CONFIRMATION

'I admit that have read this work and in my opinion this work was adequate from scope aspect and quality to award in purpose Degree of Bachelor of Mechanical Engineering (Automotive)'

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Date : ……

DESIGN AND DEVELOPMENT OF VENTILATED SINGLE DISC BRAKE ROTOR FOR UTeM FORMULA STYLE RACE CAR

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This technical report is submitted in accordance with the requirements of the Bachelor of Mechanical Engineering (Automotive)

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MAY 2010

DECLARATION

"I hereby, declare this thesis entitled Design and Development of Ventilated Single Disc Brake Rotor for UTeM Formula Style Race Car at FKM, UTeM is the result of my own research except as cited in the reference"

Signature : ……

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Date : 24 MAY 2010

DEDICATION

To my beloved father

Tn. Hj. Abu Bakar Bin Lachar

and to my beloved mother

Pn. Hjh. Mufidah Binti Embok Mohamad

because have been given their support and motivation for me to finish my study until this level

ACKNOWLEDGEMENT

Firstly, alhamdulilah thanks to Allah S.W.T cause has been given this opportunity to study until this level. During this level, this is the most of challenging part of study for degree level where student must do their own project to qualify them to get their degree scroll. I'm also not except involved in doing a project. Special thanks to my supervisor, En. Muhd Ridzuan Bin Mansor because has been given his cooperation during my projects. He also gives a motivation and inspiration for me to finish this project.

I would like to thanks to my family especially my father and my mother because giving their moral support to make me to finish my projects. I also want to thanks to all my friends for giving their support during my stress on doing this project. This is an enjoyable moment in my life where we can share our problem to our friends when our morale is going down.

For the persons that I'm not mentioned their name, I also wants to thanks to them who involve direct or indirect in my project. Without them, this thesis would become impossible for me to finish on my own.

ABSTRAK

Projek sarjana muda ini membincangkan tentang rekabentuk dan analisis piring brek berongga yang baru bagi kereta lumba UTeM. Terdapat dua aktiviti yang terlibat dalam penghasilan rekabentuk ini iaitu penghasilan rekabentuk yang baru dan analisa termal. Bagi penghasilan rekabentuk, piring brek berongga telah dipilih dan dilukis dalam bentuk 3D dengan menggunakan perisian berbantu komputer, CATIA V5R16. Seterusnya, pemilihan bahan untuk piring brek telah dipilih iaitu *Compacted Graphite Iron* (CGI). Selepas itu, analisa termal secara manual dijalankan untuk memastikan prestasi bahan yang digunakan boleh beroperasi mengikut keadaan perlaksanaan berdasarkan ciri-ciri termal bahan tersebut. Walaubagaimanapun, bagi memastikan pengiraan yang persis dan tepat sehingga pengiraan pada tahap stabil, perisian berbantu komputer, ABAQUS CAE v6.7-1 telah digunakan bagi membantu pengiraan Analisa Unsur Terhingga. Selepas itu, perbandingan nilai boleh dilihat di antara nilai pengiraan secara manual dengan nilai yang diperolehi daripada perisian. Analisa termal tekanan dilakukan untuk melihat sama ada rekabentuk akan mengalami kerosakan ataupun tidak.

ABSTRACT

Projek Sarjana Muda presents a new conceptual design of a ventilated single disc brake rotor developed for UTeM Formula Style race car. The development can be divided into two activities which are creating a new design and thermal analysis. For creating a new design, a single disc brake rotor with cross drilled was choose and a 3D design was developed by using CATIA V5R16 computer aided software. Next, the material was choose which is Compacted Graphite Iron (CGI) for this brake rotor. Thermal analysis also performed by calculating manually to see the performance of this material whether it can operate under the operating condition as well as it thermal characteristic. To see the persist calculation of thermal analysis value until steady-state, a computer aided software called ABAQUS CAE v6.7-1 was used to calculate the Finite Element Analysis (FEA). Then, the value of load analysis can be compared to the value that get from the software and manual calculation. The thermal stress analysis is conduct to see whether the design will overcome to a failure or not.

