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College of Engineering
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Design of a Solar Car
Team #9 (Chassis)

Group Members

Student					
Name	Mohammed Alqahtani	Faisal Alotaibi	Ahmed Alabdullatif	Hisham Alabdullatif	
ID	201501615	201600503	201600562	201600532	

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Department of Mechanical Engineering

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Senior Design Project Report

Title: Design of Space Frame for Solar Car.

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering Team Members

Team Members

Student Name	Student ID
Hisham Alabdullatif	**201600532**
Ahmed Alabdullatif	**201600562**
Mohammed Alqahtani	**201501615**
Faisal Alotaibi	**201600503**

Advisor: Dr. Raguraman Kannan

Abstract

This project report presents about design and analysis of solar car chassis and body. The objective of this project is to design and analysis of the elements of body and chassis of a solar car for the target of the most lightweight and lowest material cost design. The solar car chassis is designed using Solid Work. Two designs of solar car chassis are analyzed. The maximum displacement magnitude, worst stress and worst strain is compared between solar car chassis Design 1 and Design 2. The solar car body is developed using Solid Work 2018.

Acknowledgements

We are extremely beholden and own an irredeemable dept, of gratitude to our project advisor for their valuable guidance and help extended to us in our project. We consider it as a great opportunity to do project under his guidance and to learn from his research expertise. It was incredible to get his professional direction that positively impacted work on a major deal. We thank you for all your contributions of time, insightful discussions, instructions, reviews, and recommendations about the project.

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On the other hand, the efforts of the team members were tremendous. The division of work among the team members was clear, remarkable, and productive too. Every team member has been helped to carry out their functions efficiently and effectively. It was a great time to work with team members. The leader of the group addresses his strongest gratitude to each of the members of the team.

Table of Contents

1 Chapter 1: Introduction

1.1 Project definition

Solar car is a solar vehicle used for land transport, usually run on only power from the sun, although some models will supplement that power using a battery, or use solar panels to recharge batteries or run auxiliary systems for a car that mainly uses battery power. Solar cars combine technology typically used in the aerospace, bicycle, alternative energy, and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car.

This project is indented to design the space frame chassis of the solar car. Designing and fabricating space frame chassis structure requires a set of knowledge especially in design, material selection, metal joining and fabrication which result in rigid, sturdy, and competitive chassis design. This project outcome will be chassis design parameter which can be used for solar car. This project only focuses on the analyzing the initial chassis design and analysis. The modelling is done using solid works software. The analysis however is done on ANSYS. This project is focusing on design and development of the integrated chassis of a four-wheel solar car which should be more aerodynamics and able to travel in long distance. This focus area is done based on the following aspect:

i. Design a chassis of four-wheel solar car.
ii. Perform analysis spaceframe chassis characteristic and discover the effects of stress, torsion, and deflection on a chassis.

1.2 Objectives

After making a consideration with the project background and problem faced, we decide the main objectives that we are looking for in this project are:

i. To design the elements of body and chassis of a solar car for the target of the most lightweight and lowest material cost design.

ii. To analyze the elements of a chassis of a solar car.

iii. To design and model the solar car that can withstand the load from the solar panel body, driver, actuator, and the suspension.

iv. To analyze what happens to the chassis during a crash.

1.3 Project specifications

The project consists of different aspects in order to make this spaceframe light weight and lower cost. The components will be discussed in section 3.1. Based on the solar car rules and features of car design, the solar car must be designed follows these criteria:

i. Design solar car which does not exceed the maximum length is 5000 mm, maximum width is 1800 mm and minimum height of the driver's eye is 700 mm above the road.

1.4 Applications

Solar car is a solar vehicle used for land transport, usually run on only power from the sun, although some models will supplement that power using a battery, or use solar panels to recharge batteries or run auxiliary systems for a car that mainly uses battery power. Solar cars combine

technology typically used in the aerospace, bicycle, alternative energy, and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car. Most solar cars have been built for the purpose of solar car races. Some prototypes have been designed for public use, and the Lightyear one solar charged battery electric vehicle is expected to be available starting in 2021; currently, no cars primarily powered by the sun are available commercially.

