

## **SUPERVISOR DECLARATION**

“I hereby declare that I have read this thesis 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 (Automotive)”

Signature: .....

Supervisor: .....

Date: .....

## SECOND SUPERVISOR DECLARATION

“I hereby declare that I have read this thesis 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 (Automotive)”

Signature : .....

Second Supervisor : .....

Date : .....

## DECLARATION

“I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged.”

Signature : .....

Author : .....

Date : .....

## DEDICATION

To my family and my friend, especially to Ho Kar Min, you truly make this all meaningful.

## ACKNOWLEDGEMENT

In this Final year report, I would like thank my supervisor, Mr. Muhd Ridzuan for helping me a lot in doing this report. Start from the beginning, Mr. Ridzuan give me a clear view about my title and teach me how to start a project. Mr. Ridzuan also teaches me how to prepare a good technical report, in the aspect of formatting and content.

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Thank you very much!

## **Abstract**

Formula Varsity is an event organized by Universiti Teknikal Malaysia Melaka. In the process of designing the car, brake system is one of the major components. Disc brake rotor generates an opposite torque to a shaft, converting kinetic energy to heat energy. To better understand the design limit of the rotor, simulation and manual calculation methods were employed in order to find temperature distribution on rotor and thermal capacity of the rotor and stress induced to the rotor due to the braking heat. In this PSM report, for the method of manual calculation, all the environment data has been collected during the testing event and race event. Besides, there are a few assumption also made in the manual calculation method. The result of the calculation is tabulate and present in the graph form for better understand. For the part of simulation method, the software of ABAQUS will use to do the Finite Element Analysis (FEA) process. With the aid of the FEA software, it will show us the right distribution of temperature and stress on the rotor. At the end of the project, the result of the manual calculation and result of simulation will being compared and validated. The maximum surface temperature was found to be 547°C and 541 °C for manual calculation and FE analysis respectively. The maximum stress obtain from manual calculation is 1.49 MPa, while the maximum stress obtain from FE analysis using ABAQUS is 0.82 MPa The results show that the rotor is safe for operation after 10 cycle transient braking test.

## Abstrak

Formula Varsity adalah satu program diorganisasi oleh Universiti Teknikal Malaysia Melaka. Dalam proses mereka kereta, sistem brek adalah salah satu komponen utama. Cakera rotor menghasilkan suatu momen berlawanan dengan poros, menukar tenaga kinetik menjadi tenaga haba. Untuk lebih memahami batasan rekaan, kaedah simulasi dan kaedah pengiraan dijalankan untuk mencari edaran stres-terma dalam rotor, kapasiti terma rotor. Dalam laporan ini, ia merangkumi kajian ilmiah tentang Formula Varsity, cakera rotor. Dalam kaedah pengiraan manual, semua data persekitaran telah dikumpulkan semasa acara ujian dan acara lumba. Selain itu, terdapat beberapa andaian telah dibuat dalam kaedah pengiraan manual. Bagi bahagian kaedah simulasi, perisian ABAQUS telah diguna untuk menjalankan Analisis Elemen Sehingga (FEA). Dengan bantuan software FEA, ia menunjukkan pengedaran suhu dan tekanan pada permukaan rotor. Pada akhir projek, hasil perhitungan antara manual dengan keputusan simulasi akan dijalankan. Bagi analisis permindahan haba, suhu maximum pada permukaan rotor adalah 547°C dan 541 °C masing-masing untuk kaedah pengiraan dan kaedah FEA. Bagi analisis stres-terma, stress maximum untuk kaedah pengiraan adalah 1.46MPa manakala stress maximum untuk kaedah FEA adalah 0.82 MPa. Ia menunjukkan cakera rotor selamat diguna walaupun selepas 10 pusingan perhentian.

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## LIST OF SYMBOLS

$I$	=	Mass moment of inertia of rotating part ( $\text{kgm}^2$ )
$M$	=	Vehicle mass (kg)
$V_1$	=	Velocity at begin of braking (m/s)
$V_2$	=	Velocity at end of braking (m/s)
$W_1$	=	Angular velocity of rotating part at begin of braking (rad/s)
$W_2$	=	Angular velocity of rotating part at end of braking (rad/s)
$E_b$	=	Braking energy (Nm)
$R$	=	Rotor radius (m)
$P_b$	=	Braking Power (Nm/s)
$P_{bav}$	=	Average braking power (Nm/s)
$q''_{(0)}$	=	Heat flux ( $\text{W/m}^2$ )
$a_t$	=	Thermal diffusivity ( $\text{m}^2/\text{s}$ )
$c$	=	specific heat ( $\text{J}/(\text{kg}\cdot\text{K})$ )
$k$	=	Thermal conductivity ( $\text{W}/(\text{m}\cdot\text{K})$ )
$L$	=	disc thickness (m)
$t_b$	=	braking time (s)
$\rho$	=	disc density ( $\text{kg}/\text{m}^3$ )
$T$	=	temperature (K)
$Re$	=	Reynold number
$h_R$	=	Convective heat transfer coefficient ( $\text{W}/(\text{m}^2\cdot\text{K})$ )
$E$	=	Elastic modulus ( $\text{N}/\text{m}^2$ )
$\Delta T$	=	Temperature difference



