PROJEK SARJANA MUDA

DESIGN AND ANALYSIS AN EFFICIENT LIGHTWEIGHT BRAKE DISC FOR A SINGLE SEATED RACE CAR

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SUPERVISOR DECLARATION

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

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DECLARATION

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

Signature :……
Author :……
Date :……

The dedication goes to

my mother and father

for their supports and prayers

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ABSTRAK

Sebuah piring brek yang ringan dan berfungsi dengan berkesan menyumbang kepada prestasi sebuah kenderaan lumba dengan seorang pemandu sahaja. Di dalam arena lumba kereta, berat sesbuah kereta memainkan peranan penting dalam mencipta sebuah bahagian pada sesebuah kereta perlumbaan. Berat yang minima menyumbang kepada kuasa yang maksima. Setiap bahagian pada sesbuah kereta perlumbaan direka khas atau diubahsuai mengikut piawai kereta perlumbaan tersebut. Oleh itu, bahan yang ringan dengan “coefficient of friction” yang tinggi dan kandungan haba yang rendah.akan dipilih melalui kajian analisa terhadap tegasan haba. Diameter asal piring brek tersebut (Honda Wave 125) di kurangkan utk mengurangkan berat ia. Berat piring brek tersebut juga bergantung pada bahan piring tersebut. Analisa tegasan haba ialah salah satu cara kajian tegasan haba terhadap perubahan suhu atau haba bahan tersebut. Kajian ini hanya bertumpu pada piring brek sahaja. Selalunya masalah yang menyebabkan berlakunya getaran pada piring brek tersebut ialah pengembangan haba bahan tersebut mengubah ketebalan piring brek tersebut. Perubahan ketebalan pada piring tersebut juga disebabkan oleh fenomena tegasan haba, dimana geseran antara kasut brek dan piring brek menghasilkan haba. Ketidasekata keadaan haba pada permukaan piring brek akan di alihkan ke piring brek yang berputar. Fenomena ini menghasilkan tegasan dan perubahan ketebalan pada piring brek tersebut. Beberapa cara terdapat untuk mendapatkan keputusan tersebut seperti eksperimen, analisa dan simulasi. Dalam projek ini, Finite Element Analysis (FEA) digunakan untuk analisa tegasan habapada piring brek dengan menggunakan perisian simulasi iaitu NASTRAN.

ABSTRACT

An efficient lightweight disc brake contributes to the performance of a single seated race car. In motorsports arena, the car weight plays very important roles in designing the race vehicle part. Minimum weight contributes to maximum power. Each part is custom made according to the vehicle specifications. So that, the lightweight material with high coefficient of friction and low heat capacity will be selected through the research in thermal stress analysis. The initial diameter of the stock brake disc (Honda Wave 125) will be reduced to minimize the weight of the disc brake. The weight of the disc also contributes by the material of the disc. Thermal stress is a research of stress due to temperature change. This research only concentrates on disc brake study. Usually a problem that causes the vibration (known as brake judder) in disc brake is the material thermal expansion that changes the thickness of a DTV (Disc Thickness Variation). Thickness change of a disc also is caused by a thermal stress phenomenon, where as friction between brake pad and disc brake produces heat. Unbalanced heat condition at the brake surface will be transferred to rotating disc. This phenomenon will result stress and thickness change to the disc. There are some method in order to obtain and study this case such experiment, analysis and simulation. In this project, FEA (Finite Element Analysis) is used for analysis thermal stress on disc brake by using simulation software called ANSYS 12.1.

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LIST OF SYMBOLS

T = friction torque, Nm

P_a = largest normal pressure applied onto the disc, Pascal

f = coefficient of friction (it depends on the material used)

r_o = outer radius diameter, mm

r_i = inner radius diameter, mm

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Brakes are most important safety parts in the vehicles. Generally all of the vehicles have their own safety devices to stop their car. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor disc on both surfaces. They are compulsory for all of the modern vehicles and the safe operation of vehicles. In short, brakes transform the kinetic energy of the car into heat energy, thus slowing its speed.

