DESIGN AND ANALYSIS OF CAR CHASSIS

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DESIGN AND ANALYSIS OF CAR CHASSIS

MOHAMAD SAZUAN BIN SARIFUDIN

A report submitted for partial fulfilment of the requirement for the Diploma of Mechanical Engineering award.

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JANUARY 2012

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion this project is satisfactory in terms of scope and quality for the Final Year Project.

Signature :
Name of Supervisor : HADI BIN ABDUL SALAAM
Position : LECTURER
Date : 9 JANUARY 2012

STUDENT'S DECLARATION

I declare that this report titled "Design and Analysis of Car Chassis" and the result that from my research based on the references that have been used in order to complete it. This project report not been accepted for degree, and not submit in candidature of any other degree.

Signature	: …………………………………..
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ID Number	: MB09077
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DEDICATION

To my parents especially and friends, also for whom with their effort to support me in order for me to pursue study in higher education, and also in order to complete this project and project report to fulfil the requirement for Diploma of Mechanical Engineering award.

To my supervisor too, Hadi bin Abdul Salaam, to the all lecturers, my family and friends and all the Mechanical Stuff with their helpful suggestions, guidance and assistance in order for me completes this Final Year Project for diploma course.

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Bless towards Allah the Almighty and Most Graceful for giving me the opportunity to finish my project, design and analysis of car chassis. I am also give my most sincere gratitude to my supervisor Hadi bin Abdul Salaam for his helpful ideas, priceless guidance, never ending encouragement and constant support for making this research a success. He has always gives us the professional conduct along with his enthusiasm for science and his principle in making my project worthy to be proud of. I am all grateful for his concern in our progress research, his tolerance in my mistakes and weakness and his full support for to my future career.

I am also give our thanks to my lab mates and members of the staff of the Mechanical Engineering Department, UMP, who has lend a hand to me in multiple ways and making my presences in UMP unforgettable and pleasant. I can't thank more for their cooperation, supports and inspiration in my research.

I am acknowledging my gratitude and indebtedness to my parents for their everlasting support, hopes and sacrifices towards us. It's their sincerity which gave us more spirit to study more in my research in this project making it a success. Without them, I may have not gone this far. Many thanks again to all for making this project a success.

ABSTRACT

This project concerns on the assessment on making an analysis of the car chassis will fit all aspects and concepts according to the rules of Eco Marathon Challenge. The objective of this project to design and analyse of car chassis. To avoid any possibilities of failure of the structure and thus to provide enough supporting member to make the region stronger in term of deformation. Finite element analysis enables to predict the region that tends to fail due to loading. Besides that, need to utilize the feature of CAE software named as FEMPRO to get the distribution of stress and strain on the chassis, both component as well as the material costing. The main objective is to study the effect of load that applied in term of driver weight, the car body and the equipment.

ABSTRAK

Projek ini menekankan pembelajaran berkenaan dengan cara–cara menganalisa terhadap casis kereta berdasarkan undang-undang yang terdapat di dalam pertandingan Shell Eco Marathon. Objektif projek ini ada untuk mebuat rekaan adan menganalisa casis kereta. Untuk menghindarkan sebarang kemungkinan kegagalan struktur casis kereta dan membrikan sokongan yang secukupnya kepada casis kereta. Analisa “Finite element” membantu untuk mengesan kawasan yang berkemungkinan akan gagal. Perisian CAE atau FEMPRO digunakan untuk mendapatkan taburan “stress” dan “strain”. Tambahan pula, tujuan utama adalah untuk menelaah kesan bebanan hasil daripada berat pemandu, berat body dan berat kelengkapan tambahan.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

σ	True Stress, Local Stress
δ	Displacement Magnitude
ε	True Strain, Local Strain
%	Percent
$K_{B,}$	Bending Stiffness
K_T	Torsion Stiffness
°C	Degree Celsius
°F	Degree Fahrenheit
Cr	Chromium
Fe	Iron
Mg	Magnesium
Mn	Manganese
Si	Silicon
Ti	Titanium
Cu	Copper
Al	Aluminium
Zn	Zinc
C	Carbon
S	Sulphur
θ	Angle
CAE	Computer-aided Engineering
FEA	Finite Element Analysis

FYP	Final Year Project
UMP	Universiti Malaysia Pahang
AA	Aluminium Alloy
SUV	Sport Utility Vehicle
USA	United States of America
3D	Three-dimensional

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Many types of pollution such as water pollution, noise pollution, thermal pollution and air pollution. Air pollution can be considered as one of the main hazard to the health of human being. The air pollution is due to the increasing number of vehicle use by human. When the number of vehicle increase, the usage of the petrol increase respectively. The lack of the source of the petrol makes the price increase by time to time. The emission from the vehicle makes the environment faces the air pollution that in critical level.

Many steps need to reduce the number of the vehicle in other side to reduce the price of the petrol. Besides that also use to reduce the air pollution. The big number of vehicles in each country makes the prevention to reduce the number of vehicle difficult. So, the other prevention is increase the efficiency of the vehicle's engine. When the engine at the efficient level, the emission is at the low level and the most important is the usage of petrol is low. The prevention is reducing the weight of the body and chassis of each vehicle.

This project focused to reduce the usage of petrol by design and analysis the chassis to reduce the weight of the chassis of vehicle. At the same time, the global usage of the petrol also reduced.

1.1 PROBLEM STATEMENT

Nowadays, the usage of transport increasing day to day on the road. The number increase due to those people that usually choose to use own vehicle than public transport. When the vehicle number increase, the price of petrol (fuel) also increase. At the same time, the emissions from the vehicles increase the air pollution. The prevention steps need to reduce the number of car and price of petrol. Cars emitted high emission and use high amount of petrol when the cars have bigger weight. Preventive step by reducing the weight of the body and chassis can reduce the usage of petrol.

1.2 OBJECTIVES

1.2.1 General Objectives

The objective of this project is to expose to the student on the process of design and analysis of a product. In addition, student also able to apply their knowledge and their skill that have learnt during class and outside class. Besides, student also can add their knowledge by make this project. The project challenge the student to do research and solving any problem that will be appeared towards a successful project.

Student able to practice his own soft skill on how to communicate well wit person to person by the presentation section. Besides, it can train student's capability in answering, questioning, researching, evaluating, data gathering, decision making, planning and problem solving by the research during this project.

From this project, student able to make a good research in technical writing. Furthermore, this project can encourage the student how to be more independent in searching, detailing, and expanding their knowledge and also have own experience under minimal supervisory.

1.2.2 Specific Objectives

The main objectives of this project are as follows:

i. To evaluate current chassis
ii. To redesign car chassis
iii. To analyze in term of structure failure using Algor software

1.3 SCOPES

i. This car is designed for Shell Eco Marathon Challenge (Asia) for 2012 in prototype category.
ii. Design stage for this project using Solidworks software.
iii. Algor software is used to analyze the stress at the car chassis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Basically chassis is considered as a framework to support the body, engine and other parts which make up the vehicle. Chassis lends the whole vehicle support and rigidity. Chassis usually includes a pair of longitudinally extending channels and multiple transverse cross members that intersect the channels. The transverse members have a reduced cross section in order to allow for a longitudinally extending storage space. The chassis has to contain the various components required for the race car as well as being based around a driver's cockpit. The safety of the chassis is a major aspect in the design, and should be considered through all stages. Generally, the basic chassis types consist of backbone, ladder, spaceframe and monocoque. Different types of chassis design result the different performance.

2.2 Terminology

The propose of car chassis is to maintain the shape of the vehicle and to support the various loads applied to it. The structure usually accounts for a large proportion of the development and manufacturing cost in new vehicle programme and many different structural concepts are available to the designer. It is essential that the best one is chosen to ensure acceptable structural performance within other design constraints such as cost, volume and method of production, product application and many more. Assessments of the performance of a vehicle structure are related to its strength and stiffness. A design aim is to achieve sufficient levels of these with as little mass as possible. (Jason, 2002)

2.2.1 Strength

The strength requirement implies that no part of the shape will lose its function when it is subjected to road loads. Loss of function may be caused by instantaneous overloads due to extreme load cases, or by material fatigue. Instantaneous failure may be caused by either overstressing of components beyond the elastic limit, or by buckling of items in compression or shear stress, or by failure of the joints.

The life to initiation of fatigue cracks is highly dependent on design detail, and can only be assessed when a detailed knowledge of the component is available. For this reason assessment of fatigue strength is usually deferred until after the conceptual design stage.

The strength may be alternatively defined as the maximum force which the structure can withstand. Different load cases different local component loads, but the structure must have sufficient strength for all load cases. (Jason, 2002)

2.2.2 Stiffness

The stiffness of the structure relates the deflection produced when load is applied. It applies only to structures in the elastic range and is the slope of the load versus deflection graph.

The stiffness of a vehicle structure has important influence on its handling and vibrational behaviour. It is important to ensure that deflection due to extreme loads is not so large to impair the function of the vehicle, for an example so that the doors will not close, or suspension geometry is altered. Low stiffness are lead to unacceptable vibrations, such as ‘scuttle shake’. (Jason, 2002)

Again different load cases require different stiffness definitions, and some of these are often used as 'benchmarks' of vehicle structural performance. The two most commonly used in this way are (Jason, 2002):

a) Bending stiffness $\mathbf{K_B}$, which relates the symmetrical vertical deflection of a point near the centre of the wheelbase to multiples of the total static loads on the vehicle. A simplified version of this to relate the deflection to a single, symmetrically applied load near the centre of the wheelbase.
b) Torsion stiffness $\mathbf{K_T}$, relates the torsional deflection θ of the structure to an applied pure torque T about the longitudinal axis of the vehicle. The vehicle is subjected to the 'pure torsion load case'. Twist angle is measured between the front and rear suspension mountings. Twist are intermediate points along the wheelbase is sometimes also measured in order to highlight regions of the structure needing stiffening.

The two cases apply completely different local loads to individual components within the vehicle. It is usually found that the torsion case is the most difficult to design for, so that the torsion stiffness is often used as a benchmark to indicate the effectiveness of the vehicle structure. (Jason, 2002)

2.2.3 Vibrational behaviour

The global vibritional characteristics of a vehicle are related to both its stiffness and mass distribution. The frequencies of the global bending and torsional vibration modes are commonly used as benchmarks for vehicle structural performance. These are not discussed in this book. However, bending and torsion stiffness K_B and K_T influence the vibrational behaviour of the structure, particularly its first natural frequency. (Jason, 2002)

2.2.4 Selection of vehicle type and concept

In order to achieve a satisfactory structure, the following must be selected (Jason, 2002):

a) The most appropriate structural type for the intended application.
b) The correct layout of structural elements to ensure satisfactory load paths, without discontinuities, through the vehicle structure.
c) Appropriate sizing of panels and sections, and good detail design of joints.

An assumption made in this book is that is satisfactory load path (i.e. if the equilibrium of edge forces between simple structural surfaces) are achieved, then the vehicle is likely to have the foundation for sufficient structural (and especially torsion) stiffness. Estimate of interface loads between major body components calculated by the simplified methods described are assumed to be sufficiently accurate for conceptual design although the structural members comprising load paths must still be sized appropriately for satisfactory results. Early estimates of stiffness can be obtained using the finite element method, but the results should be treated with caution because of simplifications in the idealization of the structure at this stage. (Jason, 2002)

2.3 TYPE OF CHASSSIS

Chassis is considered to be one of the significant structures of an automobile. Itis usually made of a steel frame, which holds the body and motor of an automotive vehicle. To be precise, car chassis or automobile chassis is a skeletal frame which bolts various mechanical parts like engine, tires, brakes, steering and axle assemblies. Chassis usually made of light a metal or composite plastic which provides strength needed for supporting vehicle components and load into it. Here I listed several different types of automotive chassis which include ladder chassis, backbone chassis, monocoque chassis and tubular space frame chassis (Wakeham, 2009).

Ladder chassis is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still been used by most of the SUVs till today. It is also resembles a shape of a ladder which having two longitudinal rails inter linked by several lateral and cross braces. The lateral and cross members provide rigidity to the structure (Wakeham, 2009).

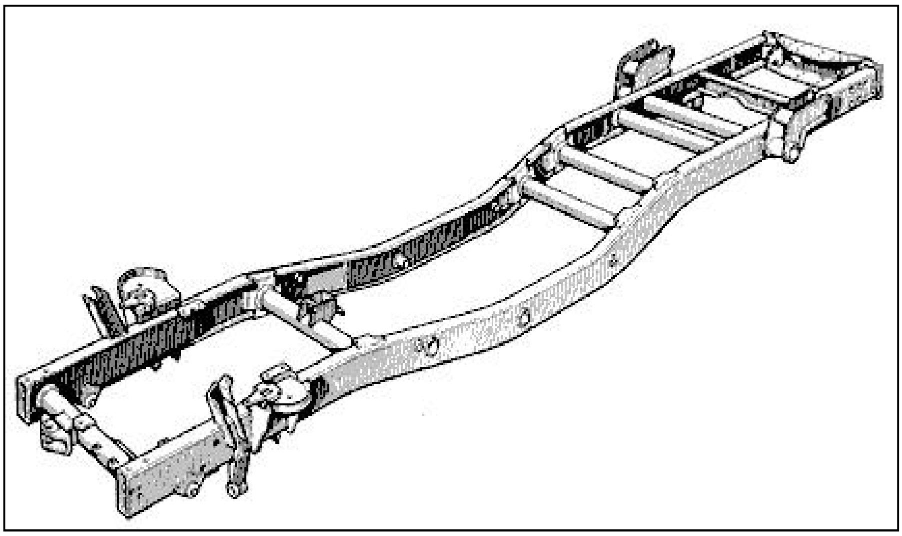

Figure 2.1: Ladder chassis

Source: (Moginalong, 2010)

The other type of chassis is backbone chassis which has a rectangular tube like backbone and simple in structure. It usually made up of glass fiber that is used for joining front and rear axle together and responsible for most of the mechanical strength of the framework. The space within the structure is used for positioning the drive shaft in case a rear-wheel drive. Furthermore, the drive train, engine and suspensions are all connected to each of the ends of the chassis. This type of chassis is strong enough to provide support smaller sports car besides it is easy to make and cost effective (Wakeham, 2009).

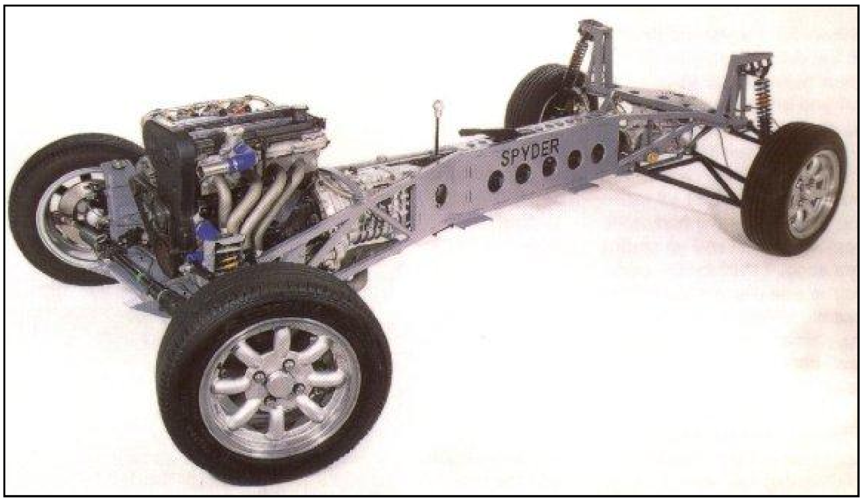

Figure 2.2: Backbone chassis

Source: (Which K, 2002)

As for monocoque chassis, most modern cars nowadays use this type of chassis.A monocoque chassis is a single piece of framework that gives shape to the car. A one-piece chassis is built by welding several pieces together. It is different from the ladder and backbone chassis as unlike them incorporated with the body in a single piece, where as the former only support the stress members. The demanding of a monocoque chassis highly increased since it is cost effective and suitable for robotized production (Christopher, 2004).

Figure 2.3: Monocoque chassis

Source: (Mark Wan, 2000)

In this study, it is decided that tubular space frame chassis is used for the urban car. Since ladder chassis is not strong enough, motor racing engineers have developed a 3-dimensional design which known as tubular space frame. Tubular space frame chassis employs dozens of circular-section tubes (some may use square-section tubes for easier connection to the body panels though circular section provides the maximum strength), position in different directions to provide mechanical strength against forces from anywhere. These tubes are welded together and form a complex structure. For higher strength required by high performance sports cars, tubular space frame chassis usually incorporate a strong structure under both doors. Tubular space frame chassis also very strong in any direction compared with ladder chassis and monocoque chassis of the same weight.

Figure 2.4: Spaceframe chassis

Source: (Wan, 2000)

2.4 CHASSIS DESIGN PRINCIPLE

The fundamental principle of a chassis design states that the chassis is to be designed to achieve the torsional rigidity and light weight in order to achieve good handling performance of a race car. By the definition, torsional rigidity is refers to the ability of chassis to resist twisting force or torque. In the other words, torsional rigidity is the amount of torque required to twist the frame by one degree. These parameters also applied to spaceframe chassis. Generally, the effect of the torsional rigidity on spaceframe is different to the monocoque due to their construction format, but the structure is used to approximate the same results as the difficult to twist monocoque chassis. Figure 2.5 shows the torsional rigidity applies to race car chassis. (Matt, 1999).

According to the statement above, chassis designed must have high torsional rigidity in order against the twisting force or torque. In order to increase torsional rigidity on the chassis, the format of tube pipes arrangement must be considered. By strategically positioning a frame member, torsional rigidity increase significantly.

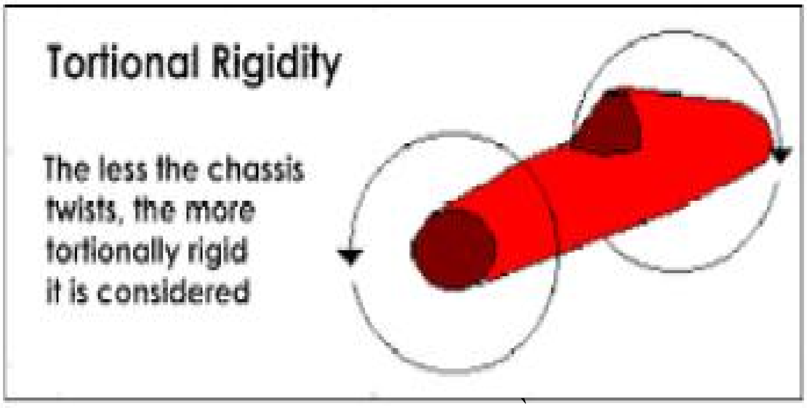

Figure 2.5: Tortional rigid of car chassis

Source: (Matt, 1999)

The triangulated box imparts strength by stressing the diagonal in tension and compression. As shown, the box will not easily deformed by bending force due to the triangulated format of frame. Hence, most race car chassis today designed in triangulated format as shown in Figure 2.6 below. (Matt, 1999).

