

DESIGN AND FABRICATE FOR KNUCKLE RACING ELECTRIC CAR WITH  
HIGH PERFORMANCE AND REALIBILITY

MUHAMAD FARHAN BIN FADZILAH HUSANI

This report is presented in  
Partial fulfillment of the requirement for the  
Bachelor of Mechanical Engineering ( Design and Innovation)

Faculty of Mechanical Engineering  
Universiti Teknikal Malaysia Melaka

JUNE 2012

‘I/We\* have read this thesis  
And from my/our\* opinion this thesis  
Is sufficient in aspect of scope and quality for awarding  
Bachelor of Mechanical Engineering (Automotive)’

Signatures : .....

Name of Supervisor I : En.Safarudin Ghazali Herawan

Date : .....

Signatures : .....

Name of Supervisor II : .....

Date : .....

*\*Line which is irrelevant*

## DECLARATION

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

Signatures : .....

Name of Author : .....

Date : .....

Especially for my father, Fadzilah Husani B Sirat and my mother,  
Zahriah Bt Muhammad Ghazali

## ACKNOWLEDGEMENT

Considerable gratitude and many thanks goes to those who have helped making this final year project possible, as well as those who have contribute to this project or my education profile.

Special Thanks To:

En.Safarudin Gazali Herawan

Dr.Muhamad Zahir B Hasan

Leopard Racing Team

Zahir Racing Team

Organizer of Formula Varsity 2010

Especially:

Faculty of Mechanical Engineering (UTeM)

## ABSTRAK

Tujuan pengendalian projek ini adalah untuk memenuhi keperluan subjek BMCU 4982 dan BMCU 4984 atau lebih dikenali sebagai Projek Sarjana Muda. Tajuk yang telah di pilih ialah “ Reka dan Fabrikasi Satu Mobil Sesendi Steering / Upright Yang Mempunyai Prestasi Dan Daya Keboleh Harapan Yang Tinggi Untuk kereta lumba racing elektrik ”. Formula Varsity adalah acara permotoran yang mana pesertanya terdiri daripada institut pengajian tinggi. Untuk tahun 2012, akan di perkenalkan satu kategori baru, iaitu konsep perlumbaan berunsurkan sumber elektrik. Selepas selesai fabrikasi kereta bagi acara tersebut, saya mendapati bahawa berat kenderaan mempengaruhi prestasi kereta tersebut. Dengan adanya projek ini, saya berharap agar ianya akan menyumbang kepada memaksimumkan prestasi kereta tersebut. Objektif projek ini adalah untuk mengurangkan berat knuckle/upright dan mengurangkan alat untuk knuckle/upright tersebut. Hal ini kerana, rekaan knuckle/upright kereta tersebut bagi masa sekarang memerlukan braket caliper. Dengan rekaan baru, penggunaan braket caliper boleh dimansuhkan. Projek ini akan melalui skops seperti, rekaan detail dengan menggunakan program CAD, analisis bagi rekaan dan fabrikasi rekaan. Saya berharap agar projek ini mampu menyumbang kepada penambahbaikan untuk Pasukan Formula Varsity Universiti Teknikal Malaysia Melaka yang akan datang.

## ABSTRACT

The purpose of this project is for the completion of BMCU 4982 and BMCU 4984 subject or also known as Final Year project. The title that I have chosen for this project is: “Design and Fabrication For Knuckle Racing Electric Car With High Performance And Realibility”. Formula Varsity is a motorsport event that is held by Universiti Teknikal Malaysia Melaka (UTeM) in which the participants are for higher learning institution. In addition, categories of electric racing car will be introduced in 2012. After finishing fabricating the race car for the event, I’ve founded that the mass of the car does affect the performance of the car. Thus, with this project I hope that it can contribute into solving the problem or maximizing the car performance. The aim of this project is to minimize the upright/knuckle weight and to reduce its part. By doing such, it can contribute in reducing the unsprung mass of the car thus it can increase the ride comfort, and decrease the force absorb by the shock absorber. The current design of the upright/knuckle needed to use a caliper bracket in order to mount the brake caliper. With a new design, we can eliminate the use of the caliper bracket. The study of this project undergoes scopes such as, detail design, analysis of the design and fabrication of the upright. Finally, I hope this project can contribute to future improvement for UTeM formula Varsity race team.

