"I hereby declare that I have read this report 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 (Thermal-Fluid)"

Signature : 

Name of Supervisor : Mr. Ruztamreen Bin Jenal

Date : 19/12/2005

THERMAL STRESS ANALYSIS ON BRAKE DRUM (SIMULATION)

NURULHUDA BINTI KHALID

A report submitted in fulfillment of the
requirements for the award o the degree of
Bachelor of Mechanical Engineering (Thermal-Fluid)

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Kolej Universiti Teknikal Kebangsaan Malaysia

November 2005

I declare that this report entitled Thermal Stress Analysis on Brake Drum (Simulation) is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:
Name	: Nurulhuda binti Khalid
Date	: 14/12/2005

Dedicate to both my beloved father and mother and my loving family.

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Alhamdulillah with His Mercy and Blessings, this study was finally completed. First of all, thank you to all individuals that have involved either directly or indirectly. This highest gratitude appreciation goes to;

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ABSTRACT

This study is for observing and investigating the heat distribution occurs on brake drum within the braking system. The temperature changes on the brake drum during the deceleration providing the heat distribution. It is includes the temperature distribution on brake drum and friction occurs due to the deceleration of cars. The distribution of temperature depends on the various factors such as friction, surfaces roughness, speed, and others. As a matter of fact, a severe brake application will create a thermal environment on the friction surface with high surface temperature. The execution of the analysis is done by using MSC Nastran software where it shows area that have been affected by heat and area that free from distortions. This method is functional with the usage of temperature to calculate the heat development and distribution. The analysis implementation has been done to a surface of related on brake drum in the braking system.

ABSTRAK

Kajian ini dijalankan bagi mendapatkan dan mengkaji pengagihan haba yang berlaku pada brek *drum* ketika sistem brek. Perubahan suhu pada brek dram ketika nyahpecutan menghasilkan pengagihan haba. Ia juga termasuk pengagihan suhu pada brek dram dan geseran yang berlaku ketika penyahpecutan kereta. Pengagihan suhu adalah bergantung kepada pelbagai faktor seperti geseran, permukaan kasar, kelajuan, dan sebagainya. Sebenarnya, penggunaan brek yang kerap akan mencipta persekitaran haba pada permukaan geseran dengan suhu permukaan yang tinggi. Perlaksanaan analisis dilakukan dengan menggunakan perisian MSC Nastran di mana ia menunjukkan kawasan yang terlibat dan kawasan yang bebas. Kaedah simulasi ini berfungsi dengan penggunaan suhu untuk mendapatkan pembetukan dan pengagihan haba. Perlaksanaan analisis dilakukan terhadap permukaan yang berkaitan pada brek drum di dalam sistem brek.

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LIST OF SYMBOLS

$Q_{conduction}$	-	Conduction heat transfer, kJ/kg
$Q_{convectiom}$	-	Convection heat transfer, kJ/kg
$Q_{radiation}$	-	Radiation heat transfer, kJ/kg
k	-	Thermal conductivity, W/mK
A	-	Cross sectional area, m^2
ΔT	-	Temperature difference, ^oC or K
x	-	Thickness, m
h	-	Convection coefficient, W/m^2K
m	-	Weight, m
C_p	-	Constant pressure specific heat, kJ/kg.k
h_R	-	Convective heat transfer coefficient, Nm/hKm^2
Re	-	Reynolds Number
D	-	Drum diameter, m
k_a	-	Thermal conductivity of air, Nm/hKm
β	-	0.70 for front drum brake, Nms/hKm^3
V	-	Vehicle speed, m/s
KE	-	Kinetic energy
W_{in}	-	Heat rate
$A_{surface}$	-	Friction surface area
Q	-	Heat flux

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, car is one of most popular vehicles compare to others since there are so many type and criteria of cars that been produced. We can see the types of cars and various car manufacturers. The car is one of the most fascinating devices that a person can own. Cars are also one of the most pervasive devices. A car contains dozens of different technologies. Everything from the engine to the tires has its own special universe of design and engineering. In the mean time, we also know that the brake system is still the same. How expensive a charge for a car, the most important is the brake system.

The study of brake is continued until today in order to inspect the condition of the brake system. On that reason, this advantage is taken to study on the thermal stress analysis on brake drum in order to improve the usage and the effect on vehicle by using NASTRAN simulation.

