DESIGN AND ANALYSIS OF URBAN CONCEPT CAR CHASSIS FOR SHELL ECO-MARATHON CHALLENGE

MUHAMAD SOLEHIN BIN DAUD

Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

EXAMINER'S APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Design and Analysis of Urban Concept Car Chassis for Shell Eco-marathon Challenge*" is written by *Muhamad Solehin Bin Daud*. I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality of the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Examiner   Signature

“In the name of ALLAH, the Most Beneficent, the Most Merciful”

This report is dedicated to:

Beloved father and mother;

DAUD BIN JAPAR

NORMAH BINTI AINI

For your love, trust and support along my journey as a student. You are my source of inspiration and spirit for me along my study and life.

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality of the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :
Name of Supervisor : MR. AZIM B. MOHD ARSHAD
Position : LECTURER
Date :

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of another degree.

Signature :

Name : MUHAMAD SOLEHIN BIN DAUD

ID Number : MH08059

Date :

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere appreciation to my supervisor, En.Azim bin Mohd Arshad and Prof.Rosli bin Abu Bakar for his germinal ideas, invaluable guidance, continuous encouragement and constant support in completing this thesis. Without his guidance, I would not be able to finish this thesis completely. I am truly grateful for his progressive vision about my experiment, his tolerance of my naïve mistakes and his commitment to my future career.

My sincere thanks go to all my classmates and members of the staff of Mechanical Engineering Department, UMP, who helped me in many ways during this thesis writing. I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. Without your support, I feel that there is no inspiration for me to keep moving in my journey of life. I am also indebted to all my friends and anyone who helped me during my completion of this thesis.

ABSTRACT

The Shell Eco - marathon is an educational project that challenges competing student teams to design, build and drive the most energy-efficient vehicle. The winning vehicle is the one that travels the furthest using the least amount of fuel. Contestants at the Shell Eco-marathon find increasingly innovative ways to squeeze more out of a litter of energy. They can make it last for the equivalent of several thousand kilometers. The Shell Eco-marathon aims to inspire engineering students to develop new approaches to sustainable mobility and fuel efficiency. One of the main points to achieve fuel consumption is by reducing the weight of the car chassis. In this study student will design a new chassis for UMP team who participated in SEM challenge. The designed chassis then will be analyzed with required load and will select the best chassis from the parameters. The selected chassis will be proposed to the UMP team to be used as the next urban concept car chassis.

ABSTRAK

Shell Eco-Marathon adalah satu projek pendidikan yang mencabar pasukan pelajar bersaing untuk mereka bentuk, membina dan memandu kenderaan yang paling cekap tenaga. Kenderaan yang menang adalah yang bergerak paling jauh dengan menggunakan jumlah bahan api yang sedikit. Shell Eco-marathon bertujuan memberi inspirasi kepada pelajar-pelajar kejuruteraan untuk membangunkan pendekatan baru untuk mobiliti mampan dan kecekapan bahan api. Salah satu perkara utama untuk mencapai penggunaan bahan api yang sedikit adalah dengan mengurangkan berat casis kereta. Dalam kajian ini pelajar akan mereka bentuk casis baru untuk pasukan UMP yang mengambil bahagian dalam cabaran SEM. Casis yang direka kemudian akan dianalisis dengan beban yang diperlukan dan akan memilih casis terbaik dari parameter. Chasis yang dipilih akan dicadangkan kepada pasukan UMP untuk digunakan sebagai casis kereta konsep seterusnya bandar.

TABLE OF CONTENTS

CHAPTER 4 RESULTS AND DISCUSSION

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SEM	Shell Eco-Marathon
CAD	Computer Aided Design
FEM	Finite Element Method
BHP	Brake horse power
kg	Kilogram
Pa	Pascal
MPa	Megapascal
2D	Two Dimension
SAE	Society of Automotive Engineering
SI units	System International units
N	Newton
mm	Millimeter
[illegible]	Density
E	Modulus of elasticity
AISI	American Iron and Steel Institute
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

The shell Eco - marathon is an educational project that challenges competing student teams to design, build and drive the most energy-efficient vehicle. The winning vehicle is the one that travels the furthest using the least amount of fuel. It does not consider the time to finish the travel but contestants are required to complete the travel with minimum given fuel. This means a lot to the efficiency of the car. Teams can enter two categories, which is, Prototypes: futuristic streamlined vehicles where the primary design consideration is reducing drag and maximizing efficiency. The other one is, Urban Concept: vehicles built to more conventional four-wheel roadworthy criteria. Contestants at the Shell Eco-marathon find increasingly innovative ways to squeeze more out of a litter of energy. They can make it last for the equivalent of several thousand kilometers.

The Shell Eco-marathon aims to inspire engineering students to develop new approaches to sustainable mobility and fuel efficiency. It is a major educational project that encourages and fosters innovation in which students work together to explore potential solutions to both current and future transport and energy challenges. Considering the type of the competition, we consider about the total weight of the car. It is because the weight of the car plays an important role in reducing fuel. The main part that will contribute to the increment of the weight is the chassis of the car. Thus in this analysis we will focus on the weight of the engine and driven. The chassis configuration must be light enough but developed at high total stiffness or rigidity to avoid deformation that might occur during accidental collision. For safety reason, first we will consider on the deflection of the chassis component especially of the concentrated load exerted by the driver. However, considering “if situation”, then we will look at the accidental collision. The roll bar is very important to protect the driver if the car gets upside down. In order to develop the car chassis that have high resist to deformation upon load, first we have to study the profile of the chassis that needed to fabricate. For this coming competition, the team has decided to build the ‘space frame chassis” rather than another type of chassis design.

1.2 PROBLEM OF STATEMENT

Based on the previous Shell Eco Marathon competition, most of the design of urban car is not satisfying these criteria:

i. Design the four wheel urban car which maximum vehicle weight, without the driver, is 205 kg, the maximum height must be less than 130 cm; the wheelbase must be at least 120 cm, the maximum total vehicle width must not exceed 125 cm, the maximum total length not exceed 350 cm.
ii. Existing design not enough strong enough due to heavy load.
iii. Ordinary design of four wheel urban car is less fuel-efficient due to the weight factors of the vehicle.

1.3 OBJECTIVES

After considerations are made corresponds to the project background and the problem faced, it is decided that the objectives of the project are such;

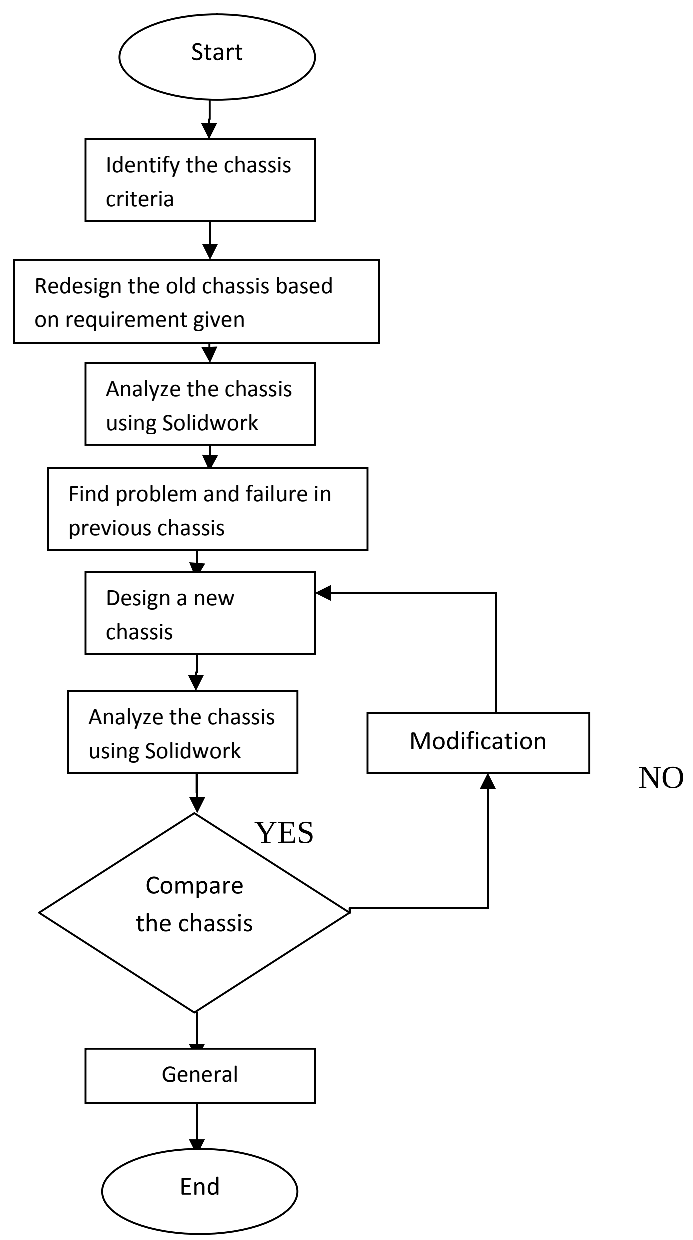
i. Improve existing design and analyze the car chases based on requirement given.
ii. Simulate the design using software.

1.4 PROJECT SCOPES

This project is focusing on the design and development of the integrated chassis of an urban concept car which able to travel with less amount of energy. This focus area is done based on the following aspect;

i. Evaluate current design.
ii. Design a new chassis based on the body shell proposed.
iii. Select the best option to be implemented.

1.5 PROJECT METHODOLOGY



The first step starts with the brainstorm to choose the design of the body. The design of the body will lead to the design of the chassis. There are several designs that have been proposed for Shell Eco Marathon Urban concept car including the previous team design and after several discussions the best design for the project is decided.
The next step is redesign the previous chassis based on the rule and regulation of the Shell Eco Marathon Urban Car Concept. The Chassis is designed for one seated and aluminum as material.

The chassis will be built on Solidwork software and then will be ready for analysis. Based on the analysis the weak point of the chassis can be determined and the point that will lead to the failure can be found.

The problem and failure in the previous design will be discussed and will come out with another idea to overcome the problem.

The next design will be based on the aluminum and fiberglass as the material. The new chassis will be designed for the three designs. The design will be made as to improve the previous design.

The new design is analyzed and compare with previous design. When the new design is better than the previous one, the new chassis will be ready for his blueprint.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The aim of this chapter is to give information about the urban concept car in terms of the design and development. The design consideration, the choice of chassis design, the material selection and load criteria of the chassis are explained in details in this chapter. Various sources including journals, thesis reference books and literature reviews have been carried out and revised in writing this chapter.

Basically chassis is considered as a framework to support body, engine and others part of the vehicle and the chassis also lend the whole vehicle support and rigidity. Any of good chassis usually will be structurally sound in every way over the expected life of vehicle and beyond. This means nothing will ever break under normal conditions.

The chassis has to maintain the suspension mounting locations so that handling is safe and consistent under high cornering and bump loads. The chassis must support the body panels and other passenger components so that everything feels solid and has a long, reliable life and also protect the occupants from external intrusion.