## Content

<b>CHAPTER</b>	<b>TITLE</b>	<b>PAGE</b>
	<b>PREFACE</b>	<b>i</b>
	<b>DEDICATION</b>	<b>ii</b>
	<b>ACKNOWLEDGEMENT</b>	<b>iv</b>
	<b>ABSTRACT</b>	<b>v</b>
	<b>ABSTRAK</b>	<b>vi</b>
	<b>TABLE OF CONTENT</b>	<b>v</b>
	<b>LIST OF TABLE</b>	<b>xi</b>
	<b>LIST OF FIGURE</b>	<b>xii</b>
	<b>LIST OF SYMBOLS</b>	<b>xiv</b>
	<b>LIST OF ABBREVIATION</b>	<b>xv</b>
	<b>LIST OF APPENDIX</b>	<b>xvi</b>
<b>CHAPTER 1</b>	<b>INTRODUCTION</b>	<b>1</b>
1.0	Formula Varsity	1
1.1	Objective	3
1.2	Problem Statement	3



1.2.1	Upright Weight	3
1.2.2	Upright Parts	4
1.3	Scopes	5
 <b>CHAPTER 2 LITERATURE REVIEW</b>		<b>6</b>
2.0	Design Review	6
2.0.1	Total Design Method	6
2.0.2	Design Error	8
2.1	Material Review	11
2.1.1	Steel	11
2.1.2	Plain Carbon Steel	11
2.1.3	Mild Steel	11
2.1.4	Aluminium	12
2.2	Joining Review	12
2.3	Analysis Review	13
2.3.1	Forces Acting On Suspension	14
2.3.2	Brake Force Equation	14
 <b>CHAPTER 3 METHODOLOGY</b>		<b>16</b>
3.0	Introduction	16
3.1	Project Flow Chart	16
3.2	Designing The Upright or Knuckle	18
3.2.1	Market Investigation	18

3.2.2	Product Design Specification	18
3.2.3	Conceptual Design	19
3.2.4	Detail Design	19
3.2.5	Fabrication	19
3.3	Material Selection	19
3.4	Analysis	20
3.4.1	Static Case	20
3.4.2	Lateral Force	22
3.4.3	Forces Determination	22
3.4.4	Structure Analysis	23

## **CHAPTER 4 RESULT AND ANALYSIS 24**

4.0	Total Design Method	24
4.0.1	Market Investigation	24
4.0.2	Conceptual Design	26
4.0.3	Evaluation and Selection of Concept	28
4.0.4	Design Rating	30
4.1	Material Selection	31
4.1.1	Introduction	31
4.1.1.1	Steel	31
4.1.1.2	Plain Carbon Steel	32
4.1.1.3	Mild Steel	33
4.1.1.4	Medium Carbon Steel	33
4.1.1.5	High Carbon Steel	33
4.1.1.6	Alloy Steels	34
4.1.1.7	Stainless Steel	34
4.1.1.8	Aluminium	35
4.1.2	Comparisons	36
4.1.3	Conclusion	36
4.2	Load Analysis	37
4.2.1	Static Analysis	37
4.2.2	Brake Force Calculation	40

