THERMAL STRESS ANALYSIS ON DISC BRAKE ROTOR BY USING FINITE ELEMENT ANALYSIS

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted
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DECLARATION

I declare that this project report entitled “Thermal Stress Analysis of Disc Brake Rotor by using Finite Element Analysis” is the result of my own work except as cited in the references.

Signature : ……

Name : Ee Wei Xiang

Date : ……

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SUPERVISOR DECLARATION

I hereby declare that I have read this project 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.

Signature : …….

Name : Dr. Mohd Zaid Bin Akop

Date : …….

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ABSTRACT

In today automotive industries, braking system is an essential component of the vehicle. Typically, there are two type of braking system, which is disc brake and drum brake. In order to achieve a better braking performance in a shorter distance, disc brake is installed on the front wheel and drum brake is installed on the rear wheel. This is because the disc brake can dissipate the heat efficiently compared to the drum brake. Therefore, thermal management is an important factor that can affect the performance of braking system. In this project, four design specification of disc brake rotor is used to analyze the thermal stress distribution. Gray cast iron is selected as the material of disc brake rotor in ANSYS. The convective heat transfer coefficient for certain surface of rotor that exposed to air directly is applied. FEA software is used to determine the thermal stress of four design specification of disc brake rotor. The result of four different design specification of disc brake rotor is compared after simulation process is completed. The slotted rotor shows a lower temperature in steady state thermal analysis and transient thermal analysis. Furthermore, slotted rotor shows a lower deformation and moderate equivalent (Von-Mises) stress in static structure analysis and transient structure analysis.

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ABSTRAK

Pada hari ini industri automotif, sistem brek adalah komponen utama kenderaan. Biasanya, terdapat dua jenis sistem brek, iaitu brek cakera dan brek dram. Untuk mencapai prestasi brek yang lebih baik dalam jarak yang lebih pendek, brek cakera dipasang pada roda depan dan brek drum dipasang pada roda belakang. Ini kerana brek cakera boleh menghilangkan haba dengan cekap berbanding brek dram. Oleh itu, pengurusan haba merupakan faktor penting yang boleh menjejaskan prestasi sistem brek. Dalam projek ini, empat spesifikasi reka bentuk cakera brek cakera digunakan untuk menganalisis taburan tekanan haba. Tuang besi kelabu dipilih sebagai bahan pemutar brek cakera di ANSYS. Pekali pemindahan haba konveksi untuk permukaan pemutar tertentu yang terdedah kepada udara terus digunakan. Perisian FEA digunakan untuk menentukan tekanan haba empat spesifikasi reka bentuk cakera brek cakera. Hasil daripada empat spesifikasi reka bentuk rotor brek cakera yang berbeza akan dibandingkan selepas proses simulasi diselesaikan. Pemutar slotted menunjukkan suhu yang lebih rendah dalam analisis haba keadaan mantap dan analisis termal sementara. Tambahan pula, pemutar slotted memperlihatkan tekanan ubah bentuk yang rendah dan tegasan sederhana (Von-Mises) dalam analisis struktur statik dan analisis struktur sementara.

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LIST OF ABBREVIATIONS & SYMBOLS

3D	Three dimensional
FEA	Finite element analysis
Q	Rate of heat transfer
m	Mass
C	Specific heat capacity
ΔT	Temperature difference
J	Joule
σ	Stefan-Boltzmann constant
x	Distance
k	Thermal conductivity
ε	coefficient of emissivity
T_S	Surface temperature
T_∞	Ambient temperature
h	Convective heat transfer coefficient

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

In order for a car to have a safe trip, brakes, tires, and steering system is the most important safety feature. This is because the accident can be prevented by changing the speed and direction of the car. A continuous adjustment of speed and direction is required for user to drive with different traffic conditions such as slippery, wet, and dry road. The main function of the disc brake is to slow the vehicle, maintain vehicle speed during downhill operation, and hold the vehicle stationary on a grade. During braking condition, the kinetic and potential energy of the vehicle is transforms to the thermal energy by frictional force that generate between brake pad and rotor. Once the user presses the brake pedal, a large amount of heat will be generated between the brake pad and rotor to opposite the torque of the wheel. Therefore, heat management on the rotor is an important factor that need to predict and control for the reason of economic and safety feature. A high temperature that exists may lead to the brake fade and cause the accident to occur. The heat energy can be dissipated through the conduction, convection, and radiation. In this project, the result of thermal stress analysis of four different design will be compared after several braking operation.

