DESIGN AND DEVELOPMENT OF LIGHTWEIGHT CHASSIS FOR UTeM FORMULA STYLE'S RACE CAR

MOHD SHAARANI BIN MOHD HASHIM

This report is presented in

Partial fulfillment of the requirements for the

Degree of Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

APRIL 2010

© Universiti Teknikal Malaysia Melaka

‘I/We* have read this thesis

and from my/our* opinion this thesis

is sufficient in aspects of scope and quality for awarding

Bachelor of Mechanical Engineering (Automotive)’

Signatures	: ……..
Name of Supervisor I	: Muhd Ridzuan bin Mansor
Date	: 24th May 2010

© Universiti Teknikal Malaysia Melaka

DESIGN AND DEVELOPMENT OF LIGHTWEIGHT CHASSIS

FOR UTeM FORMULA STYLE RACE CAR

MOHD SHAARANI BIN MOHD HASHIM

This report is presented in

Partial fulfillment of the requirements for the

Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

OCTOBER 2009

© Universiti Teknikal Malaysia Melaka

"I declare this report is on my own work except for summary and quotes that I have mentioned its sources"

Signature : ……..

Name of Author : Mohd Shaarani bin Mohd Hashim

Date : 24th May 2010

© Universiti Teknikal Malaysia Melaka

Dedicated to my beloved mom and dad

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENTS

Thanks to Allah because of bless I am sincerely appreciative to my lecturer, Mr. Muhd Ridzuan bin Mansor for serving as my supervisor and for providing guidance while conducting the research and the writing of this Projek Sarjana Muda (PSM).

I thank the laboratory management especially the lab technicians for their cooperation and support. I also want to thank my father , Mr Hashim and my mother, Siti Alwiyah for their continued support and encouragement in everything I do. All these years of education have been made possible by their support and love.

Last but not least, I thank everyone who involved directly and indirectly in this project. The sacrifice and commitment given towards me earning my bachelor's degree are indescribable and without them, this PSM thesis would have been impossible. Lastly, hope that all that have been study and research in this thesis can be use as a references to the other student in the future.

Mohd Shaarani bin Mohd Hashim

UTeM

April 2010

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Matlamat projek ini ialah untuk mereka bentuk dan membangunkan kerangka kereta Formula Student yang baru di mana kerangka yang akan di bangunkan mestilah mempunyai berat yang lebih ringan daripada kerangka yang sedia ada. Ini kerana, jisim adalah salah satu faktor utama yang akan memberi implikasi kepada kelajuan sesebuah kereta. Banyak kajian telah dilakukan semasa projek ini di jalankan untuk mencapai objektif utama projek ini. Kesimpulan yang telah di dapati daripada kajian telah mendapati cara untuk mengurangkan jisim kerangka ini adalah dengan cara mengubah rekabentuk kerangka yang sedia ada. Selain itu, pengurangan penggunaan besi yang berdiameter lebar juga telah dikurangkan. Namun, penggunaan jenis bahan masih di kekalkan seperti kerangka yang lepas. Walau bagaimanapun, setiap perubahan yang di buat mestilah selari dengan peraturan dan spesifikasi yang di keluarkan oleh pertandingan Formula Student. Kekuatan kerangka juga mestilah sama atau lebih kuat daripada kerangka yang sedia ada. Nilai simpulan torsi pula di kira untuk menentukan kadar kekuatan kerangka ini. Analisa regangan juga di lakukan untuk melihat kekukuhan kerangka ini. Kesimpulannya, banyak pengalaman dan pengetahuan yang baru dapt dipelajari hasil daripada kajian ini.

© Universiti Teknikal Malaysia Melaka

ABSTRACT

The goal of this project is to design and develop a new chassis which are lightweight than the previous of Formula Student UTeM chassis. This is because weight is the main point that affected the performance of a car. Therefore, a lot of research has been done in order to achieve the main objective of this project. From the research, this can be conclude that the method to reduce weight is by changes the geometry of chassis design and reduce the hollow tubes dimension while the material that are used still same as the previous chassis. However, changes must complying the rules and regulation of competition. The strength also must be equal or greater than the previous. The torsional stiffness value is determined in order to know the stiffness of this chassis. The chassis was later analyses for its structural performance using finite element analysis method to know the critical path and the parts that will give any possible failure effect. As a conclusion, a lot of new experience and knowledge have gather during the period of this project.

