DESIGN AND ANALYSIS OF CHASSIS FRAME
FOR EDUCATIONAL RACING VEHICLE

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This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

I declare that this project report entitled "Design And Analysis Of Chassis Frame For Educational Racing Vehicle" is the result of my own work except as cited in the references

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SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature : ....

Name of Supervisor : DR. FUDHAIL BIN ABDUL MUNIR

Date : ....

DEDICATION

To my beloved mother Rohana Binti Mat Yusoff and
my father Mohd Noor Bin Haron.

ACKNOWLEDGEMENT

In this great opportunity, I would like to thank Allah S.W.T for giving me strength and good health to finish up this final year project. I would like to express my gratitude to all those who gave me the possibility to complete this project.

I am deeply indebted to my supervisor, Dr. Fudhail Bin Abdul Munir, whose really help, stimulating suggestions and encouragement helped me in all the time during the project. He has graciously contributed his time, patience and guidance in helping me to complete my project. I really appreciated all of his support to my final year project.

I also want to thank my father, Mohd Noor Bin Haron and my mother, Rohana Binti Mat Yusoff for their continued support and encouragement in everything I do. I also want to thank to all my family members which all these years of education have been made possible by their support and love.

Finally, I really want to thank to all my friends especially my course mates who involved directly and indirectly in this project. The commitment given towards me to help me complete this final year project make me really appreciated it. Lastly, hope that all that have been study and research in this thesis can be used as a reference to the other student in the future.

ABSRACT

Chassis frame is one of the important part for every vehicle. To build an educational racing vehicle, it is started with designing and analysing the chassis frame. Therefore, this project was carried out to design and analyse a chassis frame for educational racing vehicle. It is desirable for a racing car to be light in weight. The reduction in terms of weight allows the maximum speed of the vehicle to be improved. The designing and analysing the chassis frame were conducted in this project to obtain a simple design with lighter chassis frame but strength enough for the safety of the driver. The chassis frame is designed with the aid of CATIA V5 software. For the analysis work, ANSYS-Mechanical module software was utilized to conduct analysis of the chassis frame. Different types of materials are chosen for the chassis frame in order to get a lightweight and strong chassis frame structure. The bending and torsional stiffness value is determined to know the stiffness of this chassis. The chassis was later analysed for its structural performance using Finite Element Analysis method (FEA) to determine the critical path and to predict any possible failure effect on the part. From the analysis, the value of bending stiffness, torsional stiffness, total deformation and also Von Mises stress for the chassis frame will gathered for choosing the chassis design.

ABSTRAK

Kerangka casis adalah salah satu bahagian yang penting bagi setiap kenderaan. Untuk membina sebuah kenderaan lumba pendidikan, ianya bermula dengan mereka bentuk dan menganalisis rangka casis. Oleh itu, projek ini telah dijalankan untuk mereka bentuk dan menganalisis rangka casis untuk kenderaan perlumbaan pendidikan. Adalah penting untuk sesebuah kereta lumba memiliki berat casis yang ringan. Pengurangan dari segi berat membolehkan kelajuan maksimum kenderaan diperbaiki. Mereka bentuk dan menganalisis rangka casis telah dijalankan dalam projek ini untuk mendapatkan reka bentuk yang ringkas beserta kerangka casis yang ringan tetapi mempunyai kekuatan yang cukup untuk keselamatan pemandu. Kerangka casis direka dengan bantuan perisian CATIA V5. Untuk kerja-kerja analisis, perisian modul ANSYS mekanikal telah digunakan untuk menjalankan analisis kerangka casis. jenis bahan yang dipilih untuk rangka casis untuk mendapatkan struktur kerangka casis ringan dan kuat. Nilai kekukuhan lenturan dan kilasan ini telah dipilih untuk mengetahui kekukuhan casis ini. casis kemudiannya dianalisis untuk prestasi struktur menggunakan kaedah Finite Element Analysis (FEA) untuk menentukan laluan kritikal dan untuk meramalkan sebarang kemungkinan kesan kegagalan di bahagian. Daripada analisis, nilai kekukuhan lenturan, kekerasan torsi, jumlah ubah bentuk dan juga tekanan Von Mises untuk rangka casis akan berkumpul untuk memilih reka bentuk casis.

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LIST OF ABBREVIATIONS

FSAE	Formula Society of Automotive Engineers
CATIA	Computer Aided Three-dimensional Interactive Application
SAE	Society of Automotive Engineers

LIST OF SYMBOLS

N	Newton
m	Meter
mm	Millimetre
kg	Kilogram
Pa	Pascal
W	Watt
J	Joule
%	Percent
g	Gram

CHAPTER 1

INTRODUCTION

1.1 Background

Spaceframe chassis have been in use since the start of the motor sport event. A spaceframe is consist of steel or aluminium tubular pipes placed in a triangulated format to support the loads from the vehicle caused by; suspension, engine, driver and aerodynamics.

