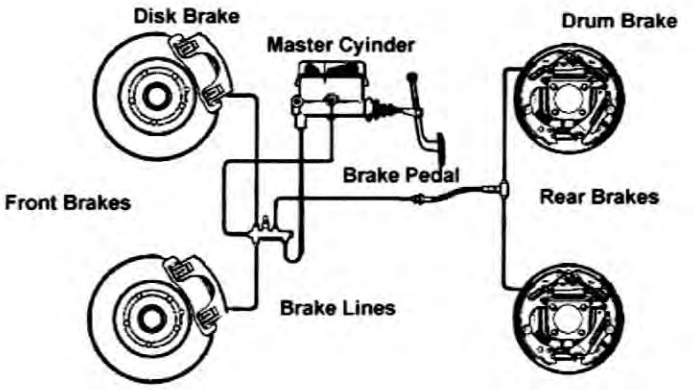

Figure 2 Brake system schematic

2.3 Principle of Brake System

The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat). When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Brakes must be able to arrest the speed of a vehicle in a short period of time regardless how fast the speed is. As a result, the brakes are required to have the ability to generating high torque and absorbing energy at

extremely high rates for short periods of time. Brakes may be applied for a prolonged periods of time in some applications such as a heavy vehicle descending a long gradient at high speed. Brakes have the mechanism to keep the heat absorption capability for prolonged periods of time.

On a disk brake, the fluid from the master cylinder is forced into a caliper where it presses against a piston. The piston squeezes two brake pads against the disk (rotor) which is attached to the wheel, forcing it to slow down or stop. This process is similar to a bicycle brake where two rubber pads rub against the wheel rim creating friction.

With drum brakes, fluid is forced into the wheel cylinder which pushes the brake shoes out so that the friction linings are pressed against the drum which is attached to the wheel, causing the wheel to stop.

In either case, the friction surfaces of the pads on a disk brake system or the shoes on a drum brake convert the forward motion of the vehicle into heat. Heat is what causes the friction surfaces (linings) of the pads and shoes to eventually wear out and require replacement.

2.4 Components in Brake System

The typical brake system consists of disc brake in front and either disk or drum brake in the rear connected by a system of brake lines that link the brake at each wheel or caliper to the master cylinder. Each part is related to the others, and proper operation of each part is necessary for correct operation of the whole 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 is a hydraulic control device that converts physical pressure (commonly from a driver's foot) into hydraulic pressure to operate other device in the hydraulic system shown in Figure 3. The most common automotive uses of master cylinders are in brake and clutch systems. In brake systems, the operated devices are brake calipers and wheel cylinders.

Figure 3 Master cylinder

2.4.2 Brake Fluid

Brake fluid is a special liquid for use in hydraulic brake systems, which must meet highly exact performance specifications. It is designed to be impervious to wide temperature changes and to not suffer any significant changes in important physical characteristics such as compressibility over the operating temperature range. The fluid is designed to not boil, even when exposed to the extreme temperatures of the brakes.

The purpose brake system uses brake fluid to transmit pressure from a brake pedal to the brakes on each wheel. The master cylinder is connected to the wheel brakes by hollow steel tubes called brake lines, which are also filled with brake fluid. The pressure is transmitted through the brake lines to additional pistons inside each brake. These pistons push brake pads against the disc/rotor attached to the wheels in order to slow the vehicle down.

Different types of brake fluid are used in different systems. Brake fluid can come in a number of forms, standard under the DOT (Department of Transportation) standard. DOT 2 is essentially castor oil DOT 3, DOT 4, and DOT 5.1 are composed of various glycol esters and ethers and DOT 5 is silicone-based shown Figure 4. Most cars use DOT 3 or DOT 4 brake fluid. DOT 3 and DOT 4 fluids also attract small amounts of water that may collect in the brake system. (Charles Ofria, 2000)

2.4.3 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. This component is look likes pipe tube and need to connect to each one, it shown at figure 4. This component will connected to overall section to be a brake system circuit from master cylinder to direct vane or wheel cylinder show in Figure 5.

Figure 4 Part of brake lines

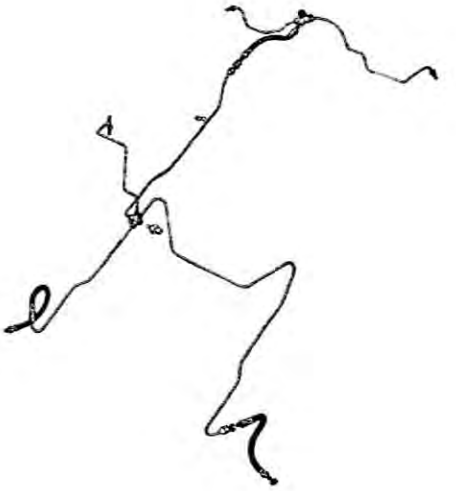

Figure 5 Connecting brake lines

2.4.4 Drum Brake

Drum brakes are old technology shown in figure 6. Early automotive brake systems, after the era of hand levers of course, used a drum design at all four wheels. They were called drum brakes because the components were housed in a round drum that rotated along with the wheel. Drum brakes consist of a backing plate, brake shoes, brake drum and wheel cylinder.

Figure 6 Drum brake