DEVELOPMENT OF FOUR WHEELS SPACE-FRAME HYBRID AIR MOTORCYCLE CHASSIS

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This thesis is submitted as partial fulfillment of the
requirements for the award of the degree of
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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled Development of Four Wheels Space-frame Hybrid Air Motorcycle Chassis is written by Ser Beng Sian. I have examined the final copy of this project and in my opinion; it is adequate in terms of terms and language standard, and report formatting requirement for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering *with Automotive Engineering.

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

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Dedicate in thankful appreciation for support, encouragement and understandings to my beloved mother, father, lecturers and brothers.

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Lastly, I would like to give my special thanks to my parents whose patient, love and have faith in me which enabled me to complete my final year project.

ABTRACT

This project presents the development of four wheels space-frame hybrid air motorcycle chassis. Studies were made to investigate the computational stress/strain analysis and fabricate the four wheel space-frame hybrid air motorcycle chassis. With the rapid growth of vehicle availability and usage on the road in recent year, the rate of pollution is increasing. To alleviate the problem, four wheels space-frame hybrid air motorcycle has been developed. The hybrid air motorcycle is one kind of hybrid vehicle. It needs a lightweight and strong chassis to support the weight of the engine, drive-train compartment, driver, and other overall packaging system. A whole new compact motorcycle chassis design was undergone a various type of testing simulation by using FEA software. The simulation data such as stress, strain, displacement and factor of safety (FOS) were utilized as a guideline to develop and fabricate a new design of four wheels space-frame hybrid air motorcycle chassis. As a conclusion, the objective was achieved where the simulation results show that the chassis design will not provide significant affect neither to the chassis structure nor the driver.

ABSTRAK

Projek ini membentangkan pembangunan empat roda Ruang-rangka hibrid udara motosikal casis. Kajian telah dibuat untuk menyiasat stres/tekanan pengiraan analisis dan membina kerangka motosikal hibrid empat roda Ruang-rangka. Dengan pertumbuhan pesat adanya kenderaan dan penggunaan di jalan raya kebelakangaan ini, kadar pencemaran semakin meningkat. Bagi mengatasi masalah ini, empat roda motosikal udara Ruang-rangka hibrid telah dibinakan. Motosikal hibrid merupakan salah satu jenis kenderaan hibrid. Ia memerlukan kerangka yang ringan dan kuat untuk menyokong berat enjin, gearbox, pemandu, dan sistem lain. Reka bentuk baru motosikal casis ini akan menjalani beberapa jenis ujian simulasi dengan menggunakan perisian FEA. Keputusan simulasi seperti tekanan, ketegangan, anjakan, dan factor keselamantan telah digunakan untuk sebagai satu garis panduan untuk membangunkan dan boleh mencipta reka bentuk empat road ruang-rangka hybrid udara motosikal casis yang baru. Kesimpulannya, objektif telah dicapai sebagaimana keputusan simulasi telah menunjukkan reka bentuk yang baru ini tidak akan menimbulkan kesan kepada struktur casis dan pemandu.

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LIST OF SYMBOLS

σ	Stress
σ_{limit}	Yield strength
$\sigma_{von\ Mises}$	Von Mises Stress
ε	Strain

LIST OFABBREVIATIONS

AISI	American Iron and Steel Institute
CAE	Computational Aided Engineering
FEM	Finite Element Method
FOS	Factor of Safety
HFE	Human Factors and Ergonomics
IC	Internal Combustion
IEA	International Ergonomics Association
MIG	Metal Inert Gas Welding’
SAE	Automotive Engineering Society
3D	Three Dimensional

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

In the automotive field, the chassis is one of the important parts of a vehicle include motorcycling. Basically, the motorcycle chassis has 2 basic types. There are static type and dynamic type (Tony Foale, 2002). In the static type, the chassis must be able to support the weight of the components of the vehicle such as engine, transmission, and other necessary systems. The material selection of the chassis is also very vital. A strong strength material must be used for the main frame to avoid crash easily when crashing occurs. For the frame dynamic's function, it is not very obvious but it is very important for the comfort, handling, stability and road holding.

Over the years, the design of the motorcycle chassis has been developed rapidly. The first motorcycle chassis is based on the bicycle chassis which is diamond-shaped structure with tubes brazed into the lugs (Tony Foale, 2002). However, the earlier motorcycle required a small size low-powered engine and this engine need to fix in the diamond-shape structure chassis. Thus, the chassis had modified to mount the small low-powered engines. Currently, there is various types of motorcycle chassis had been used in this world. These different types of chassis have their own functionality and also the limitation. It is all depend on what type of motorcycle will use what kind of chassis. For example, frontbone type chassis design is generally associated with Greeves motorcycles and step through type chassis design is used for scooters or low priced commuter bikes.

In recent year, the demand of hybrid motorcycle has been increased from time to time in the modern world. Hybrid engine motorcycle configured travel by using driving of an electric motor. This hybrid is not longer to replace the usage of internal combustion engine. The internal combustion engine required fuel and will produce harmful gas to the environment. By using a hybrid engine motorcycle, the emission from the engine will be much less. However, to build a hybrid engine on the motorcycle chassis, the design of the chassis need to modified. As known, the hybrid engine required more components compared to the IC engine. So, the chassis of the hybrid motorcycle must be bigger than the IC engine motorcycle chassis, thus the components can install on the motorcycle chassis.

1.2 PROBLEM STATEMENT

The development of the motorcycle chassis is surprisingly fast and the weakness of the chassis is also improved. Nowadays, the automotive technology is very advanced. The chassis that had manufacture is using strong strength material. Normally, the material that used for the motorcycle chassis is aluminum, alloy, and steel. These materials have high yield strength to support higher weight of the vehicle components especially for the hybrid engine type motorcycle.

Nowadays, there is a lot of the type of research about the chassis such as finite element method and the experimental modal analysis technique to analysis the limitation of chassis. Analysis of the chassis can analyze the vibration, fatigue and other properties of the product and also the weak link of the product structures (Shi and Wang, 2010). These two of analysis can give a guide to manufacture a stronger chassis as well as provide the reliable basis for the improvement of the product. Thus, before manufacture a new design of motorcycle chassis, this analysis is very useful and important for the safety of the user.

However, the chassis of hybrid engine and chassis of IC engine is not the same. There are a lot of components with a hybrid engine. With the number of components need to attach together on the chassis, obviously, the chassis will be bigger compared to the IC engine. To attach all the components, the arrangement of the components will be very compact and the weight of the motorcycle is also heavier than the IC engine chassis.

1.3 OBJECTIVES

a. To design and fabricate four wheels air hybrid space-frame motorcycle chassis.
b. To analyze computational stress/strain analysis of the four wheels air hybrid space-frame motorcycle chassis.

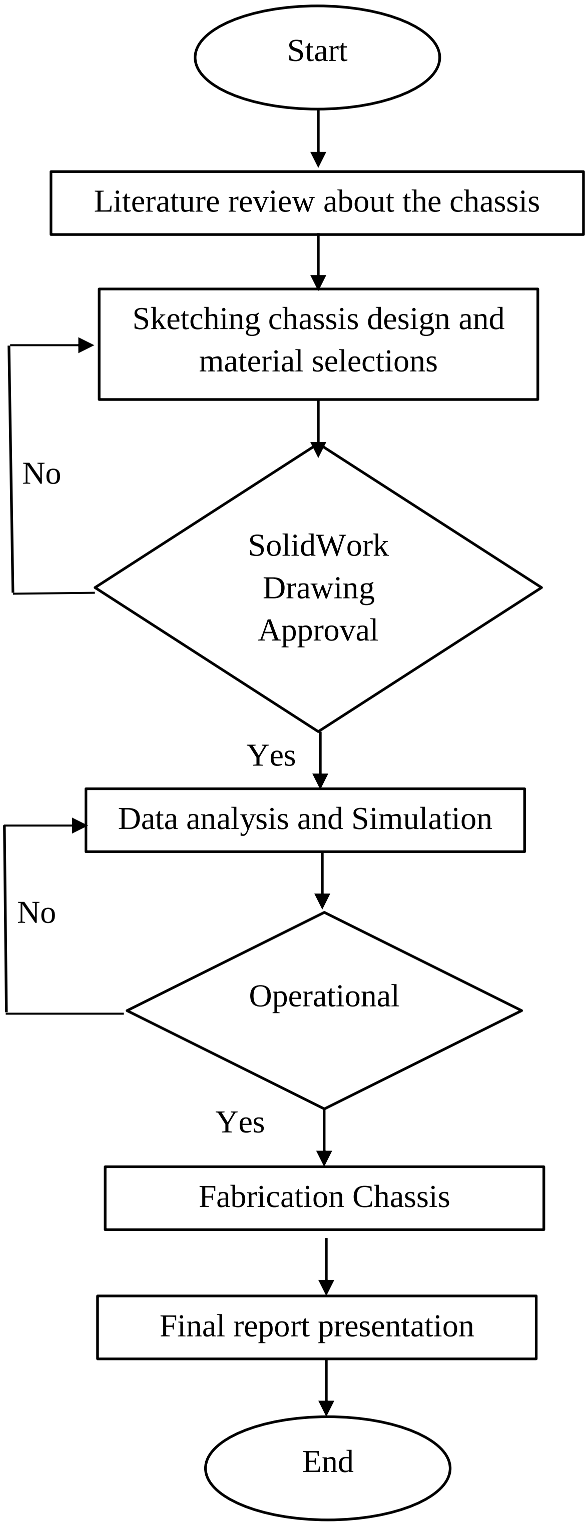
1.4 WORK SCOPES

a. Literature review on four wheels motorcycle design, chassis, suspension system.
b. Conceptual design of air hybrid motorcycle chassis.
c. Computational stress/strain analysis and design refinement.
d. System component preparations and chassis fabrication.
e. System integration
f. Final report preparation.

1.5 HYPOTHESIS

Proposed four wheels space frame hybrid air motorcycles take additional consideration of compact components packaging system as well as large powertrain compartment compared with conventional four wheels system. By the end of the development, the hybrid motorcycle design features with detail material selection and stress-strain analysis could enhance the development of innovated motorcycle chassis prototype.

1.6 FLOW CHART



1.7 GANTT CHART

The Gantt chart is refer to Appendix A

CHAPTER 2

LITERATURE REVIEW

2.1 FUNDAMENTAL OF CHASSIS

Nowadays, motorcycle is widely used on the road. The development of the motorcycle has been quite fast since 1900's. From mini size motorcycle until the racing type motorcycle, the changes of the motorcycle are very obvious. Indirectly, the technology of the motorcycle chassis is also become advance and able to manufacture different design of motorcycle chassis.

A well designed motorcycle chassis, it is important to ensure that the safety, performance, and fuel efficiency. A good chassis is able to protect the passenger from injury when a crash occurs. For the fuel efficiency aspect, the chassis is light enough and it has a low frictional resistance (Hanif and Amir, 2012).

In the motorcycle industry field, all the components of the motorcycle and the load will attach to the motorcycle chassis. The load includes the weight if each component and the forces which manifest during acceleration, deceleration and cornering. The components that usually attached to the chassis are the engine, the suspension system, the steering system and the braking system (Hanif and Amir, 2012). Motorcycle chassis is not similar to the car chassis. The size of the motorcycle chassis is much smaller than car chassis. Thus, every component must be compact between each other and attach to the motorcycle chassis.

Over the years, designers have been repeatedly criticized for their seeming reluctance to depart from the diamond-pattern frame inherited from the pedal cycle

(Tony Foale, 2002). At the beginning of the motorcycle development, the majority of early motorcycle was designed based on the bicycle frame design which is diamond-shaped structure. At that time, the diamond-shaped structure design is not very advance, so a small low-powered engine is attached at various places, which were the logical frame type to adopt.

This situation continues until the tall single-cylinder engine available. This type of engine is quite tall and cannot able to attach on the previous design of motorcycle chassis. So, a higher depth motorcycle chassis is designed to suit the tall single-cylinder engine and this chassis is popular for a long time (Tony Foale, 2002). The first motorcycle in the world was invented in the year 1894. Motorcycle development between 1900 and 1910 was rapid. The purpose to build a different type of chassis is because of the engine is more power and more torque. Over the subsequent year, the motorcycle manufacturers developed a conventional design based on type of motorcycle.

Figure 2.1: First motorcycle in year 1894

Source: *www.motorcycle-usa.com*, retrieved on 8 December 2012

2.1.1 Evolution from Two-Wheel Design for Four-Wheel Design

Two-wheel design is a chassis that use two wheels to move. The wheels are located at the front of the chassis and another is located at the back of the chassis. In 1860, the first two-wheel design was invented by a German, called Baron Karl Drais. At that time, the two-wheel design chassis is bicycle type and only can move by pushing the chassis with legs (http://www.pedalinghistory.com, 8 December 2012). In 1885, the first motorcycle was invented by Gottileb Daimler. He is a German citizen and he attached a gas-powered engine to a wooden bike. This engine is able to move up the 2 wheel design chassis but the speed is very slow.

Over the year, the size of engine is become bigger. There is insufficient slot for mounting the big size engine on the two wheels design chassis. Furthermore, the power of the engine is also higher; a simple structure two-wheel design chassis already cannot support the load acting which is from static or dynamics. To overcome this problem, four wheel design chassis was invented. The purpose of four-wheel design is to mount the bigger engine on the four-wheel design chassis. Four wheels design is also more rigid compare to the two-wheel design. It can withstand more load which acting on the chassis. Four-wheel design is able to have a good shield to protect the safety of the driver. When crashing occurs, this four-wheel design is still can protect the drivers collide with others. In additional, four-wheel design also have a good stability compared to the two-wheel design chassis.

Evolution from two-wheel design to four-wheel design is very useful for the driver and passenger. Four-wheel design not only can have a good protection to the driver and passenger, it provides a comfortable and relaxing journey to the user as well.

2.1.2 Classification of Chassis

The chassis can be classified into various types of chassis. These different types of chassis have been used in different ways. It is all depend on what the usage of the motorcycle. The following is the type of chassis which are the backbone, monocoque, stressed engines, and space frame.

- Backbone – typically utilizes a large section top tube which, in some cases, doubled up as an oil carrying member.
- Monocoque – using different type of material for the constructions. Normally, this motorcycle chassis is manufactured for the road racers, street bikes and scooters.
- Stressed engines – using the engine and gearbox as a stressed member of the chassis has been used extensively on the motorcycles.
- Spaceframe – the shape of the spaceframe is likely a"cage: which welded together with square hollow tubes or circle hollow tubes.

2.1.3 Space-frame Consideration

Space-frame type design chassis can provide a good result in torsional rigidity, weight holding, and impact protection (Keith, 2009). To build a well-designed spaceframe, triangulation is very important and must always in the consideration. Therefore, to build the chassis structure is more rigid, the motorcycle chassis must be as wide as possible.

At the earliest motorcycle, the chassis is design of space-frame chassis. Space-frame chassis is easy to build and it is strong enough to support the weight of the components. There are 2 advantages of space-frame: chassis weight and chassis stiffness.

Normally, the motorcycle chassis that design of the space frame is lightweight. With a lightweight chassis, the motorcycle can reduce emissions and increase the fuel efficiency. For the lightweight motorcycle, there is no many additional features such as power steering, which in turn reduces overall load carrying requirements; thus setting in motion a cycle of weight-saving initiative and reducing vehicle complexity (Howard, 2000).