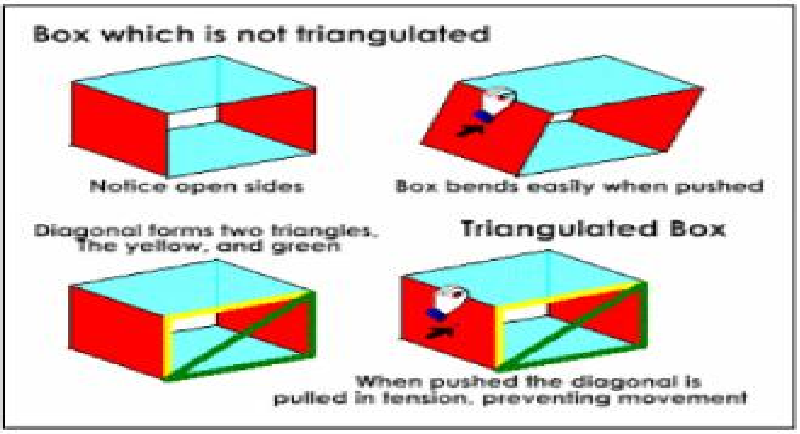

Figure 2.6: The strategy on positioning spaceframe number

Source: (Matt, 1999)

2.5 MATERIALS

Different chassis materials can reduce the weight of the vehicle, improving the vehicle power to weight ratio. Material selection can also provide advantages by reducing member deflection, increasing chassis strength and can determine the amount of reinforcement required.

2.5.1 STAINLESS STEEL

Stainless steel is selected as engineering material mainly because of their excellent corrosion resistance in many environments. The corrosion resistance of stainless steel is due to their high chromium contents. In order to make a “stainless steel” stainless, there must be at least 12 percent chromium (Cr) in the steel. According to the classical theory, chromium forms a surface oxide that protects the underlying iron-chromium alloy from corroding. To produce the protective oxide, the stainless steel must be exposed to oxidizing agents. (William, 2006). In the design principles, 317 is a higher chromium, nickel and molybdenum version of 316 stainless designed principally for increased strength and corrosion resistance. Machinability for this type of stainless steel is Low speeds and constant feeds will minimize this alloy's tendency to work hardens. Tougher than 304 stainless with a long stringy chip, the use of chip breakers is recommended. Welding process can be using all common fusion and resistance methods except oxyacetylene welding have proven successful. Use AWS E/ER317 or 317L filler metal for best results. All common hot working processes are possible with this alloy. Heat to 2100-2300°F (1149-1260°C). Avoid working this material below 1700°F (927°C). For optimum corrosion resistance, a post-work annealing is recommended and Shearing, stamping, heading and drawing can be successfully performed. To remove internal stresses, a post-work annealing is recommended. Mechanical properties and typical composition of Stainless Steel (AISI 317) is shown in Table 2.1 and Table 2.2.

Table 2.1: Mechanical properties of Stainless Steel (AISI 317)

Properties	Value and unit
Ultimate tensile strength	70 MPa
Density	8.0 g/cm3
Modulus of elasticity	200 GPa
Shear strength	152 MPa
Yield strength (0.2% offset)	205 MPa
Melting point	1454 °C
Elongation	35%

Table 2.2: Typical composition of Stainless Steel (AISI 317)

Element	Value
Ni	11-14
Cr	18-20
C	0.08 max
Mo	3-4
Fe	Balance
Mn	2 max
Si	1 max
S	0.03 max
P	0.04 max

2.5.2 ALUMINIUM

Aluminium is a nonferrous material with very high corrosion resistance and very light material compared to steels. Aluminium cannot match the strength of steel but its strength-to-weight ratio can make it competitive in certain stress application. Aluminium can also be alloyed and heat treated to improve it mechanical properties, which then makes it much more competitive with steels however the cost increases dramatically. Pure aluminium is also a possible material and is reasonably affordable and very light but it is the weakest and requires extra reinforcement to produce a rigid chassis. Aluminium is very hard to work with as it requires very skilled welding and is an overall softer metal. Basically there are several types of aluminium. For this project, decide to test with Aluminium Alloy 6063-T6. Aluminium alloy 6063 is one of the most extensively used of the 6000 series aluminium alloys.

Aluminium Alloy 6063 is the least expensive and most versatile of the heat treatable aluminium alloys. It has most of the good qualities of aluminium. It offers a range of good mechanical properties and good corrosion resistance. It can be fabricated by most of the commonly used techniques. In the annealed condition it has good workability. The typical properties of aluminium alloy 6063 include medium to high strength, good toughness, good surface finishing, excellent corrosion resistance to atmospheric conditions, good workability and widely available. It is welded by all methods and can be furnace brazed. It is available in the clad form ("Alclad") with a thin surface layer of high purity aluminum to improve both appearance and corrosion resistance. This aluminum type is used for a wide variety of products and applications from truck bodies and frames to screw machine parts and structural components. 6063 is used where appearance and better corrosion resistance with good strength are required. Mechanical properties and typical composition of Aluminium Alloy 6063-T6 is shown in Table 2.3 and Table 2.4.

Table 2.3: Mechanical properties of Aluminium Alloy 6063-T6

Properties	Value and unit
Ultimate tensile strength	195MPa
Density	2.7 g/cm3
Modulus of elasticity	69.5GPa
Shear strength	150 MPa
Yield strength (0.2% offset)	160 MPa
Melting point	600 °C
Elongation	14%

Table 2.4: Typical composition of Aluminium Alloy 6063-T6

Element	Value
Cr	0.1
Fe	0.35 max
Mg	0.45 - 0.9
Mn	0.1 max
Si	0.2
Ti	0.1 max
Cu	0.1max
Al	Balance
Zn	0.1 max

2.5.3 IRON

Iron is a lustrous, ductile, malleable, silver-gray metal (group VIII of the periodic table). It is known to exist in four distinct crystalline forms. Iron rusts in dump air, but not in dry air. It dissolves readily in dilute acids. Iron is chemically active and forms two major series of chemical compounds, the bivalent iron (II), or ferrous, compounds and the trivalent iron (III), or ferric, compounds. Iron is the most used of all the metals, including 95 % of all the metal tonnage produced worldwide. Thanks to the combination of low cost and high strength it is indispensable. Its applications go from food containers to family cars, from screwdrivers to washing machines, from cargo ships to paper staples.

Steel is the best known alloy of iron, and some of the forms that iron takes include: pig iron, cast iron, and carbon steel, and wrought iron, alloy steels, iron oxides. Iron is believed to be the tenth most abundant element in the universe. Iron is also the most abundant (by mass, 34.6%) element making up the Earth; the concentration of iron in the various layers of the Earth ranges from high at the inner core to about 5% in the outer crust. Most of this iron is found in various iron oxides, such as the minerals hematite, magnetite, and taconite.

The earth's core is believed to consist largely of a metallic iron-nickel alloy. Iron is essential to almost living things, from micro-organisms to humans. World production of new iron is over 500 million tonnes a year, and recycled iron adds other 300 million tonnes. Economically workable reserves of iron ores exceed 100 billion tonnes. The main mining areas are China, Brazil, Australia, Russia and Ukraine, with sizeable amounts mined in the USA, Canada, Venezuela, Sweden and India. Mechanical properties and typical composition of Iron (Fe) is shown in Table 2.3 and Table 2.4.

Table 2.5: Mechanical properties of Iron, Fe

Properties	Value and unit
Ultimate tensile strength	70 MPa
Density	7.9 g/cm3
Shear strength	45 MPa
Yield strength (0.2% offset)	53 MPa
Melting point	1538°C
Young's modulus	211 GPa

Table 2.6: Typical composition of Iron, Fe

Element	Value
C	3.4
Mg	0.06
Mn	0.4 max
Ni	1.0
P	0.1 max

2.6 MATERIAL MECHANICAL CONCEPT

Many materials display linear elastic behaviour, defined by a linear stress-strain relationship, as shown in the figure up to point 2, in which deformations are completely recoverable upon removal of the load that is, a specimen loaded elastically in tension elongates, but it returns to its original shape and size when unloaded. Beyond this linear region, for ductile materials, such as steel, deformations are plastic. A plastically deformed specimen not returns to its original size and shape when unloaded. Note that there is elastic recovery of a portion of the deformation. For many applications, plastic deformation is unacceptable, and is used as the design limitation.

After the yield point, ductile metals undergo a period of strain hardening, in which the stress increases again with increasing strain, and they begin to neck, as the cross-sectional area of the specimen decreases due to plastic flow. In a sufficiently ductile material, when necking becomes substantial, it causes a reversal of the engineering stress-strain curve (curve A); this is because the engineering stress is calculated assuming the original cross-sectional area before necking. The reversal point is the maximum stress on the engineering stress-strain curve, and the engineering stress coordinate of this point is the tensile ultimate strength, given by point 1. The ultimate tensile strength is not used in the design of ductile static members because design practices dictate the use of the yield stress. It is, however, used for quality control, because of the ease of testing. It is also used to roughly determine material types for unknown samples.

In Figure 2.7 shows the stress vs. strain curve of a ductile material, at point number one (1) is the ultimate tensile strength, refer to the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross section starts to significantly contract. At point number two (2) is yield strength, explained that the boundary between elastic region and plastic region. At the point number three (3) is point for the proportional limit stress, at this point explained that the amount of stress increasing proportional to the increasing of strain. Fracture occurred at the point number four (4). Fracture is the local separation of an object or material into two, or more, pieces under the action of stress. Lastly at point number five (5) is the offset strain (typically 0.2), this offset use in order to find the yield strength of material.

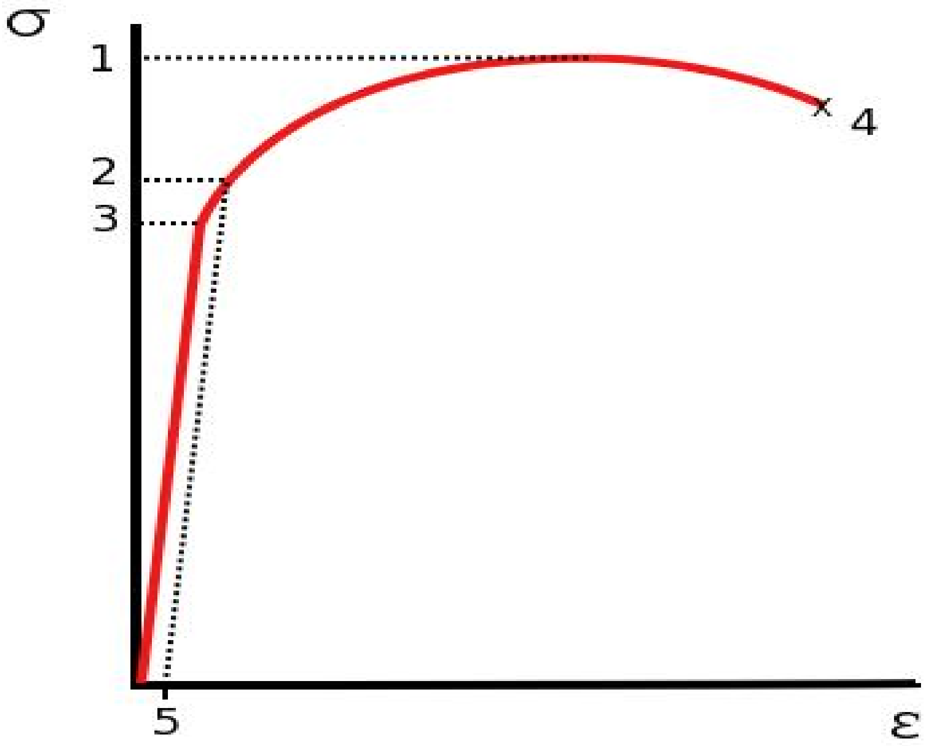

Figure 2.7: Stress vs. strain curve of ductile material

2.7 FINITE ELEMENT ANALYSIS (FEA) USING ALGOR

Finite Element Analysis (FEA) was first developed by R. Courant in 1943, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition (Widas, 1997).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology can properly refer to the theoretical analysis of the methods appropriate to the field of study or to the body of methods and also principles particular to the branch of knowledge. In this sense, one may speak of objections to the methodology of a geographic survey (that is, objections dealing with the appropriateness of the methods used) or of the methodology of modern cognitive psychology (the principles and practices that underlie research in the field).

Spaceframe more rigid to other chassis type, this is the reason race car usually use spaceframe chassis. The chassis not absolutely just a spaceframe chassis, but the combination between the monocoque and also the spaceframe chassis. As the result, driver and engine compartment, the combination reduces the weight of the car.

Theoretically, the chassis design concept state that the chassis designed must have the triangulated format of tubular pipes in order to increase the torsional rigidity of the chassis. But for the designing of the prototype car using spaceframe chassis for car, it is not important to follow this concept because the goals of the design is to have a lightweight car which can cruise further by using less amount of energy. It's mean that, the car will not go faster and not facing the twisting force or torque. The designer will ignore about the principle which is to place the frame members in a triangulated format as mentioned before.

3.2 THE DESIGN PROCESS

The engineering design process is the steps of chassis design construction process . In this chapter explain how chassis was designed and how stimulation of the chassis was performed. In this part, explained how chassis is performed. Before the last chassis design got, there are several steps must be considered to make the last result bring the best design. In this part, start from the sketching process, the n use SOLIDWORKS 2008 is used in order to create the model of the chassis. The analysis stage used ALGOR 23.1 to analyze the, model of chassis.

3.2.1 EVALUATING

Before start the projects, rough ideas and the steps proposed must be drafted to ensure the project within the planned steps. Evaluation process is important to ensure that the design needed have advantages guided from the current design. The ideas or steps can be gained from the evaluation of the current design (2011). The current design has square shape; square shape is not very good aerodynamic shape. The cockpit or driver compartment is not in sleep position. As shown in Figure 3.1.

Figure 3.1: Current design of Eco Marathon Challenge (2011)

The rough idea of the chassis designed is described by sketching the chassis as shown in Figure 3.2. The sketch describes more about monocoque type chassis. The sketch consist driver and engine compartments. Sketch describe the chassis have two tire for front and one tire of rear.

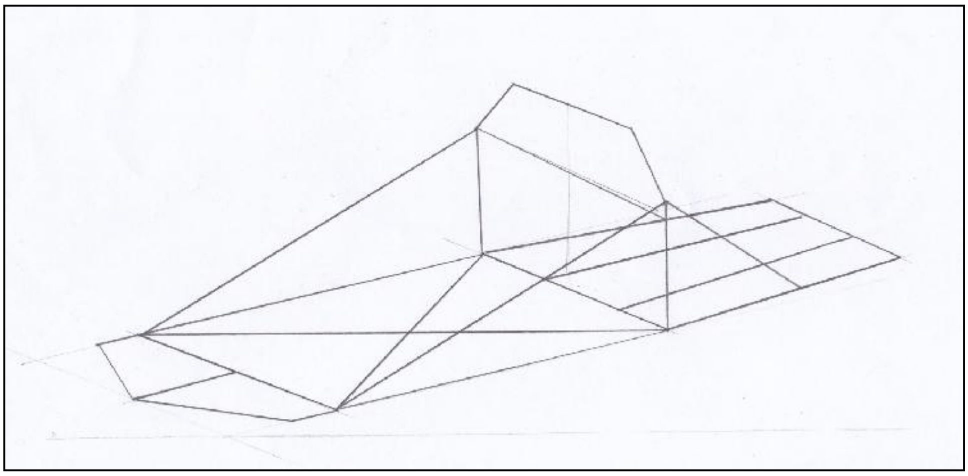

Figure 3.2: Sketch of Design A

The rough idea of the chassis designed is described by sketching the chassis as shown in Figure 3.3. The sketch describes more about frame type chassis. The sketch consist driver and engine compartments. Sketch describe the chassis have two tire for front and one tire of rear.

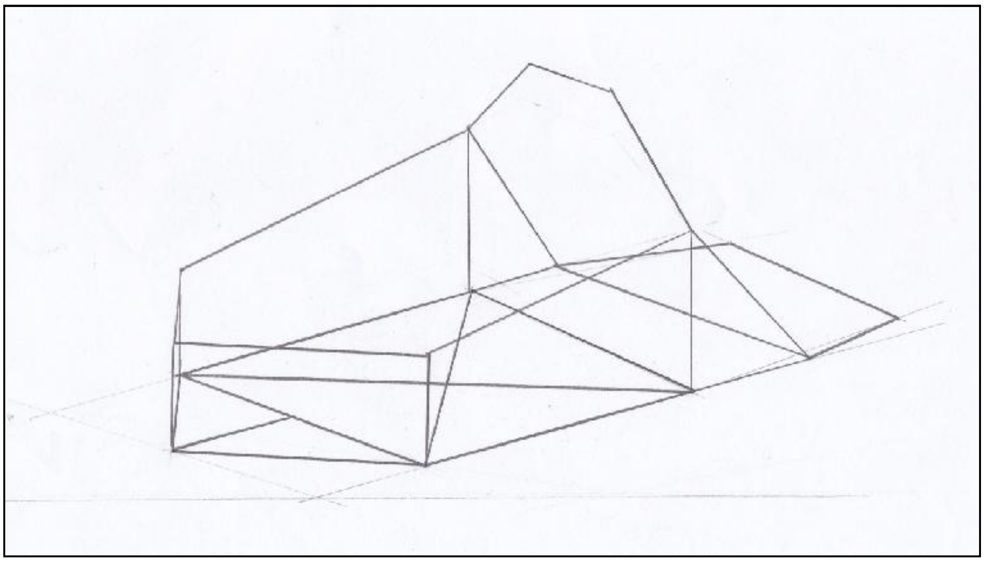

Figure 3.3: Sketch of Design B

The rough idea of the chassis designed is described by sketching the chassis as shown in Figure 3.4. The sketch describes more about frame type chassis. Sketch describe the chassis have two tire for front and one tire of rear.

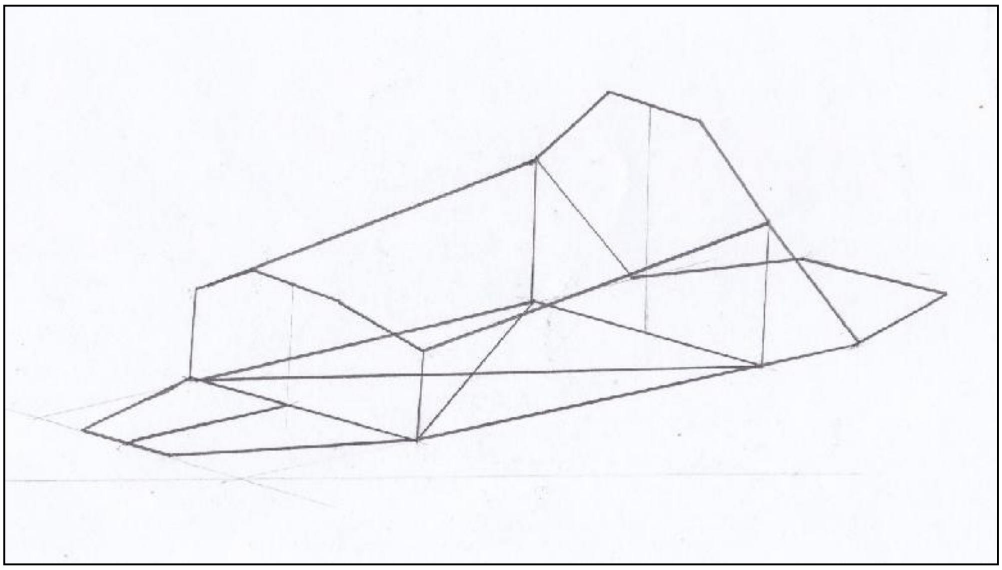

Figure 3.4: Sketch of Design C

3.2.2 CONCEPTUAL DESIGN

By using previous sketches in Figure 3.2, Figure 3.3, and Figure 3.4 as a guideline, the conceptual chassis design can be using SOLIDWORKS 2008. In this step, the best dimensions need to make the design to be draw symmetry and have logic concept. Shown in Figure 3.5, Figure 3.6 and Figure 3.7.