© Universiti Teknikal Malaysia Melaka

TABLE OF CONTENT

CHAPTER	TITLE		PAGE
	PREFACE		**Ii**
	DEDICATION		**Iv**
	ACKNOWLEDGEMENT		**V**
	ABSTRAK		**Vi**
	ABSTRACT		**vii**
	TABLE OF CONTENT		**viii**
	LIST OF TABLE		**X**
	LIST OF FIGURE		**Xi**
	NOMENCLATURE		**xiv**
CHAPTER I	**INTRODUCTION**		**1**
	1.10	**Objective**	**1**
	1.20	**Problem statement**	**2**
	1.30	**Scope**	**2**
CHAPTER II	**LITERATURE REVIEW**		**4**
	2.10	**Competition**	
	2.1.0	Competition rules	4
	2.1.1	Competition	6

© Universiti Teknikal Malaysia Melaka

	2.1.2	Car	6
2.20	**Types of Chassis Design**		**7**
	2.2.1	Ladder frame	7
	2.2.2	Space frame	8
	2.2.3	Backbone Chassis	8
	2.2.4	Monocorque	9
	2.2.5	Carbon Fiber Monocoque	9
2.30	**Types of chassis used in Formula SAE**		**10**
	2.3.1	Tubular Steel Space Frame	11
	2.3.2	Metal Monocoque	11
	2.3.3	Composite Semi-Monocoques	12
2.40	**Types of material possibly use**		**12**
	2.4.1	Steel	13
	2.4.2	Plain Carbon Steel	13
	2.4.3	Mild steel	14
	2.4.4	Medium carbon steel	14
	2.4.5	High carbon steel	15
	2.4.6	Alloy Steels	15
	2.4.7	Stainless Steel	15
	2.4.8	Aluminum	16
2.50	**Torsional Stiffness**		**16**
2.60	**Metal inert gas (MIG) welding**		**18**
	2.6.1	Welding technique	19
CHAPTER III	**METHODOLOGY**		**20**
3.10	**Flow chart**		**20**
	3.1.0	Flow chart of PSM I	21
	3.1.1	Flow chart of PSM II	22
3.20	**Analysis of last year's chassis**		**23**
3.30	**Consultation**		**23**
	3.3.1	Last Year Team Members	23
	3.3.2	Supervisor	24

© Universiti Teknikal Malaysia Melaka

		3.3.3 Workshop Staff	24
	3.40	**Process**	**24**
	3.50	**Design study and process**	**27**
		3.5.1 Aims	27
		3.5.2 Size	28
		3.5.3 Strength	28
		3.5.4 Weight	28
		3.5.5 Miscellaneous	29
		3.5.6 Requirements	29
	3.60	**Formula SAE Study and Research**	**30**
	3.70	**Modeling**	**30**
	3.80	**Selection of materials**	**31**
		3.8.1 Comparisons	31
		3.8.2 Conclusion in choosing the material	33
	3.90	**Finite element analysis**	**33**
CHAPTER IV	**DESIGN ANALYSIS AND PROCESS**		**36**
	4.10	**Flow chart of the design process**	**37**
	4.20	**Design planning**	**38**
	4.30	**3D Model of previous chassis**	**39**
	4.40	**Concept generation**	**40**
		4.4.1 First concept	41
		4.4.2 Second concept generation	41
		4.4.3 Third concept generation	42
	4.50	**Explanation of evaluation concept**	**43**
		4.5.1 Characteristics	41
		4.5.2 Concept selection	44
		4.5.3 Weighted Rating Method	45
		4.5.4 Final concept selection	45
		4.5.5 3D model of new design	45
	4.60	**Design dimension and specification analysis**	**49**