Lightweight is a primary goal for all race cars as lightweight only required less force to accelerate by the same amount. According to the newton's 2nd law, the acceleration of a body is parallel and directly proportional to the net force acting on the body. If in the direction of the net force, the net force is inversely proportional to the mass of the body. The following is the equation of newton's 2^{nd} law as expressed in Eq. (2.1):

$$F = ma \tag{2.1}$$

From the equation, if the same force is applied to the car, the lighter car will accelerate faster than heavier car. This is the reason the racing car is fabricating space frame type chassis. (Brendan. J. Waterman, 2011)

Besides the weight of the chassis, stiffness of the chassis must be considered. A well-built chassis required a high stiffness to protect damaging to the chassis. Thus, choosing a high stiffness material is the key in order to build out a chassis which is space frame type chassis. Stiffness material is also known as Young's Modulus. The mechanism for stiffness in a material is the inter-molecular force, so this stiffness cannot be modified by any mechanical or chemical processes (Brendan, 2011). The stiffness of the material can be calculated from the equation as expressed in Eq. (2.2)

$$\mathrm{E} = \frac{tensile\ stress}{tensile\ strain} = \frac{\sigma}{\varepsilon} = \frac{F/A_o}{\Delta L/L_O} \tag{2.2}$$

2.2 CHASSIS FOR HYBRID MOTORCYCLE

To design a chassis which is hybrid type, there are many aspects to be considered, including component packaging, material selection, strength, and weight (Michael and Terry, 2009). Firstly, before the chassis can be developed, it is first important to understand what hybrid engine component will be used and attached to the motorcycle chassis. The number of hybrid engine components is much more than IC engine, so the location of the attachment of the components must be identified so that the load acting on the chassis capable of withstanding.

Secondly, the key design of the chassis is the material selection. Normally, the material has been chosen is stainless steel. Stainless steel is better than other materials because stainless steel has better expansion and contraction. This property allows bending and curving is much easier if compared to other type of material.

Thirdly, chassis for hybrid motorcycle required a high strength to protect the component packaging and the passenger. As mentioned, there is a lot of hybrid engine component. The weight of the component adds up together will give a load acting on the chassis. So, the strength of the chassis must be strong enough to withstand the weight of the components.

The last aspect is weight. The purpose of hybrid engine motorcycle is to replace the IC engine so that emission can be reduced. However, the power of hybrid engine is not as high as IC engine, thus, the weight of the chassis of hybrid motorcycle needs to minimize in order to increase the speed of the motorcycle.

2.3 IMPORTANCE OF ERGONOMICS CHASSIS DESIGN

Design and ergonomics are the most important terms in the design process. According to the international ergonomics association (IEA), ergonomics as the discipline that involves the understanding of the interaction between humans and other elements of a system and the profession that applies theory, principles, data and methods to designing in order to optimize human well-being and overall system performance (Karmegam Karyppiah, Mohd Sapuan, Mohd Yusof, Napsiah Ismail, ShamsulTamrin, 2011).

The four basic criteria in an ergonomic chassis design are increasing production, decreasing injuries, decreasing human error and increasing user satisfaction. An ergonomic chassis design can give the human comfort, clear vision, safety, as well as reduce fatigue during the reading process.

The Applied Human Factors and Ergonomics (HFE) design and engineering continue to permeate the manufacturing industry. One of the most commonly experienced applications of ergonomics design and engineering resides in the automotive. The development in ergonomic cockpit, instrument, seating, and safety design are all the evidence in practically every new automobile (Robert, 2002).

The development of applied human factor and ergonomics (HFE) motorcycle chassis design has still remained an engineering challenge. The motorcycle unlike other automotive, motorcycle is an unconstrained vehicle platform, saddle-based vehicle which does not offer lumbar, thoracic or thigh support (Robert, 2002). To design an ergonomics chassis, there are six important components; market study, product design specification, conceptual design, manufacturing, and lastly sale. The Figure 2.2 is the total design process model:

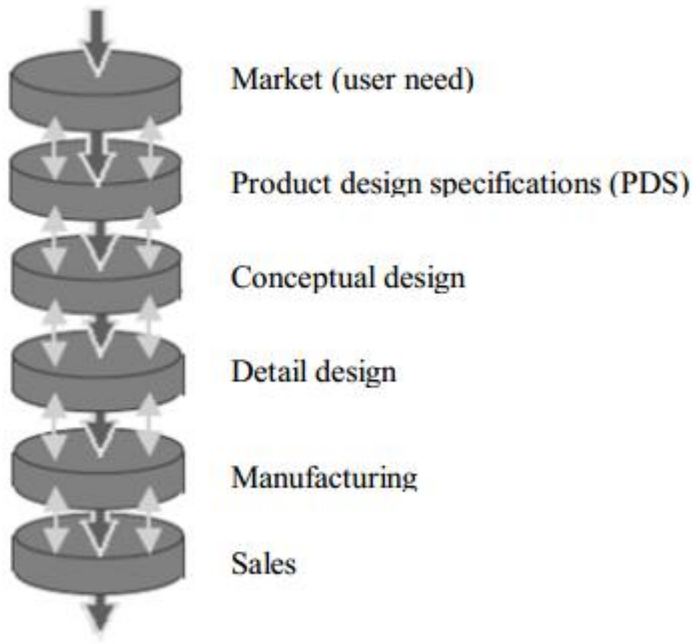


Figure 2.2: Total Design Process Model

Source: Karmeganm, Sapuan, Yusof, NapsiahShamsul (2011)

2.4 TYPE OF ANALYSIS

The chassis is to use to support all the components such as engine compartment, drivers and other packaging components. The force of chassis mainly includes the gravity of the components, the weight of the driver, and acceleration force during the process of running (Wang, Liu, Zeng, Chen, 2012). Because of these criteria the strength and the rigidity of the chassis must be considered during the structure of the design. Normally, to determine the strength and rigidity of the chassis, there are two types of analysis can be obtain to know that the stress and strain of the chassis. These two analyses are finite element method and the experimental modal analysis technique.

2.4.1 Finite Element Analysis Method

Finite Element Analysis is a kind of mathematical approximation method, which can simulate the true physical phenomena. The simulation will analysis the 3D model in the software which in geometry and loading condition. From the FEM method, the value and position of maximum stress and maximum strain will be obtained and show clearly on the 3D model. The range of stress and strain will also show on the structure of the model represented by different color. The color close to red (shown in Figure 2.3) means the stress or strain is nearly close to the maximum value while the color closest to blue (shown in Figure 2.3) means the stress or strain is in very small value and can be ignored.

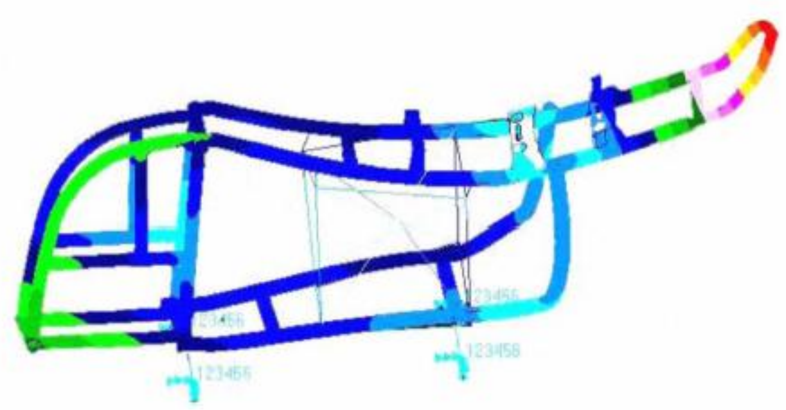


Figure 2.3: Stress Analysis Diagram

Source: Shi and Wang (2010)

The result of the finite element analysis method is very significant to improve the stability and service life of the chassis structure. By going through the FEM analysis, the dangerous structure can be found and the design can be modified before starting the fabrication process.

2.4.2 Experimental Modal analysis

Unlike FEM analysis, experimental modal analysis is a hands-on experiment. This analysis is not using any software to simulate the maximum stress and maximum strain. Without using any software, the experimental results could get higher accuracy as long as the experimental modal measurement tools are accurate (Shi and Wang, 2010). The advantage of experimental modal analysis is the result could reflect the true dynamic characteristics of the frame, so it could compensate for the lack of finite element analysis and verify the reliability of model in finite element analysis.

The equipment for the whole test system that will be used are the actual chassis frame, charge amplifier, acceleration sensor, force sensor, the hammer, rubber rope and the modal analysis software which is a data collection instrument and analysis system. The Figure 2.4 is the test system theory diagram to obtain the analysis result:

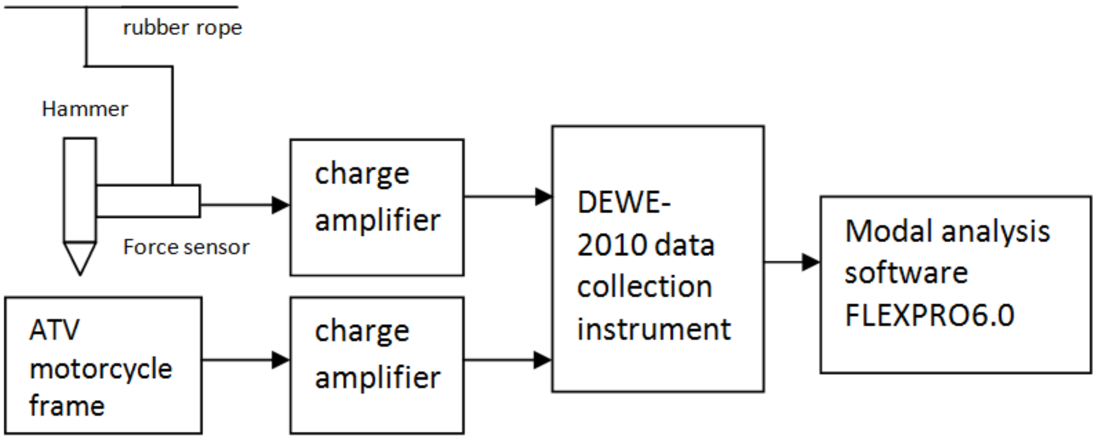


Figure 2.4: Test System Theory Diagram

Source: Shi and Wang (2010)

CHAPTER 3

METHODOLOGY

3.1 CONCEPT OF AIR HYBRID FOUR WHEELS MOTORCYCLE CHASSIS

Concept is the basic to begin to sketch the design of the motorcycle chassis. Without the concept, the chassis design cannot able to draw and start to sketch. For this project the concept is based on the formula SAE concept and chopper style concept. The front part of the air hybrid four wheels motorcycle chassis is using formula SAE concept. This concept is chosen because the formula SAE concept is more focus on the aerodynamics. However for the concept of chopper style, the seat position is more like relaxing or enjoying the pattern. Both concept will combine together and become the new air hybrid four wheels motorcycle chassis. After deciding the concept that want to refer, the sketching work can begin.

3.2 DESIGN SKETCHING

The dimension of the wheel base must be considered first prior starting sketch chassis design. After deciding the dimension of Length x Width x Height (L x W x H), then the method of snapshot photo is carried out. Snapshot photo method is the more easy method to sketch the chassis in the photo. In the photo, a person as the driver is sitting on the chair where between two motorcycle wheels. This photo act like as a reference. To sketch a design, three view need to take; top view, side view and front view. It is very convenient to see and analyze the wheels and the person located in the sketched chassis.

3.3 DESIGN CONSIDERATION

To design a four-wheel air hybrid motorcycle chassis, the design consideration is very important. This consideration can fulfill the concept of the air hybrid motorcycle chassis which is ergonomics motorcycle. Before deciding the length, height and width, it must be considered which components need to use for the motorcycle chassis and the dimension of the component that available on the current market.

In additional, the length, height and width of the motorcycle chassis also must be based on the average dimension of the human body. The dimension of the human body is very important to determine the size of the seat, the height of the seat, and other consideration. An average height and weight for a human is 172 cm and 70kg respectively.

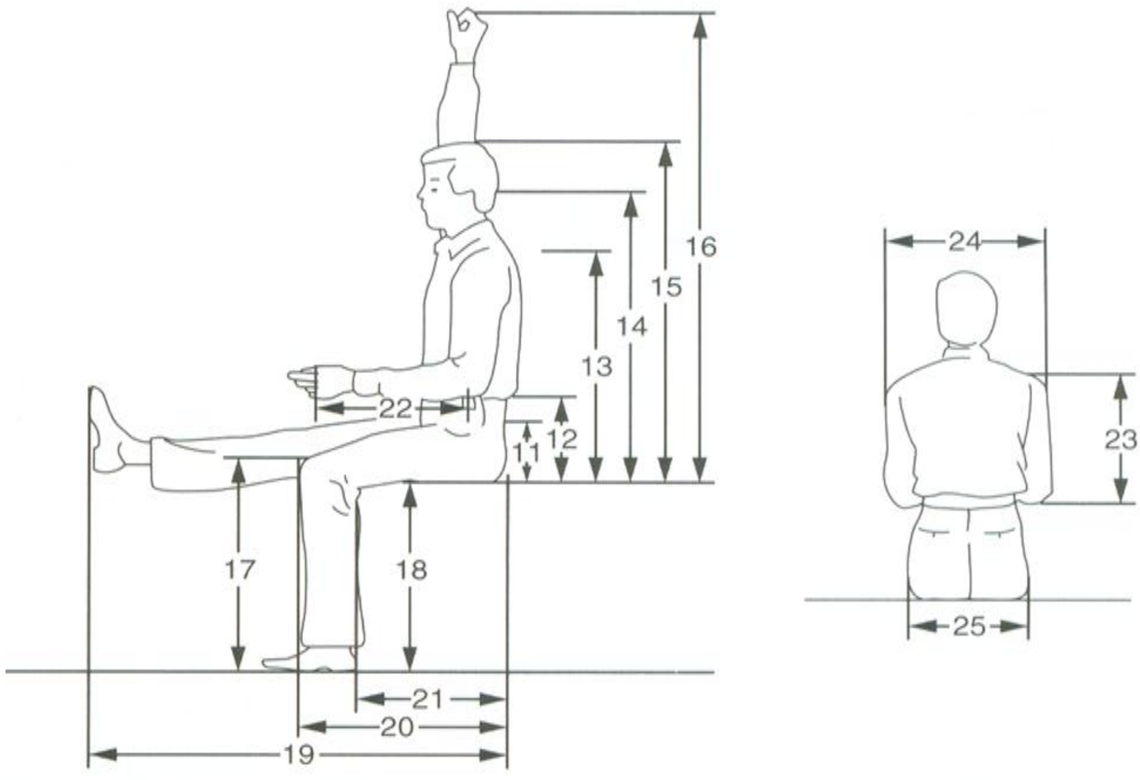


Figure 3.1: Seated Position of Human

Source: *misi.jsc.nasa.gov*, retrieved on 20 December 2012

Table 3.1: Anthropometric Data

No	Measurement	Metric (mm)
11	Thigh Clearance Height	5.8
12	Elbow Rest Height	9.5
13	Mid-shoulder Height	24.5
14	Eye Height	31.0
15	Sitting Height, Normal	34.1
16	Functional Overhear Reacl	50.6
17	Knee Height	21.3
18	Popliteal Height	17.2
19	Leg Length	41.4
20	Upper-Leg Length	23.4
21	Buttocks to Popliteal Leng	19.2
22	Elbow to fit Length	14.2
23	Upper Arm Length	14.5
24	Shoulder Breadth	17.9
25	Hip Breadth	14.0

Source: *misi.jsc.nasa.gov*, retrieved on 20 December 2012

The Figure 3.1 and Table 3.1 above shows that a human is in the seated position and the table illustrate the Anthropometric Data of the human body. All dimensions of the chassis will be identified based on the anthropometric data.

3.4 3D DRAWING PROCESS

3D drawing process is a process to draw every component of the motorcycle into the software. The software that will be used is Solidwork 2012. Every dimension of the components needs to be measured by caliper and measurement tape. These two measure equipment are very useful to measure all the dimensions of the components and can able to achieve an accurate dimension. However, the process may delay especially in the 3D drawing. The lacking of knowledge of 3D software will cause unable to draw the components accurately. At the end of the drawing, it will cause the components cannot match with other components in the 3D drawing software.