## **LIST OF ABBREVIATION**

FEA	Finite Element Analysis
SAE	Society of Automotive Engineers
PSM	Projek Saujana Muda
3D	Three Dimension

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION OF THE PROJECT**

This project is the final year project for the student of bachelor of mechanical engineering (Automotive) in University Technical Malaysia Malacca. The management and execution of the project is fully under the student responsibilities and under the supervision of the lecturer. The project has divide into two stages: PSM 1 and PSM 2 which separate the project into 2 sections and each section is given a timeline of one semester to finish.

In the period of PSM 1, student need to fully understand the title, objective and scope of the project, then undergo deep and wide research into the relevant subject. In the PSM 1 report, there are included abstract, objective, problem statement, literature review, methodology, equipment and apparatus, procedure and conclusion. Besides, student also needs to read at least 30 reference of the support of the report. The references are included journal, reference book, trustable internet resource, and academic review.

In the stage of PSM 2, student has to execute the simulation or experiment in order to obtain the research data. The summary and analysis is done after the simulation or experiment. The collected data is present in systematic form. For instance: graph,

table, chart and diagram. In PSM 2 report, there are included result, analysis result, discussion, conclusion and suggestion for further research.

Furthermore, in every stage of final year project, student has to present twice to the academic panel to ensure that the student has follow the progress of the schedule and heading to the right direction of the project.

## 1.2 OBJECTIVE

To study thermal capacity, temperature distribution and stress distribution of the cross-drilled disc rotor for UTeM formula style car as show in figure 1.1 below.

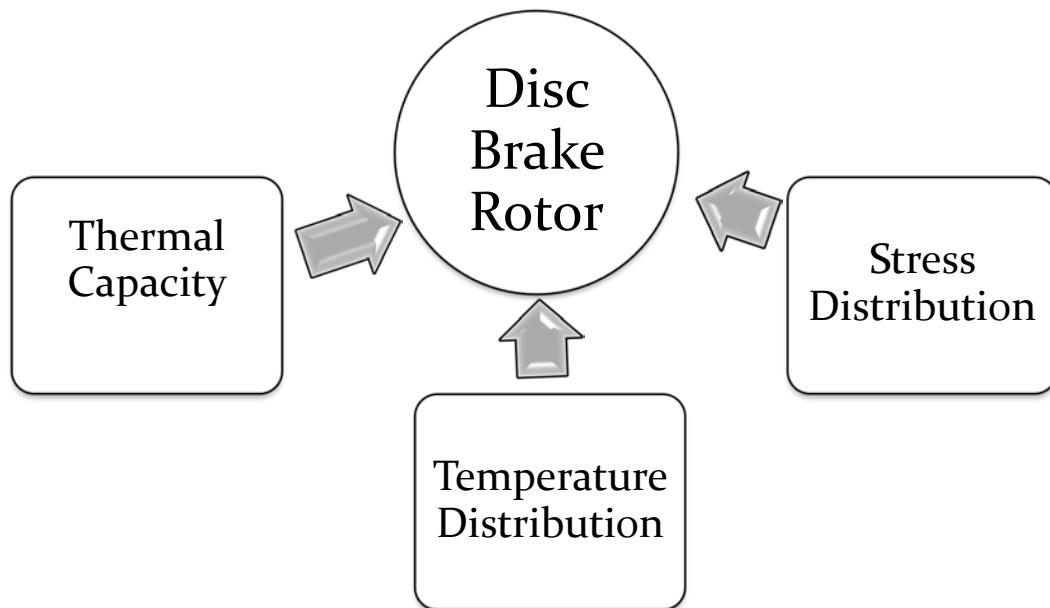


Figure 1.1: Project Objective

### 1.3 PROBLEM STATEMENT

Due to the main objective of this project it to help the UTeM Formula Varsity car achieve to the maximum performance and test the limitation of the braking system. In the previous design, the vehicle is heavy and low acceleration performance. The braking system is directly transferred from the motorcycle, therefore it is not fully adapt to the design of the formula style car. Furthermore, the design team does not understand the maximum tolerant limit of the braking component. In order the increase the performances of a race car, light weight is one of the effective ways.