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NOMENCLATURE

SAE	=	Society of Automotive Engineers
UTeM	=	Universiti Teknikal Malaysia Melaka
FAE	=	Finite Element Analysis
3D	=	Three Dimensional
CAD	=	Computer-aided Design
CATIA	=	Computer Aided Tridimensional Interactive Application
CGI	=	Compacted Graphite Iron
PSM 1	=	Projek Sarjana Muda 1
PSM 2	=	Projek Sarjana Muda 2
CAE	=	Computer-aided Elements
A_h	=	Area of cross-drilled holes, m^2
A_s	=	Area of brake surface, m^2
A_i	=	Area of inner cooling vanes, m^2
A_p	=	Area of a part inside the cooling vanes, m^2
A_T	=	Total Area, m^2
V	=	Volume, m^3
T_{disc}	=	Disc brake rotor thickness, m
ρ	=	Density, kg/m^3
m	=	Mass, kg
KE	=	Kinetic Energy, J
ΔE	=	Total Kinetic Energy, J
v	=	Vehicle Speed, m/s
L/Q	=	Braking Energy, J
q	=	Thermal Flow, J/s

$q_{specific}$	=	Heat Flux, kW/m^2
S_{flux}	=	Brake Surface, m^2
R_D	=	Radius of disc brake rotor, m
$R_{i-vanes}$	=	Radius of inner cooling vanes, m
ω_{disc}	=	Angular speed of disc brake rotor, s^{-1}
V	=	Viscosity of air, kg/ms
ρ_a	=	Density of air, kg/m^3
d_h	=	Hydraulic diameter, m
v_{avg}	=	Average air velocity, m/s
μ_a	=	Dynamic air viscosity, Ns/m^2
h_R	=	Heat transfer, W/m^2K
k_a	=	Thermal conductivity of air, W/m.K
D_D	=	Diameter of outer disc brake rotor, m
Re	=	Reynolds number
Pr	=	Prandtl number
l	=	Depth of cross-drilled holes, m
d_{holes}	=	Diameter of one cross-drilled holes, m
R_{holes}	=	Radius of one cross-drilled holes, m
$D_{o-vanes}$	=	Diameter of outer cooling vanes, m
D_{i-disc}	=	Diameter of inner disc rotor, m
$R_{o\text{-}vanes}$	=	Radius of outer cooling vanes, m
V_{avg}	=	Average of air velocity, m/s
V_{in}	=	Velocity of air into the cooling vanes, m/s
V_{out}	=	Velocity of air out of the cooling vanes, m/s
A_{in}	=	Area of air into the cooling vanes, m^2
A_{out}	=	Area of air out of cooling vanes, m^2
N_{disc}	=	Disc brake rotor speed, rpm
kg	=	Kilogram

m	=	Meter
W	=	Watt
K	=	Kelvin
J	=	Joule
GPa	=	Giga Pascal
.igs	=	IGES
SI	=	International System of Units
Δt	=	Braking time, s
Δx	=	Stopping distance, m
R_{tyre}	=	Radius of tyre, m
ω_{tyre}	=	Angular speed of tyre, s^{-1}

CHAPTER I

INTRODUCTION

1.1 Introduction

Formula Society of Automotive Engineers (SAE) is a student competition organized by SAE International that challenge students to design, build, develop and working in one team to produce a small race car and compete to win the race. The purpose of this race is to give an experience to the student in terms of technical knowledge and soft skill in a problem based learning approach before they graduate and work as engineers after graduation later on. Figure 1.1 shows an example of completing Formula SAE racing car.

Inspired by this event, Universiti Teknikal Malaysia Melaka (UTeM) has taken similar initiative by organizing similar formula style competition called Formula Varsity. The first competition was held in 2007 involving 2 teams from UTeM and University Tun Hussein On. In October 2008, the second competition was organized involving 5 teams from UTeM, Universiti Putera Malaysia, University of Nottingham Malaysia, Politeknik Shah Alam, and Politeknik Kota Bharu. In order to win the competition, many improvements created to the race car such as creating a lightweight chassis. The braking system also include for this improvement in order to have an efficient braking during race.

A ventilated disc rotor that is used in braking system can be improved by changing the material used. The material used must be having this characteristic which are lightweight and also can be able to reach higher temperature. The most important reason for have an efficient braking system is for the safety for the driver. By changing the material of the ventilated disc rotor, the performance of the braking system can be increased. Figure 1.1 shows an example of formula SAE race car.

Figure 1.1: Formula SAE race car (http://fsae.eng.wayne.edu/)

1.2 Objective

To create a new disc brake rotor for UTeM Formula Style race car and determine thermal capabilities for the material choose using steady state and transient analysis condition for Finite Element Analysis (FEA).

1.3 Problem Statement

Weight saving and material selected is important in producing a fast, efficient and competitive race car. By reducing the weight and selected a suitable material of the overall components without affecting the performance and the safety requirements. Due to this problem, responding towards the weight saving and material choose, this project will focus on developing a ventilated single disc brake rotor with a new weight and material selection for UTeM Formula style race car.