3.5 SOFTWARE COMPUTATIONAL ANAYLSIS

At the end of the chassis design, simulation or analysis of the chassis will be carried out. From the simulation, it can clearly show that what is the chassis ability and where is the member of the chassis is on the high stress/strain concentration area. To carry out this process, inside Solidwork 2012, there is a feature call Simulation Analysis wizard on the Evaluate section. This simulation Analysis wizard is able to analysis the von Mises stress analysis, stress/strain analysis and also displacement analysis.

To use SimulationXpress analysis wizard in Solidwork 2012, there is a simple way and shown as below:

a. Open model and go to “Simulation” tab and press “new study” option.
b. In the study list, select static type simulation.
c. Select the fixture which is a standard geometry that will not move then a force is applied
d. Click “add fixture” and select the geometry that want to fix.
e. Define the loads by choosing either adding force or adding pressure on the model.

f. Select the face on which the load has to act on, and then select the direction of the load.

g. Select the materials of the model. (Solidwork 2012 provide all the materials and their materialistic values.
h. Create meshing with determining the mesh size (coarse give more inaccurate results but the time taken is short, fine give more accurate results but the time taken is long)
i. Run the simulation.
j. Check for Von Mises stress analysis, stress/strain analysis and displacement analysis.

With computational analysis software, the analysis of the chassis can be analyzed in detail information. From the information that shown by the software, we can know that, the amount of stress and strain is acting on the chassis. It also can show the deflection of the chassis when the load is applied to the chassis. This result is useful to understand where the constraint location is. So that, there will be adding a frame near the constraint location to avoid the constraint location collapsed. This supported frame is also called reinforcement. Normally, the constraint location will locate on the mainframe which connects to another frame and will have more load acting on the frame.

3.6 SIMULATION OF LOADING CONSTRAINTS

In this project, in order to get more complements and details results, the simulation of different loading condition are carried out. The different loading constraints that will be used in the analysis are static load, acceleration load, deceleration load, and frontal impact load. The purpose of carrying out different loading constraint is to prove and show that the stiffness and strength of the frame structure chassis can be supported all the force without creating significant affects neither chassis nor rider.

The parameter of static load constraint, deceleration constraint, acceleration constraint and front impact constraint are shown in the Figure 3.2, Figure 3.3, Figure 3.3, and Figure 3.4 respectively.

3.6.1 Static load Constraint

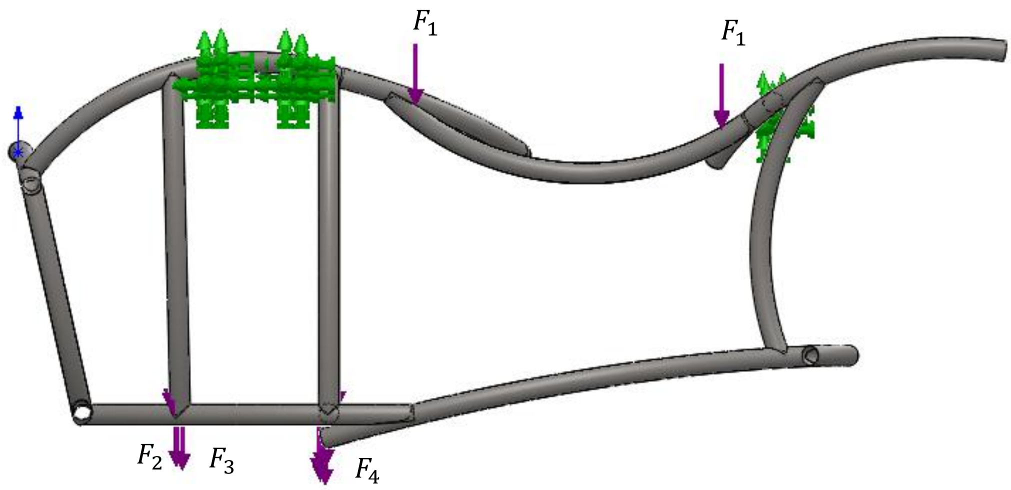


Figure 3.2: Chassis with Fix Geometry and Static Loads

Static load stress-strain parameter:

Fix geometry at the bracket of front suspension and the bracket of rear suspension

Table 3.2: Force Distribution of Static Load Constraint

Force	Value (N)
Driver weight, F_1	600
Engine weight, F_2	830
Engine weight, F_3	830
Engine weight, F_4	830

3.6.2 Deceleration Constraint

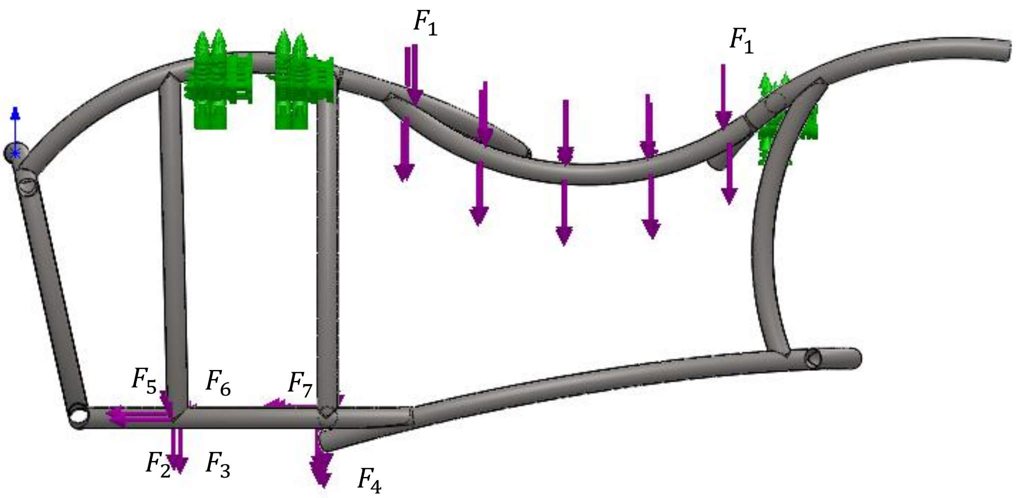


Figure 3.3: Chassis with Fix Geometry and Deceleration Loads

To calculate the acceleration force, two equations need to use. The following is the calculation to get the acceleration force.

$$a = \frac{v_i - v_o}{t}$$

According to the specification of engine, the speed of the engine can run from 0 km/h to 100km/h within 13 second. From the equation, the acceleration of the engine can be obtained:

$a = \frac{100-0}{13}$

= 7.69km/h

= 2.136 m/s

According to the newton's second law, the acceleration of a body is directly proportional to the same direction. Thus, the equation is F=ma. Where m is the total mass of the engine and the driver (250kg)

F = 250 x 2.136

= 534N

From the calculation, it found that the acceleration force action on the engine is 534N, thus each mounting point of the engine estimated is 180N.

Deceleration load stress-strain parameter:

Fix geometry at the bracket of front suspension and the bracket of rear suspension

Table 3.3: Force Distribution of Deceleration Constraint

Force	**Value (N)**
Driver weight, F_1	600
Engine weight, F_2	830
Engine weight, F_3	830
Engine weight, F_4	830
Deceleration force, F_5	180
Deceleration force, F_6	180
Deceleration force, F_7	180

3.6.3 Acceleration Constraint

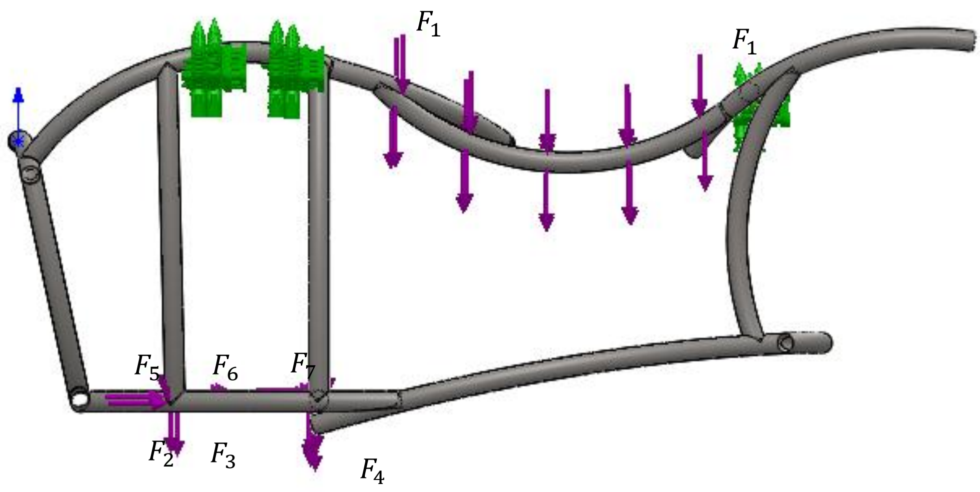


Figure 3.4: Chassis with Fix Geometry and Acceleration Loads

The equation that will be used to calculate for the deceleration force is the same with accelerated force, thus the calculation expressed as:

$$a = \frac{v_i - v_o}{t}$$

$$a = \frac{0-100}{13}$$

= -7.69km/h

= -2.136 m/s

Due to the negative sign of acceleration, so the direction of the force will become opposite direction which means, the deceleration force will act backward on the engine parts. The acceleration force is 534N, thus, 180N of acceleration force will act on the 3 mounting points of the engine.

Acceleration load stress-strain parameter:

Fix geometry at the bracket of front suspension and the bracket of rear suspension

Table 3.4: Force Distribution of Acceleration Constraint

Force	Value (N)
Driver weight, F_1	600
Engine weight, F_2	830
Engine weight, F_3	830
Engine weight, F_4	830
Acceleration force, F_5	180
Acceleration force, F_6	180
Acceleration force, F_7	180

3.6.4 Frontal impact Constraint

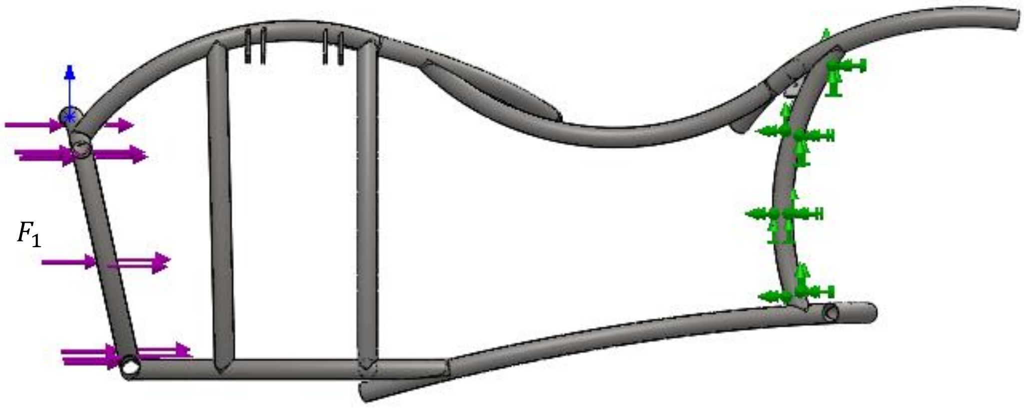


Figure 3.5: Chassis with Fix Geometry and Frontal Impact Loads

To calculate the impact force, the force need to determine by estimating a maximum allowable force where start with a simplified injury criterion. According to Motor Insurance Repair Research Center, the maximum force used for analysis for the spaceframe chassis is 7.9G. To continue the frontal impact analysis in this project, 7.9G has been used to determine the force value of the analysis. To calculate the forces again newton's second law was used, the force calculation was shown below in the equation.

F = ma

m = 250kg (include weight of driver, engine, transmission and other overall packaging system)

a = 7.9 x 9.81m/s^2
= 77.5 m/s^2

F = 250 x 77.5
= 19375N

Frontal impact load stress-strain parameter:
Fix geometry at the rear side of the chassis

Table 3.5: Force Distribution of Frontal Impact Constraint

Force	Value (N)
Frontal Impact force, F_1	19500

3.7 MATERIAL SELECTION

3.7.1 Stainless Steel AISI304

Stainless steel divided into six groups, martensitic-austenitic, ferritic, ferritic-austenitic, and austenitic and precipitation hardening steels. For this project, Stainless steel AISI 304 is in the category of austenitic steel. AISI 304 stainless steel is better than other materials because of the high amount of chromium contained. Chromium is the most important alloying element in stainless steel and it gives high corrosion resistance. The content of chromium has also increased the resistance to oxidation at high temperatures. The Table 3.2 is the AISI 304 stainless steel composition:

Table 3.6: The percentage of the element in the stainless steel

Element	Percentage (%)
Carbon	**0.08**
Chromium	**18.00-20.00**
Manganese	**2.00**
Nickel	**8.00-10.50**
Phosphorus	**0.045**
Sulfur	**0.03**
Silicon	**1.00**

Source: BelaLeffler (2000)

Nowadays, the application of stainless steel is become wider. The unique properties of the stainless steel attract the focus from many industries especially automotive industries. In the automotive field, stainless steel is widely used in car exhaust system and for auto part. It will soon be common in chassis, suspension, body, fuel tank and other applications. The most usual stainless steel that had been used is stainless steel AISI304. This type of stainless steel is very suitable for the automotive parts. Following table 3.3 is the properties of stainless steel AISI304:

Table 3.7: Properties of stainless steel AISI 304

Properties	**Metric**
Tensile Strength, Ultimate	505 MPa
Tensile Strength, Yield	215 MPa
Elongation at Break	70%
Modulus of Elasticity	193-200 GPa
Poisson's Ratio	0.29
Shear Modulus	86 GPa
Density	8000kg/m^3
Elastic Modulus	193GPa
Endurance limit	240MPa

Source: BelaLeffler (2000)

Stainless steel AISI304 is an optimal material to create a chassis with superior stiffness and strength. These high-strength stainless steel was convinced the manufacturer to use stainless steel AISI304 to build the chassis especially the motorcycle chassis. The weight of motorcycle chassis which made from stainless steel AIS304 is less than other material. Although some motorcycle is made from aluminum which is much lighter than stainless steel, the strength and stiffness of aluminum is much lower than stainless steel. In additional, the cost of stainless steel AISI304 is also much cheaper than aluminum. Stainless steel also requires no surface treatment after the chassis is completely build, whereas aluminum material still need surface treatment like anodizing.

All stainless steel contain amount of chromium ranging from about 18% to 20%. Chromium provides the basic corrosion resistance to stainless steel so this steel has excellent resistance to corrosion compare to other materials. This steel will not rust and strongly resists attack from gas, liquid, and chemicals. Due to the great properties of the stainless steel AISI304, it can be welded using several different procedures such as shielded metal arc welding, gas tungsten arc welding, and gas metal arc welding.

Figure 3.6: Stainless steel AISI 304

Source: www. stainlesspipechine.com, retrieved on 10 June 2013

3.8 FABRICATION EQUIPMENT

There are four main process in fabricate the chassis structure which are cutting, bending, notching, as well as welding. In order to assist in the fabrication process, a set of equipment are used for a particular purpose. Table 3.4 shows the list of apparatus and function in the fabrication process.

Table 3.8: Function and List of Apparatus

No	Equipment	Function
1	Rotary disc cutter**(shown in Figure 3.7)**	Used to cut a long tube into component by rotating the disc with a high speed.
2	Bending machine**(shown in Figure 3.8)**	Used to acquire the desire shape and avoid any of the possible drawbacks or limitations of the processes. The shape can be determined by adjust the radius of the bended tube.
3	Hand grinder**(shown in Figure 3.9)**	Used to cut different desire shape of notching on the tube for matching on other tube. The grinder also can smoothen the surface from the roughest to the finest surface by using grinder disc but not cutting disc.
4	Metal inert gas welding (MIG) **(shown in Figure 3.10)**	Used to melt and join pieces of metal together by creating bonds between their constituent atoms

Figure 3.7: Rotary Disc Cutter

Figure 3.8: Bending Machine

Figure 3.9: Hand Grinder

Figure 3.10: Metal Inert Gas Welding Machine

3.9 FABRICATION PROCESS

To start fabricating a chassis, a jig has played a very important role. The jig is the basic references of the chassis; it means that the dimension of the jig must be very accurate. Once the jig is run out from the dimension, the whole chassis structure will also run out from the exact measurement. To build a jig, chassis design with the dimension need to highlight especially the wheel base and the wheel track. After determining the dimension, the jig can be built. Apart from that, the function of jig is also can hold the stainless steel tube with an exact position and dimension. Figure 3.11 is the jig of the 4 wheels motorcycle chassis.