2.2 DESIGN CONSIDERATIONS

As stated by Shell Eco – Marathon Asia 2012 rules and regulations, the dimensions provide by the organizer during designing the chassis. The dimensions need to be followed;

i. The total vehicle height must be between 100 cm and 130 cm.
ii. The total body width, excluding rear view mirrors, must be between 120 cm and 130 cm.
iii. The total vehicle length must be between 220 cm and 350 cm.
iv. The track width must be at least 100 cm for the front axle and 80 cm for rear axle, measured between and the midpoints where the tires touch the ground.
v. The wheelbase must be at least 120 cm.
vi. The driver's compartment must have a minimum height of 88 cm and a minimum width of 70 cm at the driver's shoulders.
vii. The ground clearance must be at least 10 cm.
viii. The maximum vehicle weight (excluding the driver) must be 205 kg.

2.3 TYPE OF CHASSIS

Different basic chassis design each have their own strengths and weaknesses. Every chassis is a compromise between weight, component size, complexity, vehicle intent, and ultimately cost. And even within a basic design method, strength and stiffness can vary significantly, depending on the details.

2.3.1 BACKBONE

A backbone chassis is the simplest structure design. It consist of a sturdy tubular backbone that joint the front and rear axle. These chassis is full enclosed to be rigid structure and handle all loads (Keith J. Wakeham, 2009). It should be noted that the backbone chassis can be built through many types of constructions. The space within the structure is used to place the driveshaft in case of front engine and rear wheel drive layout.

Further, the drive train, engine and suspensions are all connected to each of the ends of the chassis. The body is built on the backbone usually made of glass-fiber. Almost rear wheel drive and front engine vehicles use backbone chassis. The figure below shows the backbone chassis type.

Figure 2.1: Lotus backbone chassis

Source: Keith J. Wakeham, 2009

2.3.2 LADDER

The ladder frame is a shorthand description of a twin-rail chassis, typically made from round or rectangular tubing or channel. It can use straight or curved members, connected by two or more cross members. Body mounts are usually integral outriggers from the main rails, and suspension points can be well or poorly integrated into the basic design.

The ladder frame is originally adapted from 'horse and buggy' style carriages as it provided sufficient strength for holding the weight of the components (Keith J. Wakeham, 2009). Larger beams could be used if there were higher weight capacity required. The engine of the vehicle using the ladder frame is placed in front or something in the rear and supported at suspensions points. Their construction consists of two longitudinal rails interconnected by many lateral/cross braces, typically made from round or rectangular tubing or channel (Automotive Online, 2008). The figure below shows the type of ladder chassis.

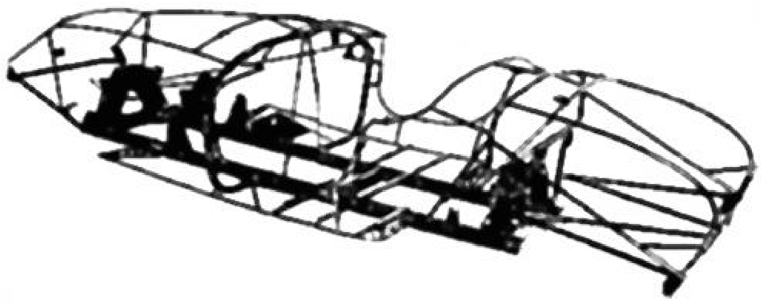


Figure 2.2: Shelby 289 Cobra chassis

Source: Autozine Technical School, 1997

2.3.3 Monocoque

A monocoque chassis can be referred to the vehicle where the external body is load bearing (Keith J. Wakeham, 2009). Monocoque is a one piece structure which defines the overall shape of the car. While ladder, tubular space frame and backbone chassis provide only the stress members and need to build a body around them.

Monocoque chassis already incorporates with the body in a single piece. It's built by welding several pieces together. It’s different from the ladder and backbone due to the body construction as mentioned before. The floor pan, which is the largest piece, and other pieces are press-made by big stamping machines. They are spot welded together by robot arms some even use laser welding in a stream production line. The whole process just takes minutes. After that, some accessories like doors, bonnet, boot lid, side panels and roof are added. The figure below shows the type of monocoque chassis.

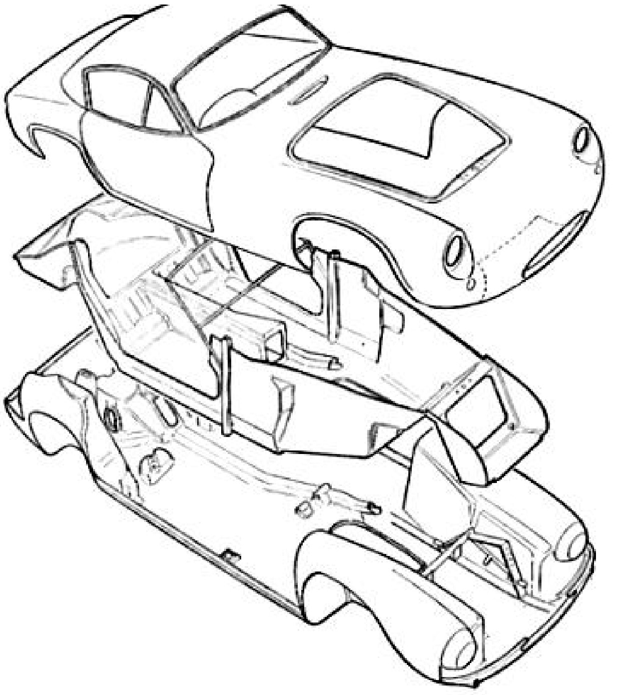


Figure 2.3: 1958 lotus elite chassis

Source: AutoZine Technical School,1997

2.3.4 Spaceframe

A true space frame has small tubes that are only in tension or compression - and has no bending or twisting loads in those tubes. That means that each load-bearing point must be supported in three dimensions. A spaceframe chassis uses a series of straight small diameter tubes to achieve strength and rigidity with minimal weight. The technique was formalized during the Second World War, when they were used for the construction of large frames in combat aircraft. This design was first developed by Barnes Wallis who was an English aviation engineer (Christoper, 2004).

Now days, mostly there are two main types of chassis used in race cars which are tubular space frames and composite monocoque (Christoper, 2004). Spaceframes have been used in the construction of racing car chassis, since the introduction of car racing in the 1940's (Christoper, 2004). Spaceframes chassis have been used since the start of the Motorsport scene. A spaceframe consists of steel or aluminum tubing pipes placed in a triangulated format to support the loads from the vehicle caused by suspension, engine, driver and aerodynamics (Christopher, 2004).

Although the spaceframe type are look like the traditional style, but they are still very popular today in amateur Motorsport. Their popularity maintains because of their simplicity, the only tools required to construct a spaceframe are a saw, measuring devices and welding equipments. The advantage of a spaceframe, comparable to the monocoque type is it can easily be repaired and inspected for damage after a collision. Figure 2.3 below shows an example of spaceframe chassis.

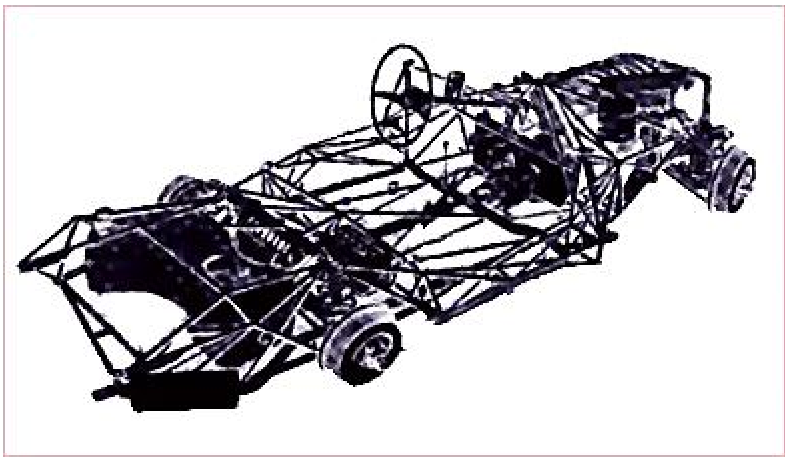


Figure 2.4: Mercedes 300LR chassis

Source: Keith J. Wakeham, 2009

2.4 COMPARISON BETWEEN FOUR TYPES OF CHASSIS

Table 2.1: Advantages and disadvantages types of chassis

Type of chassis	Advantages	Disadvantages
Spaceframe	i. Provide maximum strength and minimum deflection due to the	i. Very complex due to their triangulated tubular pipes format.

	support of tubular pipes Spaceframe chassis systems is lighter than traditional steel. ii. Provides significant economy in foundation costs. iii. Higher torsional rigidity can be achieved as well as its light weight.	ii. Construction of spaceframe chassis is expensive and requires maximum time consuming to be built. iii. The construction is impossible for robotized production.
Ladder	i. Cheap for hand build. ii. More suited for heavy duty usage such as towing and off-roading; can be more durable. iii. Easier to design, build and modify	i. Little torsional rigidity, that is because it is a 2D chassis. ii. Poor resistance to torsion overall height will be higher due to the floor pan sitting above the frame. iii. Center of gravity is usually higher-compromising stability and handling.
Backbone	i. Strong enough for smaller sports cars. ii. Easy to be made by hand thus cheap for low-volume production. iii. The most space-saving other than monocoque chassis.	i. Not strong enough for high-end sports cars. ii. The backbone does not provide protection against side impact or off-set crash. iii. Cost ineffective for mass production.

Monocoque	i. Cheap for mass production. ii. Inherently good crash protection. iii. Space efficient.	i. Monocoque construction does not suit all situations. ii. Damage to a skin of monocouque construction will weaken the whole construction.

Since the spaceframe chassis is the most suitable chassis type used in the urban concept car construction in Shell Eco-marathon compared to others chassis types, hence this concept is applied in this project. It is because the spaceframe chassis provide a maximum strength and minimum deflection, more lighter and also provides significant economy in foundation cost.

Space frame chassis design is a tubular space frame that employs dozen of circular section tubes which provides the maximum strength and it is positioned in different directions to provide mechanical strength against the force from anywhere. Space frame chassis uses a series of straight tubes and welded together to achieve strength and rigidity with minimal weight.

A space frame consists of metal element such as steel or aluminum tubing pipes placed in the triangulated format to support the loads from vehicle caused by suspension, engine, driver and aerodynamics effect (Cristopher, 2004). Space frame chassis is chosen considering the low cost of fabrication compared to other type of chassis fabrication such as a monocoque. However, before we go to fabrication, we need to understand the principle of how this welded tubular component is working together so that the part will perform at the best result. By performing the simulation in Solidwork, it is important to know where to draft the connector.

The fundamental principle of a chassis design is that the chassis is designed to achieve rigidity in term of torsional or lateral forces. The concept of the supporting frame is by sticking a diagonal element to a rectangular frame to avoid extension of the frame when applying the load. For this competition, we define the main component as the front box, driver compartment and engine compartment. The figure below shows the torsional rigidity applies to race car chassis.