The first steps taken in early 70's, when manufacturers decided to switched from drum to disc brakes on a widespread scale to improve braking. Only the front brakes were upgraded to disc since the stopping power is contained in the front wheels. Since then, many manufacturers have adopted four-wheel disc brakes on their high-end and performance models as well as their low-line economy cars.

The most important system in a car is the braking system, where if the brakes fail, the result can be disastrous. Brakes convert the kinetic energy (momentum) of the vehicle into thermal energy (heat). When the brakes is step on, it will command the brake a stopping force ten times as powerful as the force that puts the cars in motion. The braking system can exert thousand or pounds of pressure on each of the four brakes.

In modern system, brakes are more complex but also much safer than earlier braking system. All newer cars have dual systems with two wheels operated by each subsystem. That way, if one subsystem fails, the other can provide reasonably adequate braking power.

The brake shoes rub against the brake drum to slower a car. During the acceleration process, braking creates heat but brakes are designed to take a lot of heat. However, by using them too much and not relying on the engine braking effect, brake can fail.

Excessive use of the service brakes results in overheating and leads to brake fade. Brake fade results from excessive heat causing chemical changes in the brake lining which reduce friction and also causing expansion of the brake drums. As the overheated drums expand, the brake shoes and linings have to move farther to contact the drums, and the force of this contact is also reduced. Continued overuse may increase brake fade until the vehicle cannot be slowed down or stopped at all.

As a matter of fact, a severe brake application will create a thermal environment on the friction surface with an excessively high surface temperature. At a high temperature, the degradation of yield strength of a drum material may become significant and an important factor to be taken into account in the analysis. Its deals with the thermal distortions produced in a brake drum during severe braking condition, taking account of the temperature dependence of the yield strength of a drum material.

Nowadays, there are many kind of analysis done on brake system to investigate the crack, distortion, erosion, thermal stress behavior, numerical and analytical investigation of temperature distribution and brake performance prediction [1 , 2 , 3]. The brake performance is also significantly affected by driver behavior, not only by the materials and vehicle hardware design [4].

1.2 Objectives

The objectives of this study are:

i. To simulate the distribution and development of heat in brake drum under a range of deceleration.

- Simulation is a one of the method that can be use to study on the thermal stress and to make an analysis on brake drum.
- The simulator chosen to implement the study on the thermal stress is NASTRAN.
- This method will help the investigation on the development and distribution of heat in brake drum under a range of deceleration.

ii. To analysis the thermal distributions on brake drum when friction occurs.

- The heat of brake drum will develop and distribute in the time where friction is occur which is in the duration of car deceleration.
- When the brakes are applied, the brake shoes are forced into contact with the inside surface of the brake drums to slow the rotation of the wheels and that is the time the friction occurs.
- That's mean the thermal distribution analysis on brake drum is one way to discover the performance of car brake system.

iii. To study on the effect of thermal distribution to brake drum.

- From the analysis, brake drum is also being test to check on the effect of thermal stress.
- The analysis will show the result on the effect of thermal stress to the brake drum on certain speed.
- On the mean time, we can see how the heat is distributed when the brake drum is operated.

1.3 Scope

The thermal distribution analysis are discovering on brake drum of local made car by using finite element analysis software, MSC Nastran.

CHAPTER 2

BRAKE SYSTEM

2.1 Brake System

Brake [5] is a device that used to deceleration and stopped vehicles in users required time. The size of brake depends on the size, weight and speed of a vehicle. It can be used in repeated situation in the same impressive. The idea for brake designing is begun in the time of one wheel vehicle. Wagon was the first brake created. The speed of vehicles increased when the tire technology changes the concept to air type and the road condition were improved. Then, to make the vehicles decelerated and stopped properly, the brake is being improved to give more clutches to the tires. When the brake drum created in late 1960's [Robert S. (1989)], the usage of brake also grows.

The following basic components shown in figure 2.1 and 2.2 are the example of a typical brake system. The master cylinder, which is located under the hood, and is directly connected to the brake pedal, converts foot's mechanical pressure into hydraulic pressure. The entire master cylinder is being connected to the slave cylinders that located at each wheel by the steel 'brake line' and flexible 'brake hoses'. Brake fluid, specially designed to work in extreme conditions, fills the system. To slow the car, shoes and pads are pushed by the slave cylinders to contact the 'drums' and 'rotors' to causing drag.