Figure 3.11: Jig for 4 wheels Motorcycle Chassis

There are four main fabrication processes to build a four wheel air hybrid space-frame chassis. These processes include cutting process, bending process, notching process and also welding process.

3.9.1 Cutting

To start fabricating a chassis, the initial step is cutting process. Before cutting from a long material, an accurate measurement must be taken from the drawing design. As mentioned previously, the material that had been used for the project is stainless steel AISI304. This is a steel tube which around 6 meters long and need to cut according to the drawing dimension. Normally, to avoid overcast the steel tube, tolerance about 2cm will leave on the steel tube. After marking the dimension, the rotary disc cutter will be used to cut the stainless steel tube.

3.9.2 Bending

This chassis is combined of 25 stainless steel tube. Each stainless steel tube has different arc length and radius based on the drawing. Figure 3.12 and Table 3.9 shows the list of stainless steel tube with detail dimension.

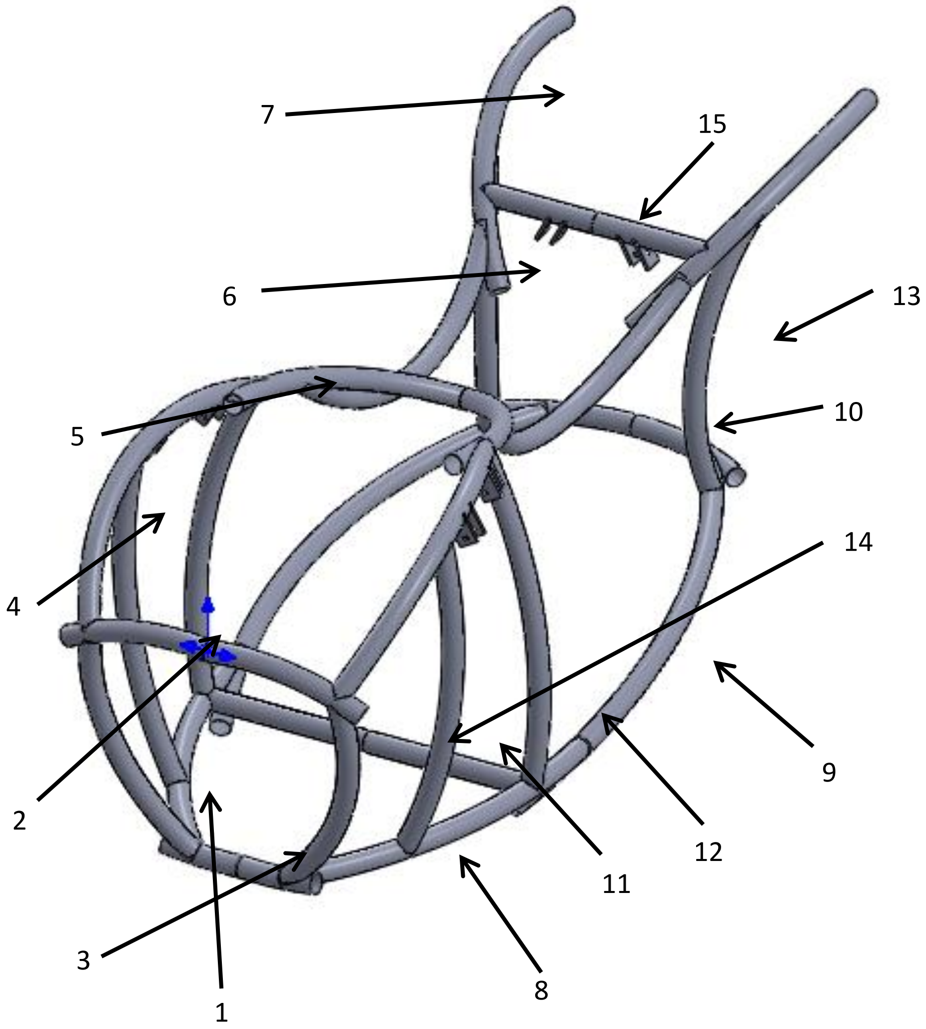


Figure 3.12: 3D Model with List of Stainless Steel Tube

Table 3.9: List of Stainless Steel Tube

No	Quantity	Arc length (mm)	Radius (mm)
1	2	500	500
2	1	300	500
3	1	600	500
4	2	700	500
5	2	500	500
6	2	750	500
7	2	650	500
8	2	680	500
9	2	970	1000
10	1	550	680
11	2	650	1000
12	2	660	1000
13	2	560	500
14	1	650	Straight
15	1	450	Straight

3.9.3 Notching

In the matching process, the equipment that only use is a grinder. To do a notching on the end of the stainless steel tube, the shape of the notching part is very critical. To make a notching, the shape of notching must be based on the particular steel tube location. Try and error method is very useful in this process. In this process, it must be slowly and rapidly make the notching, until it is perfectly fit into the particular location.

The reason of making notching at the end of the tube is to reduce the gap of two connecting parts. The gap between the two connecting parts can be determined how strong of the chassis strength. The smaller gap between the two connecting parts, the chassis will stronger. After done the notching process, then welding process will proceed.

Figure 3.13: Notching

3.9.4 Welding

The last process is to combine all the parts into one assemble by using Metal Arc Gas welder. There are total 25 parts to be weld in this section. To weld all parts into one assembles; all the stainless steel tube must make sure clear from burr. Burr will cause some gap between two connecting points. To clear out the burr, grinder is to be used for grinding out the burr from the notching. Apart from that, burr will also cause a weak link between two connecting points after the welding process.

To make sure the stainless steel tube is properly weld at the correct point; a jig is needed to hold the tube tightly. The purpose to make a jig is to avoid the stainless steel tube position run out from the correct position. Normally, tab welds carry out before seam weld all the chassis. The function of the tab weld is to connect two tubes temporary, this is to easily adjust when there is error position. Figure 3.14 is the temporary chassis which is using tab weld. After confirming the chassis is satisfied, this chassis will be seam welded all joint completely.

Figure 3.14: Tab Weld Chassis

3.10 GOVERNING EQUATION FOR STRESS/STRAIN ANALYSIS

The study of analysis of the four wheel hybrid chassis is to analyze the stress and strain as well as the displacement of the deformed chassis. When load is applied on the chassis which geometry is fixed at the particular position, the 3D model chassis will deform and show the stress and strain at the chassis structure. In general, the stress obtains in the computer software called von mises stress. The von Mises stress is expressed in Eq. 3.1:

$$\sigma_{von\ Mises} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}} \tag{3.1}$$

To calculate the factor of safety (FOS) at a certain location, the below equation Eq. 3.2 can be used.

$$FOS = \frac{\sigma_{limit}}{\sigma_{von\ Mises}} \tag{3.2}$$

A bigger value of factor of safety mans the strength of the chassis is stronger. To know the chassis structure is strong enough, factor of safety must be always bigger than 1.

$$FOS > 1 \tag{3.3}$$

To determine the strain of the chassis structure, displacement deform of the chassis need to obtain. The strain equation expressed in Eq. 3.4

$$\epsilon = \frac{\Delta \boldsymbol{L}}{\boldsymbol{L}} \tag{3.4}$$

The acceleration force/ deceleration force which applies to the chassis structure and the engine, transmission can be calculated from the following equation expressed in Eq 3.5, Eq. 3.6:

$$a = \frac{v_i - v_o}{t} \tag{3.5}$$

$$F = ma \tag{3.6}$$

The velocity v_i can be obtained from the specification of engine.

CHAPTER 4

RESULT AND DISCUSSION

4.1 FINITE ELEMENT ANALYSIS (FEA)

The finite element analysis method will perform on the 3D model chassis by using SOLDIWORK 2012 simulation. The analysis divided into 2 main analyses. The 2 main analyses are static analysis and dynamic analysis. The purpose of the analyses is to investigate the strength and flexibility of the new design of four wheel air hybrid chassis. Static analysis will be analysis the static load constraint while dynamic analysis will be an analysis deceleration load constraint, acceleration load constraint and frontal impact load constraint. A maximum Von mises stress, strain, and displacement will be shown. The following Figures as shown in the Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 are the final design of four wheel air hybrid chassis which is in isometric view, top view, front view and side view that will be going through the simulation process.

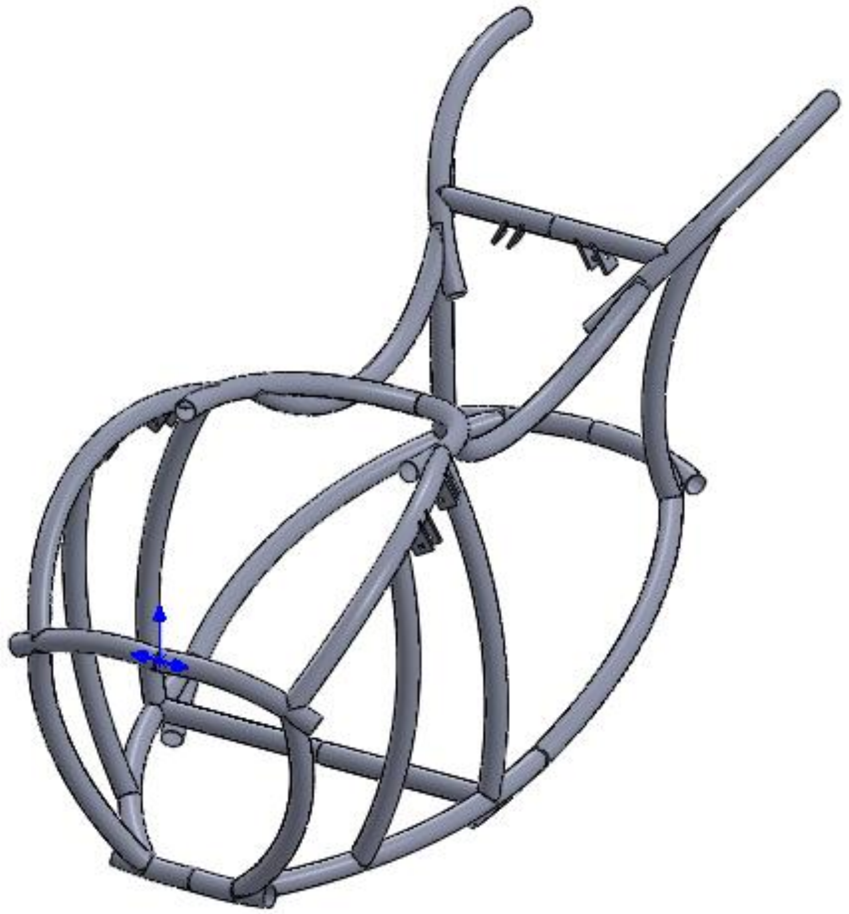


Figure 4.1: Isometric View of 3D Model Chassis

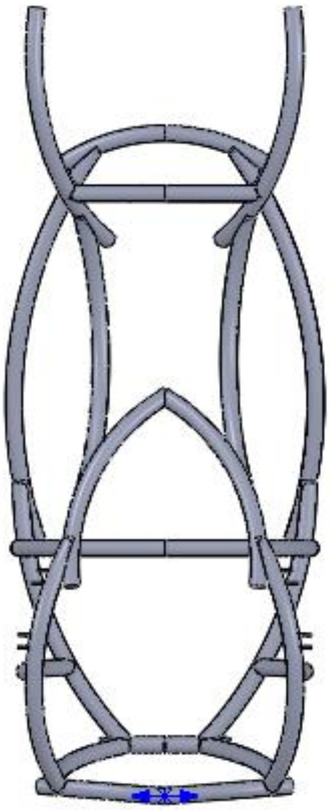


Figure 4.2: Top View of 3D Model Chassis

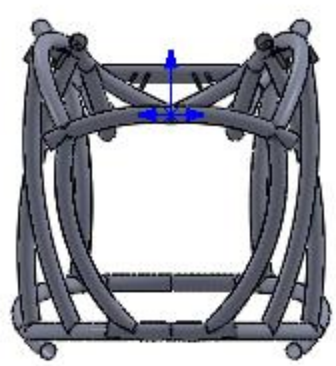


Figure 4.3: Front View of 3D Model Chassis

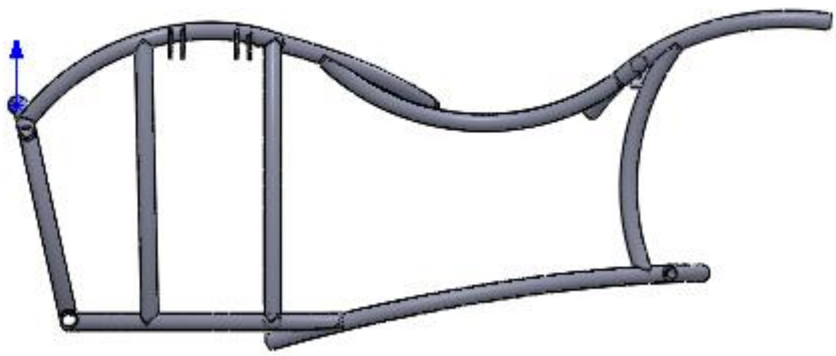


Figure 4.4: Side View of 3D Model Chassis

4.1.1 Static load constraint

In the static load constraint, the load will be applied to the driver seat, and also at the bracket of mounting point of the engine. The weight of the driver is assumed as 60kg, so the force will be applied to the driver seat is 600N. Same goes to the weight of the engine which estimate is 190kg (1900N). However, there are 3 mounting points of the engine, so the weight distributes for each mounting point is 63kg (630N). Figure 4.5, Figure 4.6, Figure 4.7 show the results of the Von Mises stress analysis and critical point at particular point.