Figure 3.5 shown drawing perform using SOLIDWORKS. The design shown that the design shape is monocoque type. Consist cross shape beam under the driver compartment to support weight of driver and the chassis designed with tow tire at front and one tire at the rear or back.

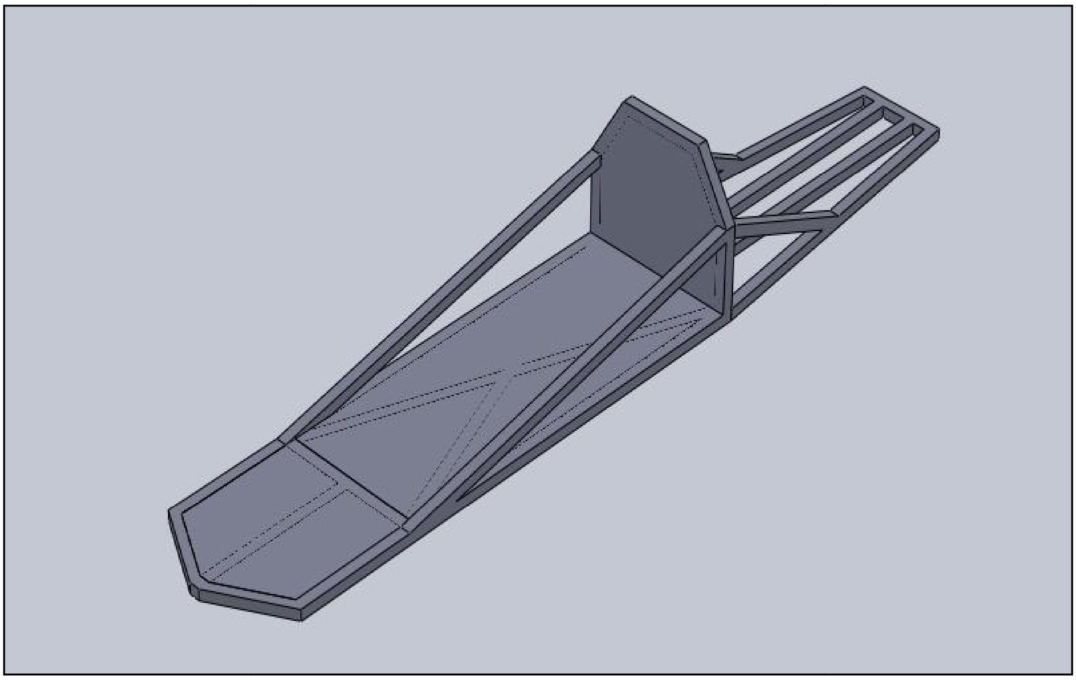

Figure 3.5: Conceptual design of Design A

Figure 3.6 shown drawing perform using SOLIDWORKS. The drawing shown that the design shape is frame type chassis. Consist cross shape beam under the driver compartment to support weight of driver and the chassis designed with tow tire at front and one tire at the rear or back.

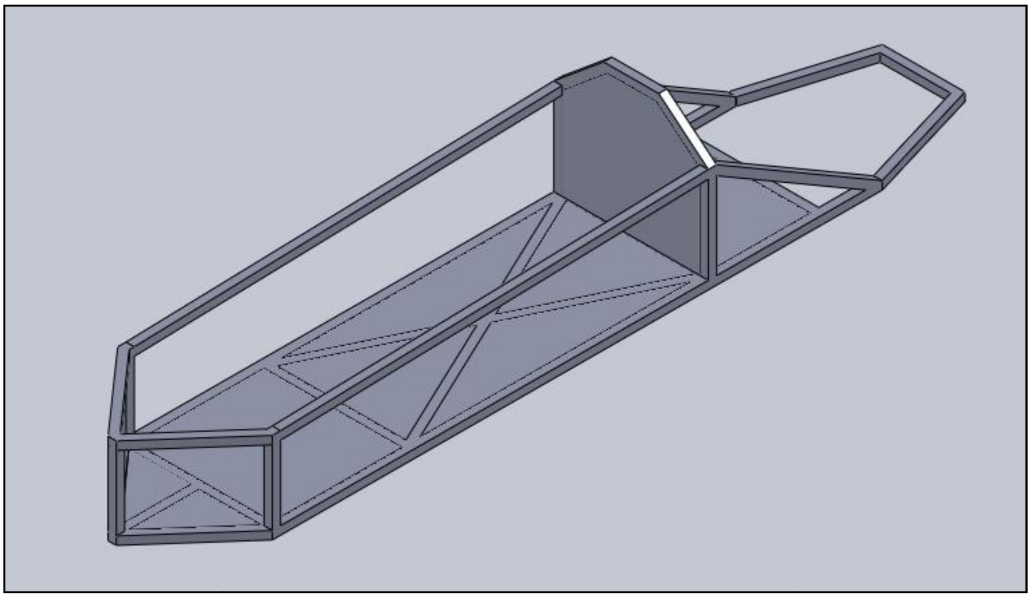

Figure 3.6: Conceptual design of Design B

Figure 3.7 shown drawing perform using SOLIDWORKS. The drawing shown that the design shape is frame type chassis. Consist cross shape beam under the driver compartment to support weight of driver and the chassis designed with tow tire at front and one tire at the rear or back.

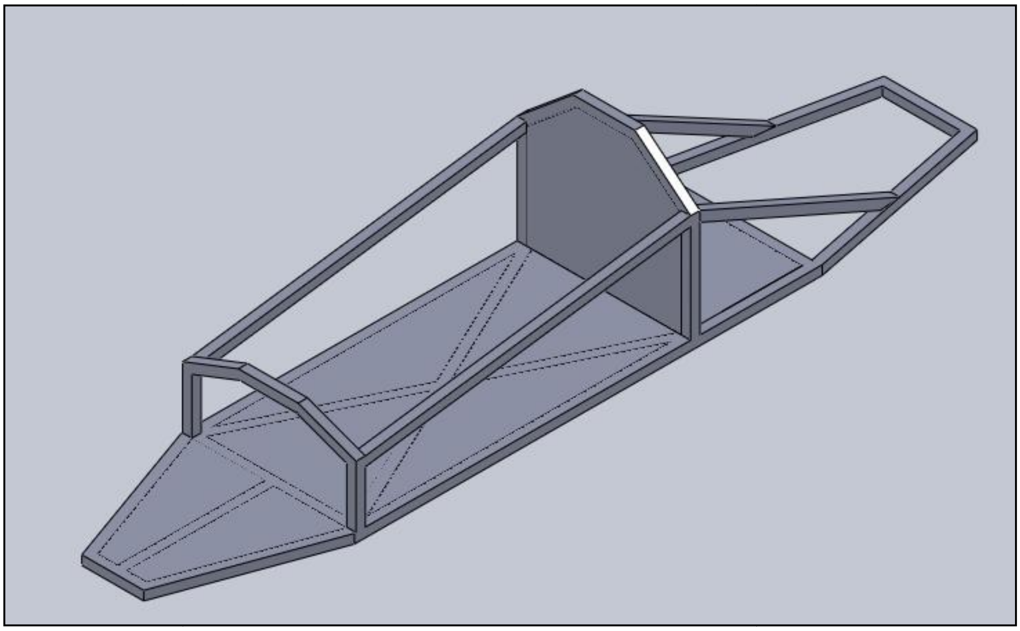

Figure 3.7: Conceptual design of Design C

3.2.3 PREMILINARY DESIGN

Preliminary design process is the evaluation leading up to the selection of the best overall design. It includes the overall system configuration, basic schematics and layout. The basic design must follow the regulations. A decision then must be made on one of the design as the preliminary design.

3.2.4 CHASSIS DESIGN ANALYSIS USING ALGOR

The three-dimensional (3D) wire frame is developed using FEMPRO which is shown in Figure 3.8. The finite element model is developed using the brick type element as shown the linear static analysis is considered to determine the stress with linear material.

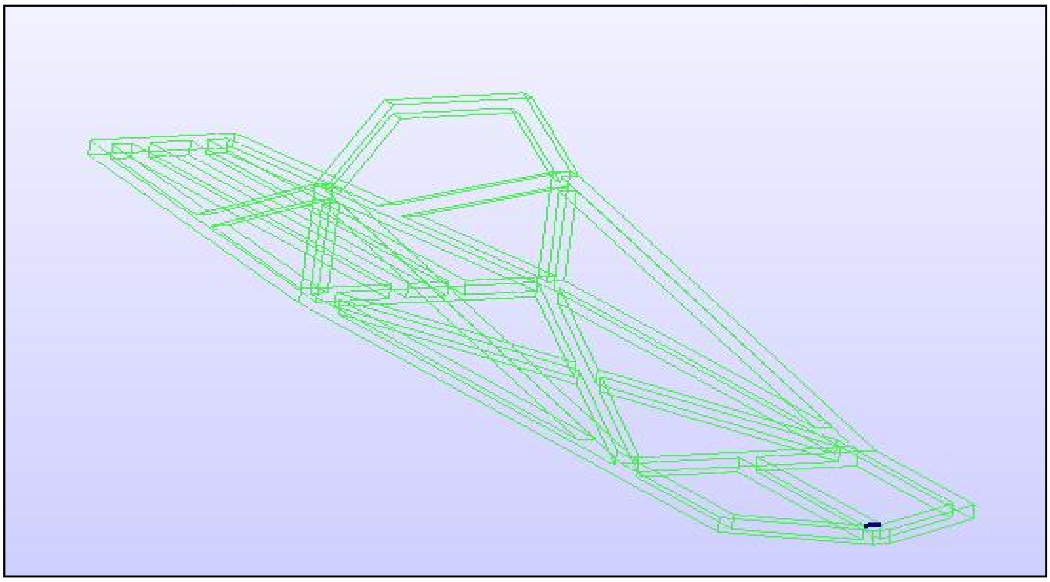

Figure 3.8: 3D wire frame design for car chassis Design A

The three-dimensional (3D) wire frame is developed using FEMPRO which is shown in Figure 3.9. The finite element model is developed using the brick type element as shown the linear static analysis is considered to determine the stress with linear material.

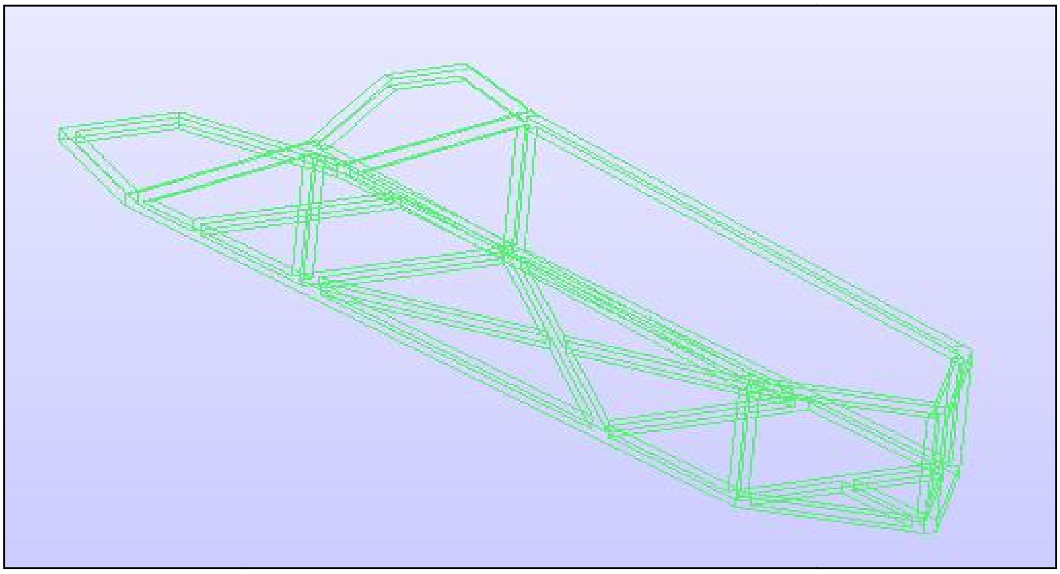

Figure 3.9: 3D wire frame design for car chassis Design B

The three-dimensional (3D) wire frame is developed using FEMPRO which is shown in Figure 3.10. The finite element model is developed using the brick type element as shown the linear static analysis is considered to determine the stress with linear material.

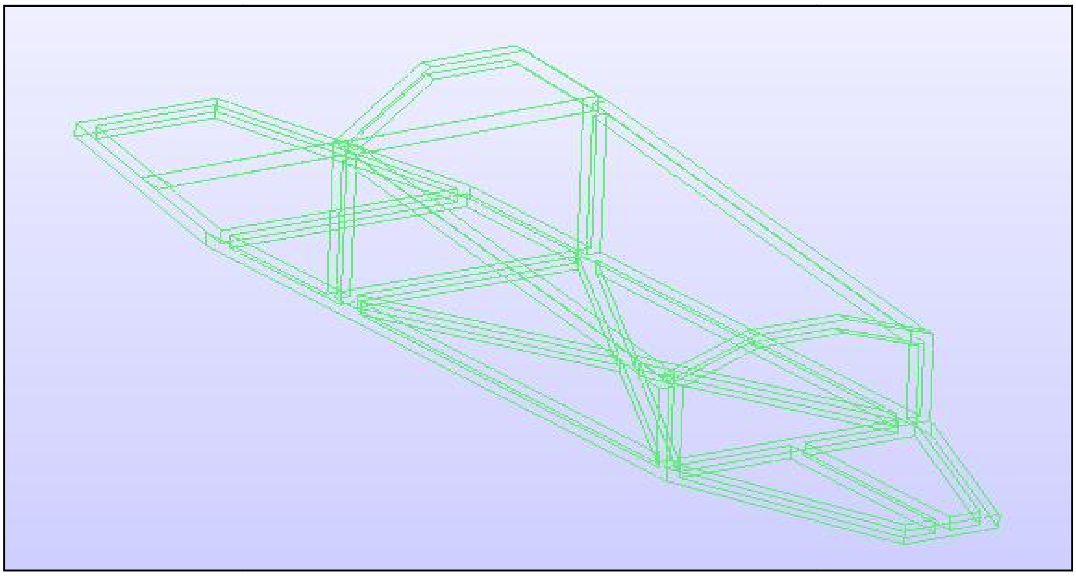

Figure 3.10: 3D wire frame design for car chassis Design C

Material properties is important in order to build the car chassis. In this project, there are three (3) types of materials proposed to be used; which is Aluminium Alloy, Stainless Steel and Iron.

Force loading is important as important of the material properties to analysis the car chassis. In the Algor software, force type use is nodal force and boundary condition is the boundary for the nodal force applied. The nodal force is from the weight applied to the chassis and the force distributed to the car chassis.

The car chassis was loaded with forces applied whereas the front arm and rear arm was fixed. The forces are from 800N to 900N due the weight applied to chassis. The loading and constraints of the chassis is shown in Figure 3.11.

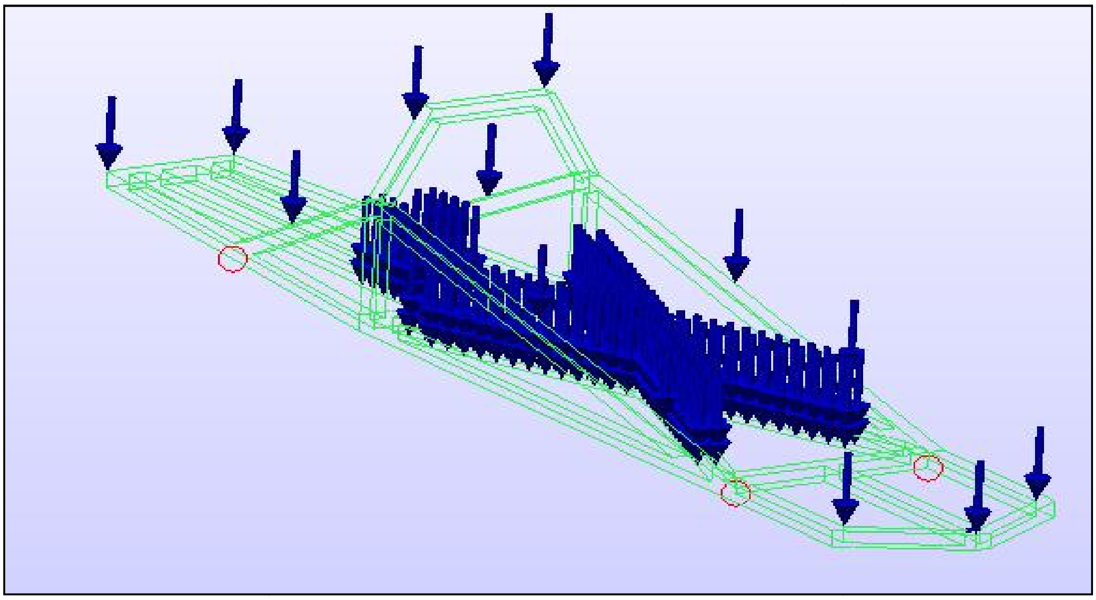

Figure 3.11: The loading and boundary condition Design A

The car chassis was loaded with forces applied whereas the front arm and rear arm was fixed. The forces are from 800N to 900N due the weight applied to chassis. The loading and constraints of the chassis is shown in Figure 3.12.

