

**THERMAL STRESS ANALYSIS ON FORMULA VARSITY (FV) DISC BRAKE
ROTOR BY USING FINITE ELEMENT ANALYSIS (ANSYS)**

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DECLARATION

I declare that this project entitled “Thermal Stress Analysis On Formula Varsity (FV) Disc Brake Rotor By Using Finite Element Analysis (ANSYS)” is the result of my own work except as cited as reference.

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APPROVAL

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 (Plant & Maintenance).

Signature :

Name of Supervisor : Mohd Zaid Bin Akop

Date :

DEDICATION

To my beloved mother and father

ABSTRACT

As we know, the braking system is important part in a vehicle. The braking system function is to slow down and slowly stop the vehicle. In this Final Year Project, the braking system was applied in Formula Varsity Car. The disc brake rotor of this Formula Varsity is design and creating by using SolidWork. This research project consists of thermal stress analysis on Formula Varsity Car disc brake rotor by using Finite Element Analysis (ANSYS). The analysis consists of steady-state and transient analysis to determine the temperature distribution on the disc brake rotor. Thermal analysis is also performed by calculating the heat transfer coefficient on the disc brake rotor based on the obtained results. The value of heat transfer coefficient has been used in steady-state and transient analysis. The findings of this research are to improve the brake performance in Formula Varsity Car and analyzed the stress distribution on the disc rotor during operation. This project also was conduct to see whether the design of disc brake rotor will overcome the failure or not. The results shows the temperature of disc brake rotor is increasing when the brake is applied and it slowly cool down when the brake pad is released. The material that has been used for this research can withstand the heat generated and high stress during the braking process.

ABSTRAK

Seperti yang kita tahu, sistem brek adalah bahagian yang penting di dalam sesebuah kenderaan. Sistem brek berfungsi untuk memperlahankan dan memberhentikan kenderaan. Di dalam projek sarjana muda ini, sistem brek telah digunakan ke atas kereta Formula Varsity. Reka bentuk cakera brek Formula Varsity direka dengan menggunakan SolidWork. Penyelidikan ini terdiri daripada analisis tegasan haba ke atas cakera brek Formula Varsity dengan menggunakan Finite Element Analysis (ANSYS). Analisis ini terdiri daripada keadaan mantap analisis dan fana analisis untuk menentukan pengedaran suhu di dalam cakera brek. Analisis tegasan haba juga dilakukan dengan mengira pekali pemindahan haba pada cakera brek berdasarkan maklumat yang telah dijumpai. Nilai pekali pemindahan haba telah digunakan di dalam keadaan mantap analisis dan fana analisis. Hasil kajian ini adalah untuk meningkatkan prestasi brek di dalam Formula Varsity dan menganalisis agihan tegasan pada pemutar cakera semasa ia beroperasi. Projek ini juga dijalankan untuk melihat sama ada reka bentuk cakera brek akan mengatasi kegagalan ataupun tidak. Keputusan menunjukkan suhu cakera brek rotor semakin meningkat apabila brek digunakan dan ia perlahan-lahan menjadi sejuk apabila brek pad dilepaskan. Bahan yang telah digunakan di dalam kajian ini boleh menahan haba yang dihasilkan dan tekanan yang tinggi semasa proses pembrekan.

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LIST OF ABBREVIATIONS & SYMBOLS

FV	Formula Varsity
CGI	Composite Graphite Iron
FEA	Finite Element Analysis
Q	Rate of Heat Transfer
h	Convection Heat Transfer Coefficient
As	Surface Area of Rotor
T_s	Surface Temperature
T_∞	Ambient Temperature
ε	Emissivity
σ	Stefan Boltzmann's Constant
[K]	Heat Conduction Matrix
{u}	Vector of Unknown Temperature
[R]	Radiation Exchange Matrix
{P}	Vector of Constant Applied of Heat Flow
{N}	Vector of Temperature Dependent Heat Flow
K	Kelvin
{ \dot{u} }	du/dt
MPa	Mega Pascal
°C	Degree Celsius

CHAPTER 1

INTRODUCTION

1.1 Background Research

Formula Varsity (FV) is an event that challenges engineering students that come from entire Malaysia to design, build and test their self-developed formula style racing cars. In this event also the technical skills of students were tested. It covers every aspects of automotive industry including design, assembly and prototype building and testing of the product. The most important part of this Formula Varsity is brake system. Brakes are required to stop the vehicle within the possible distance. It also functions to slow down the car when approach a corner or to stop the car. The kinetic energy of vehicle was converting into heat energy by friction which is dissipated into atmosphere. A disc brake assembly consists of disc rotor, calipers and disc pad. Disc brake is widely used because its design is far superior to that of drum brakes. Disc brakes use a slim disc and small caliper to halt wheel movement. Fluid is used to transfer the movement of the brake pedal into the movement of the brake pads. Friction between the contact area of pad and disc during braking process cause wear as the pad degraded gradually.