- i. To analyze the limitation of the rotor
- ii. Reduce the weight of unsprung body.
- iii. Study the braking behavior of the rotor and find out the ways to reduce the weight base on the studied result.

### 1.4 SCOPE

- i. To produce detail design of the component using 3D CAD Software.
- ii. To perform material selection for the component.
- iii. To calculate the load acting on the component during operation.
- iv. To perform linear thermal stress analysis of the component in transient condition using ABAQUS FEA software.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 FORMULA VARSITY

##### 2.1.1 History of the Formula Varsity

The initial concept of the formula varsity is based on the FSAE championship which is held in United State of America and Canada. Although size of the car is small, but purely a race machine. It can consider as “mini F1 “among university. The championship is challenging the engineering student in the aspect of design, build and compete with formula style racing machine. This competition has given chance for the University to prove them a better engineering college then other.

The concept behind Formula Varsity is that a fictional manufacturing company has contracted a design team to develop a small Formula-style race car. The prototype race car is to be evaluated for its potential as a production item. The target marketing group for the race car is the non-professional weekend autocross racer. Each student team designs, builds and tests a prototype based on a series of rules whose purpose is both to ensure onsite event operations and promote clever problem solving.

Formula Varsity promotes careers and excellence in engineering as it encompasses all aspects of the automotive industry including research, design, manufacturing, testing, developing, marketing, management and finances. Formula

Varsity takes students out of the classroom and allows them to apply textbook theories to real work experiences. ([www.formulavarsity.wordpress.com](http://www.formulavarsity.wordpress.com)). The Figure 2.1 and Figure 2.2 show the photos obtain from UTeM Formula website.



Figure 2.1: Logo of Formula Varsity during 2006



Figure 2.2: Team 2006

### 2.1.2. Design Rules

In the rules book of formula Varsity 2010, there are some basic rule and regulation for the brake system. There all listed in section 10.4.

i. Separate Circuits

All cars must have a brake system which has at least two separate circuits operated by the same pedal. This system must be designed so that if leakage or failure occurs in one circuit, the pedal shall still operate another brake.

ii. Brake Discs

Brake discs must be made from ferrous material.

At least 2 discs must be attached to the rear wheel axle.

iii. Brake Calipers

All brake calipers must be made from the homogeneous metallic Material.

Each disc may only be operated by one caliper, and each calliper must have no more than four pistons.

The use of steel-braided hose is permitted.

iv. Brake Cooling

Brakes may only be cooled by air.

Liquid cooling of any part of the braking system is forbidden.

v. Brake Pressure Modulation

Anti-lock brakes and power braking are forbidden

## 2.2 Disc Brake

### 2.2.1 Rotor Design

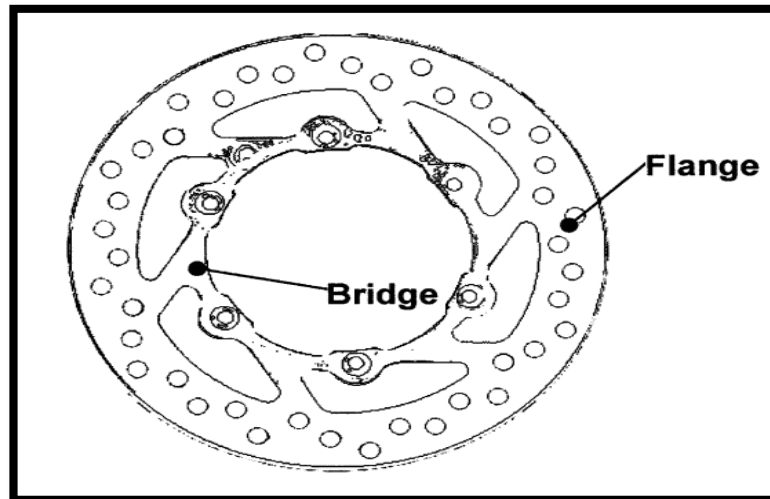


Figure: 2.3 Schematic diagrams for disc brake rotor (Boniardi., 2006)

Bridge is the section to support the flange area. The design of the bridge is simple as possible to decrease the weight of the rotor. Flange is the area where the frictions occur. The area of the flange is so called swept area where the mating area between the brake lining and the rotor.

The design of the disc varies somewhat. Some are simply solid cast iron, but others are hollowed out with fins or vanes joining together the disc's two contact surfaces (usually included as part of a casting process). This "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily-loaded front discs. The front brakes provide most of the stopping power.

Many higher performance brakes have holes drilled through them. This is known as cross-drilling and was originally done in the 1960s on racing cars. For heat dissipation purposes, cross drilling is still used on some braking components, but is not favored for racing or other hard use as the holes are a source of stress cracks under severe conditions.