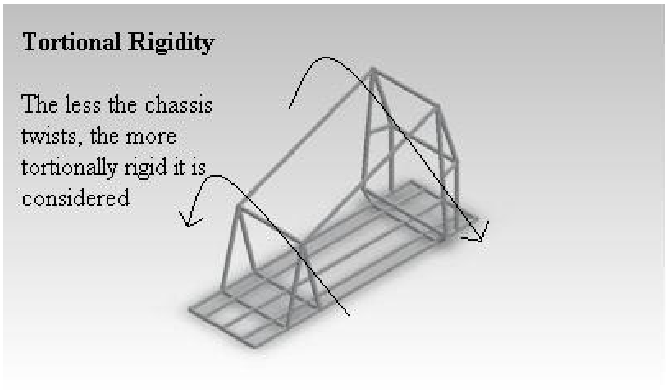


Figure 2.5: Torsional rigidity of race car chassis.

There are several parameters that are important to take into account. Although the car will run at low speed, the aerodynamic effect contributes to lateral forces coming from the front. The frame has to overcome the load from front, side, rear and from the top (in case of the car get upside down during the accidental collision). The space frame is by nature are very efficient. Bending moment is transmitted as tension and the pressure load along the length of each tube. Manufacturing of the frame can be done by welding extruded tubes together using conventional methods.

2.5 MATERIAL SELECTION

The material that will be used for designing the chassis is aluminum. Due to its low weight, good formability and corrosion resistance, aluminum is the material of choice for many automotive applications such as chassis, auto body and many structural components.

Aluminum alloys tailored by suitable variations in chemical composition and processing best fit many requirements, like the non-heat treatable A1-Mg alloys used in chassis optimized for superb resistance against intercrytalline corrosion and concurrent high strength or the heat treatable A1MgSi alloys for extrusions and autobody sheet modified for improved age hardening response (Hirsc, 2004).

With a sound knowledge about the specific material properties and effects excellent lightweight solutions for automotive application have been successfully applied by the European automobile industries (Hirsc, 2004).

It is expected that in the near future the use of aluminum with specifically improved properties will grow in many automobile applications due to the increased an economical and ecological pressure and due to the positive experience gained from many successful applications and current developments and that it will multiply its volume fraction used in cars in all classes and all sizes (Hirsc, 2004).

2.6 CHASSIS LOADING

The frame is defined as a fabricated structural assembly that supports all the functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composites and welded structures. Depending upon the type of loads and their direction, chassis is deformed in a respective manner briefed as follow.

i. Longitudinal torsion
ii. Vertical bending
iii. Lateral bending
iv. Horizontal lozenging.

2.6.1 Longitudinal Torsion

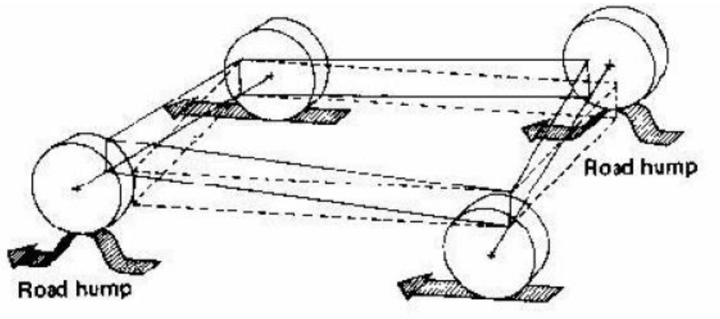


Figure 2.6: Longitudinal Torsion

Source: O`Neil, A.M 2005.
Chassis design for SAE Racer, University of Southern Queensland.

Application of equal and opposite forces act at a certain distance from an axis tends to rotate the body about the same axis. Automobiles also experience torsion while moving on road subjected to forces of different magnitudes acting on one or two oppositely opposed corners of the cars as shown in Figure 2.7. The frame can be thought as a torsion spring connecting the two ends where suspension loads act. Torsional loading and resultant momentary elastic or permanent plastic deformation and subsequent unwanted deflections of suspension springs can affect the handling as well as performance of the car. The resistance to torsional deformation is called as stiffness and it is expressed in Nm/degree in SI units. Torsional rigidity is a foremost and primary determinant of frame performance of cars.

2.6.2 Vertical Bending

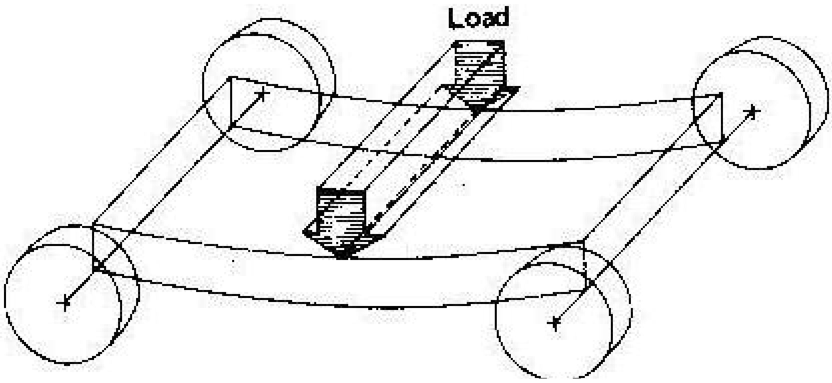


Figure 2.7: Vertical Bending

Source: O`Neil, A.M 2005. Chassis design for SAE Racer, University of Southern Queensland

Weight of driver, engine, drive-train, radiator and shell etc. Under an effect of gravity produce sagging in the frame as shown in Figure 2.8. The frame is assumed to act as simply supported beam and four wheels as supports tend to produce reactions vertically upward at the axles. Vertical dynamic forces due to acceleration/deceleration further increase the vertical deflections, hence stresses in the chassis.

2.6.3 Lateral Bending

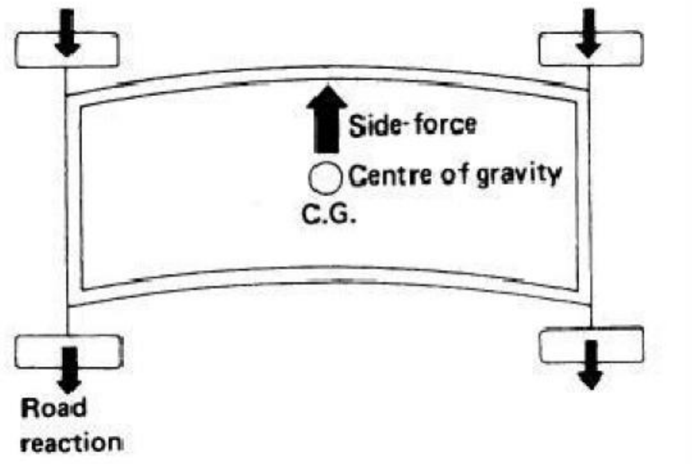


Figure 2.8: Lateral Bending

Source: O`Neil, A.M 2005. Chassis design for SAE Racer, University of Southern Queensland

Lateral bending deformation occurs mainly due to the centrifugal forces caused during cornering and wind forces to some extent. Lateral forces act along the length of the chassis and is resisted by axles, tires and frame members viz. Hoops, side impact members and diagonal hoops etc. As shown in Figure below.

2.6.4 Horizontal Lozenging

This deformation is caused by forward and backward forces applied at opposite wheels. These forces may be caused by vertical variations in the pavement or the reaction from the road driving the car forward. These forces tend to distort the frame into a parallelogram shape as shown in the Figure 2.10. The magnitude of these load changes with the operating mode of the car.

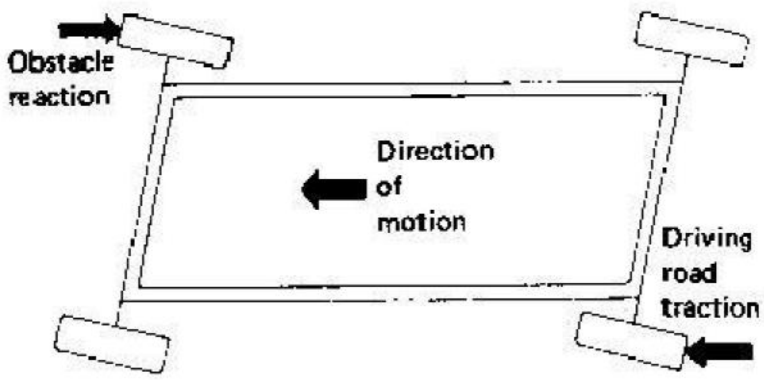


Figure 2.9: Horizontal Lozenging

Source: O`Neil, A.M 2005. Chassis design for SAE Racer, University of Southern Queensland

2.6.5 Load Estimation

Here we will define how the load acting onto the car chassis. On this subject of analysis, we focused on the type of vertical load only which by clear means, we take account the weight of the driver as well as the engine and equipment that caused the frame to sag. We don't apply suspension system due to the simplicity of the design based on the rules provided by the organizer. In fact, the tire itself acts like a suspension on the road. This analysis basically considers the static load which means we do not observe the result in dynamic condition.

2.7 ANALYSIS METHOD

2.7.3 Stress Analysis

The analysis that will be done is stress analysis. Stress analysis is an engineering (civil engineering and mechanical engineering) discipline that determines the stress in materials and structures subjected to static or dynamic forces or loads. A stress analysis is required for the study and design of structures, tunnels, dams, mechanical parts, and structural frames among others, under prescribed or expected loads. Stress analysis may be applied as a design step to structures that do not yet exist (Jaeger, John Conrad; Cook, N.G.W, & Zimmerman, R.W. 2007).

The aim of the analysis is usually to determine whether the element or collection of elements, usually referred to as a structure, can safely withstand the specified forces. This is achieved when the determined stress from the applied forces is less than the ultimate tensile strength, ultimate compressive strength or fatigue strength the material is known to be able to withstand, though ordinarily a factor of safety is applied in the design.

The analysis of stress within a body implies the determination at each point of the body of the magnitudes of the nine stress components. In other words, it is the determination of the internal distribution of stresses.

A key part of the analysis involves determining the type of loads acting on a structure, including tension, compression, shear, torsion, bending, or combinations of such loads. When forces are applied, or expected to be applied, repeatedly, nearly all materials will rupture or fail at a lower stress than they would otherwise. The analysis to determine stresses under these cyclic loading conditions is termed fatigue analysis and is most often applied to aerodynamic structural systems.

2.7.2 Finite Element Method (FEM)

The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as integral equations. A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in the design and development of their products (Giuseppe Pelosi 2007). Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements. FEM software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy required and associated computational time requirements can be managed simultaneously to address most engineering applications. FEM allows entire designs to be constructed, refined, and optimized before the design is manufactured. For this study, the analysis will be focusing on static load and beam using the finite element formula.