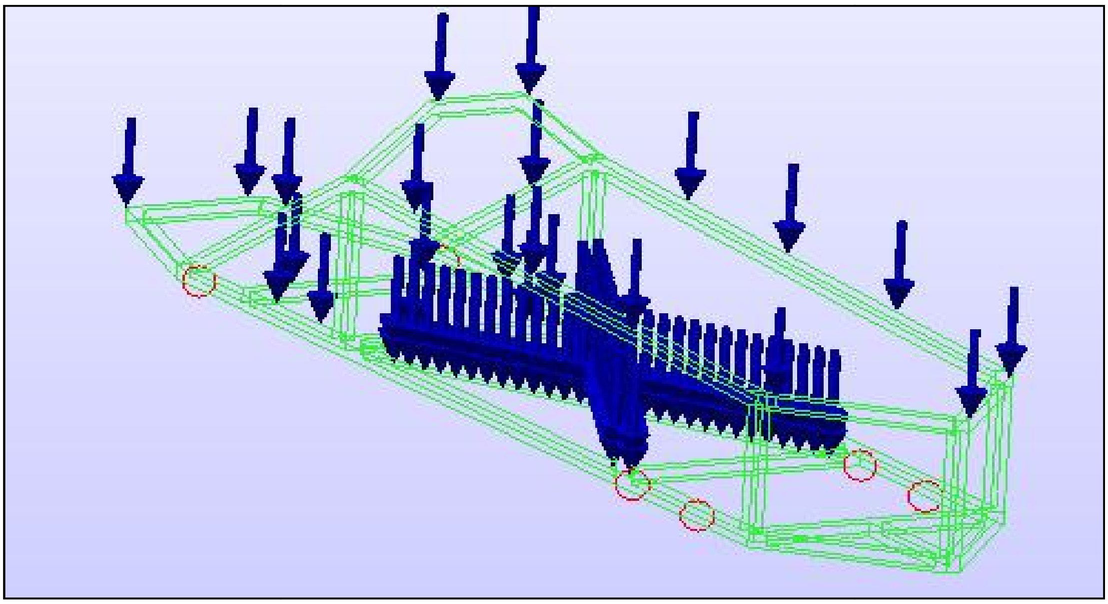

Figure 3.12: The loading and boundary condition Design B

The car chassis was loaded with forces applied whereas the front arm and rear arm was fixed. The forces are from 800N to 900N due the weight applied to chassis. The loading and constraints of the chassis is shown in Figure 3.13.

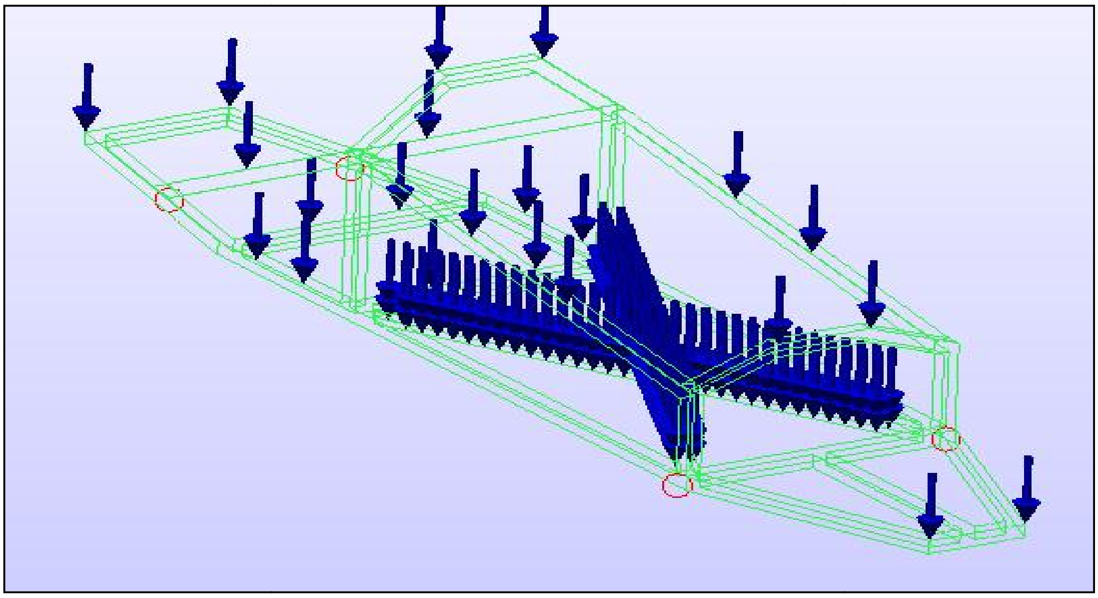

Figure 3.13: The loading and boundary condition Design C

3.2.5 DEVELOP PROTOTYPE

The best design chosen from the analysis, the design that performed the best result. That best design chosen to made a prototype. The dimension of the prototype is scaled down (1:3) from the actual design that chosen. Several processes need to do to make a complete prototype. The processes start with cutting the material, setting the 90 degree of parts, welding, grinding and lastly painting process. Figure 3.14 shown the process of cutting the raw material into parts. The machine that use is vertical bend saw.

Figure 3.14: Cutting metal process

Figure 3.15 shown the process of setting the parts of the prototype before the process of welding. This process is important to get the 90 degree shape and actual shape.

Figure 3.15: Setting process

When the squareness of the parts gotten, the parts need to be weld. Before the parts needed fully weld, spot weld need to do to ensure the part attached is correct. Fully weld can be done after all the spot weld completely checked. Welding equipment use is MIG welding machine shown in Figure 3.16.

Figure 3.16: Welding process

After the welding process finish, the part welded need to be grinded by the hand grinder tool shown in Figure 3.17. This process important to ensure the welded part is smooth and the sharp and the defect is removed.

Figure 3.17: Grinding/finishing process

Painting process is the last process of prototyping as shown in Figure 3.18, this process need to do to ensure the prototype is long lasting by the paint cover that corrosion resistance and make the prototype more attractive by the colour of the paint.

Figure 3.18: Painting process

The making of this project started with evaluate the previous design of car chassis. From the evaluation, rough idea can be come out by sketches the car chassis randomly to make the process easily. Sketches used as the guideline to design the car chassis in the Solidworks software. Preliminary design choose from the best design, there are three design selected. The chosen design from the preliminary stage imported to the Algor software to be analyzed. The process can be proceed to develop the prototype after one of the best of those three design finalized. Lastly the report can be written after all the data from each stage or process obtained. The flow of the process shown in flow chart in Figure 3.19.

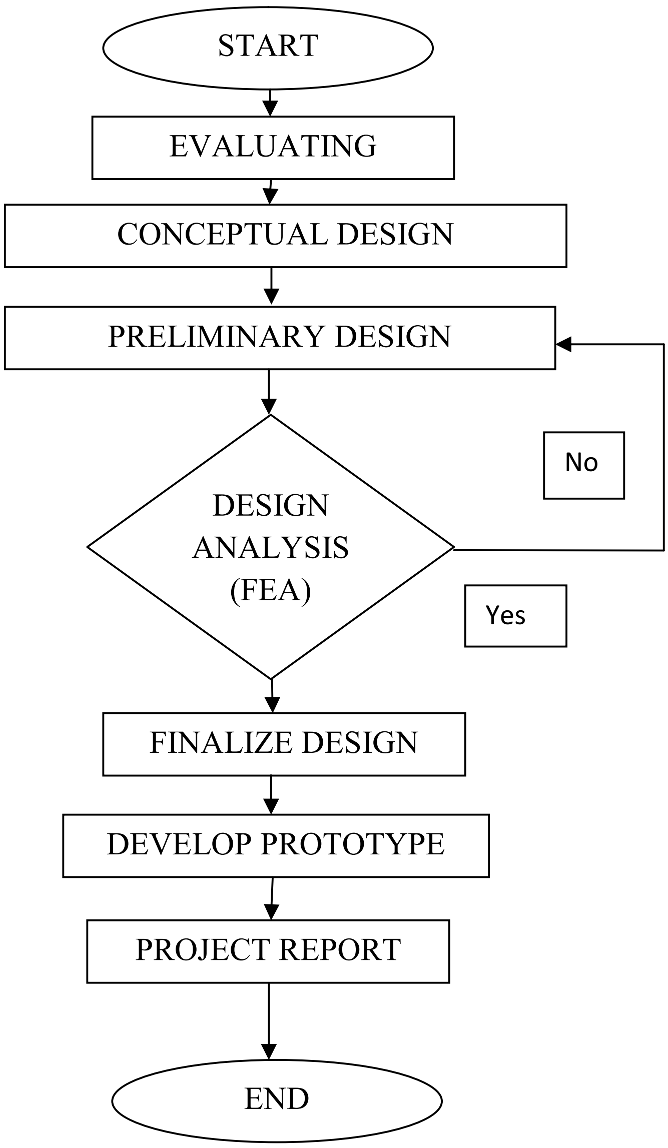

Figure 3.19: Chassis design flow chart

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter discussed about the result of car chassis. Finite element analysis of car chassis has been tested using FEMPRO ALGOR. Three chassis design was analyzed.

4.2 FINITE ELEMENT ANALYSIS (FEA) ON CHASSIS USING ALGOR

Finite element analysis has been tested to these three designs. The linear static analysis is performed utilizing the ALGOR software. There were three major mass have been consider in this analysis. Consist 70 kg weight of driver, 7 kg of engine weight and 10 kg weight of body. The three weights are the major weight in the car chassis. The results has been take, stress contour, strain contour and displacement distribution. Results taken for three chassis, and each chassis performed with different material aluminium alloy, stainless steel, and iron.

4.3 SIMULATION RESULTS USING ALGOR SOFTWARE

4.3.1 ALUMINIUM

From the analysis that has perform, the result of displacement distribution of car chassis Design A as shown in Figure 4.1. In this analysis it is observed the maximum displacement is 0.34 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design A.

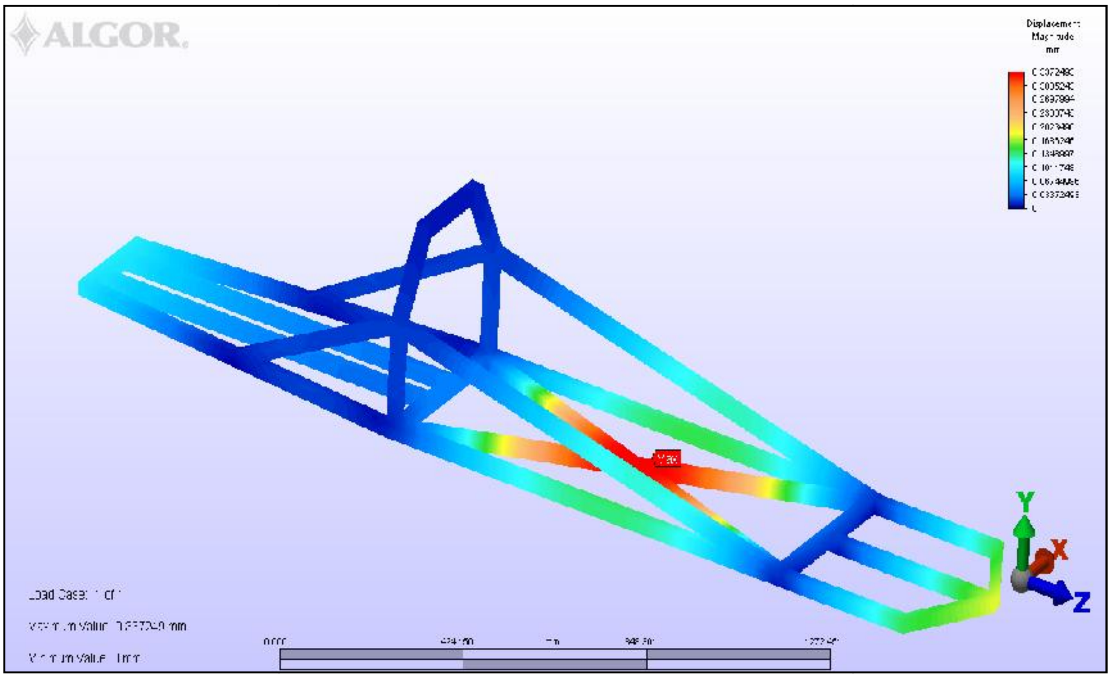

Figure 4.1: Displacement distribution of car chassis Design A

From the analysis that have been perform the stress contours of car chassis Design A is shown in the Figure 4.2. In the analysis it is observed the maximum stress is 6.4 MPa and minimum stress is 0.064 MPa. The result shown that the high stress at the lower cockpit support and the low stress at the upper of the cockpit support of the Design A.

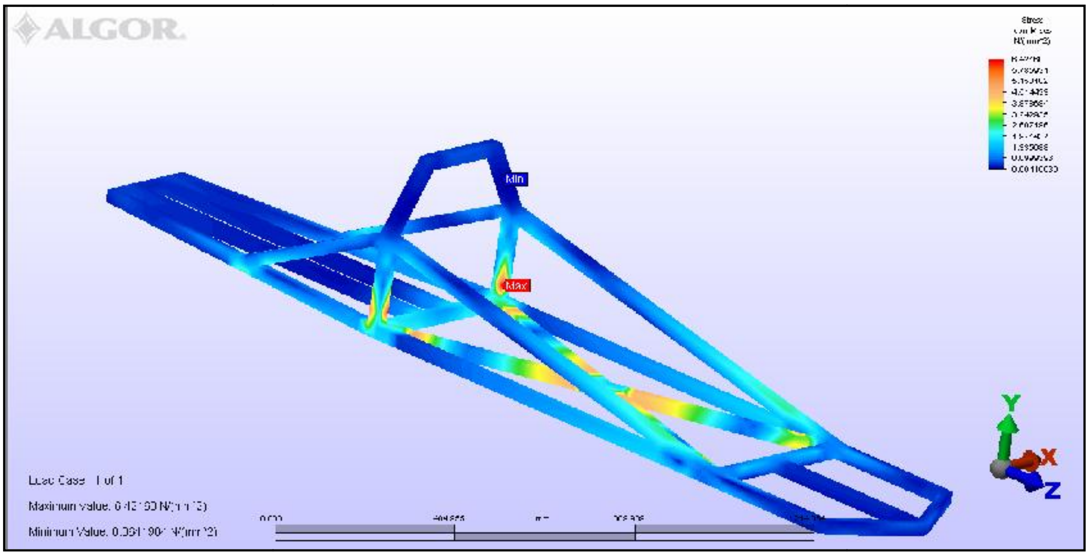

Figure 4.2: The stress contours of car chassis Design A

From the analysis that have been perform the strain contours of car chassis Design A is shown in the Figure 4.3. In the analysis it is observed the maximum strain is 0.000124 mm and minimum strain is 1.24e-6 mm. The result shown that the high strain at the lower cockpit support and the low strain at the upper of the cockpit support of the Design A.

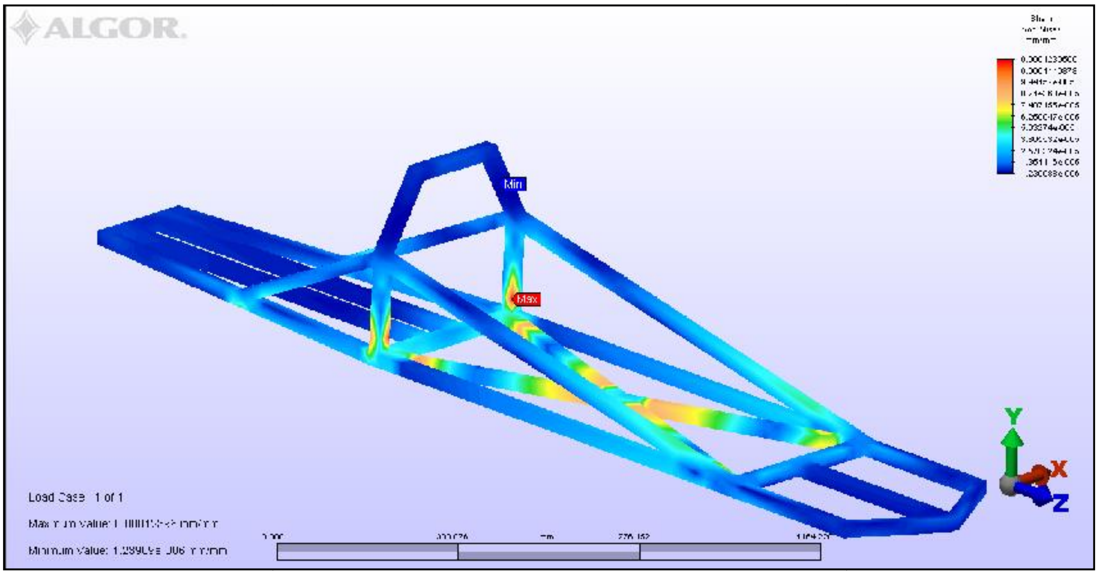

Figure 4.3: The strain contours of car chassis Design A

From the analysis that has performed the result of displacement distribution of car chassis Design B as shown in Figure 4.4. In this analysis it is observed the maximum displacement is 0.85 mm. The result show a high displacement is occurring at the centre of the chassis and the upper middle of car chassis Design B.

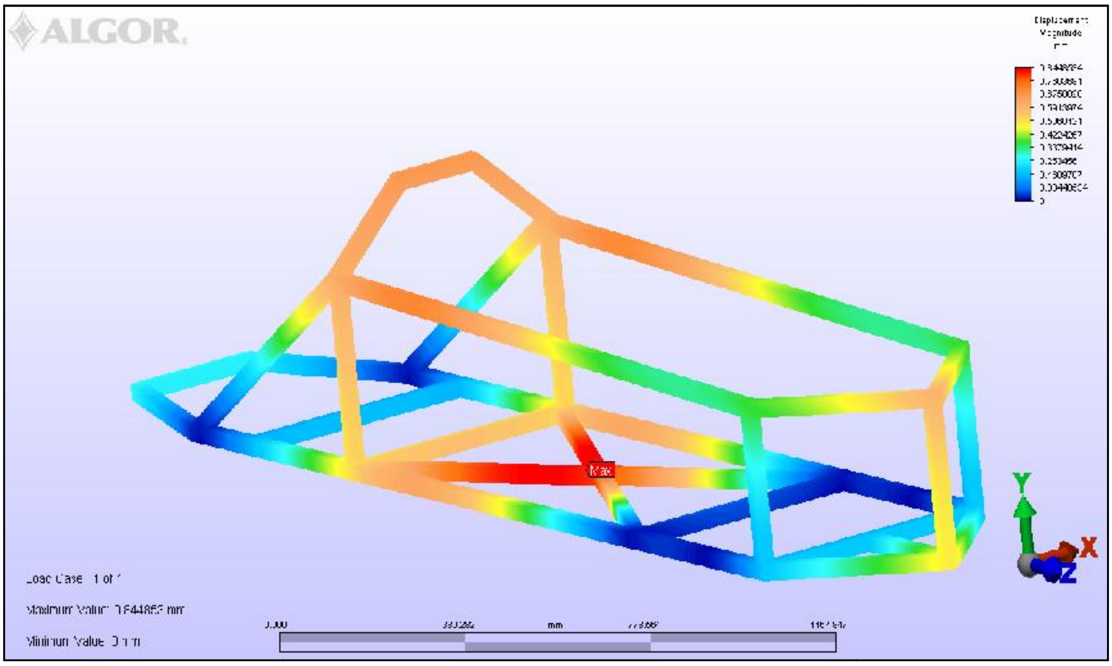

Figure 4.4: Displacement distribution of car chassis Design B

From the analysis that have been perform the stress contours of car chassis Design B is shown in the Figure 4.5. In the analysis it is observed the maximum stress is 9.0 MPa and minimum stress is 0.021 MPa. The result shown that the high stress at the centre of cockpit support and the low stress at the tip of the front arm of the Design B.