There are two main types of chassis used in race cars, steel spaceframes and composite monocoque. Although spaceframes can be considered as conventional style, they are still very popular today in amateur motorsport. Their popularity maintains because of their simplicity, the only tools required to construct a spaceframe is a saw, measuring device and welder.

The spaceframe still has advantages over a monocoque as it can easily be repaired and inspected for damage after a collision. The chassis must contain the various components required for the race car as the safety of the driver in the cockpit is the major aspect in the design. The design is based on the requirements and regulations set by the FSAE which all the requirements will be references for designing. Due to limited budgets and time constraints the design of the chassis will need to be geared towards simplicity and strength.

1.2 Problem Statement

The design of a chassis for a formula style race car contains all the necessary components to support the car and the driver. It must comply with the Formula Varsity rules and regulation. In order to produce a competitive vehicle with optimum chassis performance, many areas need to be studied and tested.

Weight is the main point that affected the performance of the car. Therefore, the main purpose of this project is to design and develop a lightweight chassis. The new chassis is must be lighter than the past year chassis but must maintain the strength of the chassis when load is applied on it.

Some factors that can affect the weight of a vehicle are the types of material used, the diameter or dimension of tubes use to build space frame chassis, and the design geometry of chassis.

This project was started by performing background research required to sustain an accurate database of design criteria. Design criteria is allowed the design process and methodology to be derived as well as and to allow for smooth construction of an efficient and effective space frame chassis. Once construction of the chassis was completed, analyses were conducted to investigate the effects of working loads on the chassis. Finite element analysis was used to simulate the conditions of various load combinations.

1.3 Project Objectives

The main objectives of this project are to design and analyse a chassis frame for educational racing vehicle. The design chassis must be simple so that it will lighter but strength enough for the safety.

1.4 Scope of the Project

The scopes of this project are:

i. To produce three-dimensional (3-D) design and the detail design of the chassis using CATIA.
ii. To perform the static Finite Element Analysis to the chassis.
iii. To make an analysis and calculate the load acting on chassis during operation.
iv. To select suitable material for the chassis.
v. To evaluate the torsional stiffness for the chassis based on the load analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Chassis

"Chassis" a French term, which is means the complete automobiles without body (N.R.Hema Kumar., 2009). It is a fabricated structural assembly that supports all functional vehicle systems. It includes all the systems related to automobile like engine, transmission, steering, suspension, wheels tyres, auto electric system and braking system which are attached to chassis without body (N.R.Hema Kumar., 2009).

Apart from supporting all the car components, the propose of automotive chassis is to take care of the form of the vehicle and to support the varied loads applied to the chassis that act like the protection as a major aspect. Chassis is the most important component among the many structures of associate automobile. It is fabricated from a steel frame that holds the body of an automotive vehicle. To be exact, the automobile chassis could be a frame that bolts numerous mechanical elements like engine, tires, brakes, steering and shaft assemblies (Chandan, S. N. et al., 2016).

For a normal car, the chassis has to last for a pretty long period of time. Also, the chassis has to designed in a manner to fulfil the passenger comfort when they are driving and as such, various vehicle components have to be mounted in a different manner. However, it is different for the race car chassis structure because the driver comfort will not be the main focus on the designing. It has to be stiff and lightweight, plus has to be durable enough to last for the entire duration of a race or series of races, which have various of high forces.

The chassis frame in an automobile such as racing car is important as it holds different mechanical parts like engine, tires, axle assemblies, brake, steering, suspension systems, and so on. The chassis also provides flexibility, strength, and stability to the car under many circumstances. Other than that, chassis frame minimizes vibration, noise, and harshness of the vehicle (Shreepathi et. al., 2015).

According to Dardinski and Norcross (n.d.), the chassis of any automobile is the main structure of the vehicle. The chassis is responsible for resisting breaking or deforming excessively under the loads experienced by the car during acceleration, braking, cornering, and combinations thereof. To properly manage these loads, a chassis must be a rigid structure. A chassis must be stiff when in torsion, a twisting force applied on the chassis. Having a chassis that is very high in torsional rigidity, meaning very resistant to flexing when a torsional load is applied, is important to a controllable car (Aird, F.,2008).

As a car travel along the road, the car chassis is excited by forces induced by the road roughness, engine, transmission and more. Under such various forces, the car chassis tends to vibrate. Whenever the natural frequency of vibration of a machine or structure coincides with the frequency of the external excitation, there occurs a phenomenon known as resonance, which leads to excessive deflections and failure. The literature is full of accounts of system failures brought about by resonance and excessive vibration of components and systems.

2.1.1 Passenger Car Chassis

For a passenger car, the main function of the chassis is to support the car components and payload mounted upon it including engine, body, passengers and also luggage. Chassis function's also to maintain the relationship between the suspension and steering mechanism mounting points.

2.1.2 Racing Car Chassis

Generally, a racing car chassis design is not being focus on the comfort of the driver itself. The design of the chassis actually should help the racing car going faster without ignore the safety as the main priority. Racing vehicles are usually required to be as light as possible but must be able to survive the immense forces that could be created in the unlikely event of a crash.