The Bernoulli-Euler or classical model assumes that the internal energy of beam member is entirely due to bending strains and stresses. Bending produces axial stresses σxx , which will be abbreviated to σ, and axial strains exx , which will be abbreviated to e. The strains can be linked to the displacements by differentiating the axial displacement u(x) of (2.72):

$$e=\frac{\delta u}{\delta x}=-y\ \frac{\delta_2 v}{\delta x2}=-y\frac{\delta 2v}{\delta x2}=-yv^{\|}=-yk \qquad (2.72)$$

Here κ denotes the deformed beam axis curvature, which to first order is κ ≈ d2v/dx2 = v The bending stress σ = σxx is linked to e through the one-dimensional Hooke’s law

$$\sigma=Ee=-Ey\frac{d2v}{dx2}=-Eyk \qquad (2.73)$$

Where E is the longitudinal elastic modulus. The most important stress resultant in classical beam theory is the bending moment M, which is defined as the cross section integral

$$M=\int_A\ -y\delta\ dA=\frac{d2v}{dx2}\int_a\ y^2\,dA=EIk \qquad (2.74)$$

Here I ≡ Izz denotes the moment of inertia A y2 dA of the cross section with respect to the z (neutral) axis. The bending moment M is considered positive if it compresses the upper portion: y > 0, of the beam cross section. The product E I is called the bending rigidity of the beam with respect to flexure about the z axis.

2.7.3 Solidworks

SolidWorks is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and is being developed by Dassault Systèmes SolidWorks Corp., A subsidiary of Dassault Systèmes, S. A. (Vélizy, France). SolidWorks is currently used by over 1.3 million engineers and designers at more than 130,000 companies worldwide (Solidworks Company History. Solidworks Official Website).
Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry (SolidWorks. Oct 10, 2011 Retrieved 2011-10-10.).

Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalence relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced features such as finite element method (FEM).

2.8 SUMMARY

This chapter presents the detail information of chassis type and the comparison between each type. In this chapter, the suitable chassis type for the new design is determined from the comparison. The description of the spaceframe chassis is described in this chapter followed by the literature analysis. Spaceframe consists of front box, cockpit, engine compartment and rear box. The details about design consideration, the choice of chassis design, the material selection and load criteria of the chassis and also the software used are explained in details in this chapter. Literature analysis contains the information about the sources gained in order to complete this project.

CHAPTER 3

ANALYSIS OF EXISTING DESIGN

3.1 INTRODUCTION

In this chapter, the previous design of shell eco-marathon urban concept car made by team UMP SAE will be analyzed using SOLIDWORK and find the problem and failed. Using the analysis data, the new improve design will be made. The method of analysis the previous design and new design will be shown clearly in this chapter.

3.2 EXISTING DESIGN OF SHELL ECO-MARATHON ASIA 2011

The previous design of the UMP SAE team for urban concept car chassis is not a perfect chassis with none exact analysis done. The chassis is based on stainless steel pipe. For the improvement for the chassis, the aluminum alloy will be replaced for the stainless steel. The previous design will be analyzed using Solidwork software under certain condition to see where the part can be improved. The design will be compared to the new design later on. The figure below shows the previous design of urban concept car for 2011 team.

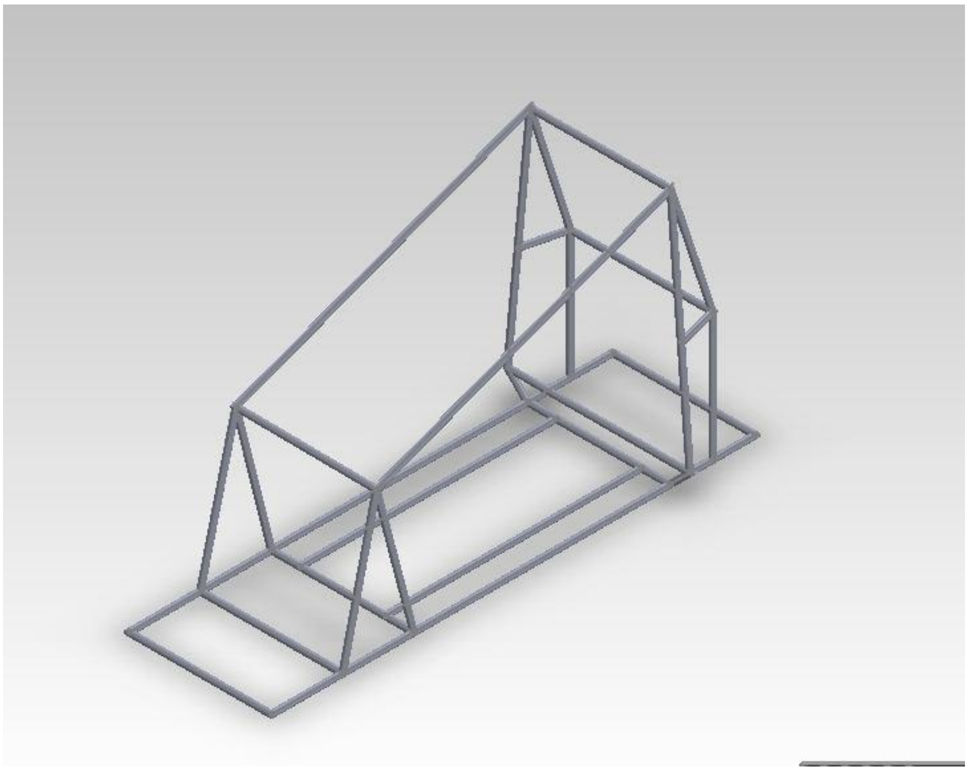


Figure 3.1: Existing chassis using Solidwork

The design was built based on the rules and regulation of Shell Eco-marathon 2011.The dimension of the chassis considers the driver compartment, luggage compartment, wheel base, height and width of the car.

3.3 Load Estimation (Load acting on chassis)

Firstly, we will define how the load acting onto the car chassis. On this subject of analysis, we focused on the type of vertical load only which by clear means, we take account the weight of the driver as well as the engine and equipment that caused the frame to sag. We don't apply suspension system due to the simplicity of the design based on the rules provided by the organizer. In fact, the tire itself acts like a suspension on the road. This analysis basically considers the static load which means we do not observe the result in dynamic condition.

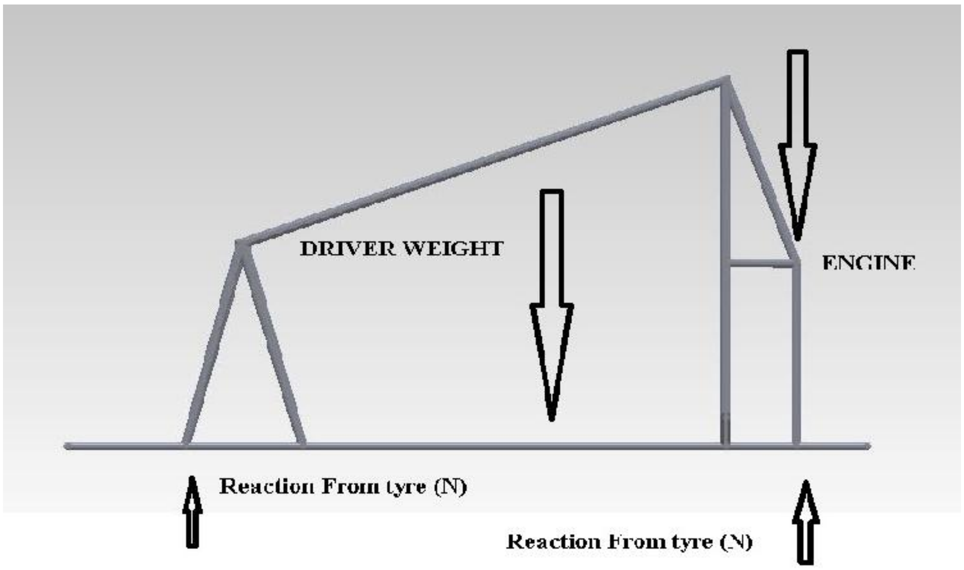


Figure 3.2: Load acted upon the previous chassis

Figure 3.2: Figure shows the correspond load that acted upon the previous design. Total weight is the sum of driver weight, engine and equipment that attached. The following table shows the approximated masses of the previous chassis design analysis.

Table 3.1: Table shown the approximated mass of the previous car model

Components	Masses (Kg)
Car body (not shown)	20
Engine	10
Driver	60
Equipment (not shown in figure)	20
Chassis	50
Total	160kg

3.4 METHOD OF ANALYSIS

3.4.1 Geometric generation

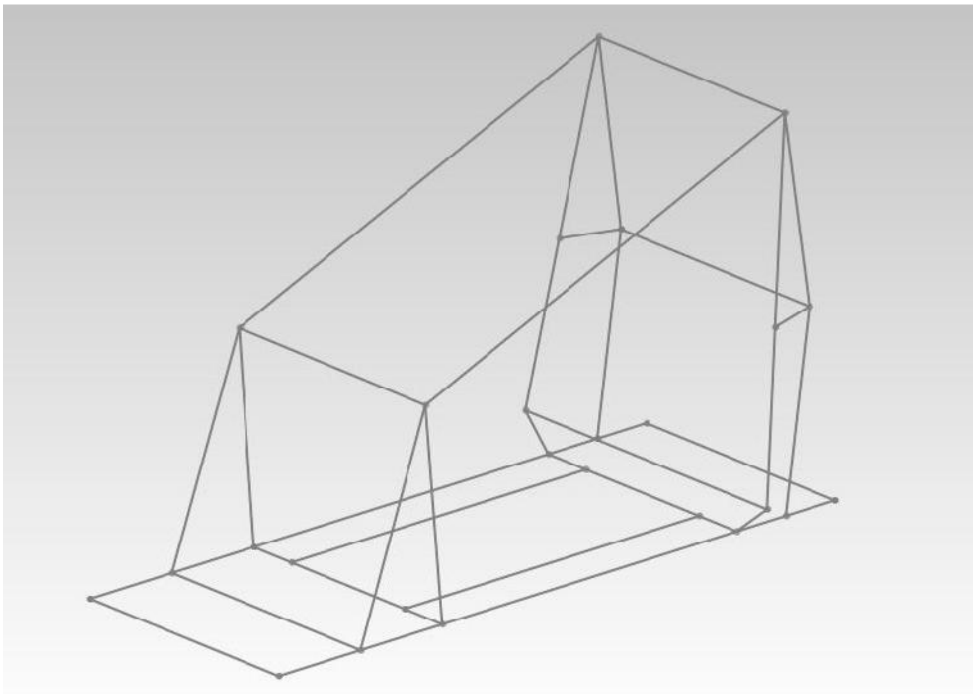


Figure 3.3: Geometry line of previous chassis

Figure 3.3 shows the line geometry that created in three dimensional sketching feature wire frame using SOLIDWORK for the urban concept car for the SEM 2011 team.

3.4.2 Dividing and define the beam elements

The chassis component was divided into several nodes so that it is now in the form of finite element. The greater number of elements created, the greater the accuracy of the result that will be obtained. Once the finite element model has been created, we will now identify the type of elements used for the nodes. The model could use more than one element type with different mesh or the density of the element. For each of the finite element models generated, the decision was made to use the beam as element type, analysis type linear static stress with linear material models.

3.4.3 Material Information

Material properties are one the most important engineering components in finite analysis. In this study, we define the material based on previous design which is stainless steel. . Material properties will define how the material behaves under applied load. The material information is as follows.

Table 3.2: Mechanical properties of AISI Type 304 stainless steel

Ultimate tensile strength	485 MPa
Density (°)	7860 Kg m^{-3}
Modulus of elasticity (E)	200 GPa
Shear Strength	152 MPa

3.4.4 Boundary and loading conditions

In this analysis we will focus on the load exerted by the driver. Thus the highest concentrated load is upon the structure of the driver pit section. Here we assigned the load distributed along the structure.