Figure 1.1: Tokai Challenger, the winner of the 2009 World Solar Challenge, with an average speed of 100.5 km/h over the 2998 km race.

Figure 1.2: The Lightyear One, scheduled to go into production in 2021.

2 Chapter 2: Literature Review

This section describes the project background, previous work and a comparative study with the literature is performed.

2.1 Project Background

Solar energy is a form of renewable and sustainable energy because it is and will be available if the sun continues to shine. Estimate for the life of the main stage of the sun are another 4-5 billion years. The energy from the sunshine electromagnetic radiation, is referred to as irradiation. The emergence of interest in solar energy utilization has taken place since 1970, principally is the world's most abundant and permanent energy source. The amount of solar energy received by the surface of the earth per minute is greater than the energy utilization by the entire population in one year. (Pimentel et al.,1994).

Solar energy is also used in commercial buildings. On an office building, atria can be covered with glass/glass PV modules, which can be semi-transparent to provide shaded light. On a factory, large roof areas have been the best location for solar modules. If they are flat, then arrays can be mounted using techniques that do not breach the weatherproof roof membrane. Also, skylights can be covered partially with PV. The vertical walls of office buildings provide several opportunities for PV incorporation.

In automotive sector, there are some races authorized to some organization to encourage corporate organization like university or college team to create their own solar car and compete each other in term of speed and the energy efficiency of solar car. The most notable solar car races in present time are the World Solar Challenge and the North American Solar Challenge which been contested by a solar car from variety university and corporate team. Solar cars combine technology typically used in the aerospace, alternative energy, and automotive industries. The

design of a solar vehicle is severely limited by the amount of energy input into the car. Most solar cars have been built for the purpose of solar car races. Solar cars depend on PV cells to convert sunlight into electricity. In fact, 51% of sunlight enters the Earth's atmosphere. Unlike solar thermal energy which converts solar energy to heat for either household purposes, industrial purposes or to be converted to electricity, PV cells directly convert sunlight into electricity. When sunlight (photons) strike PV cells, they excite electrons and allow them to flow, creating an electrical current. PV cells are made of semiconductor materials such as silicon and alloys of indium, gallium, and nitrogen. Silicon is the most

common material used and has an efficiency rate of 15-20 %. (Pimentel et. al., 1994). The biggest challenge faced by the transport sector is the carbon emissions, today, the whole world is conscious about the polluted environment and is willing to take actions in this regard due to rapid changes in the climatic conditions around the globe. 23% of the Carbon dioxide emissions are directly from the transportation industry and the 72% of these emissions are due to the road traffic. This is not an ordinary but an alarming situation. So, the best available solution for this problem is the electric vehicle. However, the primary energy source is the key thing in that case as well. Because the pollution causing emissions could be cope up with the emissions generating from the energy sector like power plants. Also, another consideration is that the centralized power source will certainly provide less energy and efficiency due to huge amount of the line losses during transmission. Hence, we get to a simple point that the deployment of the electrical vehicle will only be favorable when it will be powered by some renewable source of the energy. Also, when we look the whole scenario from the point of view of power supply, we cannot accommodate high levels of Renewable sources under specific conditions of load demand at peak and peak off times.

Hence, we can select the solar energy as the source of the power for our electrical vehicle while using the motor hub system.

2.2 Previous work

This section discusses about the chassis design literatures available from different sources.

2.2.1 Chassis Frame

Basically, chassis is considered as a framework to support the body, engine, and other parts of the vehicle. Chassis provides support and rigidity to the whole vehicle support. 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 must contain the various components which are 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 through all stages. Generally, the basic chassis types consist of backbone, ladder, spaceframe and monocoque. Different types of chassis design will result the different performance of each chassis.