Brakes have been retuned and improved ever since their invention. The increases in travelling speeds as well as the growing weights of cars have made these improvements essential. The faster a car goes and the heavier it is, the harder it is to stop. An effective braking system is needed to accomplish this task with challenging term where material need to be lighter than before and performance of the brakes must

be improved. Today's cars often use a combination of disc brakes and drum brakes. For normal sedan car, normally disc brakes are located on the front two wheels and drum brakes on the back two wheels. Clearly shows that, together with the steering components and tires represent the most important accident avoidance systems present on a motor vehicle which must reliably operate under various conditions. However, the effectiveness of braking system depends on the design itself and also the right selection of material. It is important to do some analysis on a disc brake rotor which has been designed to predict the behavior of the systems than follow with some improvements. In order to understand the behaviors of braking system, there are three functions that must be complied for all the time (Smith, 2002);

a) The braking system must be decelerate a vehicle in a controlled and repeatable fashion and when appropriate cause the vehicle to stop.
b) The braking should permit the vehicle to maintain a constant speed when traveling downhill.
c) The braking system must hold the vehicle stationary when on the flat or on a gradient.

Nowadays, there are lot of software has been developed in order to cater the modeling and the finite element analysis on the vehicle component such as MSC.ADAMS (Automatic Dynamic of Mechanical Systems), CATIA, MSC PATRAN/NASTRAN, ANSYS, DYNA and ABAQUS. There is an advantage of using that powerful computational analysis software where by using those would make it easier, less cost, better accuracy and less computing time. Most of the software is used in the wide range of industries such as automotive, oil and gas, aerospace, marine, heavy duty engineering, construction, electro-mechanical and general mechanical industries. In this project, design package CATIA and finite element package ABAQUS, ANSYS and MSC PATRANNASTRAN will be used to generate model and run analysis on the chosen component.

1.2 PROBLEM STATEMENT

A single seated race car needs an efficient brake system. An efficient brake system requires minimum stopping distance and minimum reaction time. In motorsports arena, the car weight plays very important roles in designing the race vehicle part. Minimum weight contributes to maximum power. Each part is custom made according to the vehicle specifications.

In the current design models for Formula Varsity and EIMA Race vehicle uses the brake system for motorcycle and a 850cc compact car . Motorcycle brake system which also includes its disc is only suitable for that particular model. The same goes to a passenger vehicle brake system. Therefore, there is need to design a new brake disc which is more suitable for the single seated race vehicle that equipped with the 135cc engine and below. The brake disc should be lighter in weight but yet efficient.

If looking on the overall automotive parts, besides engines, there are more crucial parts that engineers need to look into consideration. Suspension, brake, electrical, hydraulic and gear are all the crucial systems in the automotive areas. Each of all system has their own functionality which brings life to the automation industries. Brakes is such a crucial system in stopping the vehicle on all moving stages including braking during high speed, sharp cornering, traffic jam and downhill. All of those braking moments give a different value of temperature distribution and thermal stress. Good performance of disc brake rotor comes from good material with better mechanical and thermal properties. Good designs of disc brake rotor are varying across the range of the vehicles. There are different design and performance of disc brake rotor if compared between passenger, commercial and heavy duty vehicle. There are also other constraints such as cost, weight, manufacturing capability, robustness and reliability, packaging, maintenance and servicing. For example, heavy duty vehicle need large size of disc brake rotor if compared to passenger vehicle. Due to that, it will increased total weight

of vehicle as well as fuel consumption and reduces performances of the vehicle. Moreover, high weight of vehicle induces to high temperature increased during braking where the higher value of temperature during braking could lead to braking failure and cracking of disc brake rotor.