Unevenness of the pressure distribution causes uneven wear and consequently shortens the life of disc rotor. The dynamic contact pressure distribution in a disc brake system remains impossible to measure through experimental methods. This makes numerical analysis using the finite element method an indispensable alternative tool to its prediction. Simulation analysis is used to predict the failure of the brake disc rotor and help design improvement on the production of disc rotor. This project present the stress analysis of disc brake by analyzes in computer aided engineering (CAE) software. CAE or more specifically finite element analysis (ANSYS) will analyzed the stress distribution on the disc rotor during operation and prediction of failure regions can be made.

1.2 Problem Statement

As we know the speed of Formula Varsity car is a quite fast. The main problem is the higher the speed of the car, the lower their tendency to stop that car. Due to the higher speed, the braking system that has been used on the FV car must be good enough to slow and stop the car. The brake disc rotor on the car must be able to working at high temperature and high pressure. That is because when brake pedal is pressed, the brake disc rotor will heat up and slowing down the car. The braking efficiency is reduced when the brake pad starts to get too hot. This malfunction of the brake system is called brake fade. Other than brake fade, disc rotor also undergo cracking, coning, thermal judder and others possible effects due to friction. The usage of the brake may promote wear to disc and brake pad.

Uniform disc and pad wear, brake temperature, and more even friction coefficient could only be achieved when pressure distributions between the pads and disc are uniform. In addition, unevenness of the pressure distribution causes uneven stress distribution that can lead to uneven wear and consequently shortens the life of disc and pad. The design of brake disc rotor is important to determine their efficiency to stop the car. This project will focus on the simulation analysis of brake disc rotor on the Formula Varsity car. The stress distribution of disc from simulation result can be analyzed by using Thermal Stress Analysis (ANSYS). Is that the design will effects the brake system? It will be proving when this project is finish.

1.3 Objective of the Study

The purpose of this project focuses on thermal stress analysis on the brake disc rotor. The result of this project will cover based on the objective. The objectives are as follow:

- a) To investigate the temperature distribution of Formula Varsity disc brake rotor.
- b) To analyze the thermal stress analysis on Formula Varsity design of disc brake rotor.

1.4 Scope of the Work

The scope of this project is covered;

- Literature review about brake disc rotor component, working principles and theories that have been used.
- Design of 2D and 3D model of brake disc rotor by using Solid Works (2016).
- FE model of brake disc rotor (Meshing of geometry model).
- Analyze the thermal distribution of the brake disc rotor by using finite element analysis (ANSYS).
- The discussion of brake disc rotor due to ANSYS result.
- Final justification of thermal stress analysis on the Formula Varsity brake disc rotor.

CHAPTER II

LITERATURE REVIEW

2.1 Overview

This chapter is about the introduction of brake disc rotor and their working principles. There are many type of brake disc rotor that has been listed but the chosen one is ventilated disc rotor. That is because there are many advantages than disadvantages that have been found while this research is going on. In this chapter also explanation about the heat transfer such as conduction, convection and radiation that effect the brake disc rotor. The discussion concepts the heat transfer are explained including of thermal transient and modeling consideration. It can be concluded that heat transfer from high temperature to lower temperature. That means the heat from the disc rotor transfer into brake pads and dissipated into air due to the design of disc rotor with ventilated type. Finite element analysis (ANSYS) was detailed discuss about the finite element analysis stage and modeling. The history of disc brake development will be discussed in the next section.

2.2 Introduction of Braking System

One of the most important parts of vehicle is Braking System. Braking System is the system where the speed of vehicle is reduces by using brake as a mechanical device. As we know the braking system able to slow and stop the vehicle by apply the pressure at the brake pad. Actually the brake pedal is connected by brake booster. The brake booster multiplies and transfer the force produced by stepping on the brake pedal to the master cylinder. In turn, the master cylinder uses that amplified force to pressure the brake fluid from its reservoir through hydraulic lines toward the two fronts and rear brakes. The vehicle will be slow down due to the pressure that has been applied at the brake rotor. The harder the pedal was pushed, the more pressure is applied to the brakes.

The friction brakes on vehicle store braking heat in drum brake or disc brake while braking and then carry out it to the air slowly. Some of vehicle use their engine to brake when the vehicles travelling downhill. In this case the brake pedal of vehicle with hydraulic brakes was pushed against the master cylinder, in basically a piston pushes the brake pad against the brake disc which slows down the wheel down. The same system was used on drum brake as the cylinder pushes the brake shoes against the drum which also slows down the wheels of vehicle. Almost all wheeled vehicle have a brake or some sort of that. For example shopping carts and baggage carts have their own brake systems to use in moving ramp. Some aircraft also designed with air brakes to reduce their speed in flight.