2.2.2 Types of Chassis

Chassis is one of the significant structures of an automobile. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. Chassis usually made of light a metal or composite plastic which provides strength needed for supporting vehicle components and load into it. Several different types of automotive chassis are:

- **Ladder Chassis:** Ladder chassis is one of the oldest forms of automobile chassis that is still been used by most of the SUVs till today. It also resembles a shape of a ladder which

have two longitudinal rails inter linked by several lateral and cross braces. The lateral and cross members provide rigidity to the structure (Wakeham, 2009).

- **Backbone Chassis:** Backbone chassis 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 of 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).
- **Monocoque Chassis:** Most of the modern car uses this type of chassis now a days. It 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, whereas the former only support the stress members. The demand of a monocoque chassis highly increased since it is cost effective and suitable for robotized production (Christopher, 2004).
- **Tubular Space Frame Chassis:** Tubular space frame chassis employs dozens of circular-section tubes or some may have square-section tubes for easier connection to the body panels. Circular section provides the maximum strength. Tubes 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 is very strong in any direction compared

with ladder chassis and monocoque chassis of the same weight. Figure 2.1 below showed the sample tubular space frame chassis of TVR Tuscan (Christopher, 2004).

Figure 2.1: An example of chassis of TVR Tuscan Source: (Wan, 2000).

Also, there are several existing design of Aluminum chassis that had been used by automobile company around the world. Lotus Engineering as the example has been building cars with aluminum chassis for many years. Lotus succeeds to introduce that none of the chassis are welded since the strength of Aluminum is decrease once it is welded so they have decided to hold it together only with screws and adhesive. When Lotus first introduced the method on the low-volume Elise in 1996, company leaders were worried about the market acceptance for what is essentially a glued-together car, but the technique proved so successful (over 23,000 cars produced with no reported failures) that it has become the basis of a new higher volume venture that may help to bring Aluminum-intensive vehicles more into the mainstream (Whitfield, 2004).

2.2.3 Spaceframe Chassis

The advantages of using space frame chassis construction are the mass of the structure is lesser and cost effective than other types of chassis but due to complicated manufacturing process, space frame chassis platform is only used for high performance and niche market cars. The main chassis structure is divided into several segments, which are:

- Main Hoop,
- Front Hoop,
- Side Impact Protection
- Crush Zone.

The Main and Front Hoop is tasked to protect the driver in the event if the car rolls over. The Main Hoop protects the upper part of the driver's body while the Front Hoop protects the drivers arm and hand if rollover occurs. As for the Side Impact Protection section, this section is created to protect the driver from side in the event of any collision from the either side of the car. As part of the chassis, the Crush Zone is located at foremost section of the chassis. This section is specially made to absorb energy in case of a head-on collision. The main sections of the chassis are illustrated in Figure 2.2.

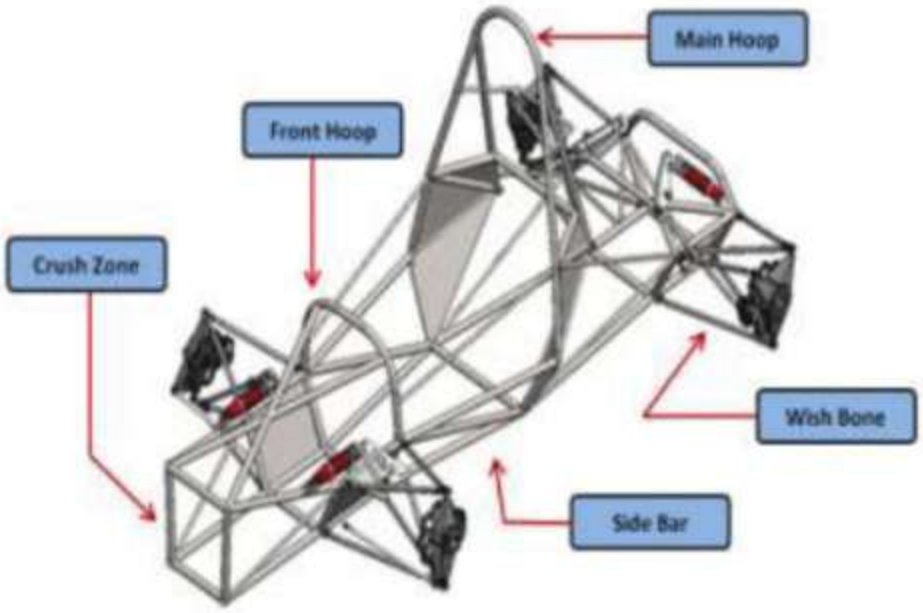

Figure 2.2: An example of space frame race car chassis structure based on Formula SAE specification.