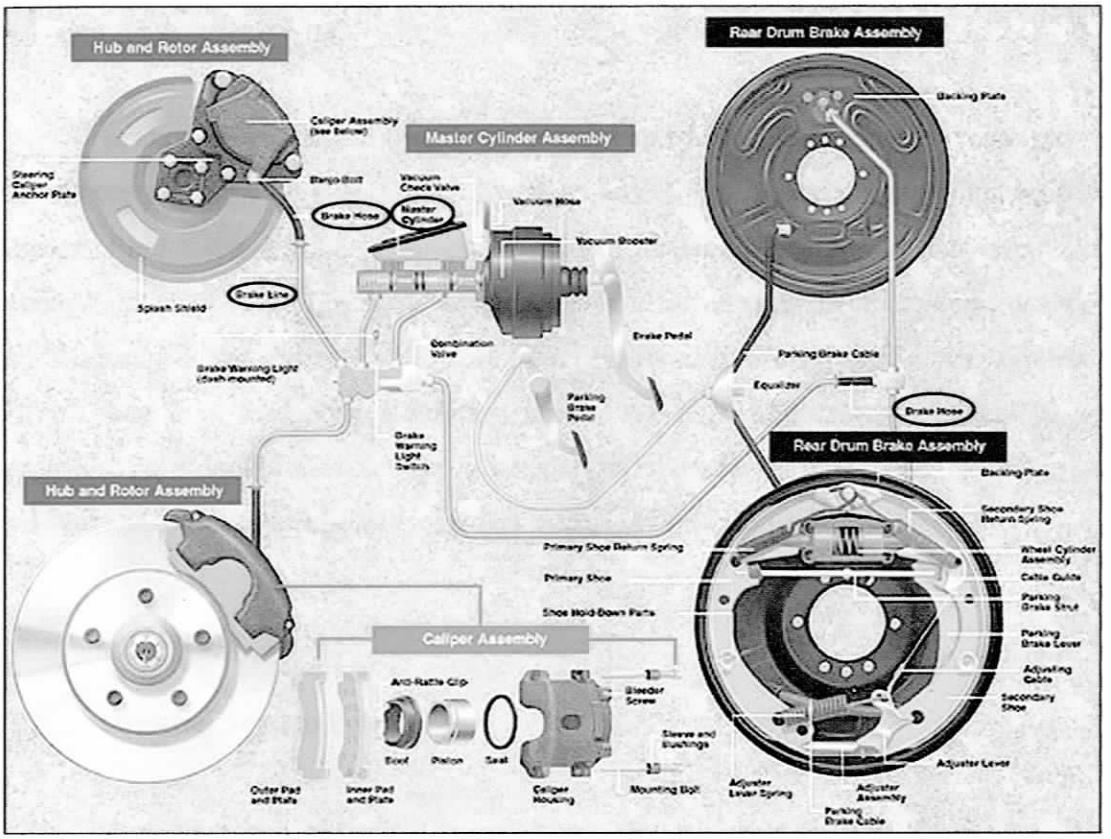

Figure 2.1 Example of a typical hydraulic disc/drum brake system [9]