© Universiti Teknikal Malaysia Melaka

	4.6.1	Main roll hoop	53
	4.6.2	Front hoop	54
	4.6.3	Bulkhead	56
	4.6.4	Rear box	57
	4.6.5	Side impact member	57
	4.5.6	Engine bay	58
CHAPTER V	**FINITE ELEMENT ANALYSIS**		**60**
	5.10	**Define load**	**61**
	5.20	**Torsion Displacement Analysis**	**63**
	5.2.1	Stress analysis on the overall chassis	64
	5.2.2	Stress analysis on the front knee box of chassis	65
	5.2.3	Stress analysis on the rear box of chassis	66
	5.30	**Analysis results**	**66**
	5.3.1	Torsional displacement of the previous chassis design	67
	5.3.2	Torsional displacement of the new chassis design	67
	5.3.3	Stress analysis on overall chassis	68
	5.3.4	Stress analysis on the rear box (differential box)	69
	5.3.5	Stress analysis on the front knee box	70
CHAPTER VI	**FABRICATION**		**72**
	6.10	**The flowchart of fabrication**	**73**
	6.20	**Project planning**	**74**

© Universiti Teknikal Malaysia Melaka

	6.30	**Construction**	**75**
	6.40	**Finishing**	**83**
CHAPTER VII	**DISCUSSION**		**85**
	7.10	**Discussion on torsional stiffness value**	**85**
		7.1.0 Calculation	85
		7.1.1 Comparison result with other researchers	87
		7.1.2 Discussion on stress analysis result	91
		7.1.3 Discussion on the design and fabrication	91
		7.1.4 Percentage of weight reduction	93
		7.1.5 Manufacturing costing	93
CHAPTER VIII	**CONCLUSION AND RECOMMENDATION**		**96**
	8.10	**Conclusion**	**96**
	8.20	**Recommendation**	**90**
	References		**99**
	Bibliography		**101**
	Appendix A UTeM Formula Varsity regulation		**102**
	Appendix B design dimension of previous design		**120**
	Appendix C Design dimension of new design		**124**

© Universiti Teknikal Malaysia Melaka

LIST OF TABLE

TABLE	TITLE	PAGE
2.1	Comparison among the chassis	10
3.1	Comparison among the material	32
4.1	Weighted rating method	45
4.2	Rating value	46
5.1	material properties of low carbon steel	61
7.1	torsional analysis results for new and previous chassis	86
7.2	Comparison the torsional stiffness value with some of Formula SAE's team (Source: Alexander M Soo. (2008),William B. Riley and Albert R. George(2002))	88
7.3	Structural analysis result	91
7.4	table of manufacturing costing and material quantity used	94

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURE

FIGURE	TITLE	PAGE
2.1	Illustration of the side impact member's location (Sources: Formula SAE Rules (2009))	5
2.2	Illustration of the clearance required above the drivers head. (Sources: Formula SAE Rules (2009))	5
2.3	95th percentile male dimensions as depicted in the 2006 rules (Sources: Formula SAE Rules (2009))	6
2.4	Last year car on track	7
2.5	The 2003 University of Queensland FSAE Chassis (Source : Blessing.J.P (2004)).	11
2.6	University of Western Washington's Composite Tub Chassis (Source : Blessing.J.P (2004)).	12
2.7	Tensile Strength and Hardness of Plain Carbon Steels (Source : Baker.C.S, (2004)).	14
2.8	Example of frame chassis in torsion	17
2.9	Free body diagram that look from front suspension bay (Source : Riley.W.B and George.A.R. 2002)	18
3.1	Flow chart of PSM I	21
3.2	Flow chart of PSM II	22
3.3	Properties of material is define	34
4.1	Flow chart of design process	37
4.2	Breakdown structure of chassis	39