2.2.4 GMR Institute of Technology

In the research done by GMR institute of technology (Manoharan, 2018), they designed the vehicle in which the battery is charged through the solar energy. Later, this battery is used to drive the solar car. The chassis for this system is made and then tested on various values of applied pressures and stresses. The diagram for the chassis is given as:

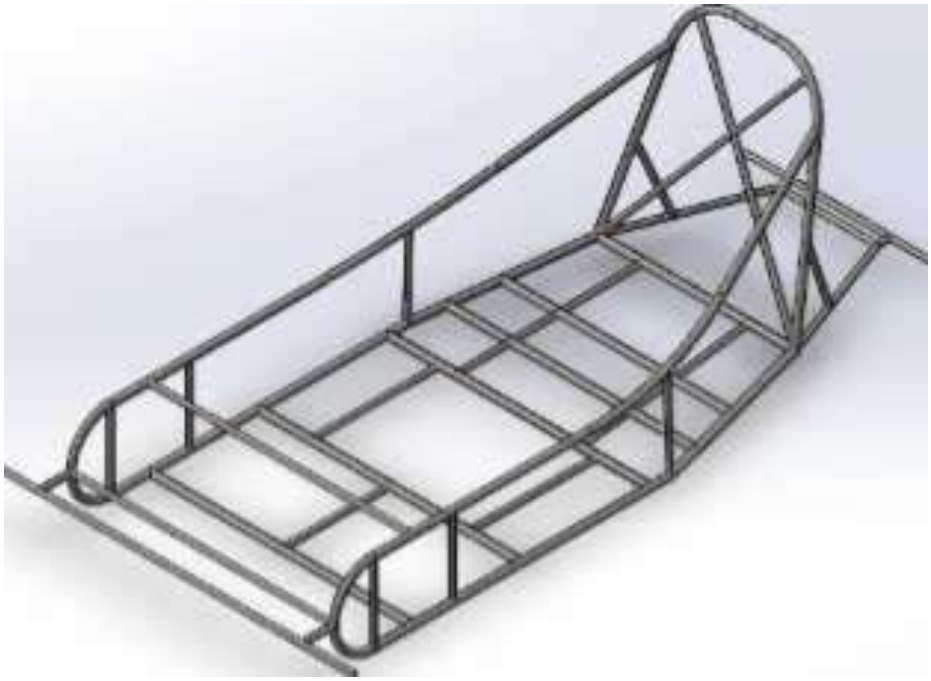

Figure 2.3: Design of Chassis for the solar vehicle (Manoharan, 2018).

3 Chapter 3: System Design

3.1 Design Constraints

When designing the chassis of the solar car, we faced four design constraints. First, geometrical. Having the student version of ANSYS made it very difficult for us to import our CAD design so we can run the analysis. It couldn't recognize the thickness of the chassis components. Second, environmental. That means that our design is only applicable for driving on concrete streets. Moreover, the chassis made of material that is subjected to corrosion. Third, economical. Most of the softwares used to analyze different technical mechanical properties require a lot of money. For example, the full vision of ANYSY costs nearly fifteen thousand dollars. Fourth, safety. Due to the recent major pandemic, we couldn't risk our safety to utilize the university's resources. In addition, to actually make the chassis we would need experience in welding and that process by itself is dangerous.