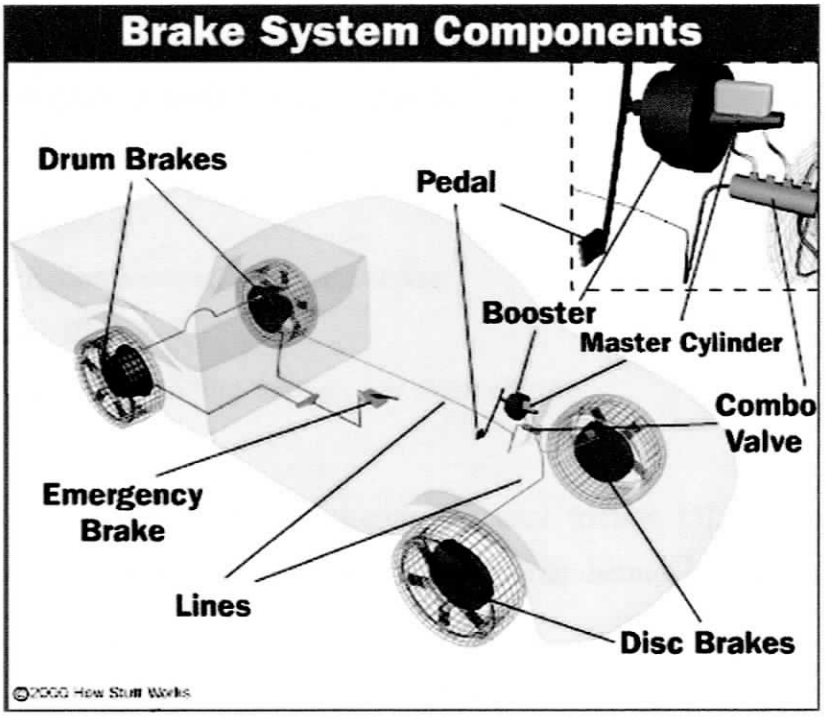

Figure 2.2 Layout of typical brake system [8]

Brakes have changed greatly in design [6]. For the modern cars, drum brakes have been replaced by disc brakes for front wheel applications. Generally, simpler design, lighter weight and better braking performance are the reason why it's been change so fast. The greatest advantage of disc brakes is that they provide significantly better resistance to brake fade compared to drum type braking systems. Brake fade is a temporary condition caused by high temperatures generated by repeated hard braking. It occurs when the pads or shoes glaze due to the great pressure and heat of hard use. Once they cool, the condition subsides.

2.2 Braking System Principles

A decelerated and stopped car in required time when it is operated is the brake main reason [5]. Energy can be created or destroyed based on the thermodynamics' first law. It just can be changed from one type of energy to others and vice versa. Kinetic energy is change to thermal when the brake is applied in brake system. Brake is a mechanical device that used friction to get over movement. There are two types of frictions that important in brake operation:

i. Static friction
   - Friction between two static object
ii. Kinetic friction
   - One object sliding through one static object.

Friction coefficient is representing the total friction [5]. Thermal develop when two body frictional with each other. The value of thermal is depends on:

i. The sum of stress applied in the sliding surface
ii. The surface roughness
iii. The type of materials.

2.3 How Brake Drum Work

On each wheel drum brakes [7] use two brake shoes mounted on a stationary backing plate. These shoes are positioned inside a circular cast iron drum that rotates with the wheel assembly. The shoes are held in place by springs; this allows them to slide toward the drums (when they are applied) while keeping the linings and drums in alignment. Generally, cars have drums brakes on the rear wheels and disc brakes on the front. Besides of having more parts than disc brakes and are harder to service, but drums brakes are less expensive to manufacture, and they easily incorporate an emergency brake mechanism.

The pistons will push the brake shoes against the drum when the brake pedal is hit [7]. Many drum brake are self-actuating. Figure 2.6 shows the brake shoes contact the drum; there is a kind of weighing action, which has the effect of pressing the shoes into the drum with more force.

The extra braking force provided by the wedging action allows drum brakes to use a smaller piston than disc brakes. But, the shoes must be pulled away from the drum when the brakes are released because of the wedging action. This is the reason for some of the springs. Other springs help hold the brake shoe in place and return the adjuster arm after it actuates.

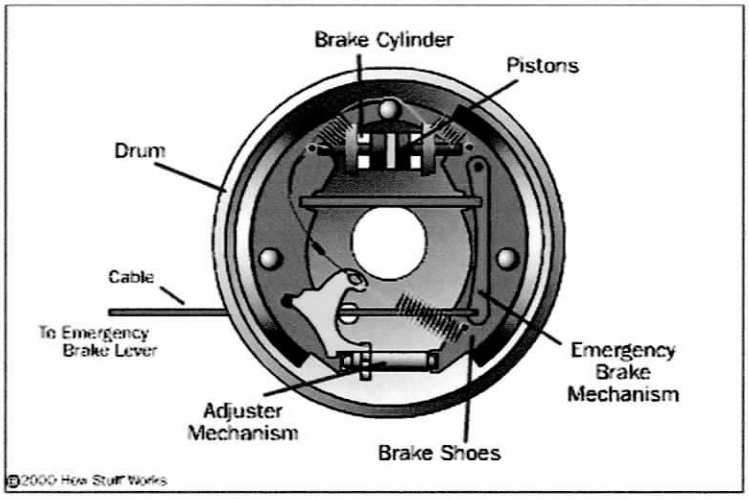

Figure 2.3 Parts of a drum [11]