3.4.5 Solving the model

As the chassis was modeled in finite element with nodes and boundary condition, we are ready to run the simulation. A final check is performed to see the direction of the applied force to ensure we get the correct result. There is the button “check” the model so that we know that the system is ready. As the system is ready, they will build up a set solution. All the data simulated will be stored in this set solution. For verification of the data, this set solution will include data for boundary condition, the output selection and other relevant option that related to the result. Once the simulation is completely performed, it will display the result and we analyzed by using post processing. This includes the three main results that related to our objectives that is displacement, stress and strain as well as worst scenario for both stress and strain.

3.5 NEW DESIGN

3.5.1 Design B

Figure 3.4 shows the first design. This is based on the existing design. The chassis is simplified to decrease the part being used. The chassis is analyzed to find the weight and displacement.

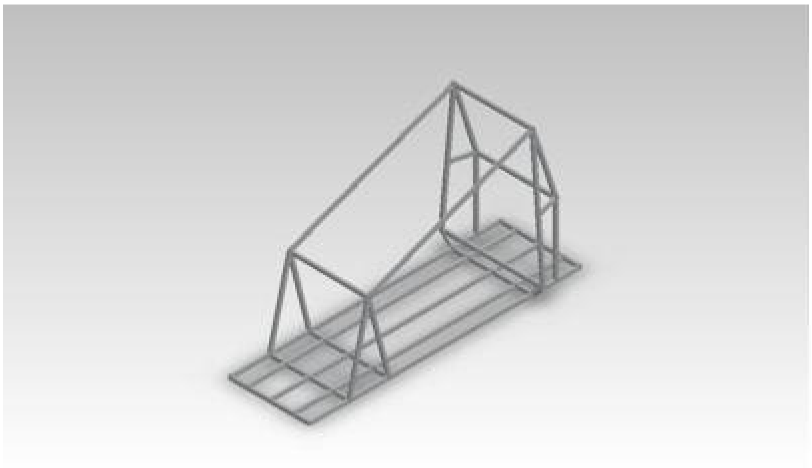


Figure 3.4: Chassis Design B

3.5.2 Design C

Figure 3.5 shows the new second design. This design is made simple to decrease weight. The chassis is analyzed to find the weight and displacement.

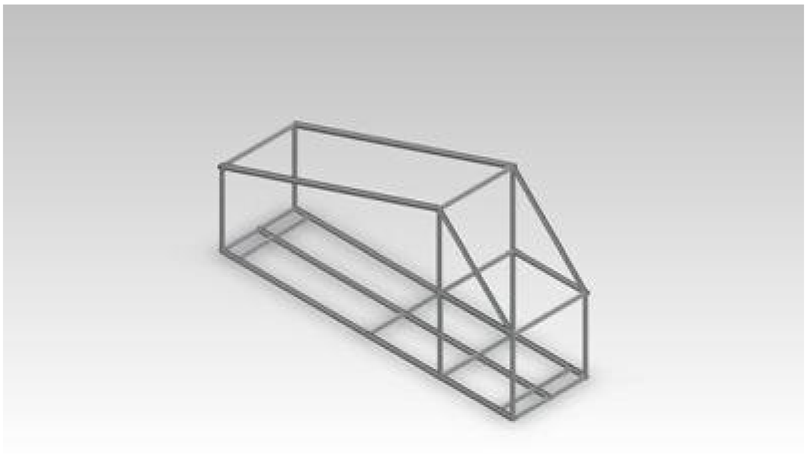


Figure 3.5: Chassis Design C

3.5.3 Design D

Figure 3.6 shows the new third design. The design is for compact and lighter car for one seat urban car type which is the regulation of Shell Eco-marathon.

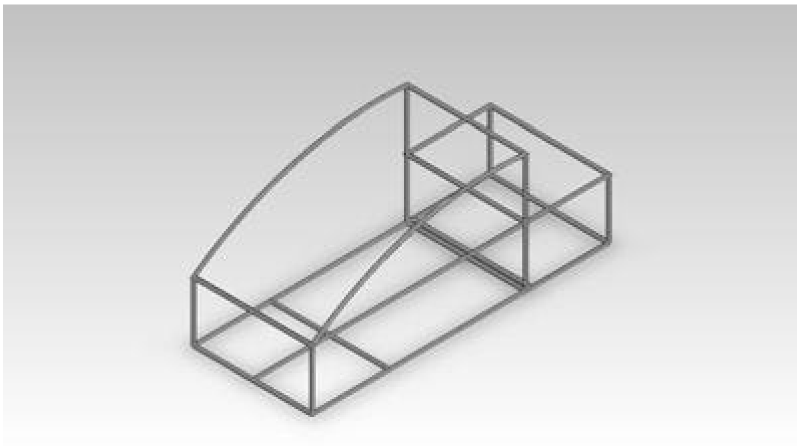


Figure 3.6: Chassis Design D

3.5.4 Design E

Figure 3.7 shows the fourth design. The design is for big and heavy engine load. Also the compartment adds more structure to support the chassis.

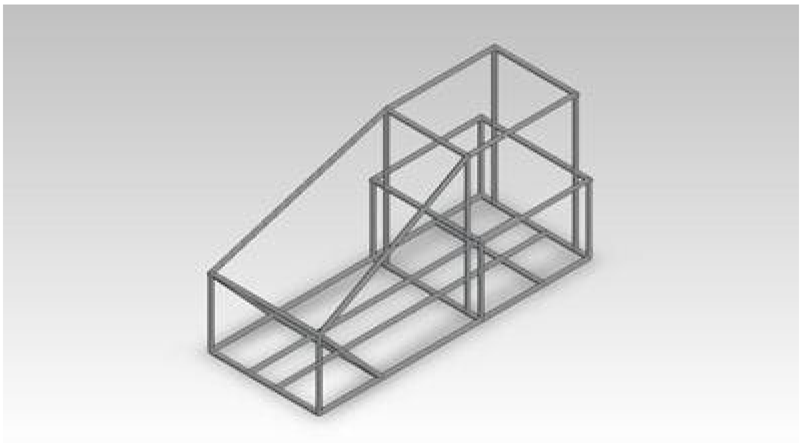


Figure 3.7: Chassis Design E

3.7 BODY SHELL PROPOSED FOR ALL OF THE DESIGNS.

Table 3.7: Body shell proposed to use with new chassis design

	Model 1	Model 2	Model 3	Model 4	Model 5
Right view					
Front view					
Top view					

3.7 ANALYSIS

The analysis was done using Solidwork software to check the displacement of the chassis when it is loaded with engine and driver. The driver weight is stated 700N based on the regulations needed by Shell Eco-marathon. The engine weight is approximately 200N which is located at the back of the chassis.

First, the dimension of the chassis is drawn in Solidwork software. The element type use beam. After that the element definition is edited. The beam type is pipe and the material will be selected which is aluminum. The existing chassis is used Stainless Steel AISI type 304.

When the design is completed, the several points are fixed based on the path that will move during the loading analysis. The load is located in the driver compartment and the engine compartment to see the displacement of the chassis because mostly all the load will focus on that point.

3.8 SUMMARY

Chapter 3 discuss about the existing chassis design of Shell Eco Marathon 2010. From the design, we will make analysis in solidwork to determine the problem and failed. From the result we will discuss and make improvement to the design. The analysis will be shown in chapter 4.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 INTRODUCTION

This chapter will contain about the results obtained from the analysis using SOLIDWORKS software. The analysis is based on 4 new models and the existing model which is from 2011 UMP SEM urban team. All of the designs are compared with low displacement and lightweight chassis. The load acting on the chassis will be divided by two compartments which is a driver and engine compartment. Other than that, all of the 4 new designs will be tested using aluminum 6061-T6 (SS) and using two different sizes of aluminum pipe. For this, the best chassis will low displacement and most lightweight will be chosen as recommendations for the next competition.

4.1 EXISTING DESIGN ANALYSIS (MODEL A)

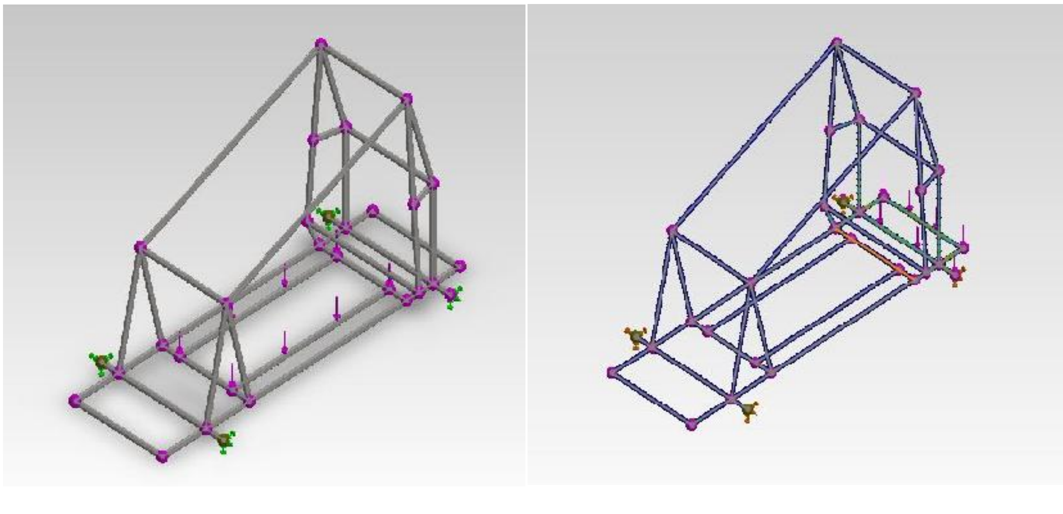
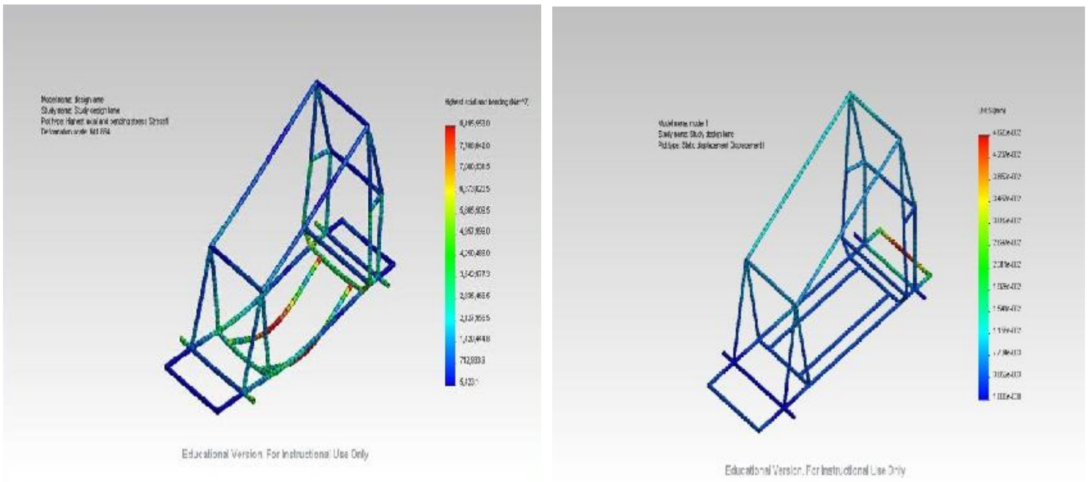


Figure 4.1: Force acts on driver (a) and engine (b) compartment

The existing design using Stainless steel AISI type 304 is analyzing with 700N load on the driver compartment and 200N load on the engine compartment. Assume all of the force is being distributed onto the chassis.