1.4 Scope of Study

The scopes of this project are:

a) To produce detail design of the component using 3D CAD software, CATIA V5R16.
b) To perform material selection for the component.
c) To calculate the load acting on the component during operation.
d) To perform linear thermal stress analysis of the component in steady state and transient condition using Finite Element Analysis software, ABAQUS/CAE v6.7-1

CHAPTER II

LITERATURE REVIEW

2.1 History of Formula SAE

For the last 31 years ago, the formula SAE starts with only SAE Mini-Indy that was held at the University of Houston. Dr. Kurt M. Marshek is a person who brings the idea to create this competition that was inspired by a how-to article inside the Popular Mechanics magazine. The vehicle was made out from wood and generates by five horsepower Briggs and Stratton engine. The competition was joined by thirteen schools and only eleven races and the winner is The University of Texas at El Paso. This competition was guide by Mini Baja competition and involves the engineering student to build their own small vehicle to race (http://en.wikipedia.org/wiki/Formula_SAE).

In 1980, Dr. Willian Shapton was come out with his idea of hosting the same competition but no one wants to handle another Mini-Indy race. Three students at the University of Texas at Austin come with new Mini-Indy proposal with a new rule after finding the advantages and potential of the competition. The new rules give the requirement to use any four stroke engine with 25.4 mm intake only. The University of Texas at Austin becomes a host for the competition until 1984. During 1985, the competition was hosted by The University of Texas at Arlington.

There are three biggest companies that become a host for this competition that are General Motor in 1991, Ford Motor Co. in 1992 and Chrysler Corp. in 1993. After

1992 competition, the three formed a consortium to run Formula SAE. Nowadays, the event was sponsored through the company sponsorships and donations along with the team's enrollment fees (http://wikipedia.org/wiki/Formula_SAE).

2.2 Specification of Formula SAE

All of the competitors must follow the rules and regulation that is created by Society of Automotive Engineers (SAE) to join this event. The car specification can be divided into eight parts which are dimension, suspension parameter, brake system, ergonomic, frame, power train, drivetrain and an aerodynamics. For braking system, the aspects must be followed are diameter rotor must be 205 mm and using ventilated single disc for front wheel while for rear wheel, the diameter of single disc must be 260 mm x 10mm. The braking system that acts on all four wheels must be operated by a single control and must be capable of locking all four wheels. Table 2.1 below shows the Formula SAE specification which are related in the design of the braking system.

Table 2.1: Formula SAE car specification (http://sae.org/students/fsae-designspecs.xls)

Dimensions	**Front**	**Rear**
Overall Length, Width, Height	2338mm long, 1476mm wide, 1404mm high	
Wheelbase	1676mm	
Track Width	1410 mm	1475 mm
Weight with 68kg driver	121 kg	138 kg

Brake System / Hub & Axle	**Front**	**Rear**
Rotors	Floating, Cast Iron, hub mounted, 205mm dia. vented	Outboard, 260 mm dia x 10mm Carbon ceramic
Master Cylinder	Student Built 22mm bore front / 19mm bore rear with driver adjustable bias bar	
Calipers	48mm dia., Opposing piston, fixed mtg	Dual piston,25mm dia., floating
Hub Bearings	Tapered roller bearings. Separate spring loaded rubber lip seal	Single 5205 dbl row ang contact bearing with integral seal
Upright Assembly	CNC 7075-Al, integral caliper mount	Weldment, 4130 sheet, heat treated, shot peened
Axle type, size, and material	Fixed spindle, 28mm dia, 4130 steel normalized	Rotating axle, 52mm ODx 2.5mm wall, 4340 steel, RC 40

2.3 Brake System

2.3.1 History of Brake System

A brake is a device for slowing or stopping the motion of a machine or vehicle or alternatively a device to restrain it from starting to move again. The first braking system that used in early years ago is a wooden block brake. This brake consists only a block of wood and a lever system. This brake system operates when the driver pull a lever that located near to him and the wooden block will touch against the wheel and decrease the speed of the vehicle. This method is proved effective in both horse drawn or steam powered vehicles. In 1980s, Michelin brothers starting replace the steel rimmed wheels with the rubber tire and make wooden brakes system is useless because the wood cannot have a conjunction with the rubber (http://www.autorevolution.com/news/braking-systems-history-6933.html).

The next generation of braking system is drum brake system. This type of brake is still used until today. In 1902, a French man called Louis Renault came out with his idea and creating this type of brake which uses external system. Dust, heat and water make them less effective. After years, the internal expanding shoes brake is introduce which placing the shoes inside the drum brake and make the dust and water kept out in terms of effective while braking.

At the end of 1918, Malcom Loughead, one of the founders which came up with the idea to using hydraulic for all four wheel brake system. This system transfer the force on the pressed pedal to the piston and then to the brake shoes. By using this system, it makes the automotive sector in this world expended. After the hydraulic was introduced by Loughead, a new design called disc braking system is created. The disc brake system becomes popular around 1950s and at that time in Europe, the company that is using disc brake system to their vehicle was Citroen. The improvement of braking