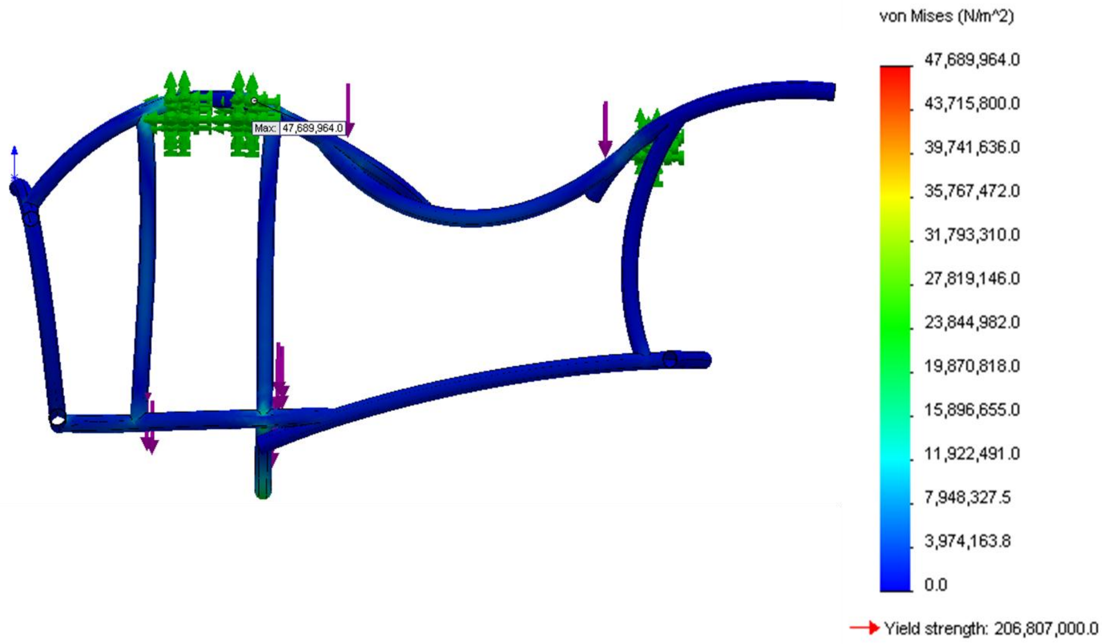


Figure 4.5: Stress Analysis for Static Load Constraint

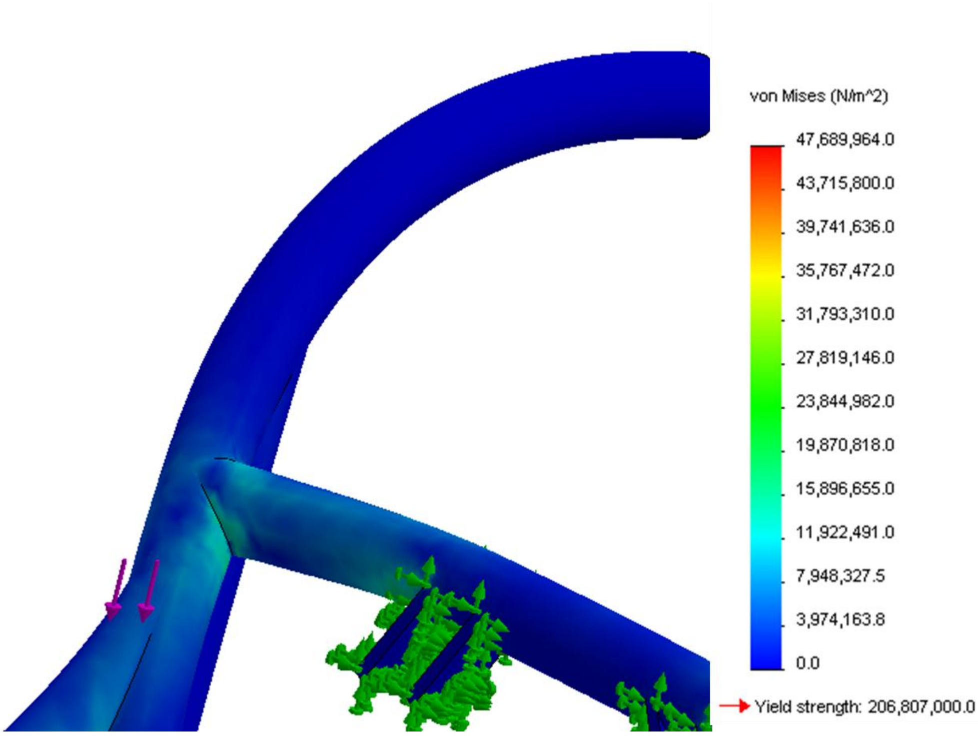


Figure 4.6: Critical Point I

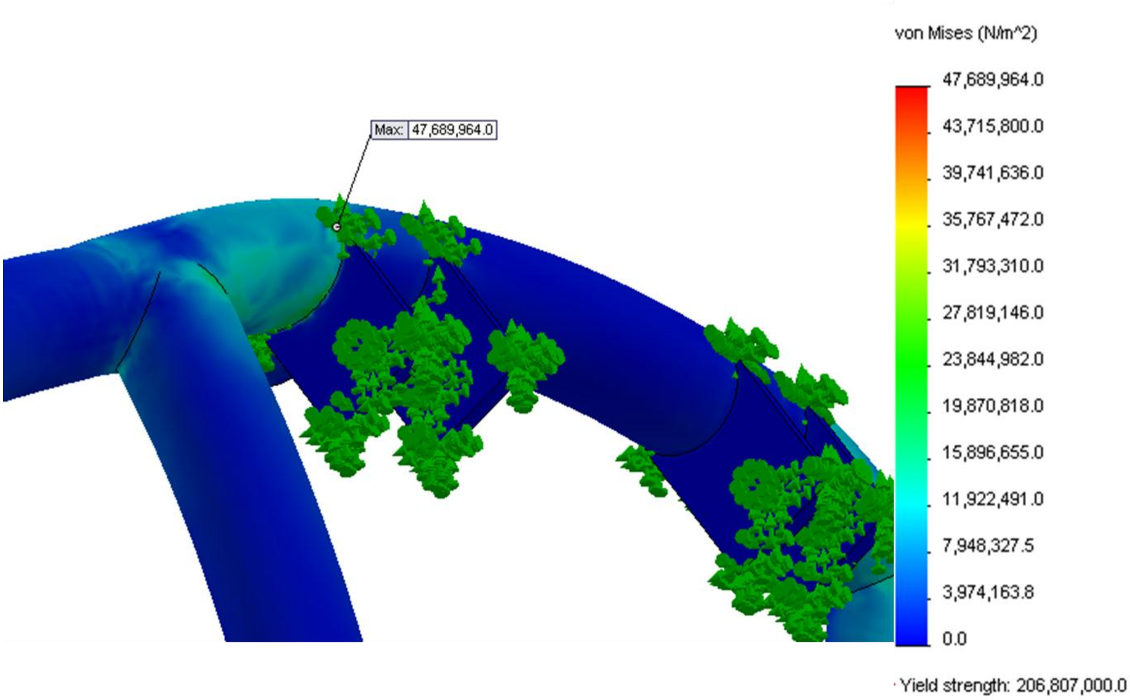


Figure 4.7: Critical Point II

From the stress analysis results, it is shown that there are a few critical points shown in Figure 4.6 and Figure 4.7. The highest stress occurs at near to the bracket of front absorber which is the fixed point as shown in the Figure 4.7and the driver seat as shown in the Figure 4.6. Overall, the maximum von mises stress is 4.77 x 10^7 N/m^2. The reason of maximum von mises stress occur at this point because the bracket is fixed when the force is applied downward, the stainless steel tube which attach with bracket will bend more and occur a critical point near the bracket. From the maximum von mises stress, it clearly shows that the maximum von mises stress is still lower than the yield strength of the material which is 2.06 x 10^8 N/m^2, As long as the factor of safety is more than 1, the chassis is safe at this constraint.

Apart from that, the strain and displacement analysis result also been simulated by SOLIDWORK 2012. The maximum displacement deflection after applied the load is 0.23mm. This value will not provide significant affect neither chassis nor driver. For the strain analysis, the maximum strain is 1.68 x 10^{-4}. Figure 4.8 and Figure 4.9 shows the details results of displacement and strain.

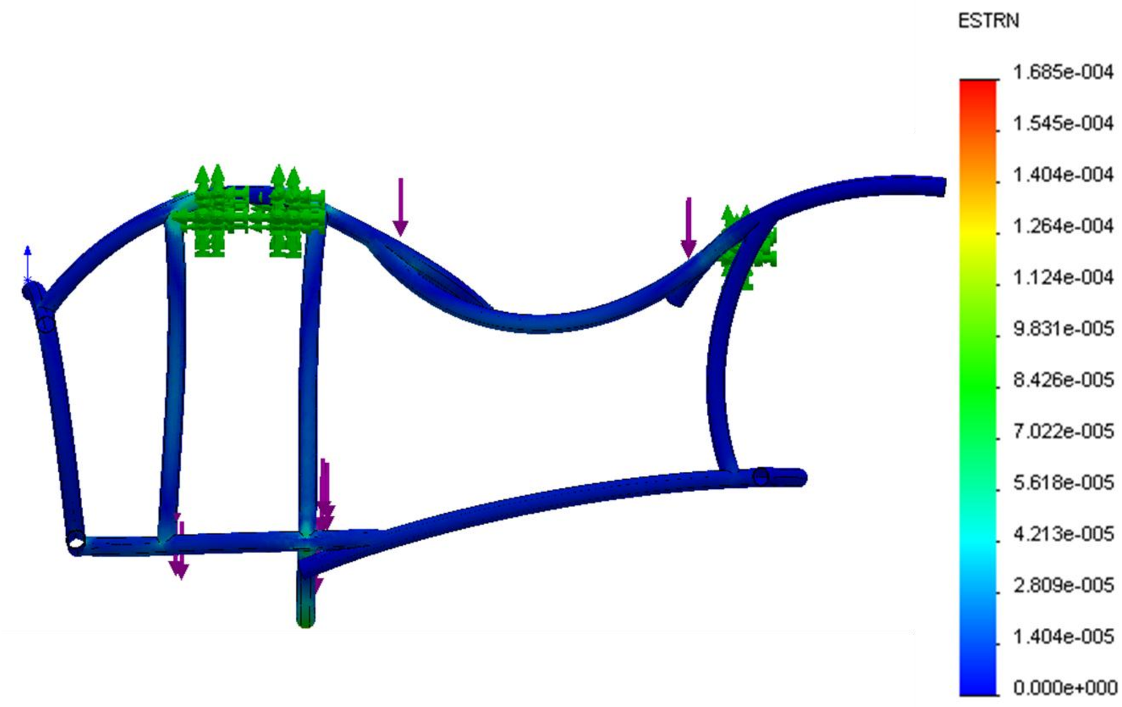


Figure 4.8: Strain Analysis for Static Load Constraint

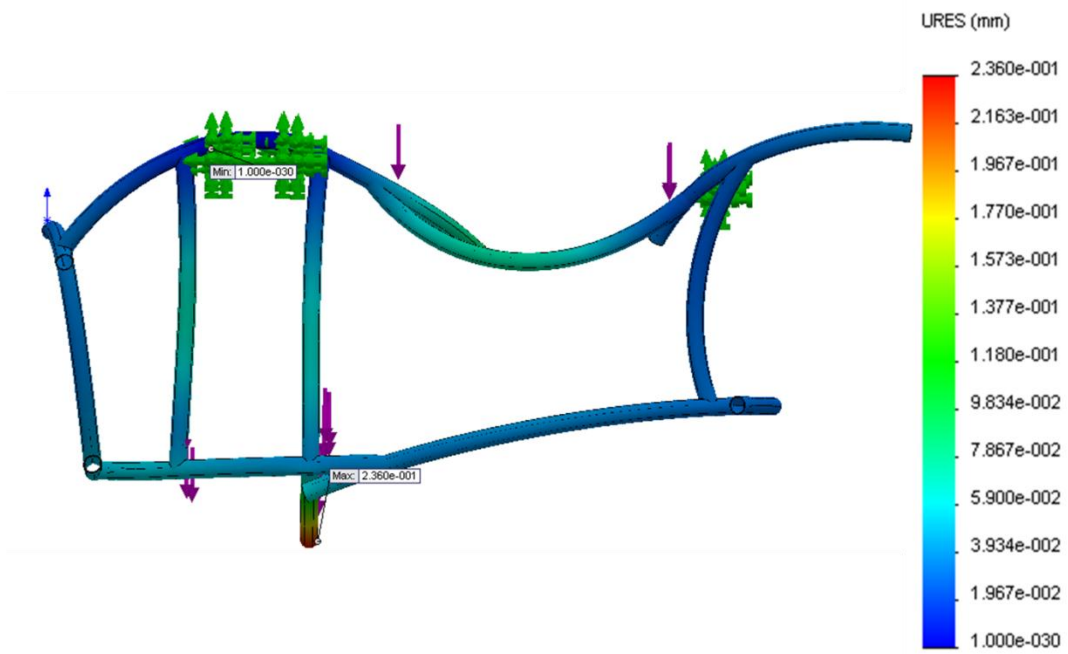


Figure 4.9: Displacement Deflection for Static Load Constraint

4.1.2 Deceleration constraint

In the acceleration load constraint, the fixed point is still remaining same which are in the bracket of front absorber and also bracket of the rear absorber. The load applied to the chassis is the driver seat which is 600N (60kg) and the mounting point of the engine. In this condition, there are two forces acting on the engine, one is normal force which is 630N acting downward on 3 mounting points of engine distributor and another force called acceleration force. The acceleration force is 180N and the forces apply at the mounting point of the engine. Figure 4.10, Figure 4.11, and Figure 4.12 are shown there details result of stress analysis and critical points.

