DESIGN OPTIMIZATION STUDY ON THE FORMULA VARSITY CAR CHASSIS

MUHAMMAD SHUKRI BIN AHMAD AZAZI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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

Signature : ……………………………………....

Supervisor : DR. ABD RAHMAN BIN DULLAH

Date : ……………………………………....

DESIGN OPTIMIZATION STUDY ON THE FORMULA VARSITY CAR CHASSIS

MUHAMMAD SHUKRI BIN AHMAD AZAZI

This report is presented in

Partial fulfillment of the requirements for the

Degree of Bachelor of Mechanical Engineering (Design & Innovation)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2013

DECLARATION

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

Signature : ………………………………………………….
Author : MUHAMMAD SHUKRI BIN AHMAD AZAZI
Date : ………………………………………………….

DEDICATION

“To my beloved parents Mr. Ahmad Azazi bin Che Hin

and Mrs. Rohani binti Md Nor”

ACKNOWLEDGEMENT

Alhamdullillah, thanks to Allah with it is consent I can finish this report for successfully. I also would like to thanks to Dr. Abd Rahman Bin Dullah and appreciative of his guide during the research I do and during prepare this report. Furthermore, many thanks to my collage friend especially my housemate because with them encouragement and support I can complete this Final Year Project report. Without their cooperation it is difficult to me to complete this report. Not forgotten to my beloved parents and family that always supporting and praying for my successful to complete my degree study. Finally, I would like to thanks to everyone have involved directly or indirectly in my research study until I finished this report.

Thank you very much.

JUNE 2013

ABSTRACT

The design of a chassis contains all necessary components to support loads of the car and the driver. A formula varsity race car chassis have different parts, among them are chassis base. In this project the goal is to optimize the chassis base using HyperWorks software. Furthermore, optimization have different methods but in this project the method are used is topology optimization. Second chapter in this report is about literature review of competition regulation, chassis design, types of material, stiffness torsional and optimization method. Then, the methods are used along conducted this project are shown in the third chapter. These projects basically use Catia software to develop CAD data and HyperWorks software to do analysis. Only linear static analysis is conducted in this project to identify the maximum displacement and maximum von mises stress of the model. The basic idea of this project is the load prediction come from the weight of the driver which is 1000N and the constraint at front and rear wheel side. In HyperWorks software, linear static analysis can only be done in Radioss or OptiStruct. Besides that, OptiStruct also act as a solver for optimization problem. The objective of optimization in this is minimum the compliance. After done the optimization process, the way to valid the optimized design with make comparison between the existing model and optimized design. Lastly, the percent are obtained from displacement reduction is 52 % and the von mises stress reduction is 53%.

ABSTRAK

Rekabentuk casis mempunyai semua keperluan dalam menyokong berat daraipada kereta dan pemandu. Casis kereta lumba formula varsiti mempunyai berlainan bahagian antaranya ialah tapak casis. Matlamat dalam projek ini adalah dengan mengoptimumkan tapak casis menggunakan perisian HyperWorks. Selain itu, pengoptimumnan mempunyai pelbagai cara tetapi di dalam projek ini kaedah yang di gunakan ialah pengoptimunan secara topology. Tajuk kedua dalam laporan ini adalah mengenai kajian ilmiah tentang peraturan perlumbaan, rekabentuk casis, jenis – jenis bahan, kilasan ketegangan dan keadah pengoptiminan. Kemudian, kaedah yang digunakan sepanjang menjalakan projek ini ditunjukkan di dalam tajuk ketiga. Pada dasarnya projek ini menggunakan perisian Catia untuk membuat CAD data dan perisian HyperWorks untuk membuat analisis. Hanya analisis statik linear di dalam projek ini untuk mengenal pasti maximum anjakan dan maximum tekanan von mises. Idea asas dalam projek adalah menjangkakan berat yang datang adalah daripada berat pemandu dan kekangannya datang daripada bahagian depan dan belakang tayar. Dalam perisian HyperWorks, analisis statik linear dilakukan dalam Radioss dan Optistruct. Selain itu juga OptiStruct bertindak sebagai penyelesai dalam masalah pengoptimuman. Objektif pengoptimuman adalah dengan meminimumkan pelbagai masalah kepada hanya satu masalah sahaja. Selepas menyiapkan pengoptimuman proses, cara untuk menilai rekabentuk yang telah dioptimumkan dengan membuat perbandingan antara rekabentuk sedia ada dengan rekabentuk yang telah dioptimumkan. Akhir sekali, peratus yang diperolehi daripada pengurangan anjakan adalah 52 % dan pengurangan ketegangan von mises adalah 53%.