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1.2 Problem Statement

There are several factors that can affect the performance of braking system during the braking condition. For example, pressure, coefficient of friction, frictional contact surface, and rate of heat dissipation. Among those factors, the rate of heat dissipation is the main factor that can affect the braking system significantly (Satope, 2017). Since the area of convection that take places between the air and rotor can affect the rate of heat dissipation, a ventilated disc brake rotor with different design which may affect the rate of heat dissipation is selected as the title of research. The temperature and deformation of disc brake after several times of braking are determined by the ANSYS. Theoretically, the bigger size or area of drilling will increase the rate of heat dissipation and increase the performance of braking system. However, the strength of the disc brake rotor may be reduced due to the drilled hole and slotted area. Therefore, it is important to study and compare the result of thermal stress distribution on these four types of disc brake rotor.

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1.3 Objective

The objectives of this project are as follows:

1. To study the thermal stress distribution in disc brake rotor on vehicle caused by temperature rise after several braking operation of vehicle.
2. To analyse the effect of design of disc brake rotor on the cooling performance and deformation after several braking operation of vehicle.
3 To compare the effect of design of disc brake rotor on the cooling performance and deformation after several braking operation of vehicle.

1.4 Scope of Project

The scopes of this project are:

1. Design 3D model of 4 different design specification of disc brake rotor.
2. Mesh the model.
3. Finite element analysis (ANSYS) will be used to analyze different design specification of disc brake rotor.
4. Compare the result of thermal stress analysis of different design of disc brake rotor.

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1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.

2. Drawing

   Different design of disc brake rotor will be drawn in SolidWorks software.

3. Simulation

   Simulation of the 3D model will be done using the ANSYS software.

4. Analysis and Comparison

   Analysis and comparison of the rate of heat dissipation will be calculated. Result will be proposed based on the analysis.

5. Report writing

   A report on this study will be written at the end of the project.

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CHAPTER 2

LITERATURE REVIEW

2.1 Trends of Industry

Both of the disc brake and drum brake system are based on a hydraulic pressure system. In today automotive technology, a disc brake is commonly found on the front wheel as well as rear wheel especially in the modern car such as Mercedes-Benz and BMW. It is attached to the rotating wheel by using the wheel hub. The disc brake rotor can be solid or vented, but the vented rotor has a better efficiency compared to solid rotor due to it has a larger surface to dissipate the heat more easily (*Complete Guide to Disc Brakes and Drum Brakes - Les Schwab*, no date). Figure 2.1 shows the solid rotor and vented rotor.

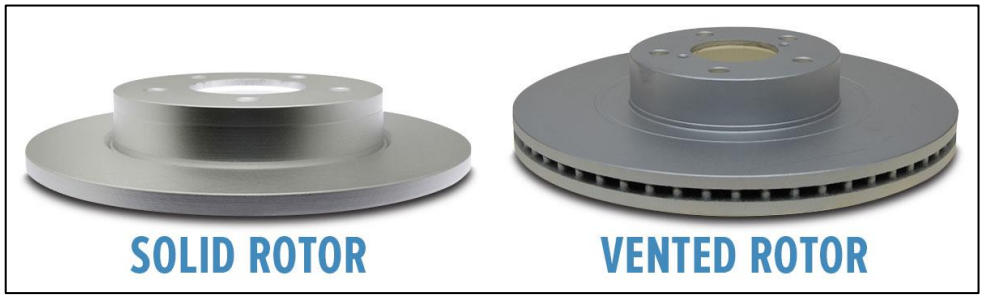

Figure 2.1: Solid rotor and vented rotor

(Source: www.lesschwab.com)