3.2 Design Methodology

We used two softwares for the design analysis. However, we started with sketching a simple design, which is similar to some chassis designs we saw with our adviser. The first software we used is Solid works. We made a 3D model of our sketch with respect to the given dimensions of the solar car. This was challenging due to having a weak computer, which took a long time to process. The second software we used is ANSYS. The aim for this project was to do a lot of ANSYS work, however that wasn't possible due to us not being able to use the university's resources. The most important test that we had to do is crash analysis. This test shows what

happens to the chassis in the case of a crash. The test yields total deformation, equivalent stress, and directional deformation.

3.3 Theory and Theoretical Calculations

Due to ANSYS limitation and not having a computer with good processing power, we couldn't analyze our design. However, we studied the results of a crash analysis on a chassis in ANSYS.

- Solid works

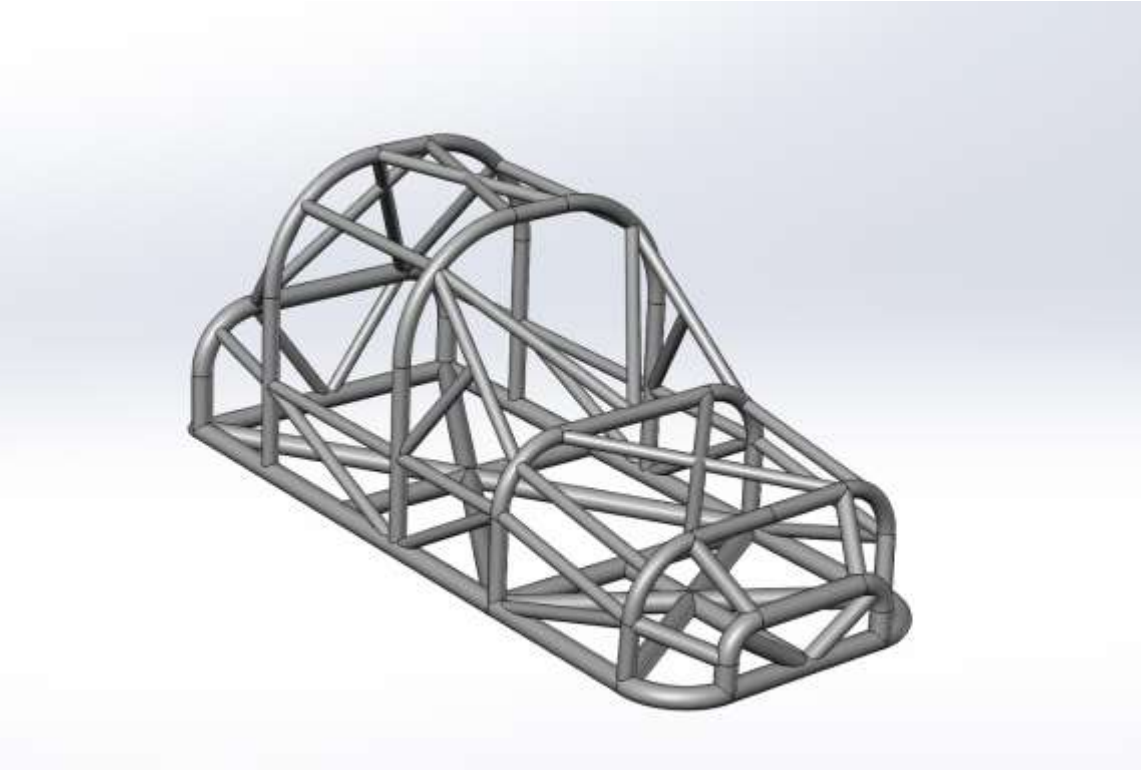

Figure 3.3 1: Simple Spaceframe Chassis model

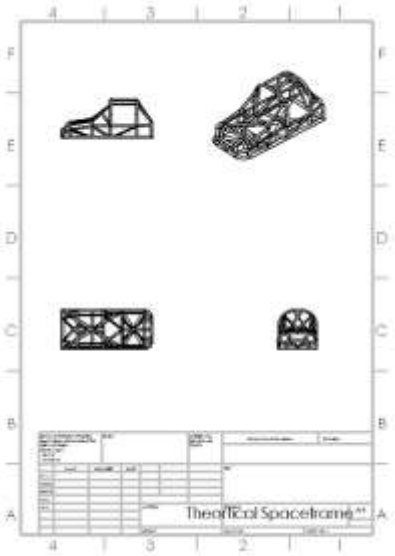

Figure 3.3.2: Simple Spaceframe Chassis Drawings