© Universiti Teknikal Malaysia Melaka

4.3	3D model of previous chassis	40
4.4	First concept generation	41
4.5	Second concept generation	42
4.6	Third concept generation	42
4.7	Model of main hoop and front hoop	48
4.8	3D Model of new design rear angle view	48
4.9	3D Model of new design front angle view	48
4.10	Top View the new chassis design	50
4.11	Top view of previous chassis design	50
4.12	Side view of new chassis design	51
4.13	Side view of previous chassis design	51
4.14	Front view of new chassis design	52
4.15	Front view of previous chassis design	52
4.16	Final design for the main role hoop	53
4.17	The most complex component the front hoops final design.	55
4.18	The front view of bulkhead	56
4.19	The dimensions of the rear box component of the final design.	57
4.20	Side impact member dimension	58
4.21	Engine bay design dimension	59
5.1	Free body diagram look from side view	61
5.2	Location of applied load and constraint for torsion displacement analysis	64
5.3	Location of applied load and constraint for stress analysis on the overall chassis	64
5.4	Location of applied load and constraint for stress analysis on the front knee box	65
5.5	Location of applied load and constraint for stress analysis on the rear box	66
5.6	Torsional displacement of the previous chassis design	67
5.7	Torsional displacement of the new chassis design	68
5.8	Stress analysis on overall chassis	69
5.9	Stress analysis on the rear box (differential box)	70
5.10	Stress analysis on the front knee box	70

© Universiti Teknikal Malaysia Melaka

6.1	Flow chart of fabrication process	
6.2	The breakdown structure of chassis	74
6.3	The full scale of design is template on trace paper.	75
6.4	The pipes is cut by the disc cutter	76
6.5	Bundle of cutting pipes	76
6.6	The frame is jig by nails and tape with template on the full scale dimension of trace paper	77
6.7	The welding procedure	78
6.8	Grinding procedure to remove surplus of welding	78
6.9	Frame is position in the straight line	79
6.10	Front box is fully constructed	80
6.11	Passenger cell construction	80
6.12	Engine bay construction which using a template and nails in order to hold the pipes	81
6.13	The final design fully constructed	81
6.14	Chassis is check for the sufficient in all areas of the dimensions and construction.	82
6.15	Chassis is check for the sufficient in all areas of the dimensions and construction.	82
6.16	Grinding to remove acces metal of welding	83
6.17	Painting the final product	83
6.18	Weighing the final product	84
7.1	Comparison the ratio of torsional stiffness per weight value with some of Formula SAE's team	89
7.2	Comparison the torsional stiffness value with some of Formula SAE's team	89
7.3	The driver and seat positioned in appropriately.	92
8.1	The construction which easily jig the main frame of chassis	98

© Universiti Teknikal Malaysia Melaka

LIST OF NOMENCLATURE

$\sigma_{von\ misses}$	=	Von misses stress
S_{ut}	=	Ultimate tensile strenght
Fz	=	Reaction force
cg	=	Centre of gravity
L	=	Length
m	=	Mass
M_{driver}	=	Mass of driver
M_{wheel}	=	Mass of wheel
$M_{chassis}$	=	Mass of chassis
Δy	=	Displacement at the location of applied load
θ	=	Angle of twist

© Universiti Teknikal Malaysia Melaka

LIST OF APPENDIX

NO	TITLE	PAGE
A	Regulation of UTeM' Formula Varsity	102
B	Design dimension of previous UTeM Formula Varsity chassis	120
C	Design dimension of new design UTeM Formula Varsity chassis	124

© Universiti Teknikal Malaysia Melaka

CHAPTER I

INTRODUCTION

Formula Varsity race car is a competition that is organized by Universiti Teknikal Malaysia Melaka in the quite few years. The competition challenges students to design, analyze, build and race the working model of a racing car in real track condition. The design guidelines were based on the specifications ruled by Formula Varsity 2008 event.

This report deals with the design of the chassis including the method that has been applied in development a formula style race car chassis.

1.10 Objective

The main objective of this project are to design and development of the Formula Style Race Car which is lightweight than a previous car's chassis. New chassis must be lighter than previous but maintain strength.

© Universiti Teknikal Malaysia Melaka

1.20 Problem Statement

The design of a chassis for a formula style race car contains all the necessary components to support the car and the driver. It must comply with the Formula Varsity rules and regulation. In order to produce a competitive vehicle with optimum chassis performance, many areas need to be studied and tested.

Weight is the main point that affected the performance of the car. Therefore, the main purpose of this project is to design and develop a lightweight chassis. The new chassis is must be lighter than the past year chassis but must maintain the strength of the chassis when load is applied on it.