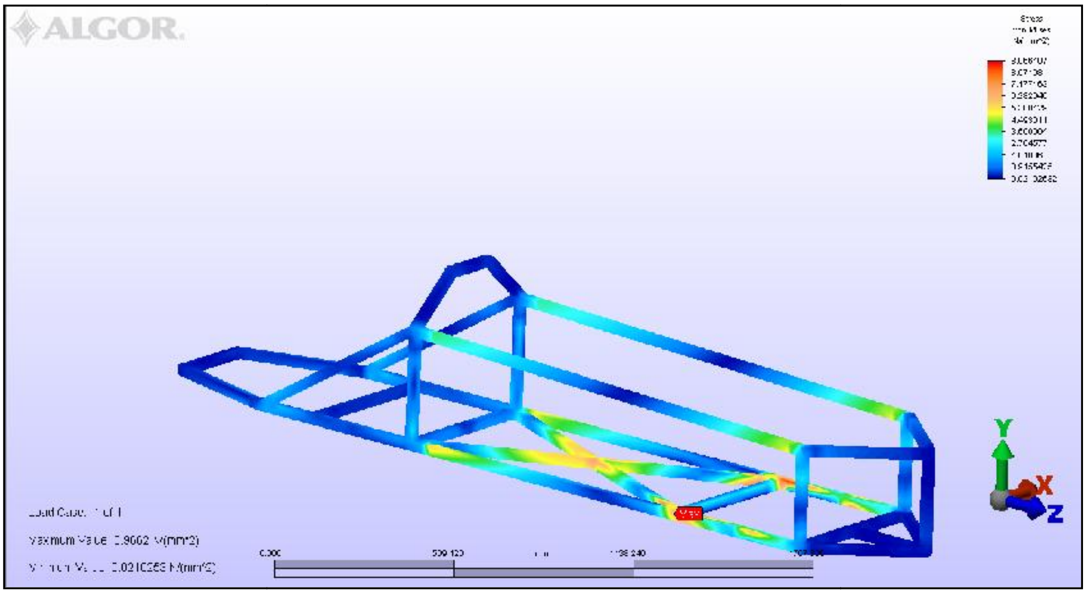

Figure 4.5: The stress contours of car chassis Design B

From the analysis that have been perform the strain contours of car chassis Design B is shown in the Figure 4.6. In the analysis it is observed the maximum strain is 0.00017 mm and minimum strain is 4.0586e-7 mm. The result shown that the high strain at the centre of cockpit support and the low strain at the tip of the front arm of the Design B.

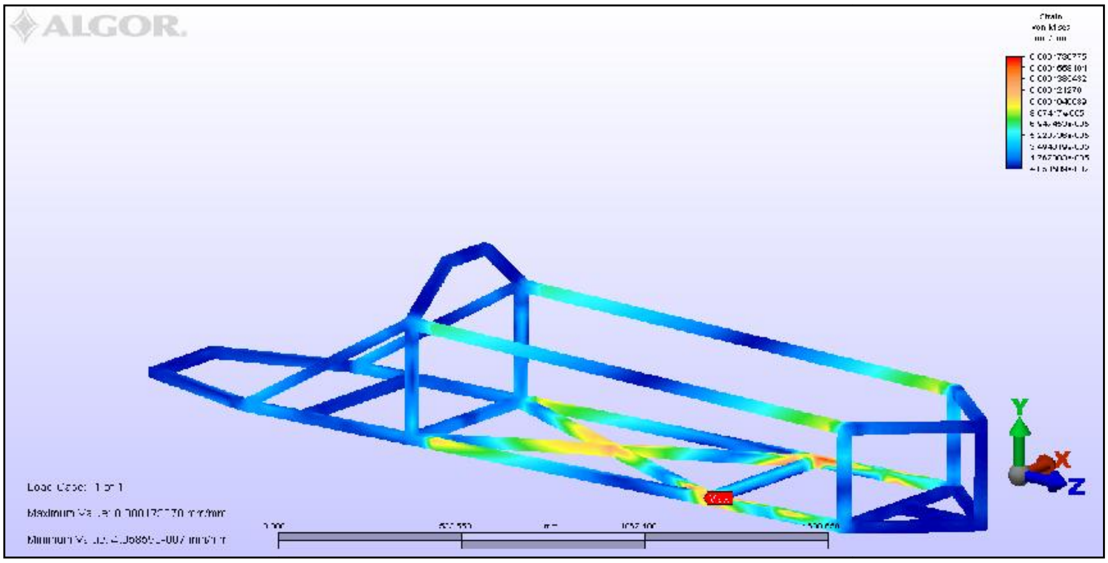

Figure 4.6: The strain contours of car chassis Design B

From the analysis that has perform, the result of displacement distribution of solar car chassis Design C as shown in Figure 4.7. In this analysis it is observed the maximum displacement is 0.44 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design C.

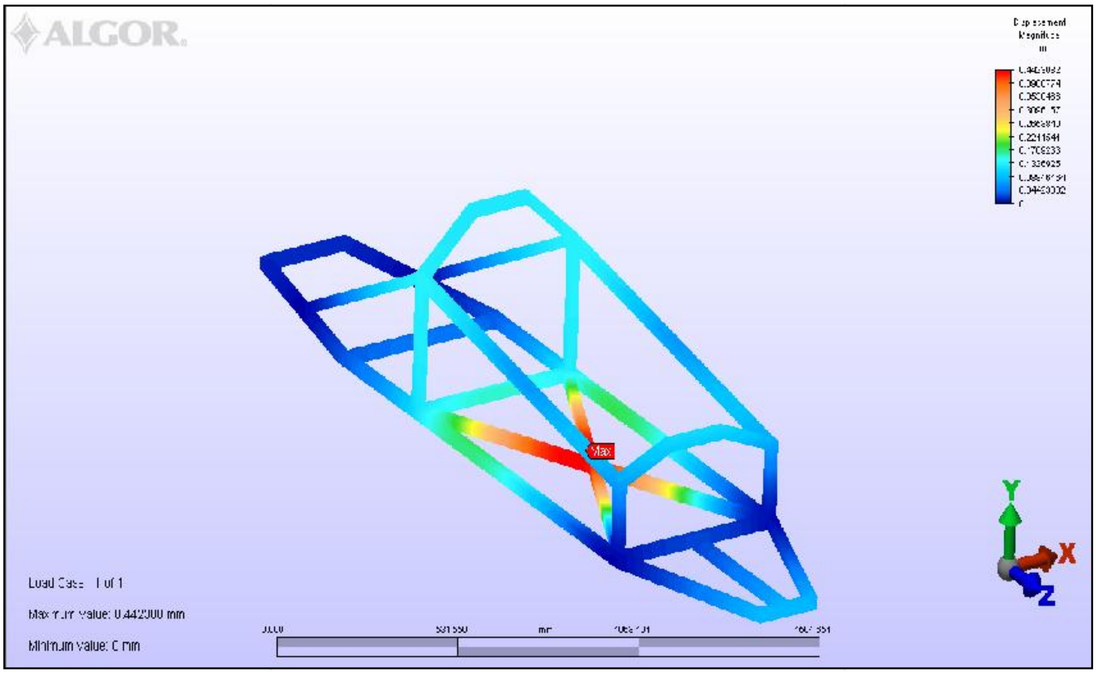

Figure 4.7: Displacement distribution of car chassis Design C

From the analysis that have been perform the stress contours of car chassis Design C is shown in the Figure 4.8. In the analysis it is observed the maximum stress is 8.2 MPa and minimum stress is 0.01 MPa. The result shown that the high stress at the tip of front arm and the low stress at the tip of the rear arm of the Design C.

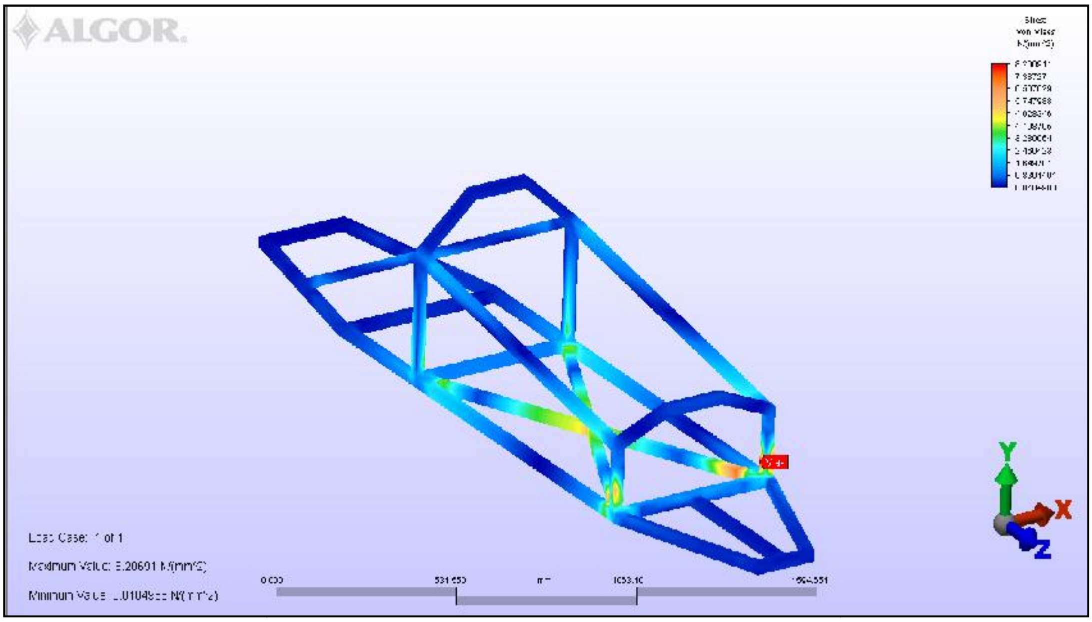

Figure 4.8: The stress contours of car chassis Design C

From the analysis that have been perform the strain contours of car chassis Design C is shown in the Figure 4.9. In the analysis it is observed the maximum strain is 0.00016 mm and minimum strain is 2.0266e-7 mm. The result shown that the high strain at the tip of front arm and the low strain at the tip of the rear arm of the Design C.

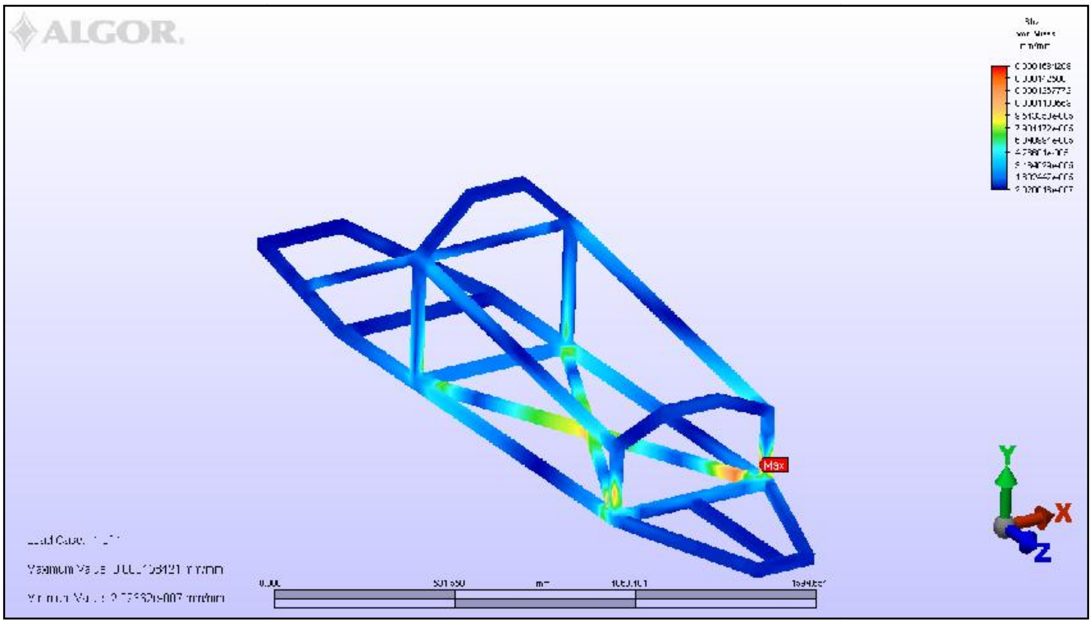

Figure 4.9: The strain contours of car chassis Design C

4.3.2 STAINLESS STEEL

From the analysis that has perform, the result of displacement distribution of car chassis Design A as shown in Figure 4.10. In this analysis it is observed the maximum displacement is 0.15 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design A.

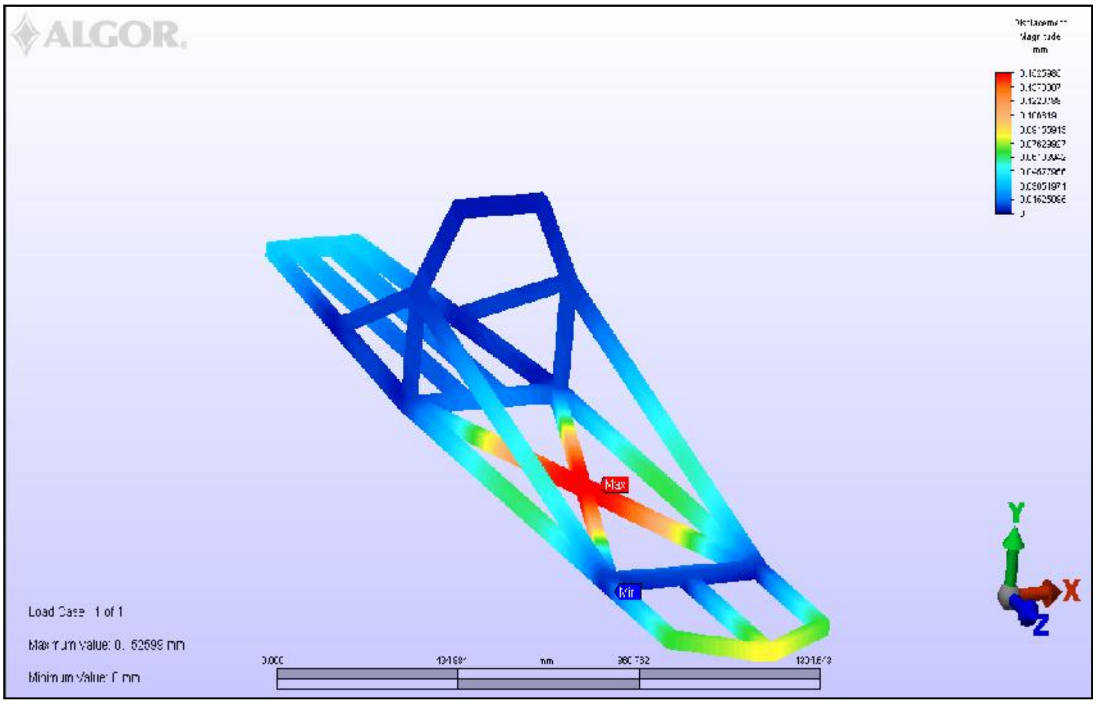

Figure 4.10: Displacement distribution of car chassis Design A

From the analysis that have been perform the stress contours of car chassis Design A is shown in the Figure 4.11. In the analysis it is observed the maximum stress is 8.2 MPa and minimum stress is 0.07 MPa. The result shown that the high stress at the lower cockpit support and the low stress at the upper of the cockpit support of the Design A.

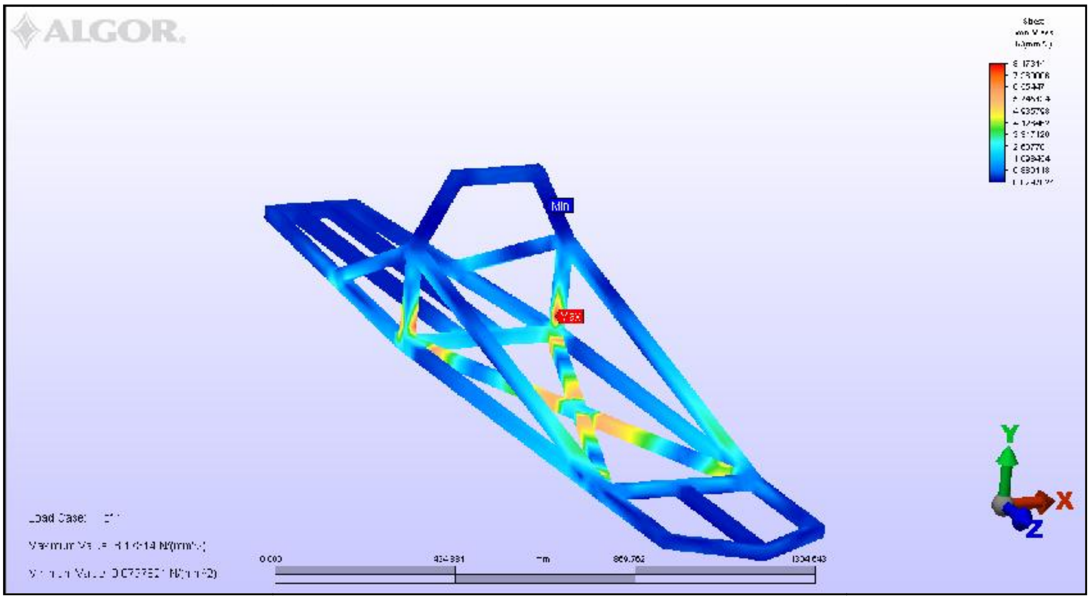

Figure 4.11: The stress contours of car chassis Design A

From the analysis that have been perform the strain contours of car chassis Design A is shown in the Figure 4.12. In the analysis it is observed the maximum strain is 5.4454e-5 mm and minimum strain is 5.3155e-7 mm. The result shown that the high strain at the lower cockpit support and the low strain at the upper of the cockpit support of the Design A.