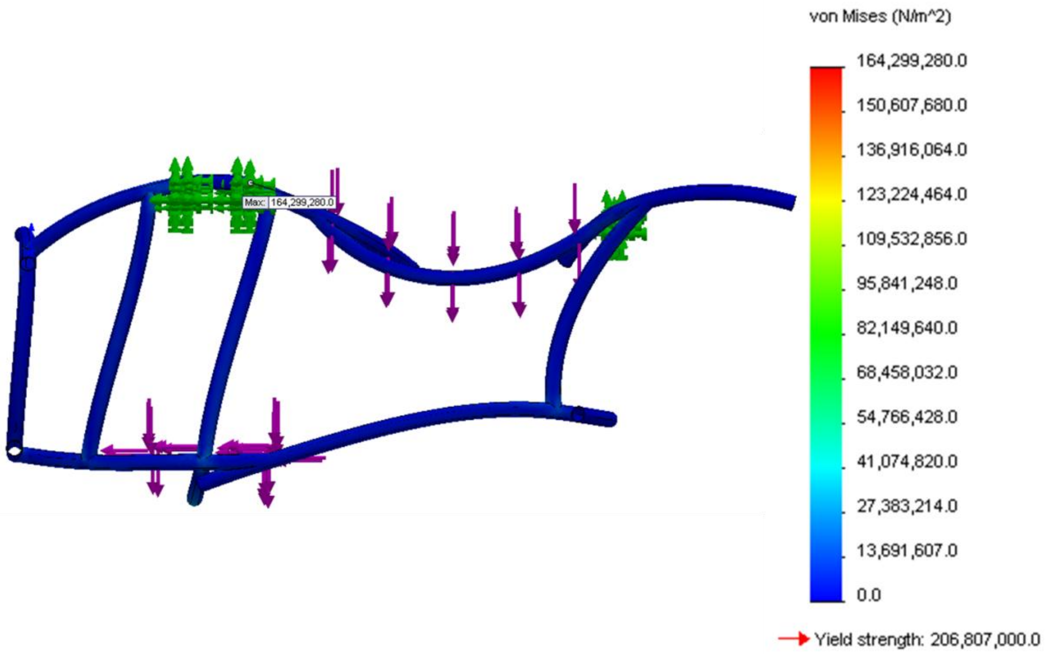


Figure 4.10: Stress Analysis for Deceleration Constraint

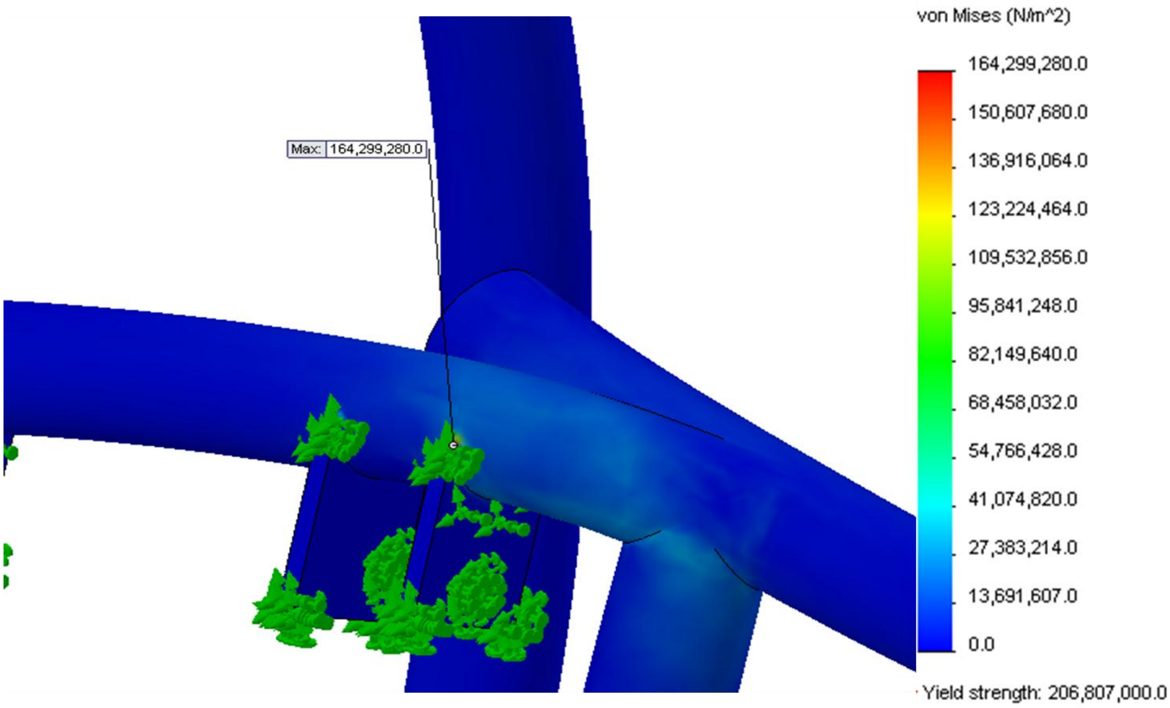


Figure 4.11: Critical Point I

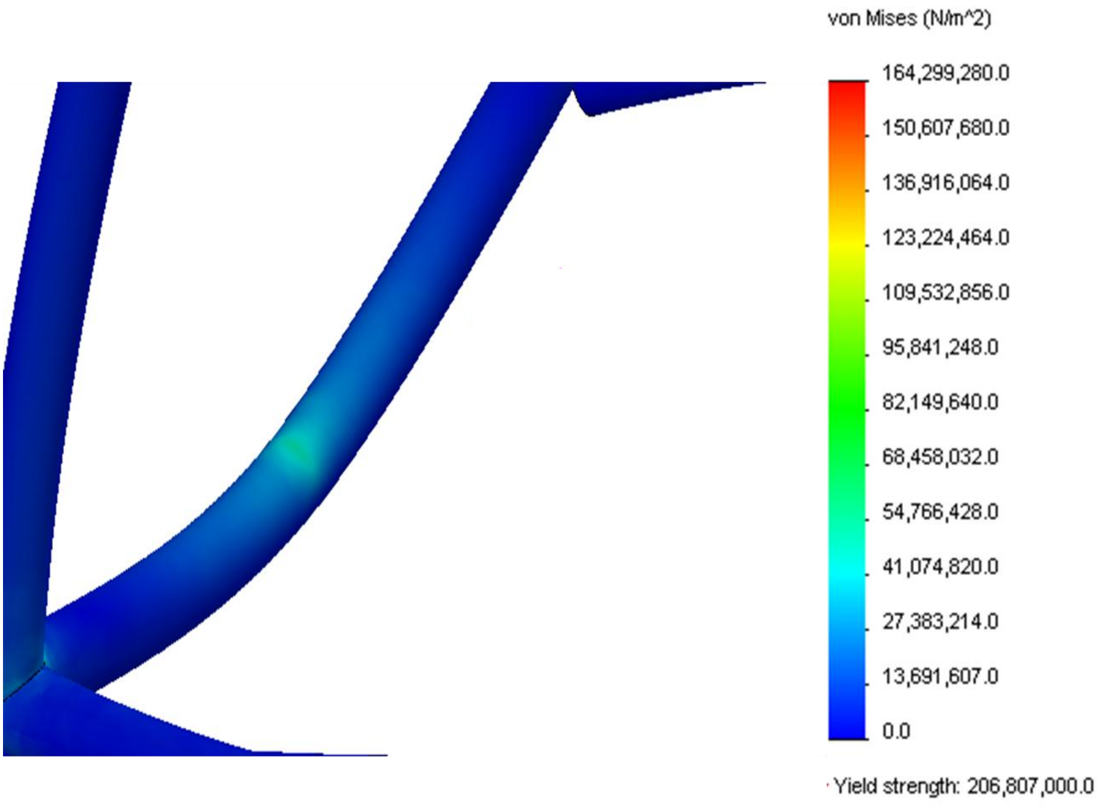


Figure 4.12: Critical Point II

For the deceleration load constraint, there are two critical points which are shown in the Figure 4.11, and Figure 4.12. The critical points are in the bracket of front absorber and the mounting point of the engine. The critical point at the bracket of front absorber is same with the static load constraint. The reason of this critical point occurs in the same position is because this point is the intersection point which is near to the force applied by the driver and the force of the engine compartment. The maximum Von mises stress in this condition is 1.64 x 10^8 N/m^2. In contrast to static load constraint, the maximum Von mises stress of deceleration load is higher than static loads. However, the safety factor of deceleration load is still more than 1, thus the chassis still remains safe.

Besides that, the maximum displacement deflection of the chassis is 0.61mm as shown in Figure 4.13, and the maximum strain of the chassis is 4.34 x 10^{-4} as shown in Figure 4.14. As a result, this chassis during deceleration constraint is under safe conditions.

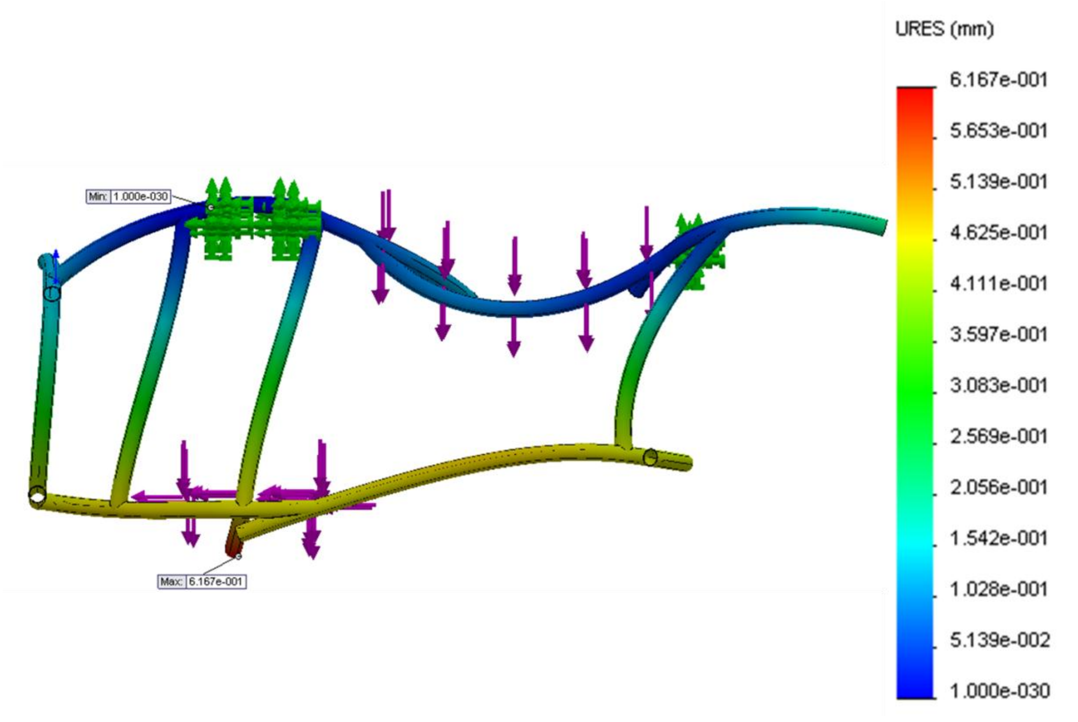


Figure 4.13: Displacement Deflection for Deceleration Constraint

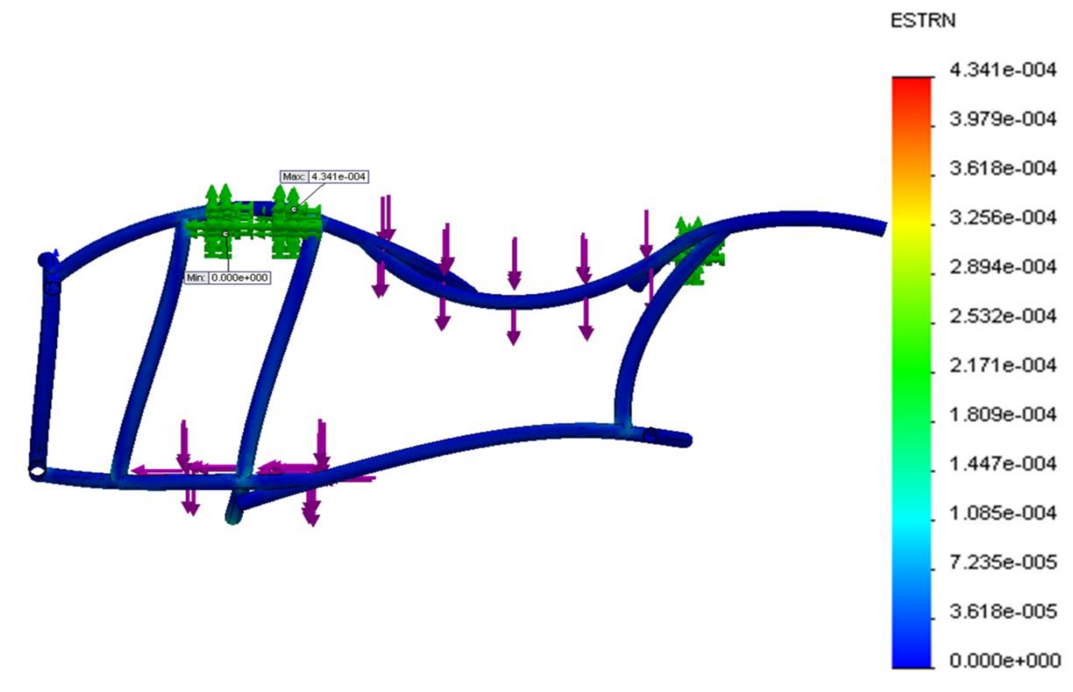


Figure 4.14: Strain for Deceleration Constraint

4.1.3 Acceleration Constraint

The acceleration constraint is more or less same with the deceleration constraint. The fixed geometry of the chassis is no different which is in the bracket of front absorber and the bracket of rear absorber. The force which applied to the driver seat is also the same which is 600N (60kg). The downward force of the engine is 630N distribute on 3 engine mouthing point. The only difference is the direction of acceleration force. The acceleration force is 534N, thus, 180N of acceleration force will act on the 3 mounting points of the engine. Analysis result for acceleration constraint is shown in the Figure 4.15, critical point I and critical point II are shown in the Figure 4.16 and Figure 4.17.

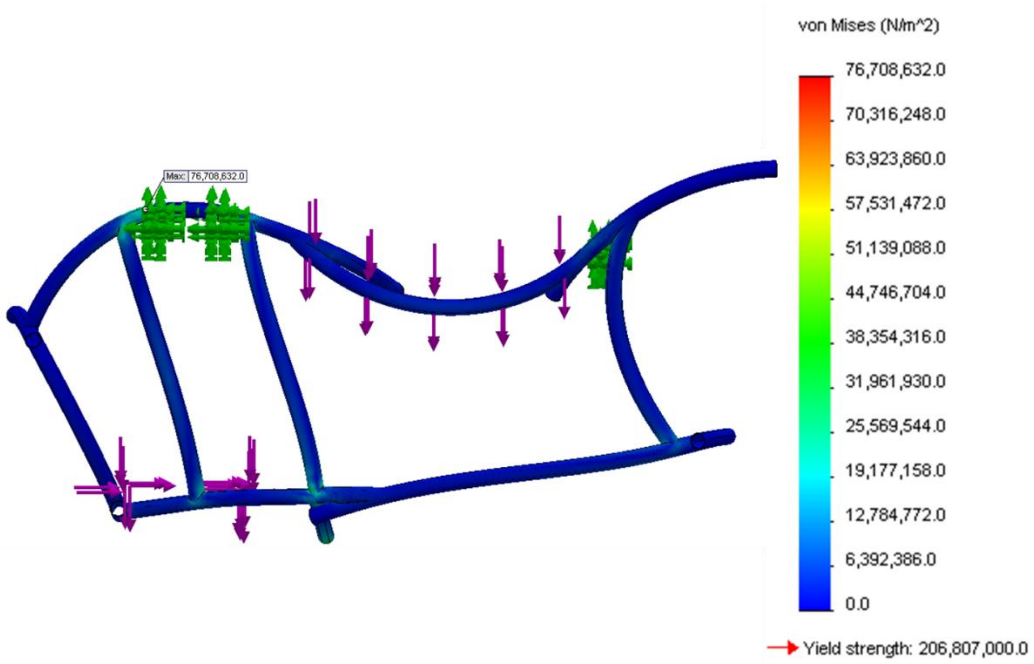


Figure 4.15: Stress Analysis for Acceleration Constraint

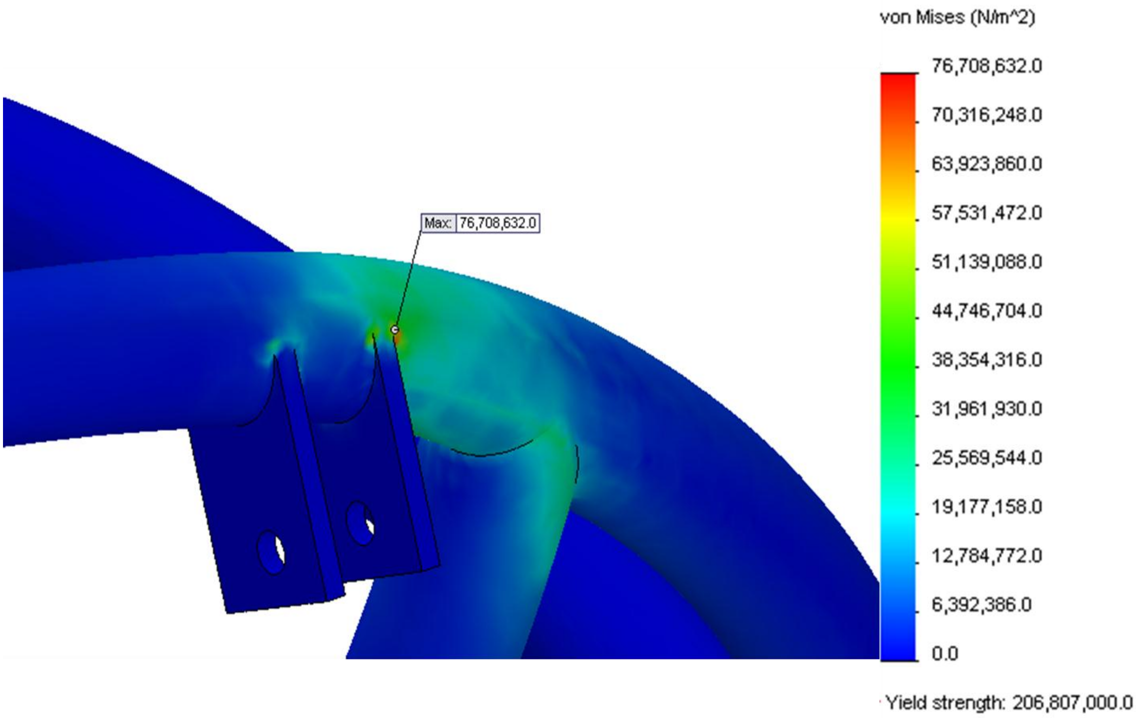


Figure 4.16: Critical Point I

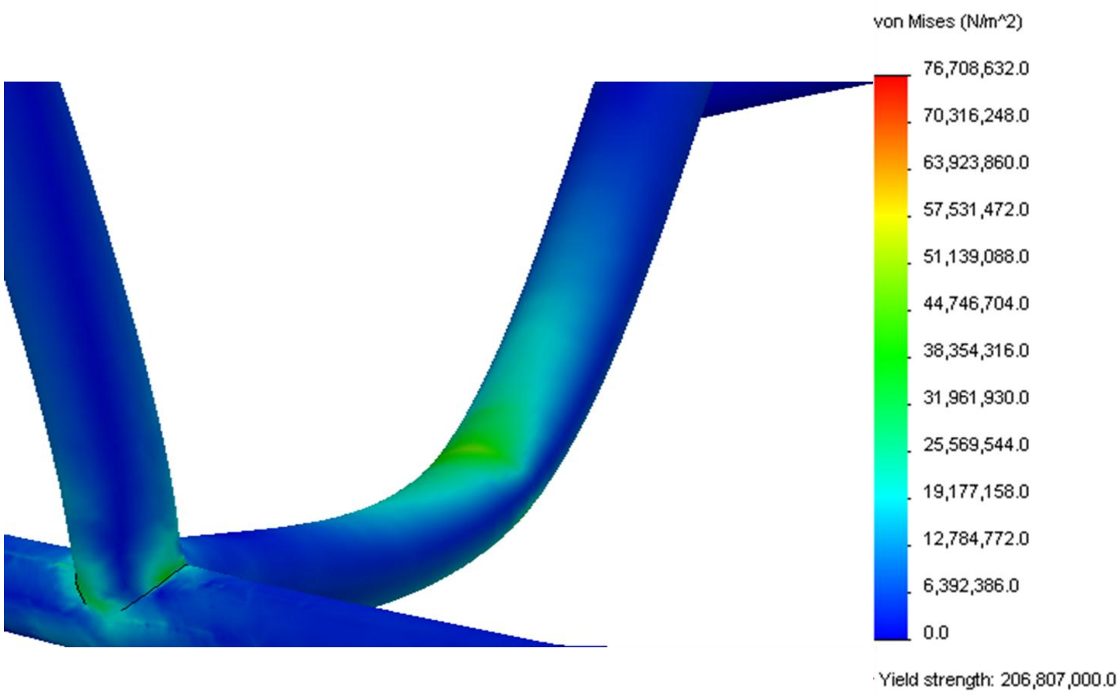


Figure 4.17: Critical Point II

For the acceleration constraint, the critical point which is shown in the Figure 4.16 and Figure 4.17 are the location that occur the highest stress. The points are at near to the bracket of front absorber, and also the mounting point of the engine. The reason of this is same with the deceleration constraint. Normally, the stress of deceleration constraint is higher than the stress of acceleration constraint. The reason of this because of the difference of chassis structure at the upper frame and the lower frame. Acceleration constraint creates more stress on the structure because when the acceleration, all the upper frame will move forward, instead of lower frame will move backward. The lower frame structure has more structure compare to the upper frame structure, so from this, the stress create will be smaller compare to the deceleration constraint.