4.1.1 Result analysis on existing design

For Figure 4.1.1 using Stainless steel AISI 304 pipe with 26.9 x 3.2 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.271062 mm for driver compartment and 0.0462262 mm for engine compartment.



(a) (b)

Figure 4.2: Displacement for driver (a) and engine (b) load

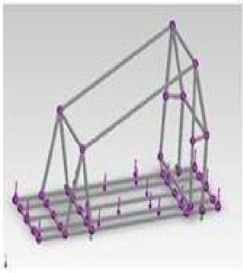
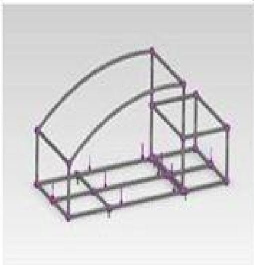
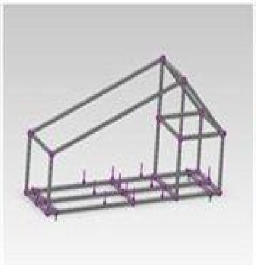
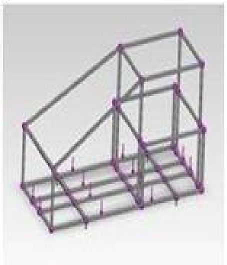
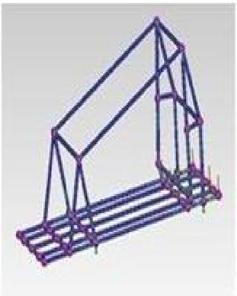
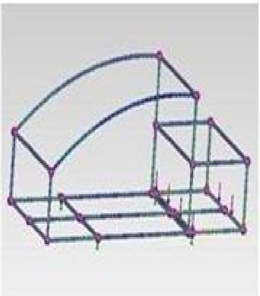
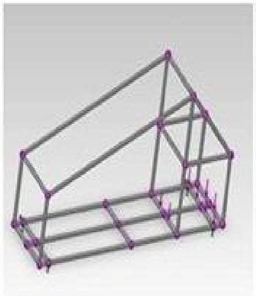
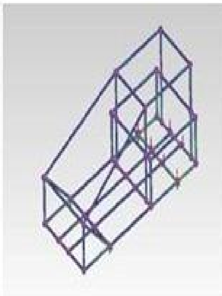
Figure 4.2 shows the displacement of the driver and engine compartment when the force acting on the chassis.

Table 4.2: Data Analysis of Existing Design Using Stainless Steel AISI 304

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
26.9 x 3.2	42.73	0.271062	0.0462262

4.1.2 The force acts on four new designs on driver and engine compartment

Table 4.1.2: Force on driver and engine compartment for the new designs

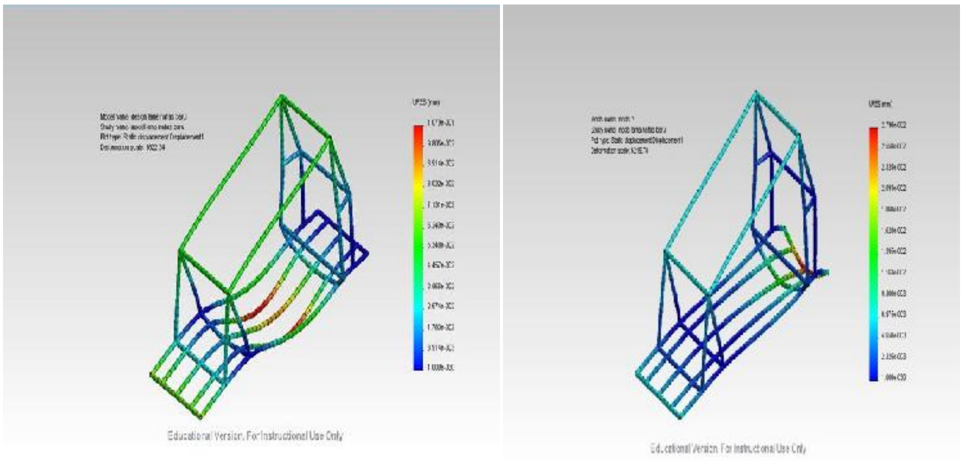
	Models			
	B	C	D	E
Driver compartment				
Engine compartment				

4.2 NEW DESIGN ANALYSIS USES 26.9 X 3.2 MM ALUMINUM 6061-T6 PIPE

Analysis on new model using aluminum 6061-T6 (SS) (model 2, 3, 4, 5) and the material size is 26.9 x 3.2 mm**.** The force acting on driver load is 700N and engine load is 200N

4.2.1 Result Analysis of Model B (26.9 x 3.2 mm aluminum pipe)

For Figure 4.2.1 using aluminum 6061-T6 pipe with 26.9 x 3.2 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.106966 mm for driver compartment and 0.0279007 mm for engine compartment.



(a) (b)

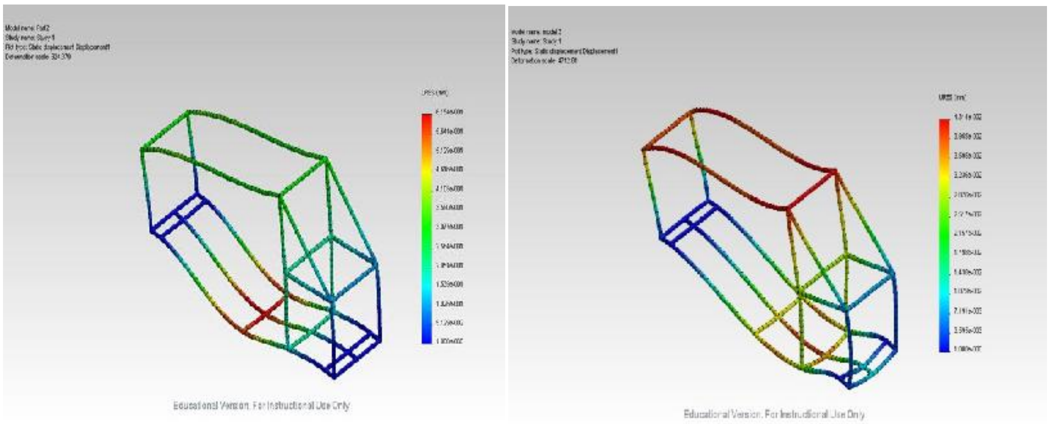
Figure 4.2.1: Displacement for driver (a) and engine (b) load

Table 4.2.1: Data Analysis of model B Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
26.9 x 3.2	13.65	0.106966	0.0279007

4.2.2 Result Analysis of Model C (26.9 x 3.2 mm aluminum pipe)

For Figure 4.2.2 using aluminum 6061-T6 pipe with 26.9 x 3.2 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.615424 mm for driver compartment and 0.0431436 mm for engine compartment.



(a) (b)

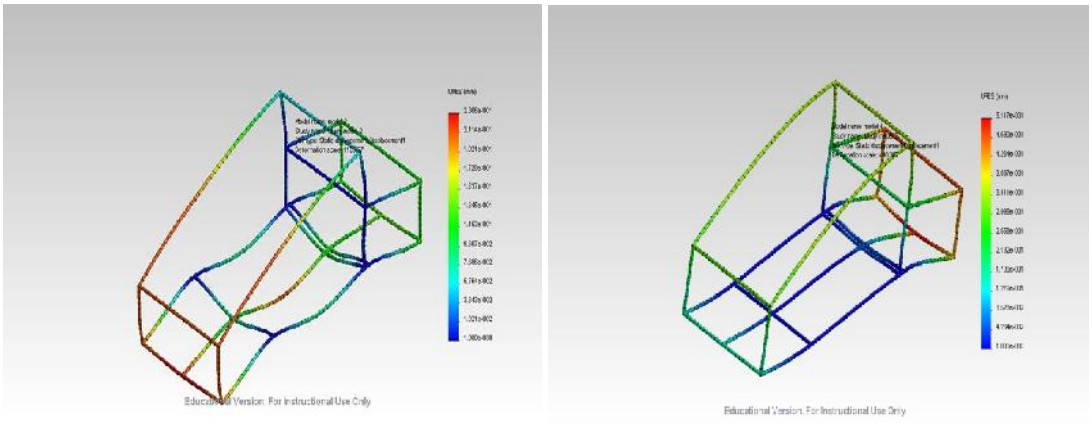
Figure 4.2.2: Displacement for driver (a) and engine (b) load

Table 4.2.2: Data Analysis of model C Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
26.9 x 3.2	13.24	0.615424	0.0431436

4.2.3 Result Analysis of Model D (26.9 x 3.2 mm aluminum pipe)

For Figure 4.2.3 using aluminum 6061-T6 pipe with 26.9 x 3.2 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.230574 mm for driver compartment and 0.511664 mm for engine compartment.



(a) (b)

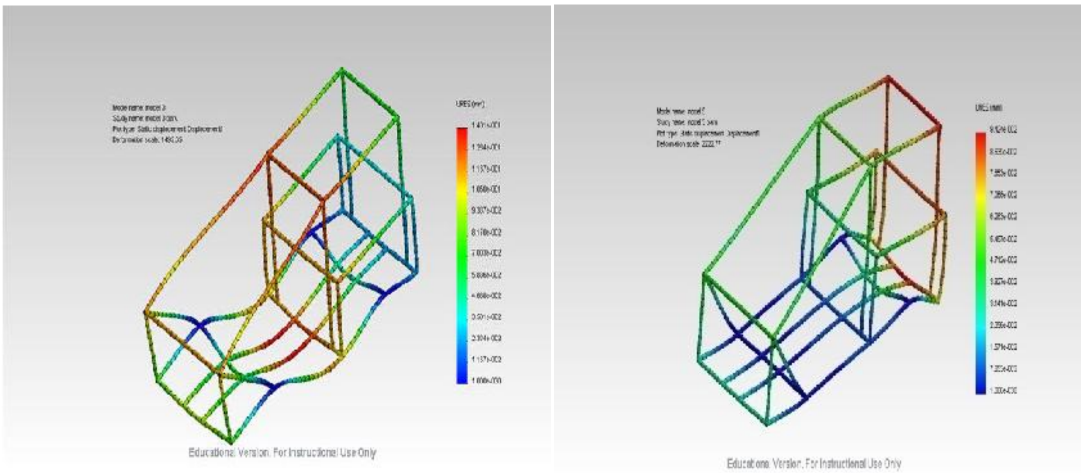
Figure 4.2.3: Displacement for driver (a) and engine (b) load

Table 4.2.3: Data Analysis of model D Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
26.9 x 3.2	16.54	0.230574	0.511664

4.2.4 Result Analysis of Model E (26.9 x 3.2 mm aluminum pipe)

For Figure 4.2.4 using aluminum 6061-T6 pipe with 26.9 x 3.2 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.140054 mm for driver compartment and 00.0942394 mm for engine compartment.