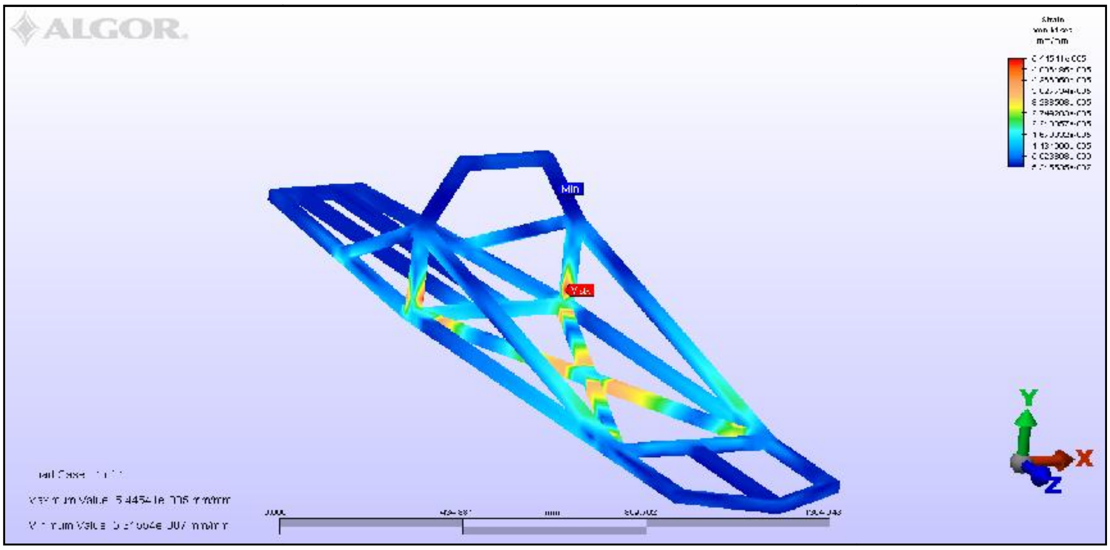

Figure 4.12: The strain contours of car chassis Design A

From the analysis that has performed, the result of displacement distribution of car chassis Design B shown in Figure 4.13. In this analysis it is observed the maximum displacement is 0.37 mm. The result show a high displacement is occurring at the centre of the chassis and the upper middle of car chassis Design B.

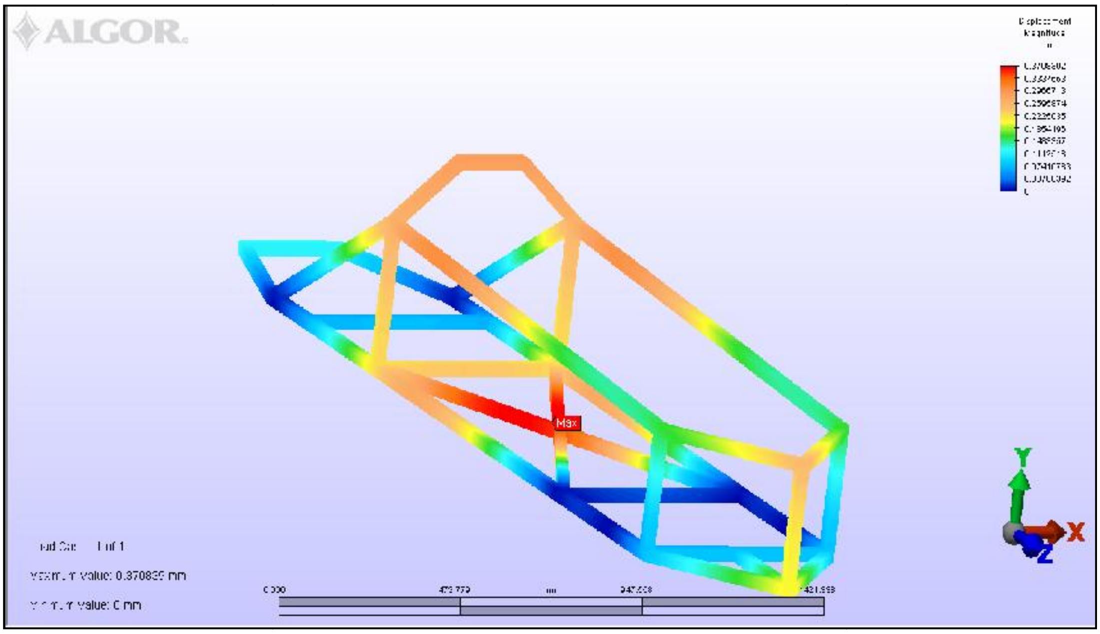

Figure 4.13: Displacement distribution of car chassis Design B

From the analysis that have been perform the stress contours of car chassis Design B is shown in the Figure 4.14. In the analysis it is observed the maximum stress is 11.0 MPa and minimum stress is 0.028 MPa. The result shown that the high stress at the centre of cockpit support and the low stress at the tip of the front arm of the Design B.

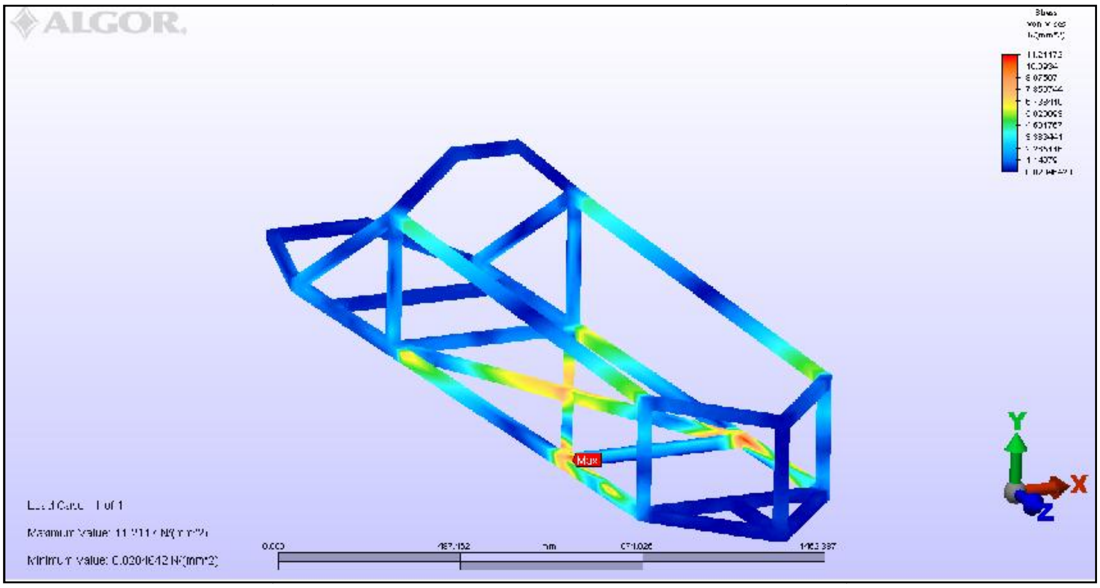

Figure 4.14: The stress contours of car chassis Design B

From the analysis that have been perform the strain contours of car chassis Design B is shown in the Figure 4.15. In the analysis it is observed the maximum strain is 7.45003e-5 mm and minimum strain is 1.8964e-7 mm. The result shown that the high strain at the centre of cockpit support and the low strain at the tip of the front arm of the Design B.

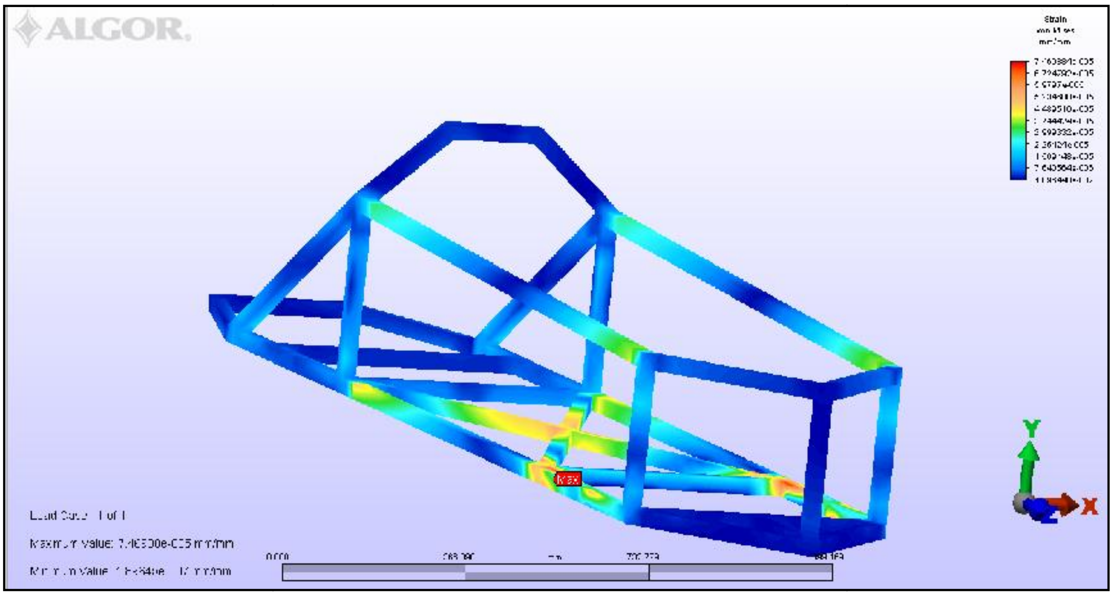

Figure 4.15: The strain contours of car chassis Design B

From the analysis that has performed the result of displacement distribution of car chassis Design C as shown in Figure 4.16. In this analysis it is observed the maximum displacement is 0.20 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design C.

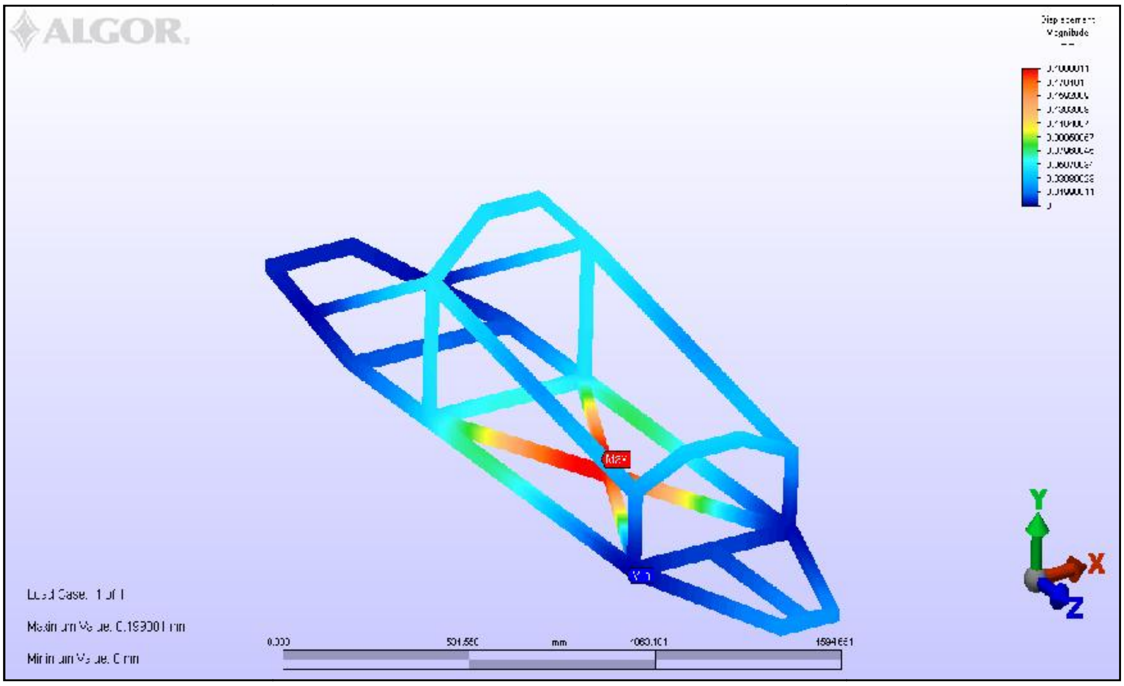

Figure 4.16: Displacement distribution of car chassis Design C

From the analysis that have been perform the stress contours of car chassis Design C is shown in the Figure 4.17. In the analysis it is observed the maximum stress is 10.4 MPa and minimum stress is 0.004 MPa. The result shown that the high stress at the tip of front arm and the low stress at the tip of the rear arm of the Design C.

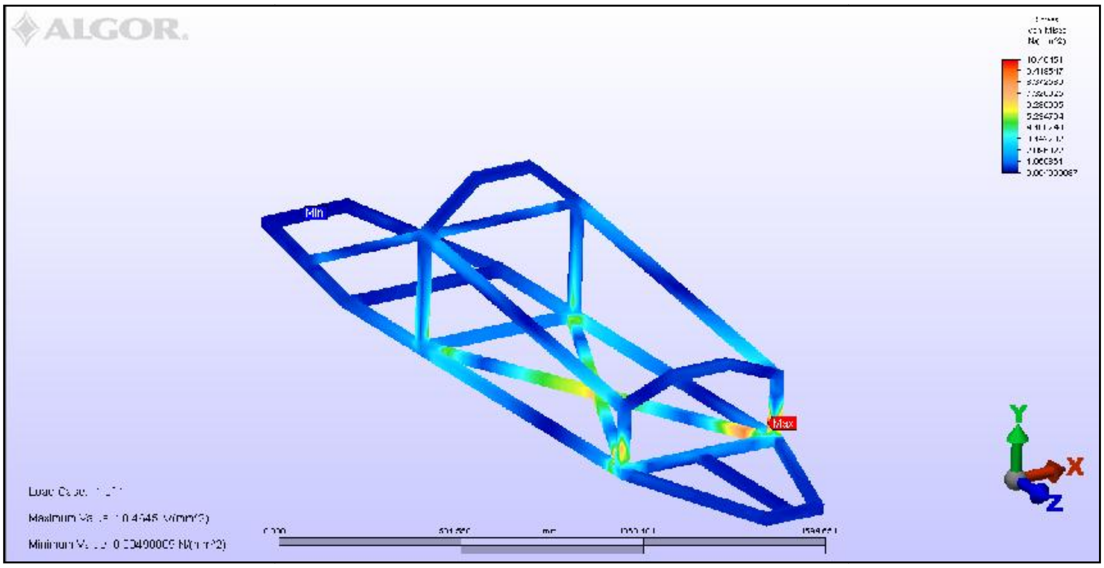

Figure 4.17: The stress contours of car chassis Design C

From the analysis that have been perform the strain contours of car chassis Design C is shown in the Figure 4.18. In the analysis it is observed the maximum strain is 6.9720e-5 mm and minimum strain is 3.2647e-8 mm. The result shown that the high strain at the tip of front arm and the low strain at the tip of the rear arm of the Design C.

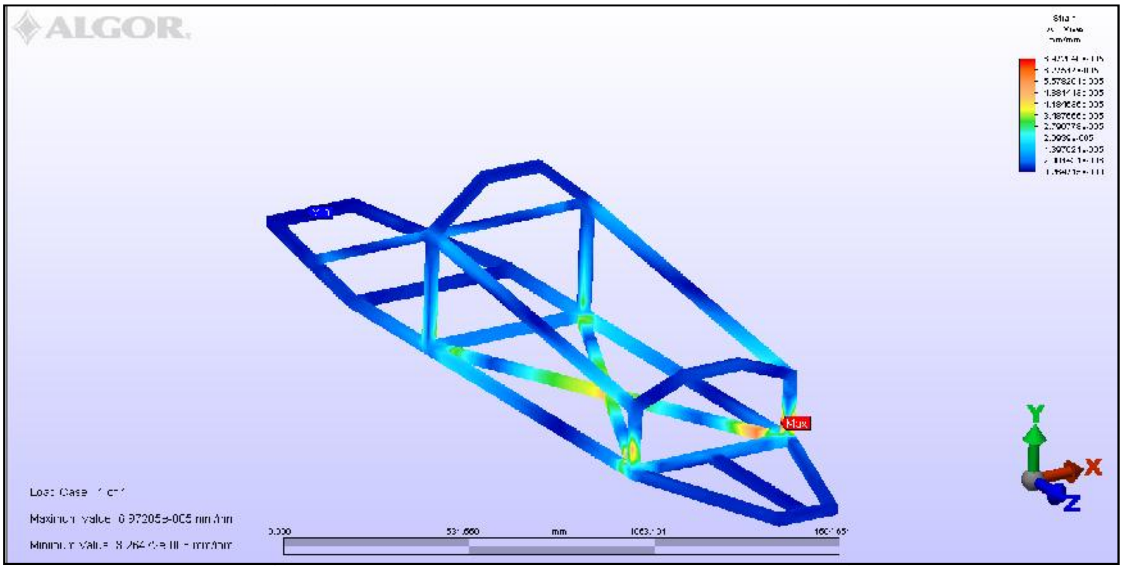

Figure 4.18: The strain contours of car chassis Design C

4.3.3 IRON

From the analysis that has perform, the result of displacement distribution of car chassis Design A as shown in Figure 4.19. In this analysis it is observed the maximum displacement is 0.15 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design A.

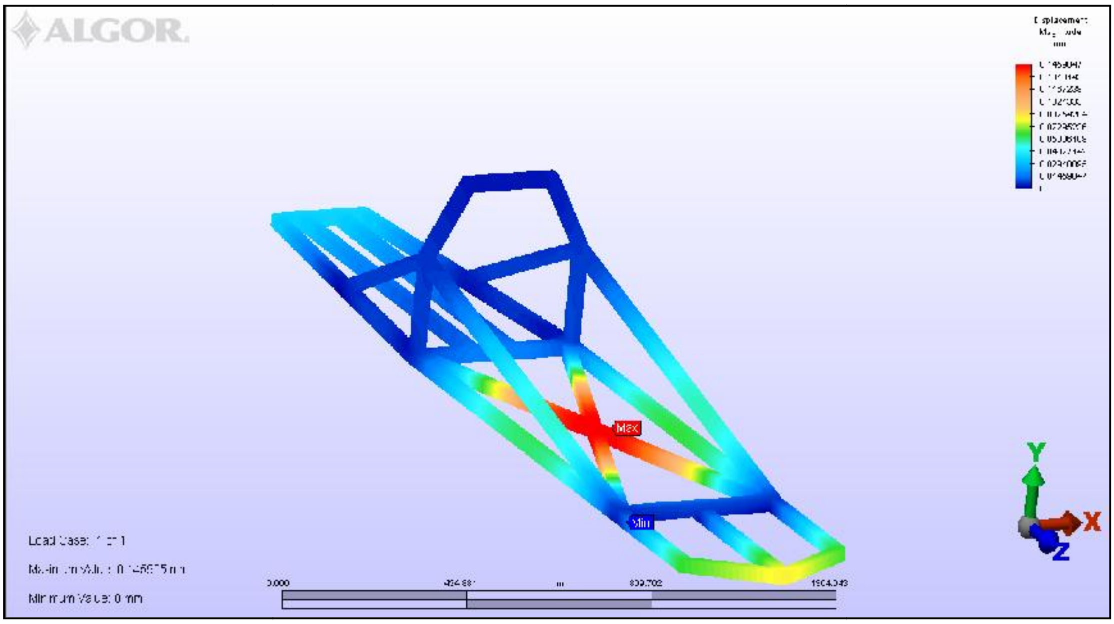

Figure 4.19: Displacement distribution of car chassis Design A

From the analysis that have been perform the stress contours of car chassis Design A is shown in the Figure 4.20. In the analysis it is observed the maximum stress is 8.1 MPa and minimum stress is 0.075 MPa. The result shown that the high stress at the lower cockpit support and the low stress at the upper of the cockpit support of the Design A.