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

UTeM	= Universiti Teknikal Malaysia Melaka
mm	= millimeter
MPa	= Mega Pascal
2D	= Two Dimension
3D	= Three Dimension
CAD	= Computer Aided Design
FEA	= Finite Element Analysis
FEM	= Finite Element Method
Catia	= Computer Aided Three Dimension Interactive Application
minmemb	= Minimum member size
mindim	= Minimum diameter
PSHELL	= Shell property
W	= Objective function
g	= Structural responses
F	= Vector of load
k	= Stiffness matrix
x	= Displacement vector
$\boldsymbol{\sigma}$	= Stress
$\boldsymbol{\varepsilon}$	= Strain
E	= Elasticity matrix

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Formula Varsity is a mini F1 race was introduced by Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) since 2006. The first program was organized on 14 September 2006 with sole participation and subsequently thrive with participation from fives Higher Education Institutions (HEI) in 2008.

Formula Varsity is a biannual event, and on the third event in October 2010 marked its own record when it succeeded to get 25 teams from various Higher Education Institutions (HEI) as well as nationwide polytechnics to participate. However, Formula Varsity 2012 has received 44 requests from the Higher Education Institutions (HEI) but only 25 teams were selected because of the advice from the circuit management.

The tournament challenges engineering students to design, build and test their self-developed formula style racing cars. It is also an event where student can test their skill and apply the theory that they have learn in class to provides students become creative problem solving and team working skill.

1.2 OBJECTIVE

The purpose of the study is to optimize a chassis base by using HyperWorks software for UTeM Formula Varsity Race Car.

1.3 PROBLEM STATEMENT

The design of a chassis contains all the necessary components to support the car and the driver. In order that many areas need to be studied and tested to produce a competitive vehicle with optimum chassis performance.

The variables that can affect the formula varsity car chassis are the types of material, the diameter or dimension of tubes use for built space frame chassis and the design geometry of chassis. In order to optimize the chassis, analysis of the chassis base will be done on the HyperWorks software.

1.4 SCOPE

i. Literature review on the chassis design, material, structural analysis, and optimization methods.
ii. To study the previous chassis base and generates idea of optimization the chassis base.
iii. To follow the finite element method by using HyperWorks.
iv. To optimize the chassis base according topology optimization method by using OptiStruct.
v. To validate the design by compare the new chassis base design with the existing chassis base design.

CHAPTER II

LITERATURE REVIEW

Here is the review about what are related or will be used in this project. This project basically related to the formula varsity competition, the race car chassis design, types of material, stiffness torsional and the optimization methods.

2.1 Competition Rules

Rules intended to give freedom to modify or replace some parts in the interest of safety, research and development. The rule also intended to provide fair competitions and maintain parity.

Participants must follow the rules to prevent the removed from the competition if one small sub-section of chassis rule is not followed. Therefore, to simplify this process a summary of the rules was created and focus on the primary structure such as main hoop, front hoop, roll hoop braces and support, side impact structure, front bulkhead, front bulkhead support and all frame member.

Figure 2.1 show the side impact structure and the normal driving position. There are three side members in side impact structure, first is upper side impact member, second is diagonal side impact member and lastly is lower side impact member. These member are function to protect the driver if had an accident.