(a) (b)

Figure 4.2.4: Displacement for driver (a) and engine (b) load

Table 4.2.4: Data Analysis of model E Using Aluminum 6061-T6

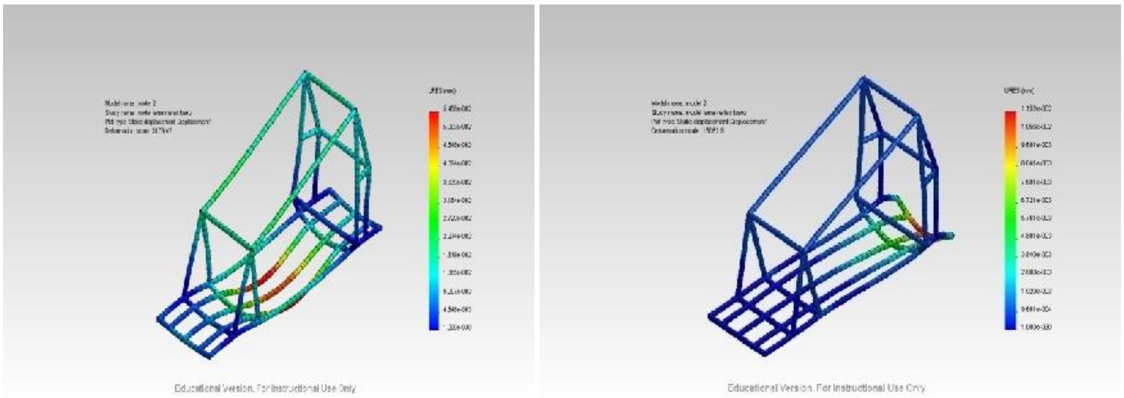
Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
26.9 x 3.2	19.15	0.140054	0.0942394

4.3 New Design Analysis uses 33.7 x 4.0 mm aluminum pipe

Analysis on new model using aluminum 6061-T6 (SS) (model 2, 3, 4, 5) and the material size is 33.7 x 4.0mm**.** The force acting on driver load is 700N and engine load is 200N.

4.3.1 Result Analysis of Model B (33.7 x 4.0 mm aluminum pipe)

For Figure 4.3.1 using aluminum 6061-T6 pipe with 33.7 x 4.0 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.0545814 mm for driver compartment and .0115215 mm for engine compartment.



(a) (b)

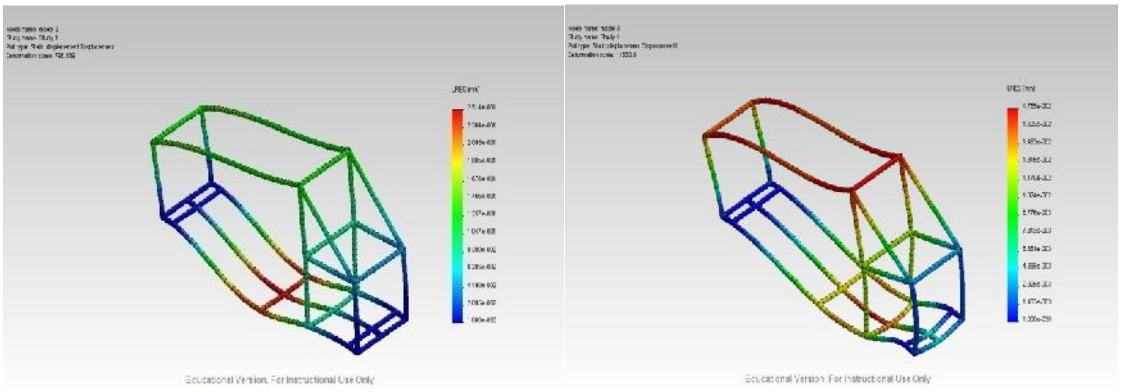
Figure 4.3.1: Displacement for driver (a) and engine (b) load

Table 4.3.1: Data Analysis of model B Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
33.7 x 4.0	21.43	0.0545814	0.0115215

4.3.2 Result Analysis of Model C (33.7 x 4.0 mm aluminum pipe)

For Figure 4.3.2 using aluminum 6061-T6 pipe with 33.7 x 4.0 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 00.251386 mm for driver compartment and 0.017552 mm for engine compartment.



(a) (b)

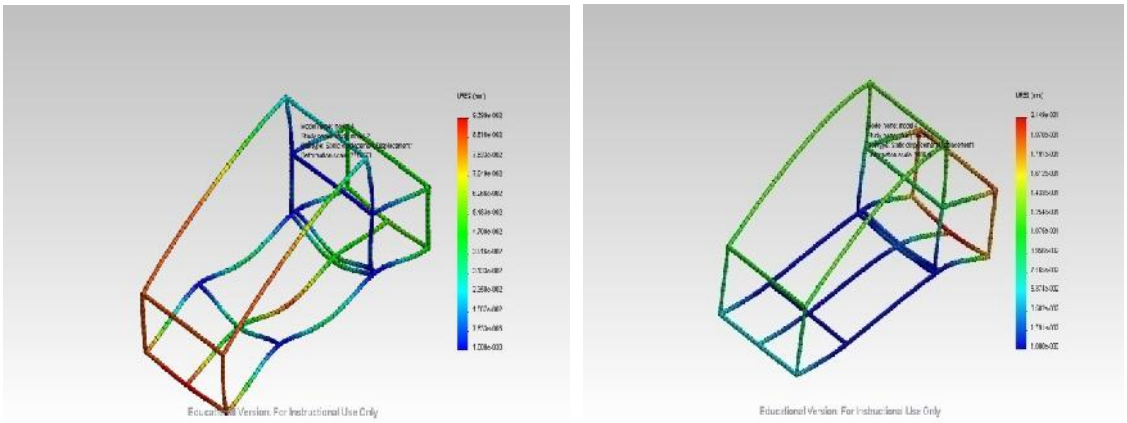
Figure 4.3.2: Displacement for driver (a) and engine (b) load

Table 4.3.2: Data Analysis of model C Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
33.7 x 4.0	20.74	0.251386	0.017552

4.3.3 Result Analysis of Model D (33.7 x 4.0 mm aluminum pipe)

For Figure 4.3.3 using aluminum 6061-T6 pipe with 33.7 x 4.0 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.0939933 mm for driver compartment and 0.214942 mm for engine compartment.



(a) (b)

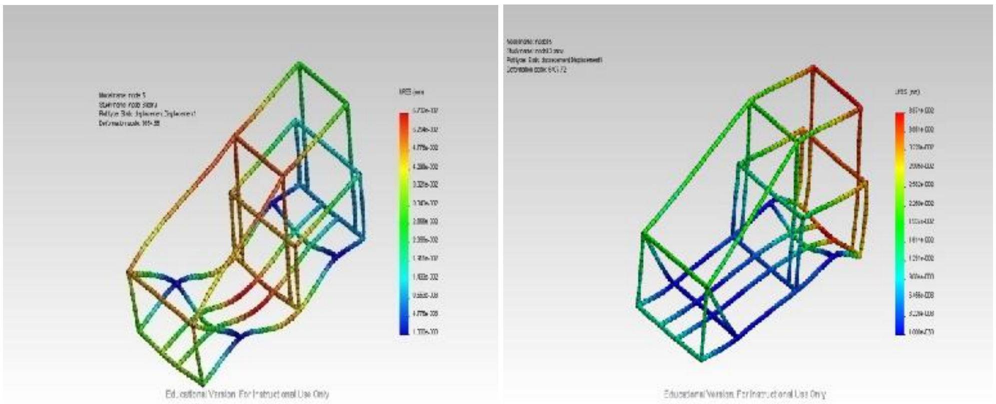
Figure 4.3.3: Displacement for driver (a) and engine (b) load

Table 4.3.3: Data Analysis of model D Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
33.7 x 4.0	25.92	0.0939933	0.214942

4.3.4 Result Analysis of Model E (33.7 x 4.0 mm aluminum pipe)

For Figure 4.3.4 using aluminum 6061-T6 pipe with 33.7 x 4.0 mm size, the minimum value which is area of blue color is 0 mm and the highest displacement which is shown with red color is 0.0573165 mm for driver compartment and 0.0387358 mm for engine compartment.



(a) (b)

Figure 4.3.4: Displacement for driver and engine load

Table 4.3.4: Data Analysis of model E Using Aluminum 6061-T6

Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
33.7 x 4.0	30.0	0.0573165	0.0387358

4.4 Comparison of displacement using 26.9 *x 3.2 mm* size material

Table 4.4: comparison of data analysis using 26.9 x 3.2 mm aluminum 6061-T6

Models	Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
A	26.9 x 3.2	42.73	0.271062	0.0462262
B	26.9 x 3.2	13.65	0.106966	0.0279007
C	26.9 x 3.2	13.24	0.615424	0.0431436
D	26.9 x 3.2	16.54	0.230574	0.511664
E	26.9 x 3.2	19.15	0.140054	0.0942394

4.5 COMPARISON OF DISPLACEMENT USING 33.7 *X 4.0 MM* SIZE MATERIAL

Table 4.5: comparison of data analysis using 33.7 x 4.0 mm aluminum 6061-T6

Models	Size of material, mm	Weight, kg	Displacement (driver load), mm	Displacement (engine load), mm
B	33.7 x 4.0	21.34	0.0545814	0.0115215
C	33.7 x 4.0	20.74	0.251386	0.017552
D	33.7 x 4.0	25.92	0.0939933	0.214942
E	33.7 x 4.0	30.0	0.0573165	0.0387358

4.6 ANALYSIS COMPARISON RESULTS

Based on the results, the graph effect of weight on different models with different aluminum pipe size, figure 4.6.1 can be made. The relation of the graph show that the weight increases when the diameter of pipe is increased. Design C using 26.9 x 3.2 mm aluminum 6061-T6 pipe has lower weight compared to other design.

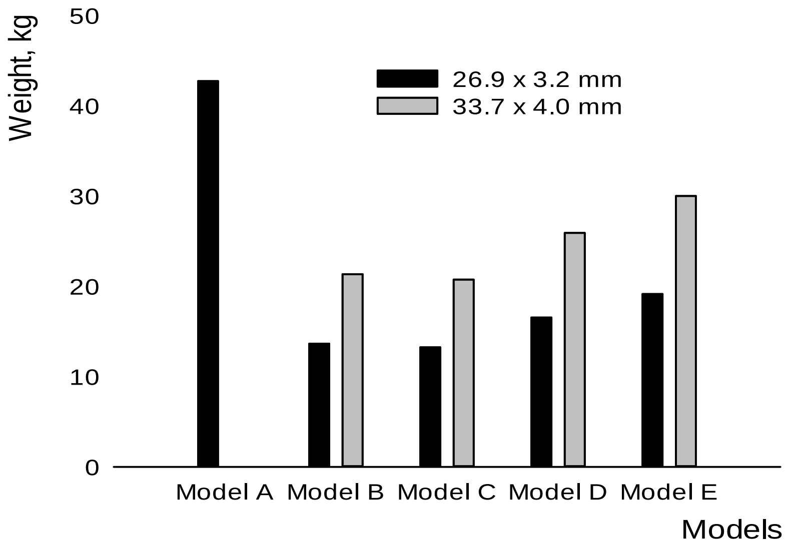


Figure 4.6.1: Effect of weight on different models with different aluminum pipe size.