4.3	Structure Analysis And Results	42
4.3.1	Structure Analysis	42
4.3.2	Result	44
<b>CHAPTER 5 FABRICATION</b>		<b>45</b>
5.0	Introduction	45
5.1	Fabrication Flow Chart	45
5.2	Project Planning	47
5.3	Material Purchasing	48
5.4	CAD Drawing and Dimension	48
5.5	Construction	50
5.2	Finishing	55
<b>CHAPTER 6 DISSCUSSION</b>		<b>56</b>
6.0	Upright After Fabrication Process	56
6.1	Weight Reduction	57
6.2	Component Reduce	58
6.2.1	Major Component	58
6.2.2	Subpart Reduction	58
<b>CHAPTER 7 CONCLUSION AND RECOMMENDATION</b>		<b>60</b>
7.0	Conclusions	60
7.1	Recommendation	61
7.1.1	Design Recommendation	61
7.1.2	Analysis Recommendation	61
7.1.3	Material Selection Recommendation	61
REFERENCES		62
APPENDICES		66

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
4.1	Weighting Factor	29
4.2	Rating for Each Upright/knuckle	30
6.1	Comparison of upright or Knuckle	59

## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Suspension Assembly	2
1.2	Quarter Car Suspension Model	3
1.3	Current Upright Design	5
2.1	Design Core	7
2.2	Failed Upright	8
2.3	FSAE Team Upright	8
2.4	Unreliable Design	9
2.5	Analyzed Upright Design	10
2.6	Sample Calculation	14
3.1	Process Flow Chart	17
3.2	Static Loads On Level Ground	20
3.3	Use Of Electronic Scale	21
3.4	Free Body Diagram of Rear Suspension	22
4.1	F1 Upright	25
4.2	F1 Upright	25
4.3	Example Of Formula Student Uprights	25
4.4	Example of RC upright	25
4.5	Upright 1	26
4.6	Design Concept of Upright 1	26
4.7	Upright 2	27
4.8	Upright 3	27
4.9	Concept Generation Of Upright 1	28
4.10	Steel	32
4.11	Tensile Strength and Hardness of Plain Carbon	32
4.12	Stainless Steel	34
4.13	Aluminium	35

4.14	Rectangular Roughness Conering	37
4.15	Front Suspension Free Body Diagram	38
4.16	Relations Between Master Pump And Caliper Piston	40
4.17	Forces Distribution on Upright	42
4.18	Torque Applied On the Caliper Mounting	42
4.19	Load Distribution	43
4.20	Displacement Of The Upright	43
5.1	Fabrication Flow Chart	46
5.2	The Breakdown Structure of Upright/Knuckle	47
5.3	Solid Steel and Hollow Square Steel	48
5.4	Detail Drawing and Dimension	49
5.5	Bend Saw	50
5.6	Conventional Lathe	50
5.7	Cutting Tool 1	51
5.8	Cutting Tool 2	51
5.9	Cutting Tool 3	51
5.10	Cutting Tool 4	52
5.11	Housing Bearing	52
5.12	Hollow Square Steel	53
5.13	Disc Cutter	53
5.14	Housing Bearing Jig	53
5.15	Curved End of Shape	54
5.16	Complete Area 2	54
5.17	Upper Mounting	54
5.18	Lower Mounting	54
5.19	Complete set 3	55
5.20	Final Desaign After Finishing Process	55
6.1	Weighting Both Upright/Knuckle	57
6.2	Caliper Mounts	58
6.5	Location of Subparts reduce	58
6.6	Eliminition of the Subpatrs	59

## LIST OF SYMBOLS

$\Theta_1$  = angle (degree)

$\Theta_2$  = angle (degree)

$\Theta_3$  = angle (degree)

$\Sigma$  = Sigma

$\Pi$  = 3.45

$\tau$  = Torsional shear (MPa)

## **LIST OF ABBREVIATION**

RC= Remote Control

F1= Formula One

FSAE= Formula Society Automotive Engineering

CNC = Computer Numerical Control

SAE= Society Automotive Engineering

UTeM= Universiti Teknikal Malaysia Melaka



## LIST OF APPENDIX

NO	TITLE	PAGE
A	Technical Drawing	66
B	Flow Chart And Gantt Chart	70
C	Regulation Of UteM's Formula Varsity	73