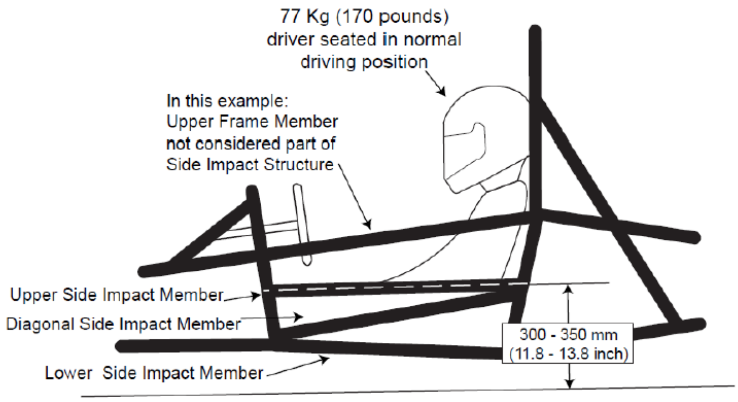

Figure 2.1: Illustrated of side impact member

(Sources: 2012 Formula SAE rules)

Figure 2.2 show the helmet clearance. The main roll hoop braces fore or aft on right and left sides. The front roll hoop and braces must be integrated into frame and surrounding structure.

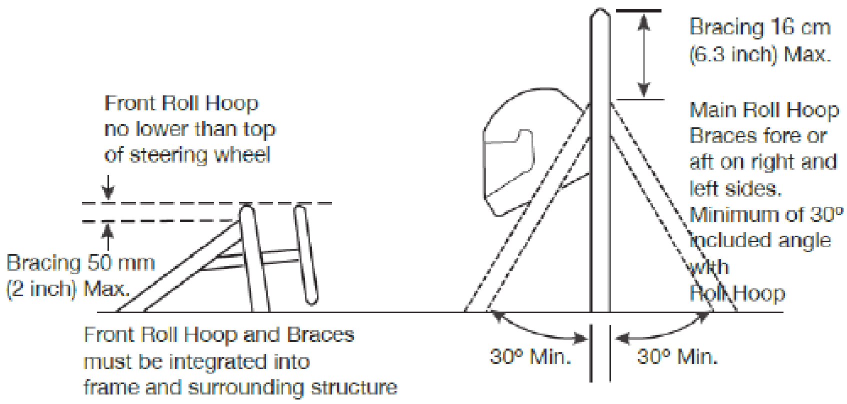

Figure 2.2: Illustrated of helmet clearance

(Source: 2012 Formula SAE rules)

2.2 TYPES OF CHASSIS DESIGN

There are four types of chassis design. In this part will be discuss the four types of chassis. The discussion is focus on the design in terms of load loading, material, and the shape. The fact of the design had obtained from the Mr. Wakeham book.

2.2.1 Ladder Frame

Ladder frame consists of two long beams that run the length of the vehicle and provide a strong support for weight and originally based on a carriage design. Body on frame architecture is a good example of this type of chassis. (Wakeham, 2009)

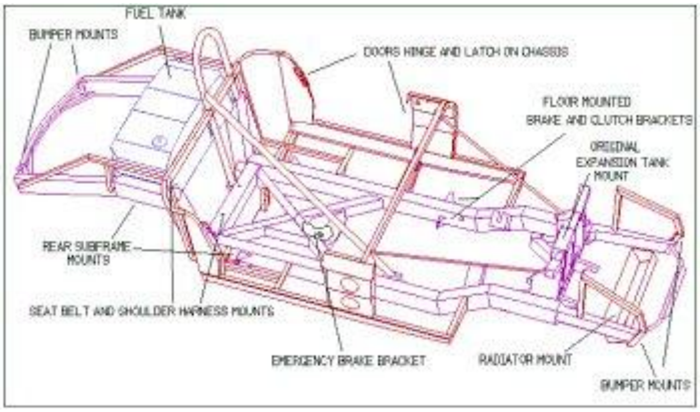

Figure 2.3: Illustrated of Ladder Frame

(Source: http://www.autozine.org/technical_school/chassis/tech_chassis.htm)

2.2.2 Space Frame

Space frame is a nodal triangulated truss network that attempts to distribute all loads into axial directions so that no part of the frame is subjected to the harsher bending forces. A good example of this type of chassis is most Formula SAE chassis or a Lamborgini Countach. (Wakeham, 2009)

Figure 2.4: Space frame chassis

(Source: http://petrolsmell.com/2010/02/04/car-chassis-construction)