The maximum Von mises stress in acceleration load condition is 7.67×10^7 N/m^2. The maximum Von Mises stress is much smaller than the yield strength which is 2.06×10^8 N/m^2. Obviously, the factor of safety is greater than 1, thus the chassis in the acceleration constraint, is still safe.

The maximum displacement deflection of the chassis is 0.52mm as shown in Figure 4.18, and the maximum strain of the chassis is 2.95 x 10^{-4} as shown in Figure 4.19. As a result, this chassis during acceleration constraint is under safe conditions.

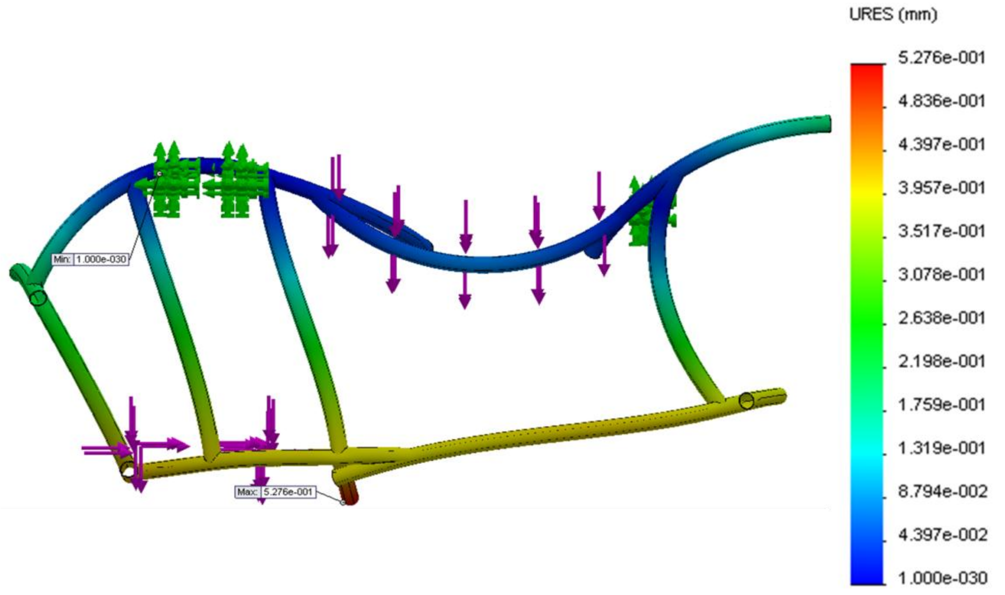


Figure 4.18: Displacement Deflection for Acceleration Constraint

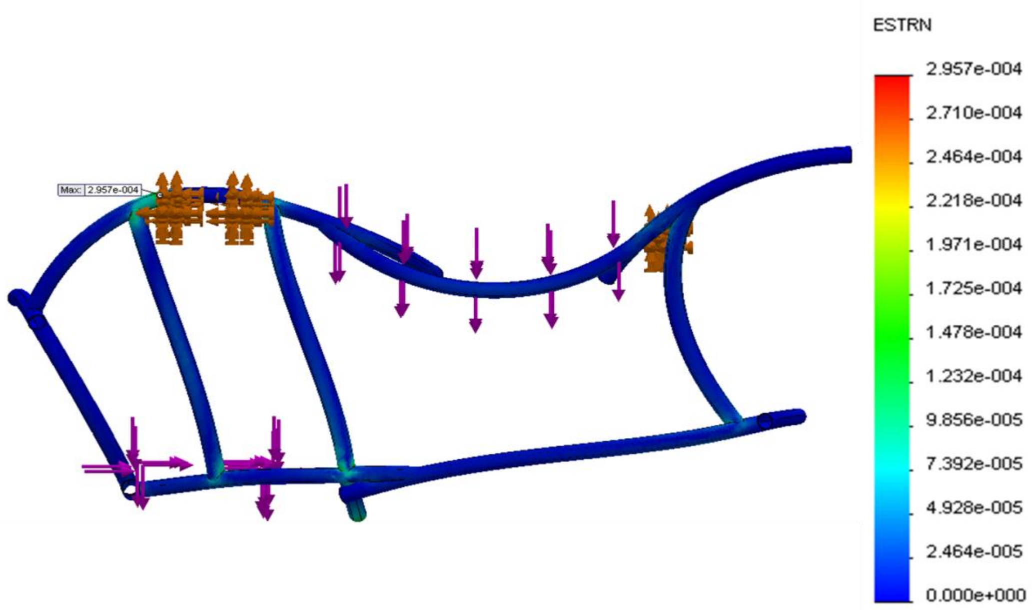


Figure 4.19: Strain for Acceleration Constraint

4.1.4 Frontal Impact Load Constraint

Frontal impact is one of the dynamic analysis and also known as crash test. In this condition, it is necessary to determine the force value to use during the frontal impact. The force (19375N) will applied on the front grill of the chassis, and the fixed point is on the rear side of the chassis. A details figure of stress analysis as shown in Figure 4.20, and Figure 4.21 is the critical point when frontal impact constraint

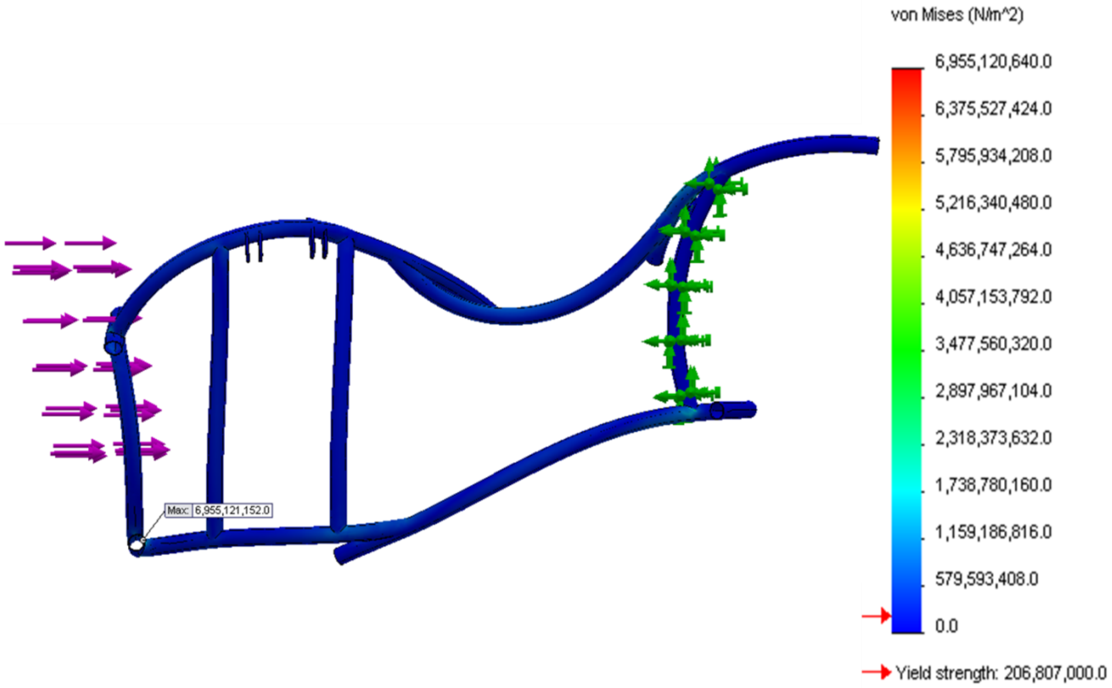


Figure 4.20: Stress Analysis of Frontal Impact Condition

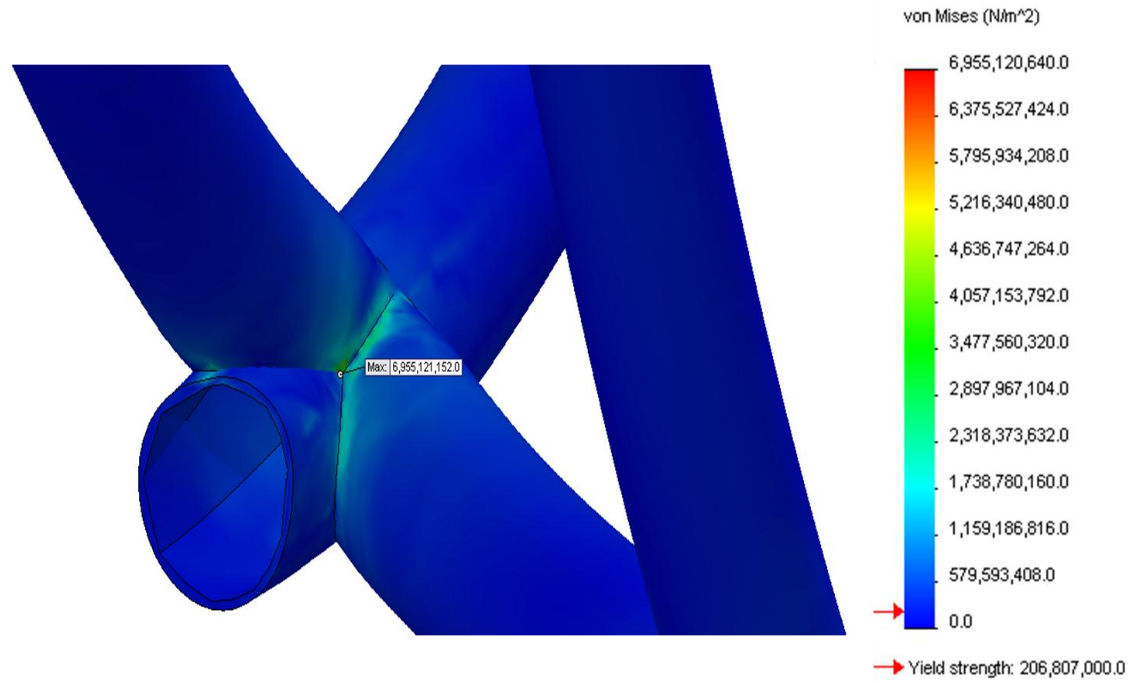


Figure 4.21: Critical Point

In this case, the critical point is shown in Figure 4.21. The maximum Von Mises stress of the chassis is 6.96 x 10^9 N/m^2. The value of Von Mises stress is much greater than the yield strength of the stainless steel AISI304 which is 2.06 x 10^8N/m^2. It means the factor of safety is less than 1. It is because when the high forces apply on the front side of the chassis, the upper side chassis structure will deform much than bottom side chassis structure. When this deformation occurs, the lower side of chassis structure will cause a critical point which is at the welding point. However, as mentioned before, frontal impact is one of the crash tests. The stress occurs in the chassis structure is no longer significant in this study. When the frontal impact test, the important part is to investigate how the chassis can support to protect the driver, thus, for this condition, displacement analysis is very important. The following is the displacement analysis and strain analysis as shown as Figure 4.22, and Figure 4.23 respectively.