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Although the use of disc brake on all four wheels become more and more popular across the century especially in heavier vehicle, but a drum brake still uses for the rear wheel of some model of car due to the cost factor. The inertia cost of the drum brake is lower than the disc brake (*Automotive Mechanics,2E - S. Srinivasan - Google book*. 2nd Edition, 2003). Furthermore, the weight factor become an important factor to install the disc brake on the front wheel. The weight of drum brake is heavier about twenty percent than disc brake (*Automotive Mechanics,2E - S. Srinivasan - Google book*. 2nd Edition, 2003). Typically, an unloaded vehicle is already about ten percent heavier in front due to the engine is located in front of car (*Complete Guide to Disc Brakes and Drum Brakes - Les Schwab*, n.d.). Once the user presses the brake pedal, the weight of the car will transfer to the front first due to the motion and inertia of the car. According to the Newton's first law, inertia is the resistance of any physical object to any change in its velocity. So, more braking power is needed for the front wheel to stop the vehicle immediately. A disc brake can provide more stopping power and a shorter stopping distance compared to drum brake. Figure 2.2 shows the important of disc brake on front wheel.

Figure 2.2: Important of disc brake on front wheel

(Source: www.6thgearautomotive.com)

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In order to achieve the safety criterion, heat management on the braking system is very important. It can ensure the braking performance is consistent across the life time. This is because overheat of friction material will cause the loss of stopping power and leading to brake fade (Belhocine *et. al*, 2016). Due to the disc brake is exposed to air directly, it can transfer the heat through conduction, convection, and radiation while for drum brake, it can only transfer the heat through the conduction because the drum brake components are not exposed to the air (*Complete Guide to Disc Brakes and Drum Brakes - Les Schwab*, n.d.). Therefore, the disc brake rotor has a better heat dissipation and consistency compared to drum brake. Figure 2.3 shows the structure of disc brake and drum brake.

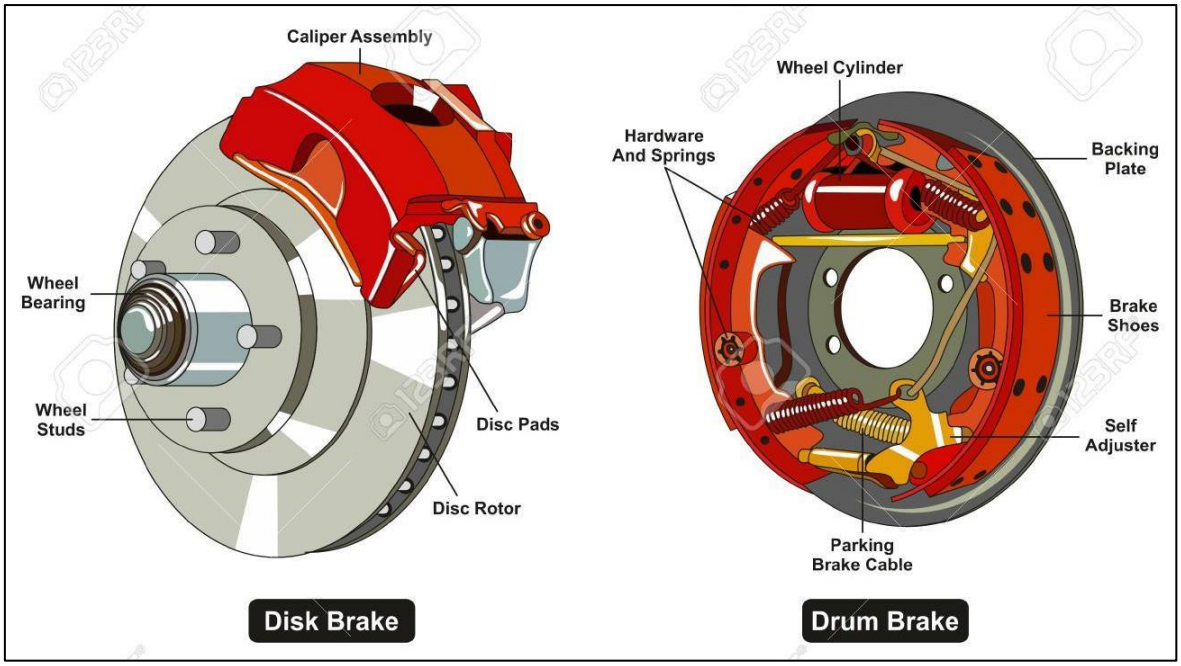

Figure 2.3: Structure of disc brake and drum brake

(Source: es.123rf.com)

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