2.2.3 Backbone Chassis

Lotus developed a different kind of chassis for its Elan sports car. It ran a fully enclosed tubular member through the center of the vehicle. Though this method definitely is trying to make a fully enclosed tubular member which directly relates to underlying theory, but because of the small size it makes it difficult to create a much ridged chassis by today's standards. (Wakeham, 2009)

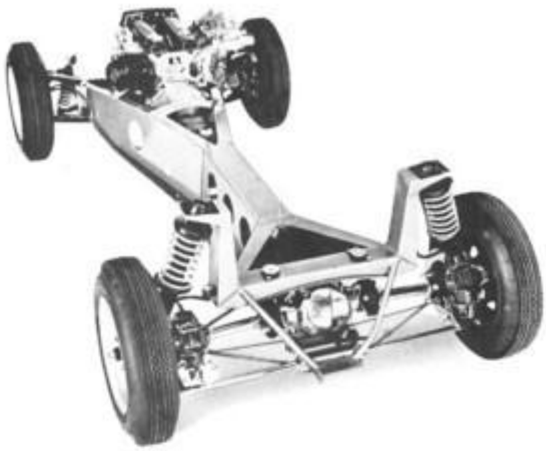

Figure 2.5: Example of Backbone Chassis

(Source: http://www.initialdave.com/cars/tech/chassisbasics01.htm)

2.2.4 Monocoque

A monocoque is similar to that of a skinned space frame but without at any underlying support through the monocoque area. It may built up of a material reinforcing the skin or more commonly using double wall honeycomb techniques. Monocoque use the outer body as a load bearing structure but in some cases it refers more to that it is constructed of continuous panels. In the case of aluminum chassis one can be constructed by rivets, glue, spot welding, or seam welding, and in the case of a fiber composite it can be glued or riveted. (Wakeham, 2009)

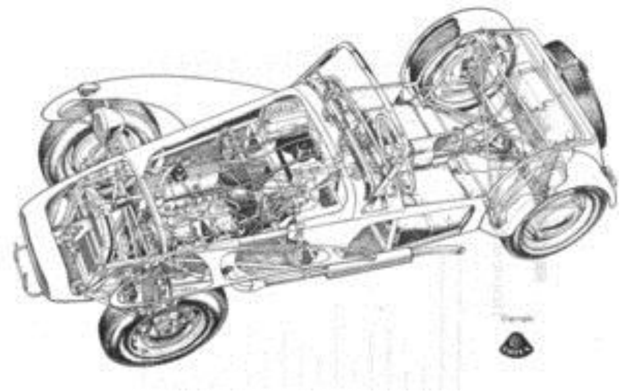

Figure 2.6: Example of Monocoque Chassis
(Source: http://www.initialdave.com/cars/tech/chassisbasics01.htm)

2.3 TYPES OF CHASSIS USED IN FORMULA SAE

In Formula SAE there are three major types of chassis currently used by the participant. This three types of chassis currently use because it is easy to fabricate and have strong structure. In this part it will be discuss about three types of chassis obtained from Blessing, 2004.

2.3.1 Tubular Steel Space Frame

Tubular steel space frames are possibly the most popular chassis design in Formula SAE. Part of the competition process is the validation of your design to the design judges; the tubular space frame is easiest. As the design judges have only a limited amount of time to inspect the vehicles, they need to see that the chassis performs as the claims. As tubular structures are common in motorsports, it is easy for judges to visually access the design of a space frame. (Blessing, 2004)

2.3.2 Metal Monocoque

Metal Monocoque design can also be easily visually assessed for load paths and expected forces, as they are usually a tubular space frame with bonded aluminum panels used to increase stiffness and to act as bodywork. The aluminum sheeting is only ¼” to ½” thick, but the claimed stiffness increase is significant. Instead of aluminum, carbon fiber panels can be used to the same effect, which is more effective for complicated geometry and sections that are out of plane. (Blessing, 2004)

2.3.3 Composite Semi Monocoque

Composite semi monocoque is usually a tub design, with the material used a carbon fiber matrix with an epoxy resin. There are usually several materials included in the lay-up process to modify the properties of composite materials available for chassis construction compared to the known and familiar properties of steel. Because of this there are significant equivalency rules in place to ensure that the minimum safety requirements for the chassis are met. (Blessing, 2004)