Some factors that can affect the weight of a vehicle are the types of material used, the diameter or dimension of tubes use to built space frame chassis, and the design geometry of chassis.

This project was started by performing background research required to sustain an accurate database of design criteria. Design criteria is allowed the design process and methodology to be derived as well as and to allow for smooth construction of an efficient and effective space frame chassis. Once construction of the chassis was completed, analyses were conducted to investigate the effects of working loads on the chassis. Finite element analysis was used to simulate the conditions of various load combinations.

1.30 Scope

i. Produce the detail design of a new chassis using 3D CAD software based on UTeM Formula style competition and regulation

© Universiti Teknikal Malaysia Melaka

ii. Select suitable material for the chassis through material selection analysis.

iii. Evaluate the torsional stiffness for the chassis based on the load analysis.

iv. Perform Finite Element Analysis on chassis.

v. Fabricate the new design of Formula Style Race Car chassis.

vi. Make a comparison about the torsional stiffness value and weight reduction of the new design chassis with the previous car's chassis.

© Universiti Teknikal Malaysia Melaka

CHAPTER II

LITERATURE REVIEW

2.10 Competition

2.1.0 Competition rules

Adhering to the rules that govern the chassis for the competition is a pivotal part of the research. If one small sub-section rule is not followed, the chassis will disqualified the whole car from the competition.

Within the competition rules that are solely for the chassis when attempting to insure all the rules are met, it is easy to miss small details when the rules are set out in this form. Therefore, to simplify this process a summary of the rules was created and broken down into all individual areas of the chassis layout. These areas were, Main Hoop, Front Hoop, Bulkhead, Main Hoop Bracing, Front Hoop Bracing, Bulkhead Support, Other Bracing and Side Impact Members.

© Universiti Teknikal Malaysia Melaka

The summarized version of the rules can be found in Appendix A. Along with this summary of the rules come some diagrams that relate to the safety aspect of the car as shown in following figure.

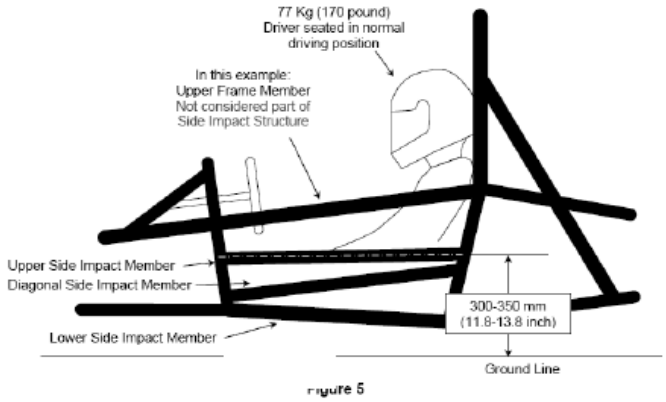

Figure 2.1: Illustration of the side impact member's location.

(Sources: Formula SAE Rules (2009))

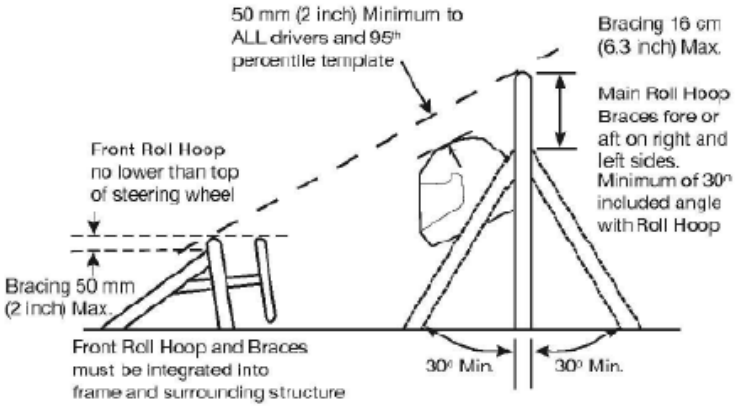

Figure 2.2: Illustration of the clearance required above the drivers head.

(Sources: Formula SAE Rules (2009))

© Universiti Teknikal Malaysia Melaka