This project concerns of the temperature distribution and constraint of the disc brake. Most of the passenger cars today have disc brake rotors that are made of grey cast iron (Mackin, 2002). Grey cast iron is chosen for its relatively high thermal conductivity, high thermal diffusivity and low cost (Mackin, 2002). In this project, the author will investigate on the thermal issues of single seated race vehicle disc brake , where the investigation are to determine the temperature behavior of the disc brake rotor due to severe braking of the disc brake rotor by using Finite Element Analysis (FEA).

According to (Valvano and Lee, 2000), braking performance of a vehicle can be significantly affected by the temperature rise in the brake components. High temperature during braking will caused to:

- Brake fade
- Premature wear
- Brake fluid vaporization
- Bearing failure
- Thermal cracks
- Thermally-excited vibration

Therefore, it is important to study and predict the temperature rise of a given brake component and assess its thermal performance in the early design stage. Finite element analysis (FEA) has been preferred and chosen method to investigate some of the above concerns such as disc brake rotor temperature rise and thermal cracks (Valvano and Lee, 2000). Finite element analysis for transient analysis will canny out through ANSYS 12.1 which applied heat transfer analysis where the 3D model imported from design tools CATIA, while the steady state analysis will be done also by ANSYS 12.1.

1.3 OBJECTIVES AND SCOPE

The aim at the end of this project is to design and analysis of a lightweight brake disc of a single seated race vehicle. In achieving this aim, project objectives are set as below:

- To understand the working principles, components, standards and theories through a literature study.
- To understand the working principle of Ansys software (Workbench) and APDL Mechanical Analysis.
- To understand the fundamental of heat transfer through thermal analysis of disc brake rotor.
- To clearly justify the result and discussion.
- To find out the total heat flux generated in the brake disk when the process of braking is done.
- To determine the best design of ventilation holes to avoid thermo elastic instability.
- Structural analysis is also performed for analyzing the stability of the structure.

The knowledge gained from this project is to be able to understand the steps needed in thermal analysis of disc brake rotor by using FEA method. The methods used in this project can later be used in future as reference for similar research and development. There is the wide range of study on the disc brake rotor. The disc brake rotor could be studied on the various areas such as material improvement on the disc brake rotor, vibration on the disc brake, noise and squeal of the disc brake and thermal stress analysis on the disc brake rotor. However, on this project, the author will intend to emphasize details on the thermal analysis on the disc brake rotor of a single seated race vehicle.

The scopes of the project are:

- To study the behavior of the suitable material for the brake disc
- To study the behavior of the suitable material for the brake disc
- To do Finite Element Analysis on the designed brake disc.
- To do thermal analysis of the designed brake disc.
- Literature review on the working principles, components, standards and theories.
- Construction of 2D and 3D model of disc brake rotor.
- FE model (Meshing of Geometry model)
- Finite element analysis on steady state and transient analysis which shows the temperature distribution of disc brake rotor.
- Final justification and conclusion.

1.4 RESEARCH METHODOLOGY

A lot of paper and journal has been read up and a part of it has been considered in this project. Meanwhile, the previous real brake disc dimension has been measured. CMM has been used in order to get accurate dimension of disc brake rotor. Later, the precise dimensions have been used to translate in 2D and 3D drawing by using CATIA.

Next, the fractional 3D model of disc brake rotor has been transfer to finite element software which is ANSYS software. Thermal analysis will be done on steady state and transient responses. Assigning material properties, load and meshing of the model will be done in ANSYS software. Finally an expected result of thermal analysis will be obtained.