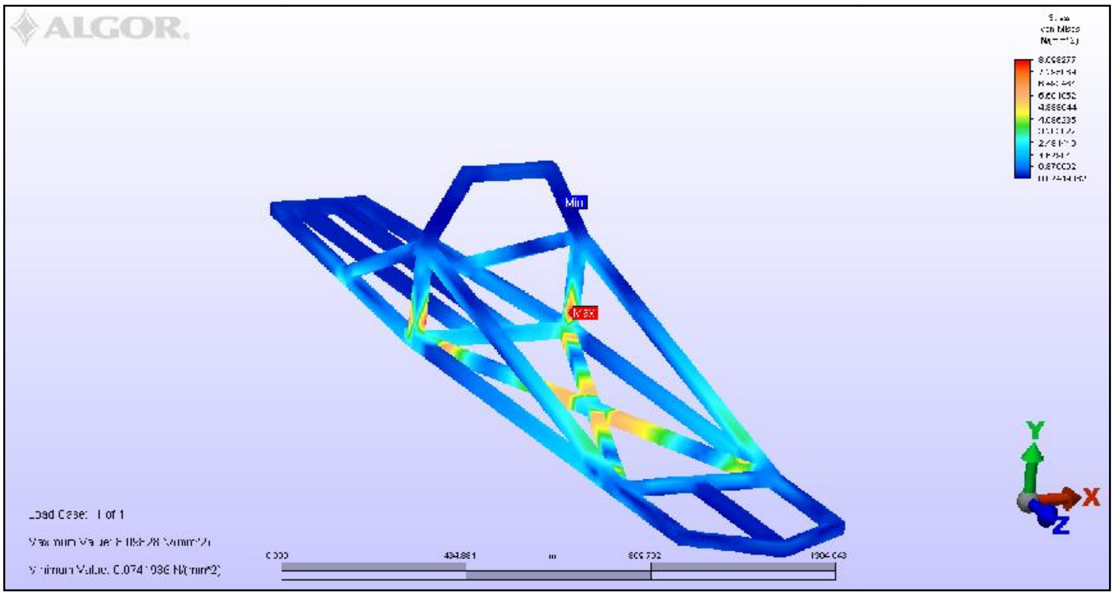

Figure 4.20: The stress contours of car chassis Design A

From the analysis that have been perform the strain contours of car chassis Design A is shown in the Figure 4.21. In the analysis it is observed the maximum strain is 5.2274e-5 mm and minimum strain is 4.7891e-7 mm. The result shown that the high strain at the lower cockpit support and the low strain at the upper of the cockpit support of the Design A.

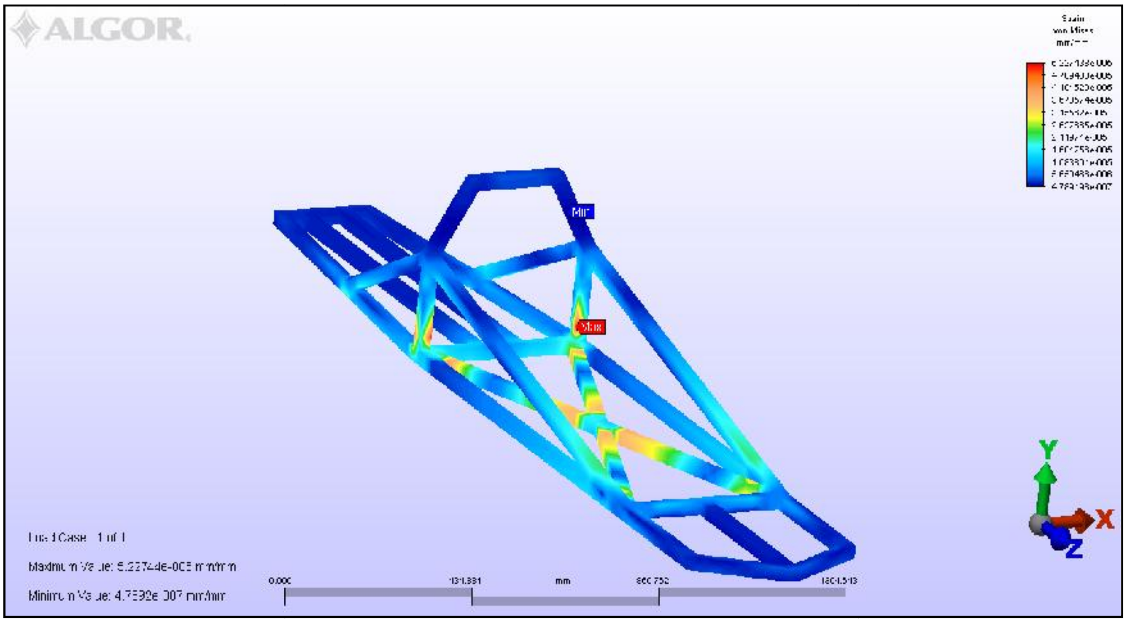

Figure 4.21: The strain contours of car chassis Design A

From the analysis that has performed the result of displacement distribution of car chassis Design B as shown in Figure 4.22. In this analysis it is observed the maximum displacement is 0.36 mm. The result show a high displacement is occurring at the centre of the chassis and the upper middle of car chassis Design B.

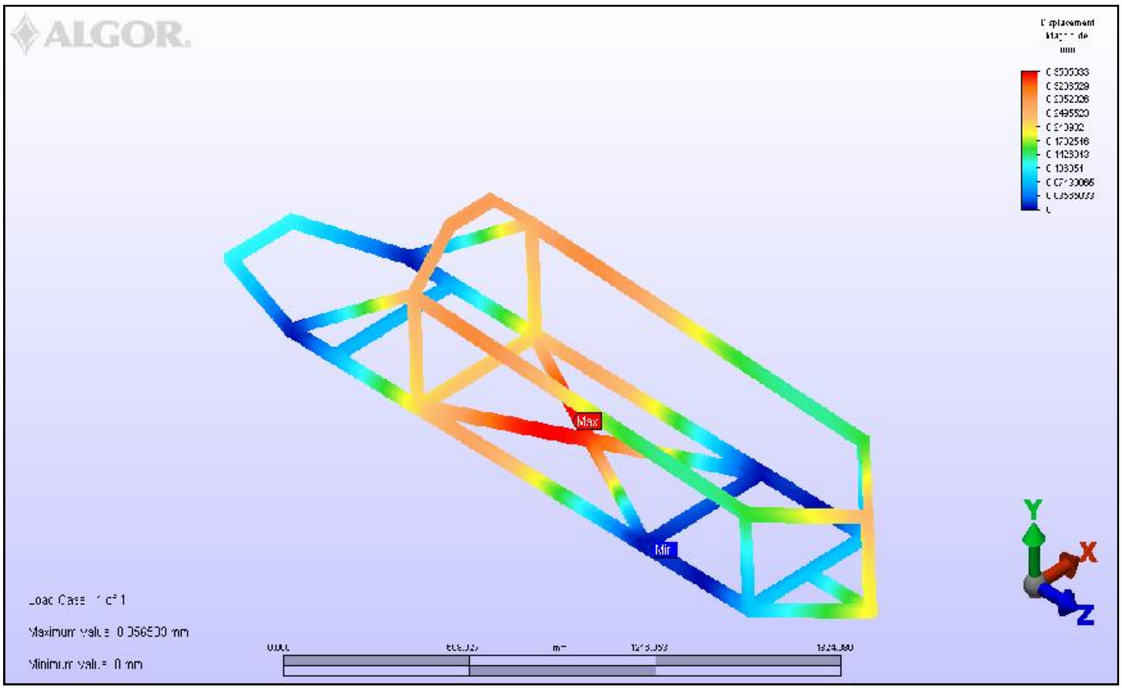

Figure 4.22: Displacement distribution of car chassis Design B

From the analysis that have been perform the stress contours of car chassis Design B is shown in the Figure 4.23. In the analysis it is observed the maximum stress is 10.9 MPa and minimum stress is 0.028 MPa. The result shown that the high stress at the centre of cockpit support and the low stress at the tip of the front arm of the Design B.

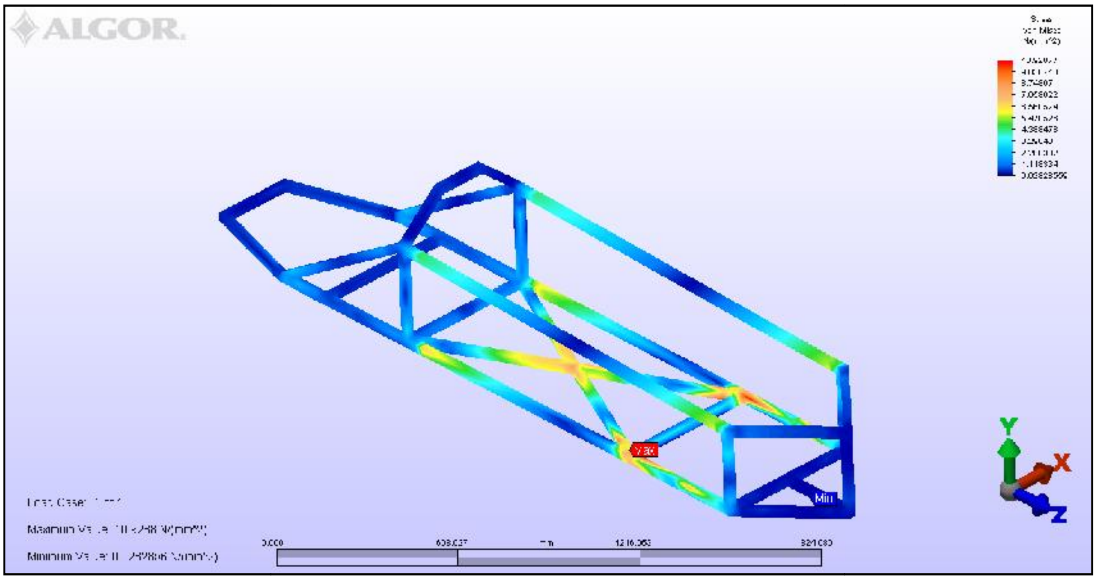

Figure 4.23: The stress contours of car chassis Design B

From the analysis that have been perform the strain contours of car chassis Design B is shown in the Figure 4.24. In the analysis it is observed the maximum strain is 7.0545e-5 mm and minimum strain is 1.8258e-7 mm. The result shown that the high strain at the centre of cockpit support and the low strain at the tip of the front arm of the Design B.

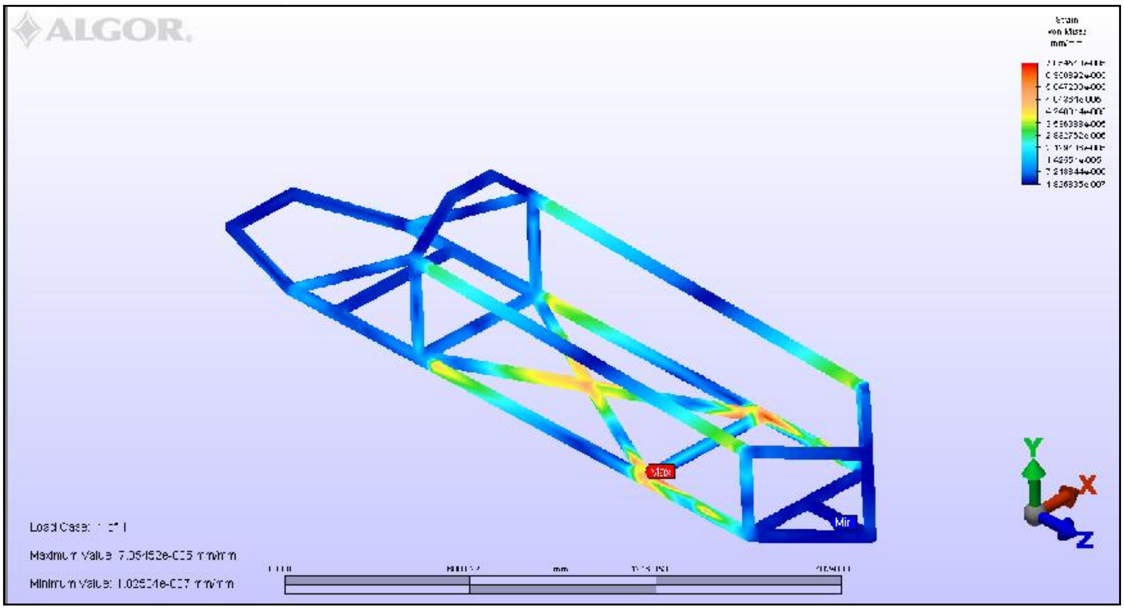

Figure 4.24: The strain contours of car chassis Design B

From the analysis that has perform, the result of displacement distribution of car chassis Design C as shown in Figure 4.25. In this analysis it is observed the maximum displacement is 0.19 mm. The result show a high displacement is occurring at the centre of the chassis of car chassis Design C.

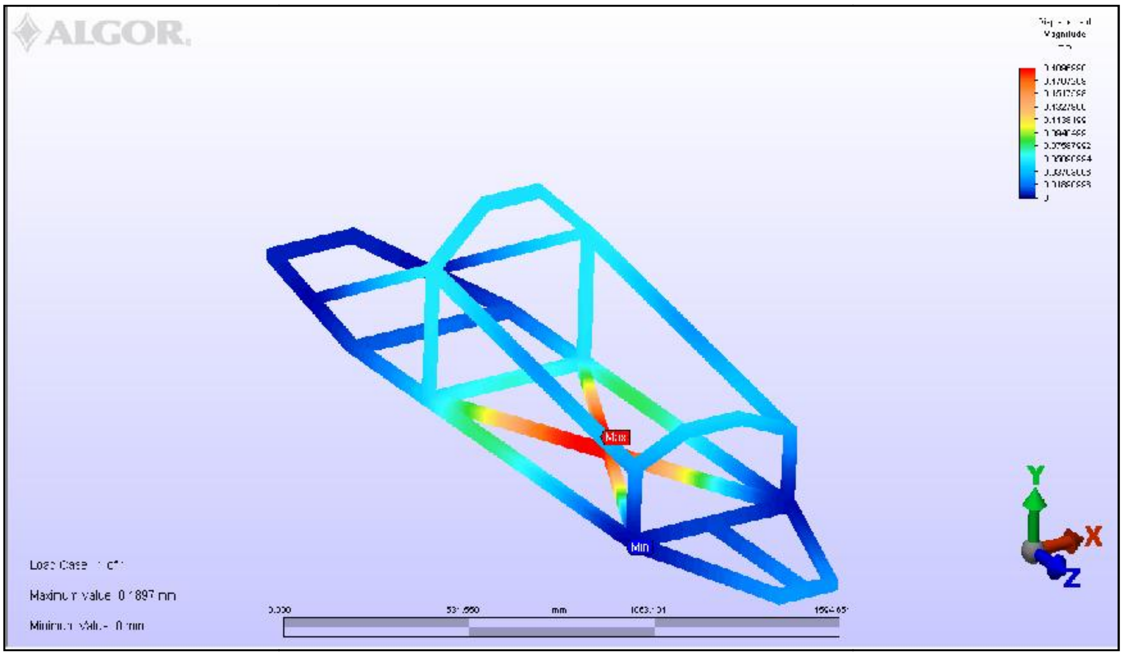

Figure 4.25: Displacement distribution of car chassis Design C

From the analysis that have been perform the stress contours of car chassis Design C is shown in the Figure 4.26. In the analysis it is observed the maximum stress is 10.3 MPa and minimum stress is 0.004 MPa. The result shown that the high stress at the tip of front arm and the low stress at the tip of the rear arm of the Design C.

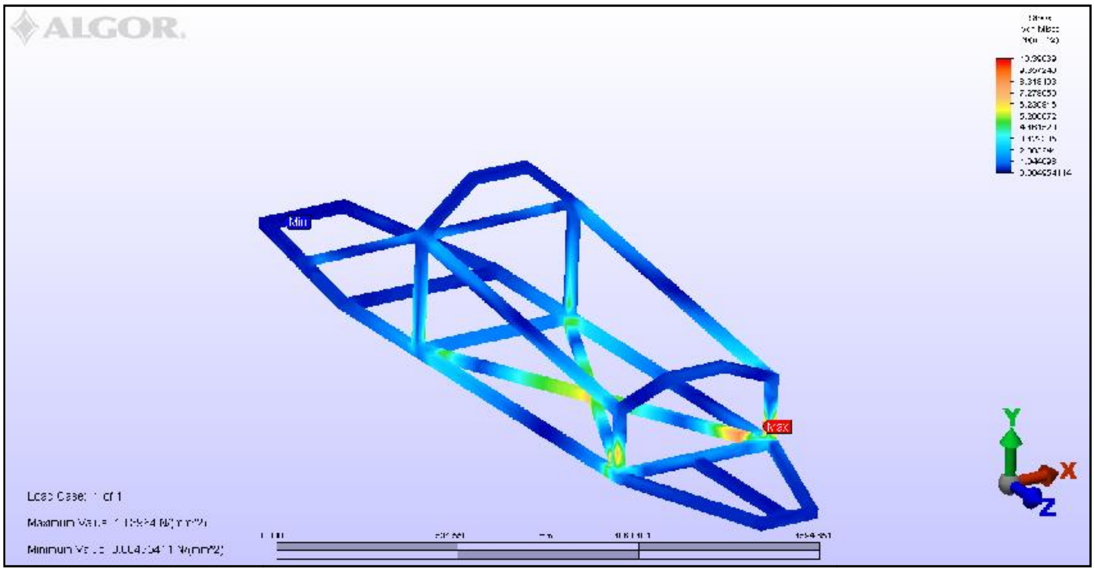

Figure 4.26: The stress contours of car chassis Design C

From the analysis that have been perform the strain contours of car chassis Design C is shown in the Figure 4.27. In the analysis it is observed the maximum strain is 6.7109e-5 mm and minimum strain is 3.1978e-8 mm. The result shown that the high strain at the tip of front arm and the low strain at the tip of the rear arm of the Design C.