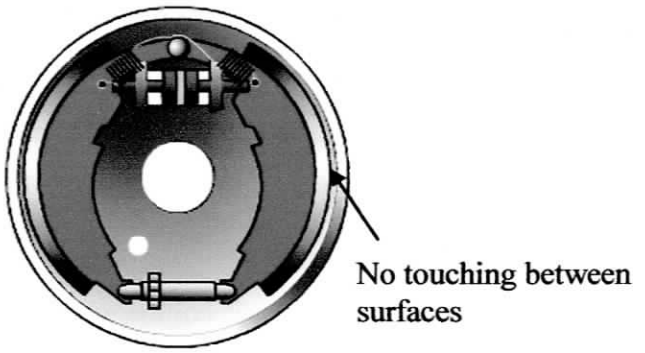

Figure 2.4a Initial Condition [11]

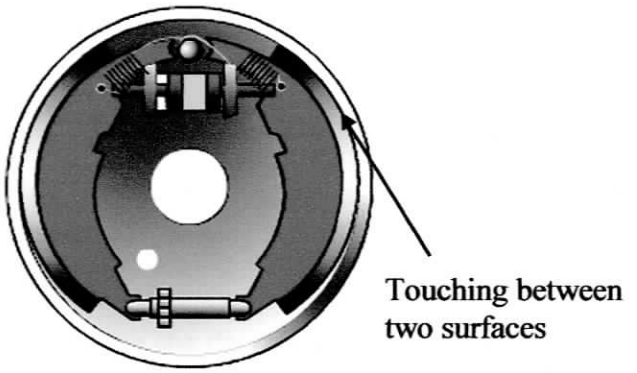

Figure 2.4b During the deceleration [11]

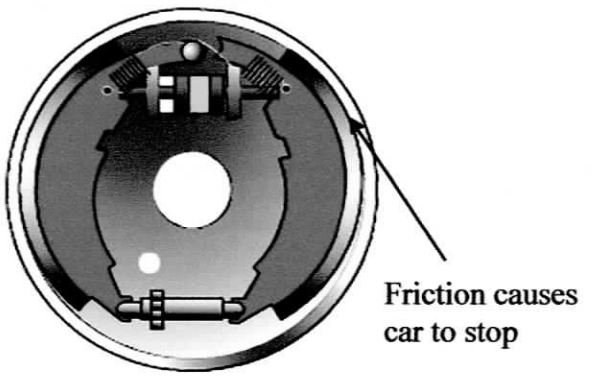

Figure 2.4c At the end of deceleration [11]

Refer to figure 2.7a, it show the initial condition before the process of deceleration where there is no touching between surfaces. Therefore, there are no friction occur. At this time, brakes are in actual form where there is no heat applied to the systems.

Meanwhile, figure 2.7b show the condition during the process of deceleration where the friction occur due to the touching of shoe and drum surfaces. The friction of these two surfaces yet generates heat and causing thermal stress occurs within the process.

Concisely, at the end of deceleration the braking system stop the car. This is due to the high value of friction surfaces stops the drum as shown in figure 2.7c. Control of friction is obtained by forcing brake shoe against a rotating drum. Friction increases as the driver presses harder on the brake pedal. The tire is also slowed down when the wheel is slowed down by the brake friction.

2.4 Brake Capability Factors [5]

The factors that involve during the deceleration of car and influencing brake capabilities are:

i. Weight
   - The kinetic energy transferred to thermal energy is increase if the weight of car is increase.
   - Brake design to control car with weight up to 2041.16 kg also can't absorb the total heat that produced by over weight vehicle.

ii. Car speed
   - Car speed will decelerate and then stop when the brake is used because the kinetic energy is change to thermal energy. The higher speed, the more thermal energy produces by brake.

iii. Wheel and road
   - The touching of wheel and road causing the friction to occur. The radius of rolling wheel is important in order to determine the potential of the car whether it can be stop or not. The big radius of rolling wheel will make the car hard to be stop.