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.0 FORMULA VARSITY**

Universiti Teknikal Malaysia Melaka (UTeM) Formula Varsity is an international student racing competition that challenges students to design, manufacture and race their single seat open-wheel formula style racing car in real track condition. This event is inspired by similar student racing event such as formula student and formula SAE. The events have provided a platform for Malaysian student to practice their knowledge in engineering through motorsport event. The event hope to foster the tie and collaboration between all Malaysian and international higher education institutions especially among the students as well as

to help create the needed competent human capitals for our country automotive industries.[20]

The UTeM formula Varsity 2010 team consists of 11 member crews that are appointed for the car fabrication. After completion, several problems were founded that affected the performance of the car, one of it was the weight of the car. This project has been dedicated to reducing the upright component weight as it helps to improve the performance of the car upright or knuckle is stated as a linkage or a bracket to the parts of suspension arms, Transmission parts and brake parts. Figure 1.1 shows the several of part for suspension assembly included upright or knuckle.

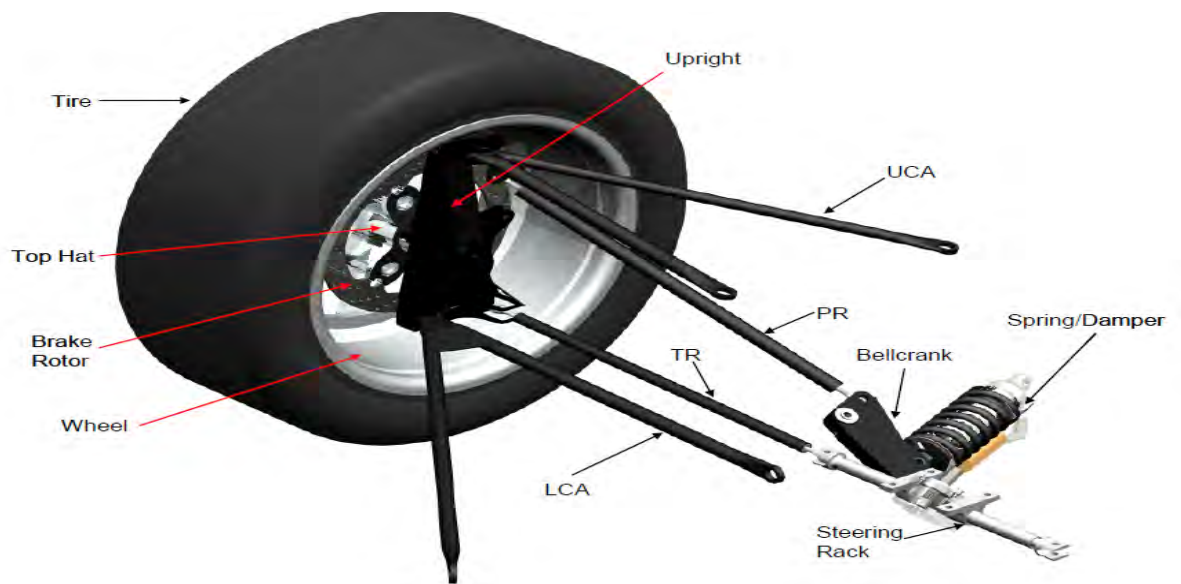


Figure 1.1: Suspension Assembly [29]

Where:

UCA : Upper control arm

LCA : Lower control arm

TR : Tie Rod

PR : Push Rod

### 1.1.1 OBJECTIVE

In this project, there are several objectives that I have identified:

- i. To obtain steering upright or knuckle lightweight design compatible with the concept of race.
- ii. Form a new steering upright or knuckle has a high resistance properties and high performance.