In this research, the braking system was focused on the mechanical brakes. That is because, mechanical brake is more suitable brake used in Formula Varsity. Actually, the type of brake is chosen depends on their design of vehicle due to performance, weight, and etc.

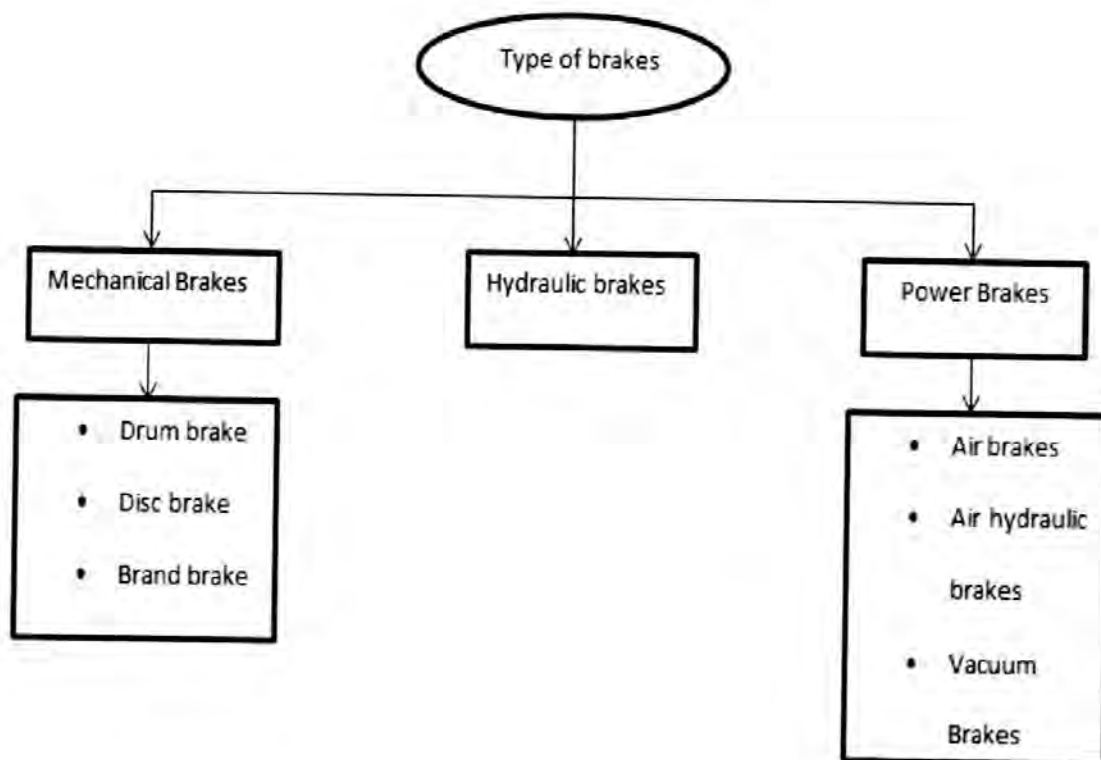


Figure 2.1: Type of brakes

Illustration above show the types of braking system used by vehicle. There are many types of brakes that have been used nowadays such as mechanical brakes, hydraulic brakes and power brakes. The braking system is the most critical system in vehicle. The maintenance and proper functioning are important to avoid from any undesirable things happens when driving.

2.3 History of Braking System

The first braking system was designed before the Roman Empire was build. The material of braking system back days is only using wooden block and lever. By pulling the lever, the wooden block will forced against the wheels and due to the frictional force the vehicle will slow down. The systems that have been used like hand break nowadays. After 2000 years went through time, there is no improvement for this technology. This technology also was applied in early locomotive as their braking system. This below picture show the early designed of braking system.

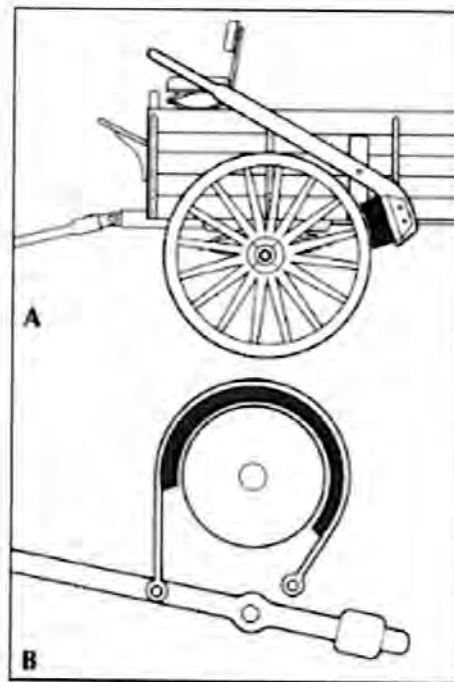


Figure 2.2: Lever and wooden lock as a braking system

(Source: <http://kids.britannica.com/students/assembly/view/53011>)