- ANSYS

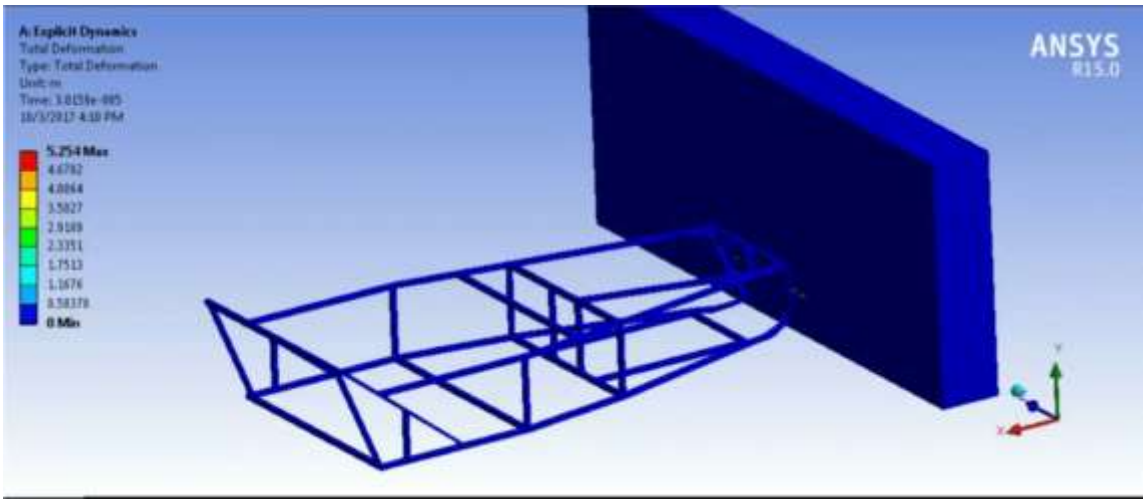

Figure 3.3.3: Total Deformation

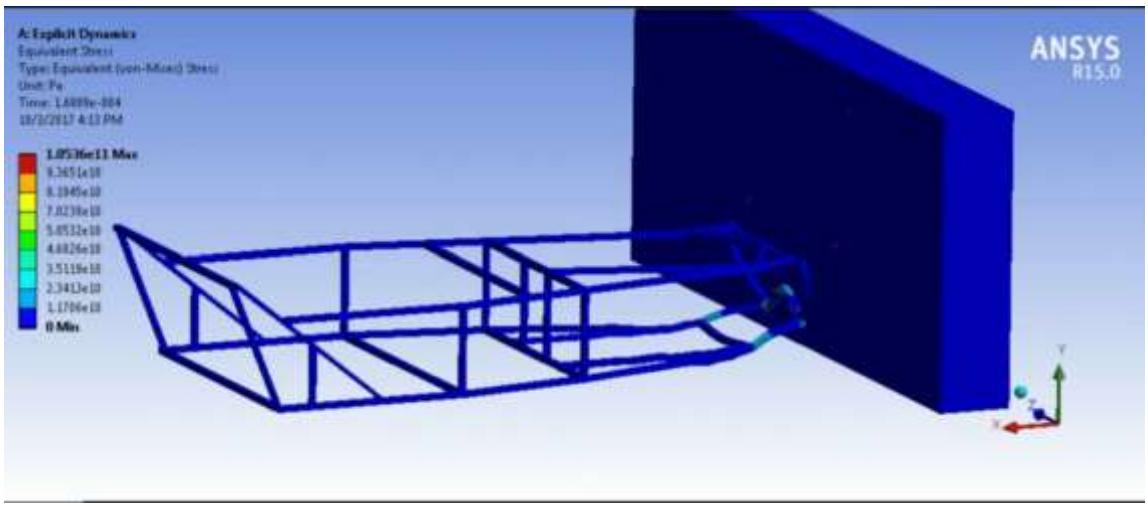

Figure 3.3.4: Equivalent Stress

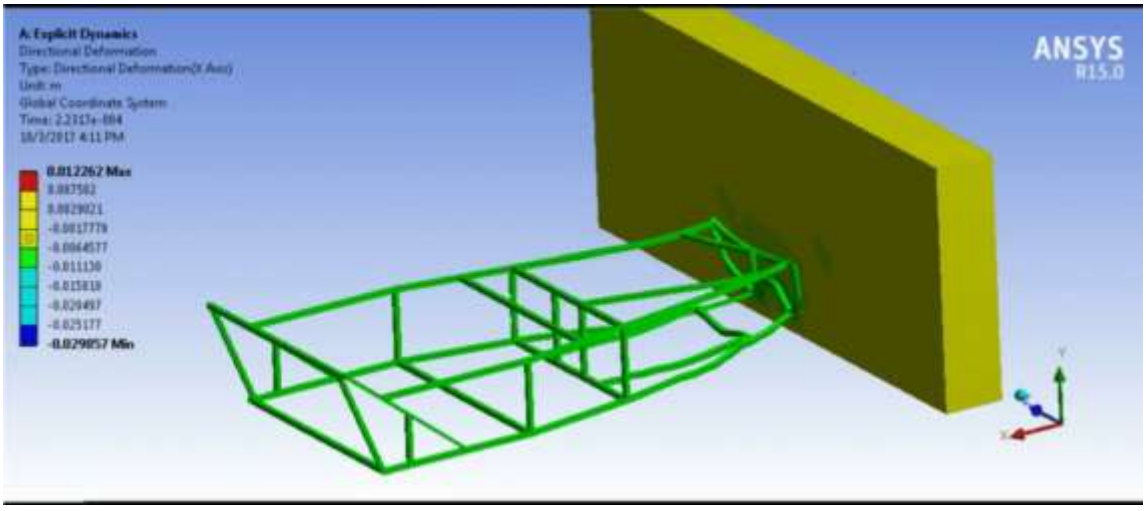

Figure 3.3.5: Directional Deformation

3.4 Product Subsystems and selection of Components

The chassis space frame is simple structure. It is mainly tubes welded together to form the structure. The components we selected were long tubes and short tubes. While doing the research, we found that some manufactures select aluminum alloys as the selected material. Others use copper alloys because it cheaper. Both materials benefit the structure because they're lighter than most used material. The values of deformation and stress in ANSYS were calculated for aluminum alloy space frame. In regards to our solar car. We consulted our advisor and with some research we think that AISI 4130 steel would be a suitable material for the space frame. We think it would provide more strength for the structure.

4 Chapter 4: Conclusion and Future Recommendation

4.1 Conclusion

A solar car is a vehicle that runs on power stored from the sun. this technology is currently rising, that's why it's science project for universities for the purpose of research. The objective of our team is to design and analyze a solar car chassis (spaceframe). The application of chassis is to protect the passengers, absorbs shocks, and a dock for various car components, especially, the body of the vehicle. The designing faze required sketching, modeling and assembly, using Solid works. The analysis mainly focuses on crash analysis in crush zone of the chassis. The material and manufacturing were selected were AISI steel and welding.

4.2 Future Recommendation

The chassis is an integral part of any vehicle. For the purposes of this project, we researched two types of chassis and their differences to advice future students. First is the monocoque chassis, which is, superior to the spaceframe chassis in terms of quality and safety. However, the disadvantages of the monocoque chassis is the difficulty of design and its cost. The second is spaceframe chassis, this type is cheaper and easier to design. If time and resources are available, we would suggest making a monocoque chassis. Otherwise, the space frame chassis would be the optimal choice.

5 References

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