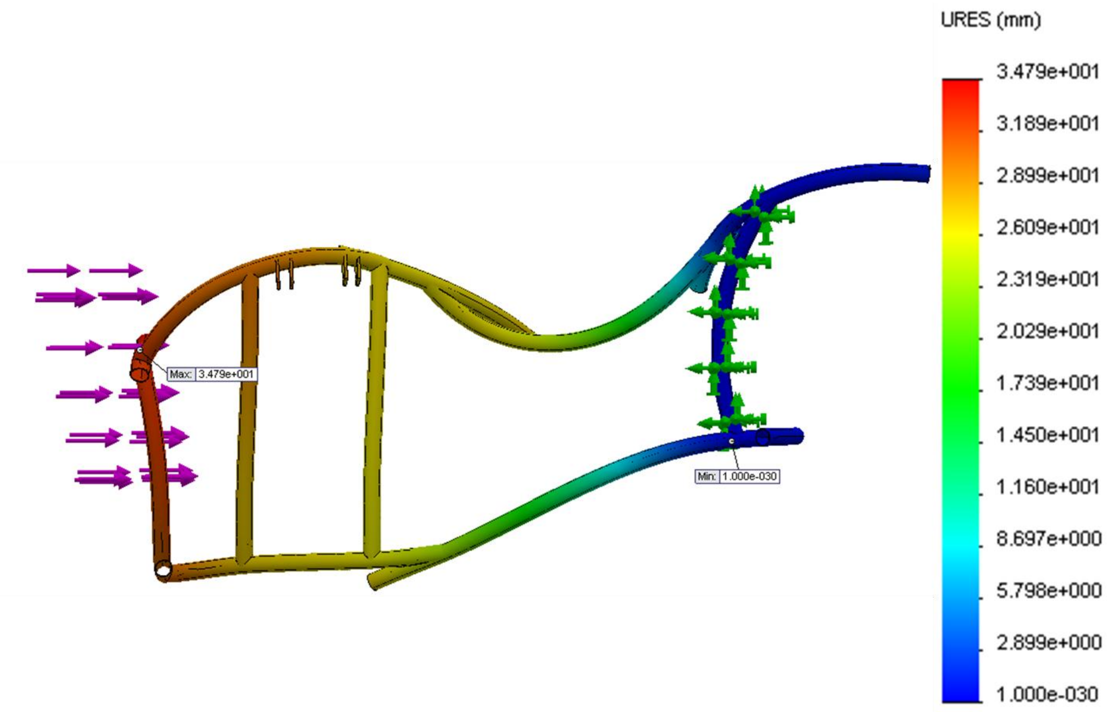


Figure 4.22: Displacement Deflection for Frontal Impact Condition

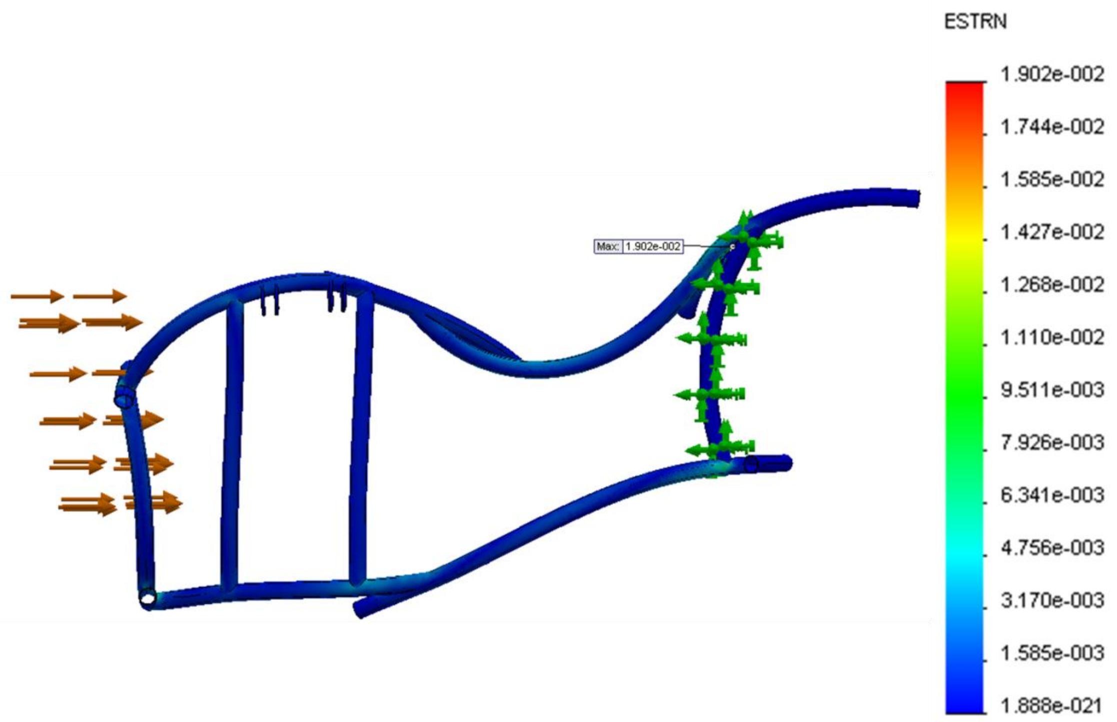


Figure 4.23: Strain for Frontal Impact Condition

From the Figure 4.22, it is clearly shown that the result of displacement deflection analysis for frontal impact condition. The maximum displacement is 34.8mm. This value is still acceptable when the force 19375N is applied to the chassis. The chassis structure is able to protect the driver but the chassis structure will be spoiled. The driver seat is on the yellowish green part, it shows that only around 20mm displacement deflection in the driver seat. With this 20mm displacement deflection, it will not provide a significant effect to the driver. As results, this design of the chassis is strong and has a high strength to protect the driver without any serious damage to the driver.

For the strain analysis, the maximum strain is 1.902 x 10^{-2} which occurs at the back side of the driver seat which shown in Figure 4.23

4.2 FABRICATION RESULT

The fabrication is one of the objective and also an important part in the development. It takes a quite long time to finish the chassis fabrication. It includes the chassis jig as well as the chassis which is shown in Figure 4.24

Figure 4.24: Completed Chassis

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This chapter presents the conclusion of the development of 4 wheels air hybrid motorcycle chassis that was carried out and also the recommendation to improve and overcome some problem for better future outcome.

First of all, this development of 4 wheels air hybrid motorcycle chassis aims to design and fabricate a new type of proposed 4 wheels motorcycle spaceframe chassis which is different with the conventional 4 wheels vehicle. This aim is also the main objectives of the project. At the end of the development, the objectives have been achieved using SOLIDWORK 2012 simulation software. The design of chassis structure is able to withstand and will not collapse in different type of constraints which is static constraints, deceleration constraints, acceleration constraints, as well as frontal impact constraints. The analysis of this chassis design shows acceptable results and clearly shows the critical part of the chassis structure. For the fabrication results, the 4 wheels motorcycle chassis has finally done and prepare for the future study.

5.2 RECOMMENDATION

The main reason of the 4 wheels air hybrid motorcycle project is to reduce the usage of energy source such as petrol. Over the year, the hybrid system motorcycle can become more attractive and competitive in the market by adding a few features to enhance this project. For instance:

- Introduce a new type material that may totally replace all steel in the chassis. These materials include duraluminum, fiberglass, carbon fiber, magnesium and carbon nanotubes. These types of material have the potential to improve the lightness and strength of the chassis structure.

- Instead of using hand grinder to make the notching, notching machine is available at the market and this machine can provide more accurate notching without any gap between two connecting points. It is better for the chassis stiffness.

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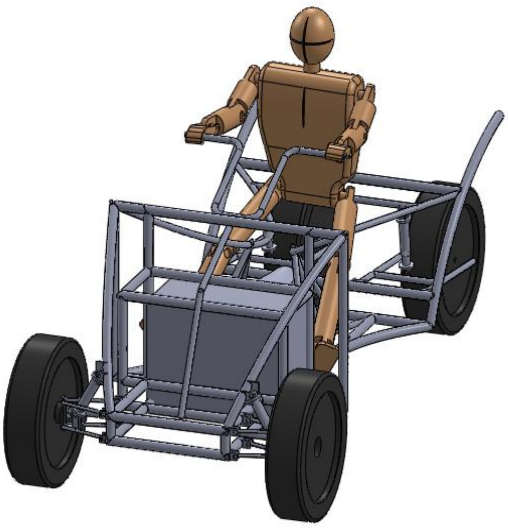
APPENDIX A

GANTT CHART

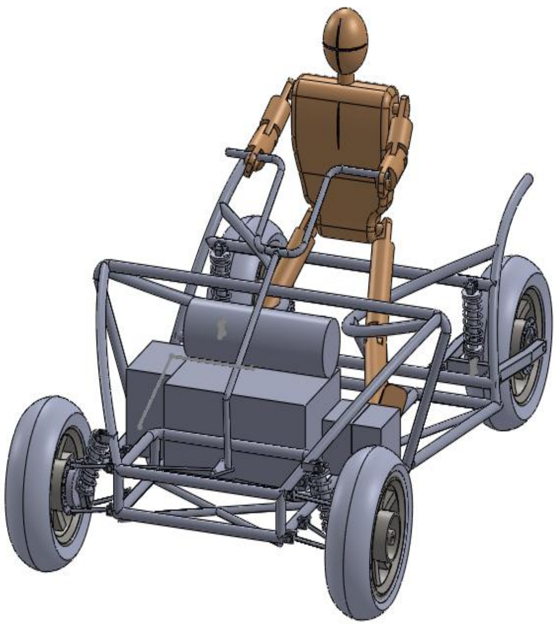
	SCOPES	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
FYP 1	Sketching Chassis Design															
	Material Selection															
	Solidwork Drawing															
	PSM1 Report Preparation															
	PSM1 Presentation															
FYP 2	Fabrication Model Refinement															
	Simulation Analysis															
	Chassis Fabrication															
	Components Assembly															
	Final Report Preparation															

APPENDIX B

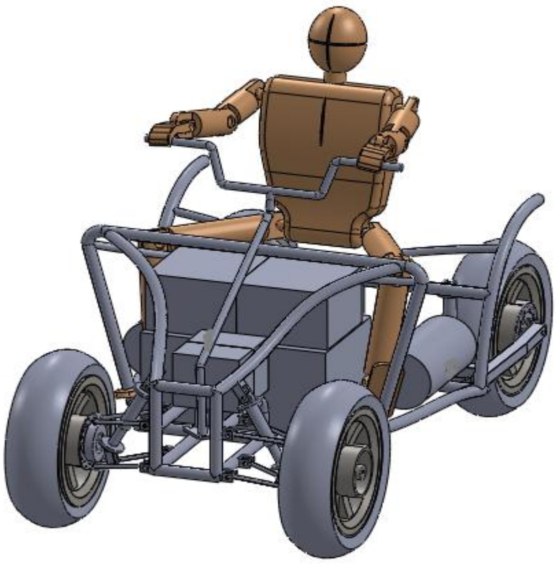
DRAWING DESIGN



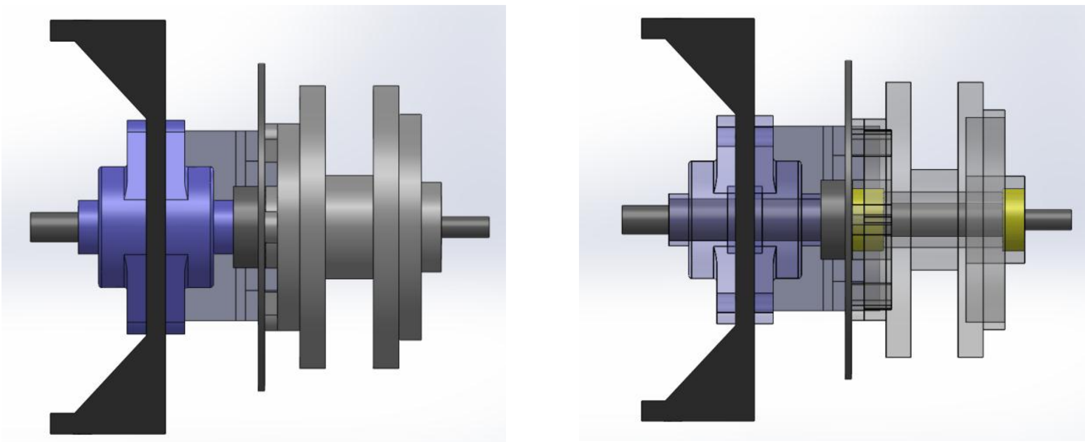
B1: First Design 3D Drawing



B2: Second Design 3D Drawing



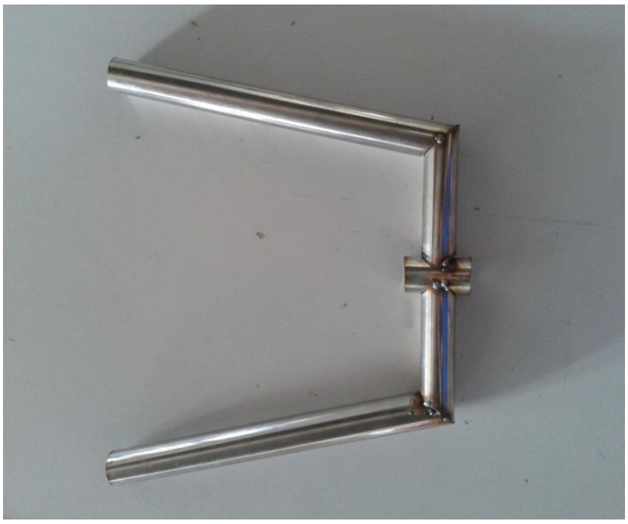
B3: Third Design 3D Drawing



B4: Complete Knuckle Design Drawing

APPENDIX C

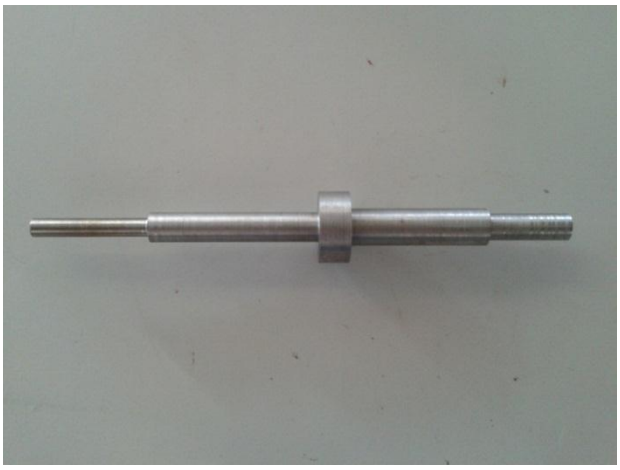
FABRICATION IMAGE



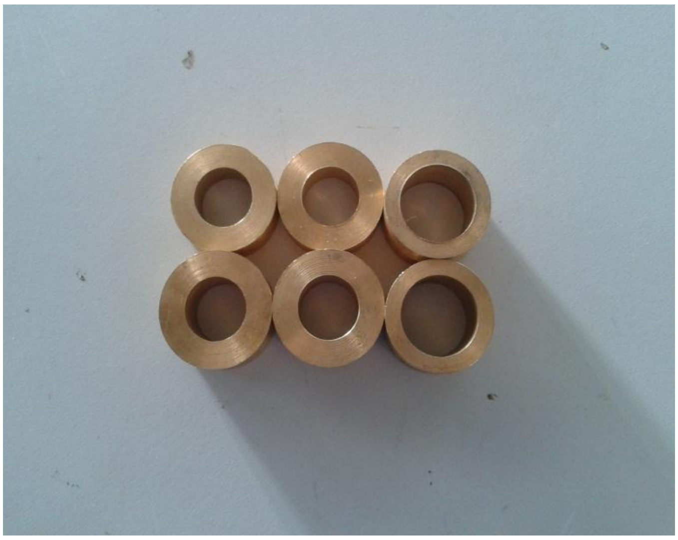
C1: Double A Arm

C2: Absorber with Bracket

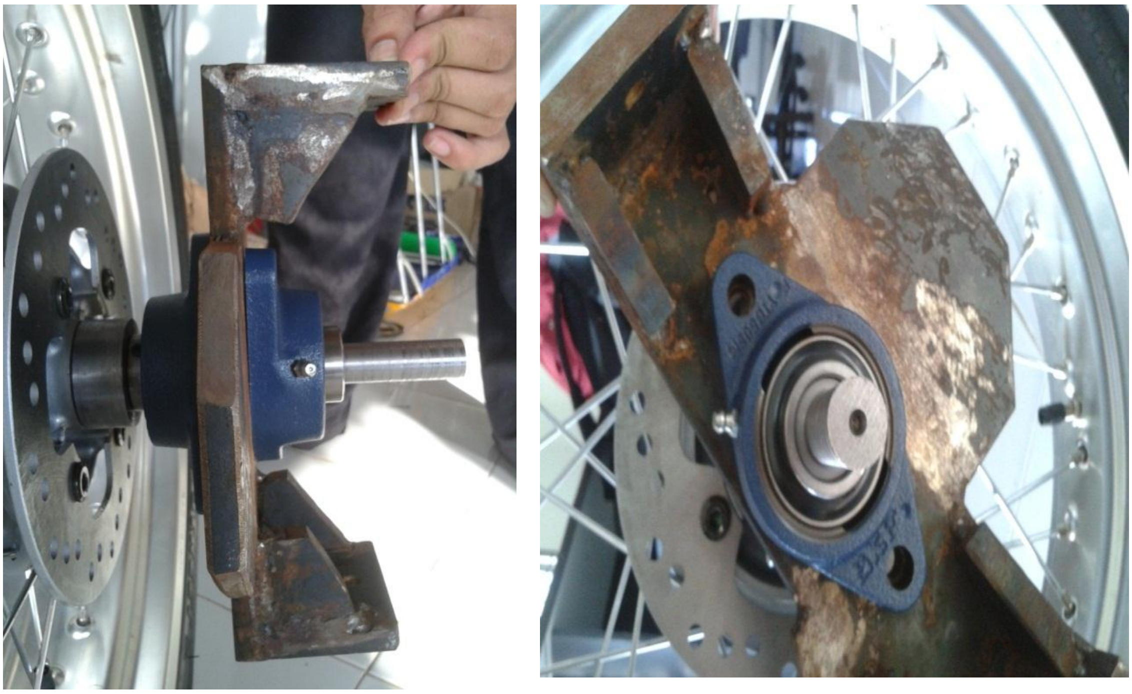
C3: Knuckle



C4: Shaft



C5: Bushing



C6: Knuckle Assembly