## 1.2 PROBLEM STATEMENT

### 1.2.1 Upright Weight

Refer at Figure 1.2, the upright is an unsprung mass, thus the shock absorber must control this load in bumps. It is important to minimize the weight as it can reduce the force acting on the shock absorber [8].

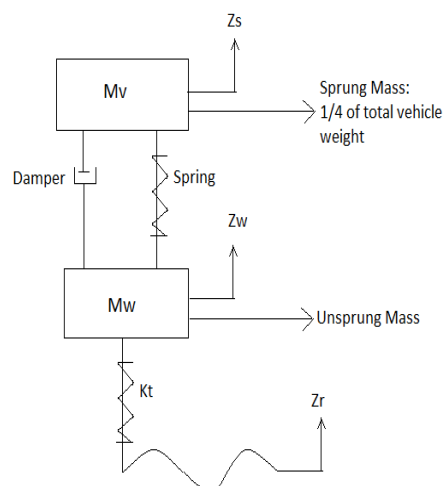


Figure 1.2: Quarter Car Suspension Model [10]

Where:

$M_v$ : Sprung mass

$Z_s$ : Body vertical acceleration

$M_w$ : Unsprung mass

$Z_w$ : Wheel vertical acceleration

$K_t$ : Tire spring coefficient

$Z_r$ : Road profile

### **1.2.2 Upright Parts**

The current upright designs have showed at Figure 1.3, uses a caliper bracket in order to mount the brake caliper. With a new upright design, the use of caliper bracket can be eliminated and it contributes to reducing number of parts



Figure 1.3: Current Upright design

### 1.1.2 SCOPES

Below, there is some scope that I have been reserved for the exercise and assists me in completing the project:

- To produce detail and 3 dimension design of the wheel upright component using CAD software based on 2010 UTeM Formula Varsity specification and regulation.
- To perform material selection and load analysis on the component
- To fabricate the upright component
- To measure the overall weight of the upright

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 DESIGN REVIEW**

##### **2.0.1 Total Design Method**

Before producing a detail drawing of the upright, we must first look for sources from previous example of upright that was build for race car. This is called market investigation. In order to produce the best possible design for the upright or knuckle, a method name “Total Design Method” has been followed [35]. Figure 2.1 show the flow chart and the steps in the method:

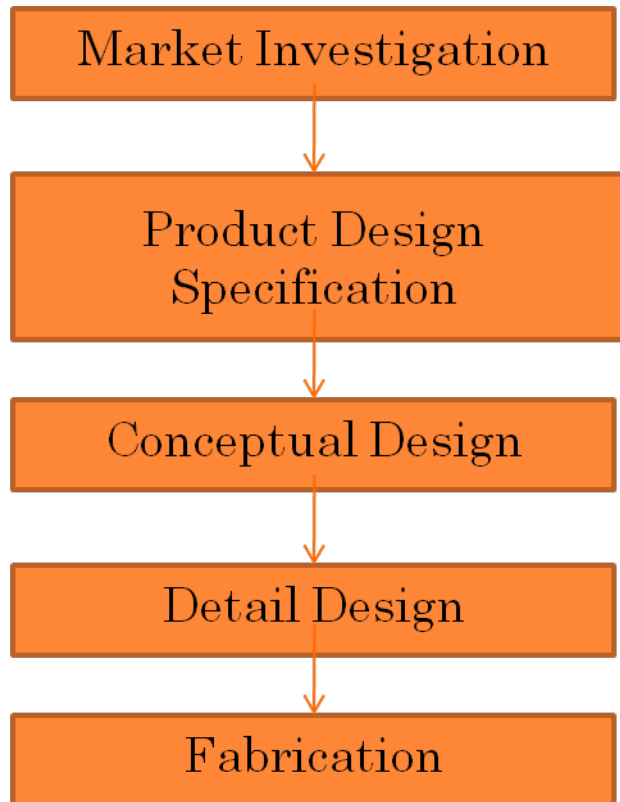


Figure 2.1: Design Core [36]