Based on figures 4.6.2, models B has the lowest displacement on driver compartment comparing to the other design. Design C has the largest displacement due to the driver load.

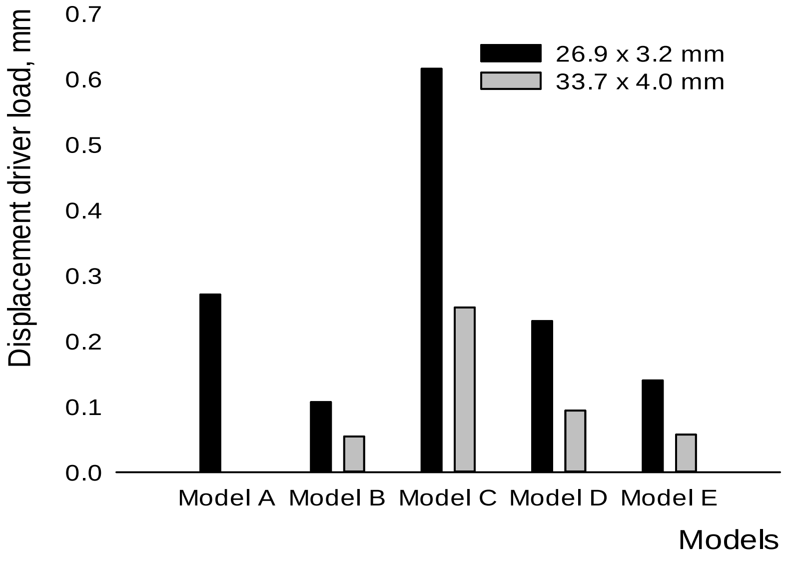


Figure 4.6.2: Effect of displacement on driver load on different models with different aluminum pipe size.

Based on figures 4.6.3, models B has the lowest displacement on engine compartment comparing to the other design. Design C has the largest displacement due to the engine load.

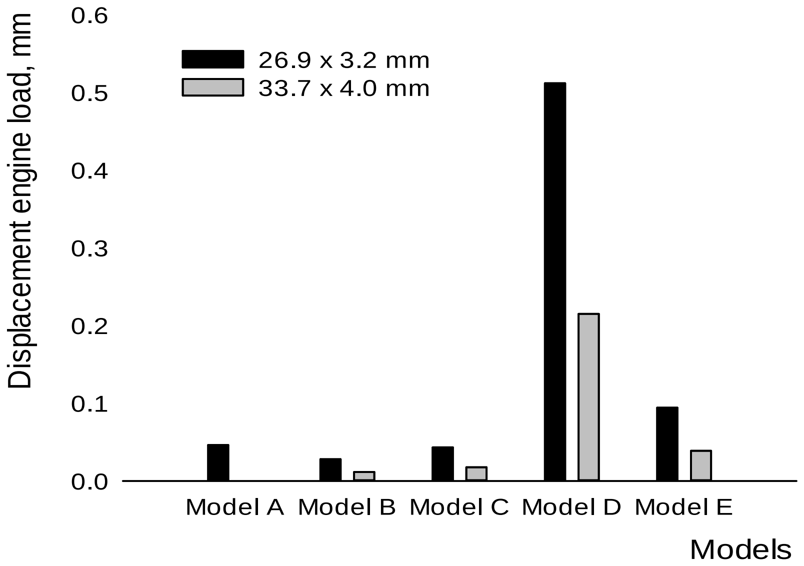


Figure 4.6.3: Effect of displacement on engine load on different models with different aluminum pipe size.

Based on the figure 4.6.4, the best design is being chosen after the parameters of the chassis have been compared. The parameters are weight, engine compartment displacement, and driver compartment displacement. The models have been rated from 1 to 5 scales. The best parameter is 5 and the bad parameter is 1.

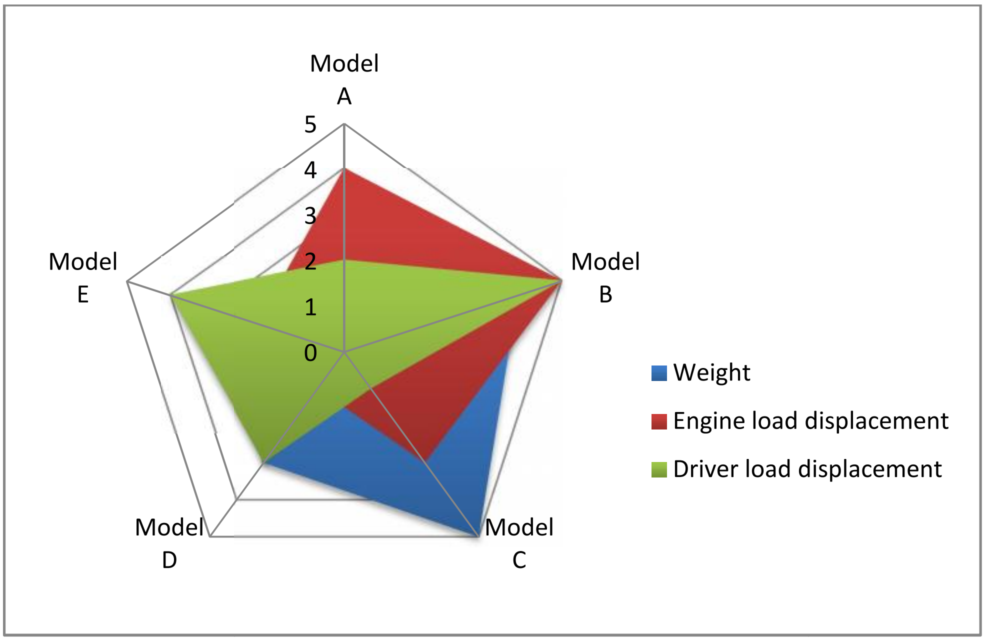


Figure 4.6.4: Radar chart for chassis parameters

Table 4.6.4: Parameters for all chassis models

Parameters	Model A	Model B	Model C	Model D	Model E
Weight	1	4	5	3	2
Engine load displacement	4	5	3	1	2
Driver load displacement	2	5	1	3	4

Table 4.6.5: Total Parameters

Models	Total Parameters
A	7
B	14
C	9
D	7
E	8

4.7 DISCUSSION

To choose the best design, all of data have been compared using radar chart. Firstly we choose the aluminum 6061-T6 26.9 x 3.2 mm pipe because of the graph, this aluminum pipe size gives lower weight compared to another pipe size.

As stated in chapter 2, aluminum 6061-T6 is widely used as pipe and chassis (Zeuger, 2009). 26.9 x 3.2 mm aluminum 6061-T6 pipe is the 1st option to be used as next chassis material, followed by 33.7 x 4.0 mm pipe due to the weight factor.

Model B using aluminum pipe provides a relevant mass of the chassis which is 13.65 kg compared to the other models respectively. It shows the decrement about 68% of mass compared to the previous models that using Stainless steel AISI 304.

From radar chart, the parameters (weight, driver and engine displacement load) of design B more higher than the other design followed by model C. Model no B which is the improved design from last year chassis have 50% more total parameters than the existing design (model A).

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

In industry especially automotive industry, the cost is the one of the important factors in producing the product. The automotive industry is seeking for low cost material, lightweight and best material properties. This is needed to improve the design and performance of the vehicles they produce.

The analysis of the previous chassis was done in order to identify the weakness of the chassis structure. The considered stories of the development are weight reduction purpose and reducing the bending displacement of the chassis structure.

New chassis design of urban car is analyzed which able to withstand the load applied to the structure and cause minimum bending displacement. The design must be suitable as to get the best result and less displacement. If the design is lightweight, but the displacement if the chassis is big, there is no safety for the user. The best design must be lightweight but also has less displacement and better material properties.

Design for model B is the most suitable to be proposed for next competition due to 68% decrement of chassis mass, slightly reduced the maximum displacement magnitude for both driver and engine compartment.

5.2 RECOMMENDATION

The design of the chassis that has been analyzed should be fabricated for the next UMP SEM urban concept car. This analysis has ensured that it is safe enough to be used. The best way to joint all the part is by welding it using gas tungsten arc welding or also known as tungsten inert gas (TIG) welding. For the competition purposed, the best body shell for urban concept car is carbon fiber and all the equipment and parts should use lightweight material also.

REFERENCES

Gartner, M. (1999). *General Spaceframe Chassis Principals*. Retrieved March 29, 2010, from http://www.gmecca.com/byorc/dtipschassis.html#ChasisGeneral.

Henningsgraad, A., & Yanchar, C. (1998). Technical Paper. *Carbon Fiber Reinforced Steel Spaceframe Techniques.* University of Minnesota, Twin Cities.

Keith, J. (2009). *Introduction to Chassis Design.* Memorial University of Newfoundland And Labrador.

Leisha, A., & Kelly, J. (2001). Magazine's Newsletter. *Finite-Element Structural Analysis: A New Tool for Bicycle Frame Design.* Pegasus Research Company, USA.

SolidWorks. Oct 10, 2011. Retrieved 2011-10-10. SolidWorks Fact Sheet, March 2010 Jaeger, John Conrad; Cook, N.G.W, & Zimmerman, R.W. (2007).
Fundamentals of rock mechanics (Fourth Ed.). Wiley-Blackwell. pp. 9–41.

Giuseppe Pelosi (2007). "The finite-element method, Part I: R. L. Courant: Historical Corner". doi:10.1109/MAP.2007.376627.

E. Stein (2009), Olgierd C. Zienkiewicz, a pioneer in the development of the finite element method in engineering science. Steel Construction, 2 (4), 264-272.

Matrix Analysis Of Framed Structures, 3rd Edition by Jr. William Weaver, James M. Gere, 3rd Edition, Springer-Verlag New York, LLC, ISBN 978-0-412-07861-3, First edition 1966.

A.Faieza, S. M. Sapuan, M. K. A. Ariffin, B. T. H. T. Baharudin & E. E. Supeni. (2009). Academic Journals. *Design and Fabrication of a Student Competition Based Racing Car.* University Putra Malaysia, Malaysia.

Abrams, & Ryan. (2008). Technical Paper. *Formula SAE Race Car Analysis: Simulation & Testing of the Engine as a Structural Member.* The University of Western Ontario, Canada.

Alexander, M. (2008). Thesis. *Design, Manufacturing, and Verification of a Steel Tube Spaceframe Chassis for Formula SAE.* Institute Technology of Massachusetts.

Christoper, S. (2004). Technical Paper. *FoES Formula SAE-A Spaceframe Chassis Design.* University of Southern Queensland.

Erik, H., & Johan, P. (2008). Bachelor's Thesis. *Analysis and Optimization of a Race Car Chassis.* University Technology of Lulea.

APENDIX

GAN CHART FYP 1

GAN CHART FYP 2