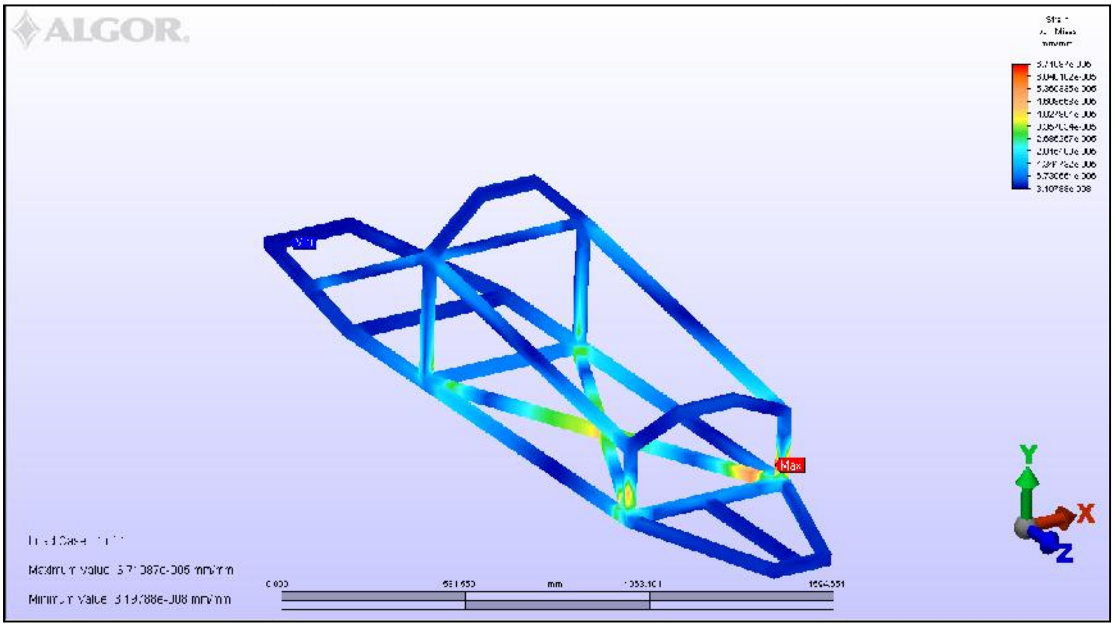

Figure 4.27: The strain contours of car chassis Design C

4.4 DISCUSSION

4.4.1 COMPARISON RESULTS OF CHASSIS

In this section, overall result comparing the car chassis Design A, Design B, and Design C. The result measure with the same force applied. Compared car chassis Design A with Design B and Design C that the displacement and maximum stress is smaller to other chassis or other design. All these design are not fail due to the maximum stress smaller than the yield strength.

Comparing all designs, the result shows the car chassis Design A is more strength than Design B and Design C due to the lower value of displacement magnitude, stress and strain contour when tested with AA6063-T6. The chassis Design A chosen. The comparison state in the Table 4.1.

Table 4.1: Analysis result for material aluminium alloy 6063-T6

Parameters and Unit	Design A	Design B	Design C
Displacement magnitude, δ (mm)	0.3372	0.8448	0.4423
Max stress, σ (MPa)	6.4217	8.9661	8.2069
Min stress, σ (MPa)	0.0641	0.0210	0.0105
Max strain, ε (mm)	0.00012	0.00017	0.00015
Min strain, ε (mm)	1.2391e-6	4.0585e-7	2.0266e-7

Comparing all designs, the result shows the car chassis Design A is more strength than Design B and design C due to the lower value of displacement magnitude, stress and strain contour when tested with Stainless Steel (AISI 317). The chassis Design A chosen. The comparison state in the Table 4.2.

Table 4.2: Analysis result for material Stainless Steel (AISI 317)

Parameters and Unit	Design A	Design B	Design C
Displacement magnitude, δ (mm)	0.1526	0.3708	0.1990
Max stress, σ (MPa)	8.1731	11.2117	10.4645
Min stress, σ (MPa)	0.0797	0.0284	0.0049
Max strain, ε (mm)	5.4454e-5	7.4698e-5	6.9720e-5
Min strain, ε (mm)	5.3155e-7	1.8964e-7	3.2647e-8

Comparing all designs, the result shows the car chassis Design A is more strength than Design B and Design C due to the lower value of displacement magnitude, stress and strain contour when use Iron (Fe). The chassis Design A chosen. The comparison state in the Table 4.3.

Table 4.3: Analysis result for material Iron, Fe

Parameters and Unit	Design A	Design B	Design C
Displacement magnitude, δ (mm)	0.1459	0.3565	0.1897
Max stress, σ (MPa)	8.0982	10.9289	10.3964
Min stress, σ (MPa)	0.0742	0.0283	0.0049
Max strain, ε (mm)	5.2274e-5	7.0545e-5	6.7109e-5
Min strain, ε (mm)	4.7891e-7	1.8258e-7	3.1979e-8

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this study, it is successfully achieving the objectives in the acceptable result outcome. The design of car chassis has been developed referring to the design in the Eco Marathon Challenge, prototype category. The chassis that have 3 wheels, which are 2 wheels for front and 1 wheel for rear.

Three designs of car chassis have been develop. Those designs was analysed using ALGOR. The Design A is chosen for modelling process because the result from the analysis is better than Design B and Design C in each different testing of material. Aluminium Alloy 6063-T6 chosen due to light weight compare to other material and suitable in this project that design car chassis have light weight.

5.2 RECOMMENDATION

Based on the findings through this study, the recommendation can be made. The suggestion is as follow:

- The concept design of the car chassis using cylindrical tube replaces the square tube to increase the safety shape.
- The design of the car chassis can be used Catia software by Dassault Systèmes.
- The analysis of the chassis can be done using other software; the most recommend by lecturers is MSC.Nastran.
- Add more material selections to get more results of analysis.

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APPENDIX A

3D Design of Car Chassis

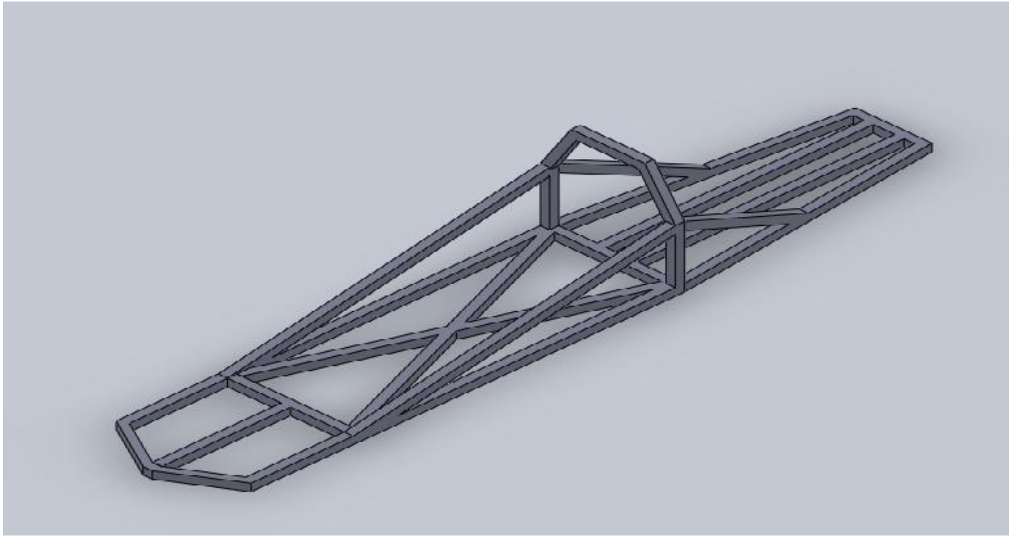

Figure A1: 3D design of car chassis Design A

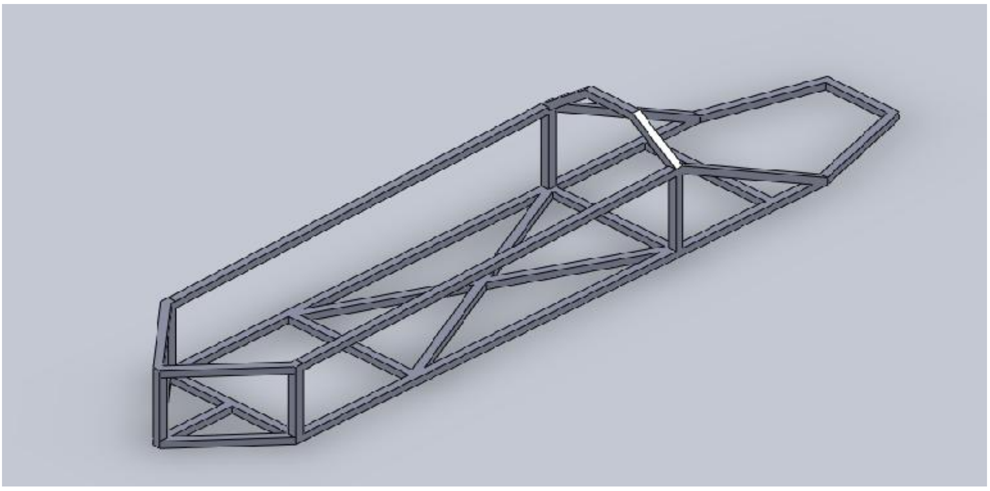

Figure A2: 3D design of car chassis Design B

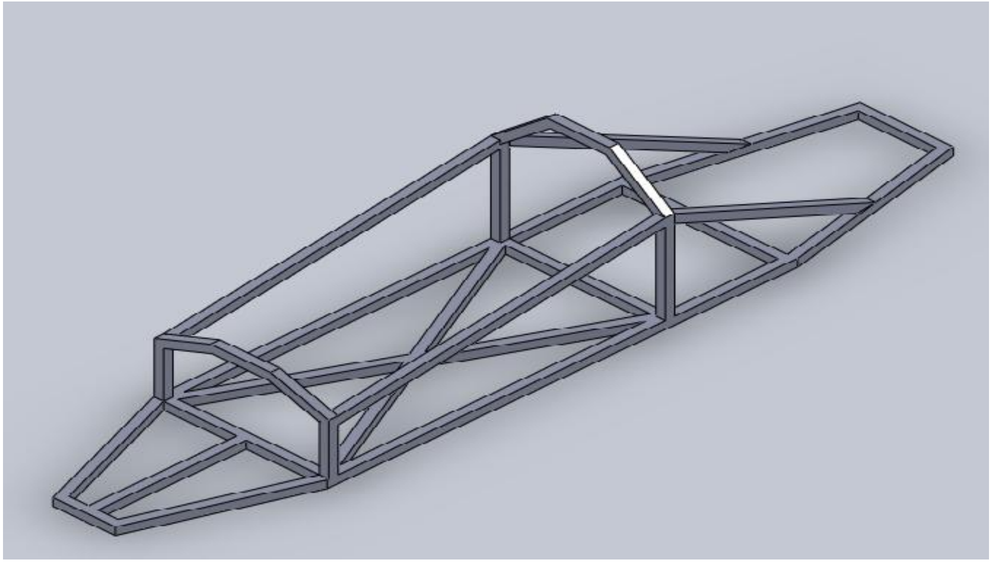

Figure A3: 3D design of car chassis Design C

APPENDIX B

Dimension of Car Chassis

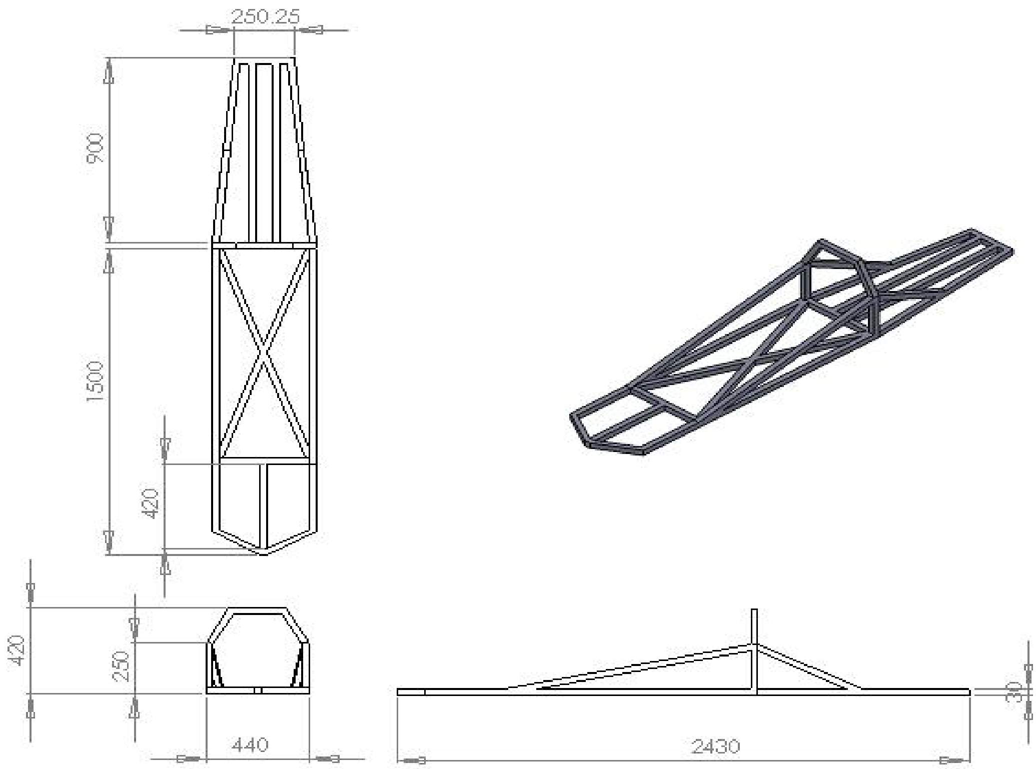

Figure B1: Dimension of car chassis Design A

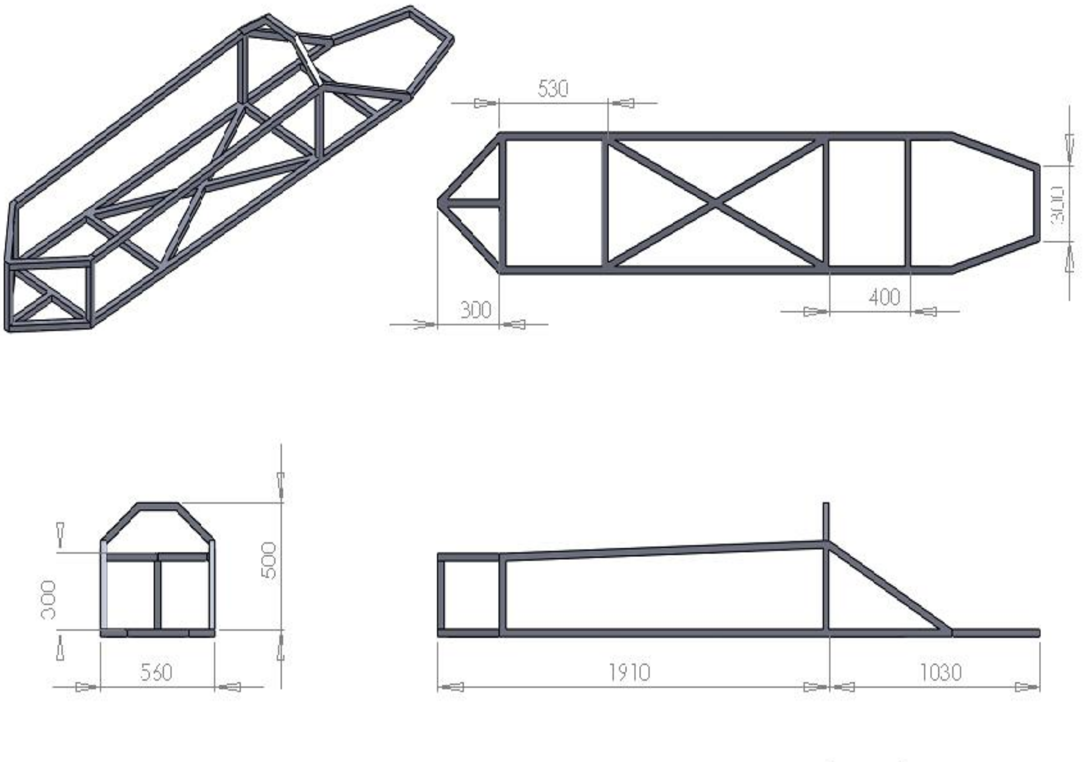

Figure B1: Dimension of car chassis Design B

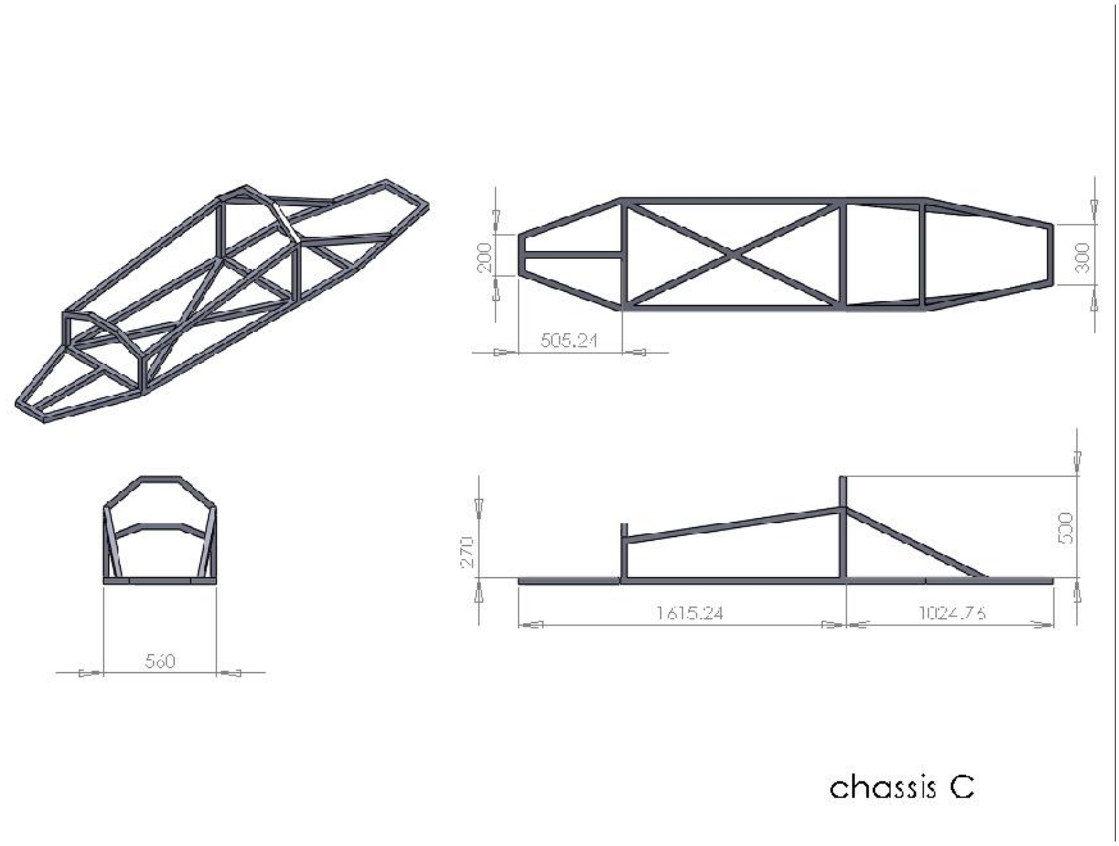

Figure B3: Dimension of car chassis Design C

APPENDIX C

Fabricated of Model of Car Chassis Design A

Gantt Chart

ACTIVITIES		WEEK													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Identify the problem	Planning														
	Actual														
Identify project scopes,objectives	Planning														
	Actual														
Literature review	Planning														
	Actual														
Evaluate current design	Planning														
	Actual														
Conceptual design	Planning														
	Actual														
Material selection/concept analysis	Planning														
	Actual														
Concept evaluation/finalized design	Planning														
	Actual														
Develop prototype	Planning														
	Actual														
Report writing	Planning														
	Actual														
Presentation	Planning														
	Actual														