For the first step, I have to design the specific dimension of the disc according to the factor safety value that is 1.5. That is, I reduce the diameter of the disc brake to decrease the weight of the disc. The efficiency of the brake will be determined on the thermal elongation and the thermal analysis. So that from the result, we can decide which one is most efficient according to the thermal analysis. The result for the efficient on the ventilation holes also can be observed in ANSYS software analysis results.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Disc brakes are an order of magnitude better at stopping vehicles than drum brakes, which is a disc brake on the front of almost every car and motorbike built today (Will, 92). Sportier vehicles with higher speeds need better brakes to slow them down, so disc brakes on the rear of those too. Disc brakes are again a two-part system. Instead of the drum, the part is a disc or rotor, and instead of the brake shoes, there will be brake caliper assemblies. The caliper assemblies contain one or more hydraulic pistons which push against the back of the brake pads, clamping them together around the spinning rotor. The harder they clamp together, the more friction is generated, which means more heat, which means more kinetic energy transfer, which slows down the vehicle. The disc brake or disk brake is a device for slowing or stopping the rotation of a

wheel. A brake disc (or rotor in U.S. English), usually made of cast iron or ceramic composites (including carbon, Kevlar and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc.

Normally, thermal stress analysis has been performed to any of material related to thermal process in order to oversee the behavior and character of material. Any abnormality regards to thermal input will give the high values on the stress magnitude of the studied materials. The high values of stress magnitude will shows deformation on certain areas which load has been applied on it. Design and analysis of certain parts or component will took much time and it is costly. Therefore, without any analysis or design tools, it would be limitations on repeated analysis. For decades, finite element analysis (FEA) has been a preferred method to address some of the above concerns. It can be used to compare the design alternatives and hence, optimize the brake rotor design prior to production of prototype components (Valvano and Lee, 2000). A literature review was conducted to investigate the past research that has been done in many areas related to this work. In addition, description, histories, functions and theory of disc brake rotor will be discussed in this chapter. Furthermore, theory of finite element method related to thermal analysis will be presented as well in this chapter.

2.2 BRAKE SYSTEM REVIEW

2.2.1 History of Brake System Development

In the early days of the automobile, drum brakes were standard. Drum brakes offered several advantages over other types of brakes. One of these was that the drum could keep out water and dust, materials that could damage disc brakes which were out in the open. Major advancement in brake technology came in 191 8 with the invention of four-wheel hydraulic brake systems by Malcolm Loughead. The hydraulic brake system replaced the mechanical brake system that was in use at this time. The mechanical system had numerous disadvantages. It made it difficult to brake all the wheels evenly, often causing a loss of control. In addition, it required drivers to exert tremendous amounts of force on the brake pedal to slow the car. The hydraulic brake system multiplied the force that was applied to the brake, lessening the amount of force needed to be applied to the brake pedal by the driver. This system was first used in the 1918 Duesenberg. Its advantages quickly caught on and by 1929, four wheel hydraulic braking systems were standard equipment on higher priced cars. The main problem with drum brakes is that the heat is not efficiently disbursed. The heat that is produced inside the drum does not escape easily since the drum prevents wind from drawing it away. However, disc brakes killed the issues when it allowed the heat to be carried away which increased the efficiency of the brake. However, their use was limited up until the 1950's since their efficiency was not required and they required more pedal pressure to operate. The reason for the higher pedal pressure is that disc brakes have no self-servo effect or no self-energizing capacity that the drum brakes have. The self-servo effect is caused by the forward motion of the car. This forward motion helps pull the brake shoe into contact with the drum. This helped lower the required pedal pressure.

Now that their efficiency was needed and the hydraulic brake system multiplied the force applied to the brake pedal, disc brakes seemed to be the better alternative. Chrysler was the first to widely introduce the disc brake in its cars in the early 1950's.

The system did not have much success till automaker Studebaker to reintroduce the system in 1964. This time it saw much more success and in a few years, disc brakes were common on most new cars. One of the reasons that disc brakes were a success with the Studebaker and not the Chrysler was due to the development of the power braking system. Power brakes became common in the 195Ots, after Chrysler had developed and dropped its disc brake program.

The system assisted the movement of the piston in the master cylinder which meant that the driver needed to apply less peddle pressure to get the same braking effectiveness. Therefore, since ease of braking was no longer an issue, the adoption of the more efficient disc brake became widespread.