In the present, the highlight for the racing vehicle design is generally considered to be the Formula 1 motor racing series. These cars are built with the highest budgets and can achieve the fastest speeds of up to 220 mph yet are strong and safe enough to survive crashes above speeds of 100 mph (Wright, P., 2001).

Figure 2.1: Example of the Formula 1 race car (Wright, P., 2001).

2.1.3 Educational Racing Vehicle

For an educational racing vehicle, the chassis design often is single seater chassis. It is actually based on the regulation for the chassis specifications. The educational racing vehicle normally design and fabricate focus on to has lightweight and strong chassis structural.

Among the well-known university level, the race car competitions are Formula SAE, organised by the Society of Automotive Engineers and Formula Student, organised by the Institute of Mechanical Engineers UK. Locally, the competitions like Formula Varsity and EIMA RACE usually organised by a university and supported by Malaysian car manufacturers, i.e. PROTON and PERODUA. The structure of the chassis specifications is based on regulation of UniMAP-MODENAS Racing Challenge specification which only allowed the participant to construct a space frame race car platform (Marzuki, M., et al, 2015).

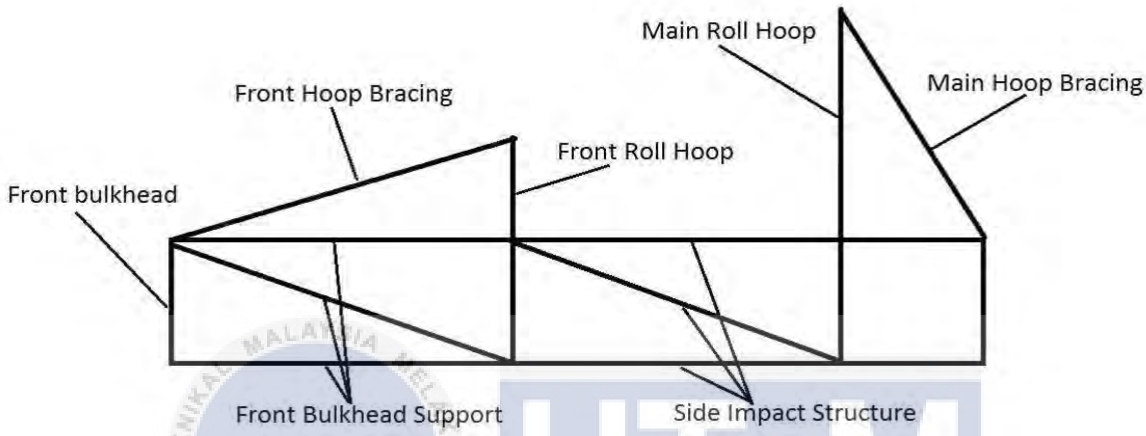


Figure 2.2: Drawing representation of the members required by the FSAE rules (Lavanya, D., 2014).

2.2 Role of Chassis in Automotive

Every vehicle body include of two parts chassis and bodywork or superstructure. The chassis is the framework of any vehicle that are manufacture. Its function is to safely carry the maximum load for all designed operating conditions. It also has to absorb engine and driveline torque, endure shock loading and accommodate twisting on uneven road surfaces. The chassis receives the reaction forces of the wheels during acceleration and braking and absorbs aerodynamic wind forces and road shocks through the suspension. So, the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing.

It should be noted that the 'ladder' type of frame construction is designed to offer good downward support for the body and payload and at the same time provide torsional flexibility, mainly in the region between the gearbox cross member and the cross member ahead of the rear suspension. This chassis flexing is necessary because a rigid frame is more likely to fail than a flexible one that can 'weave' when the vehicle is exposed to arduous conditions. A torsional flexible frame also has the advantage of decreasing the suspension loading when the vehicle is on uneven surfaces.

The chassis which made by pressed steel members can be considered structurally as grillages. It acts as a skeleton on which, the engine, wheels, axle assemblies, brakes, suspensions etc. are mounted. The frame and cross members form an important part of the chassis. The frame supports the cab, engine transmission, axles and various other components. Cross members are also used for vehicle component mounting, and protecting the wires and tubing that are routed from one side of the vehicle to the other. The cross members control axial rotation and longitudinal motion of the main frame, and reduce torsion stress transmitted from one rail to the other.

2.3 Type of Chassis Frame

There are many different styles of frames that being used for race car frames, for example space frame, monocoque, and ladder. Space frame chassis will be more focused because this type of chassis is typically used on educational racing cars based on the FSAE specification.

2.3.1 Space Frame Chassis

Space Frame chassis consist of combination of metal tubes, usually steel, that is joined together by welding work to form the whole chassis (Dardinski and Norcross, n.d.). This type of chassis may consist of various shapes of metal combination according to the desired design. Dardinski and Norcross (n.d) also stated that this kind of chassis apply the "triangulation" method which strong triangles are created in the Space Frame structure. Figure 2.3 shows the concept of the "triangulation" method.

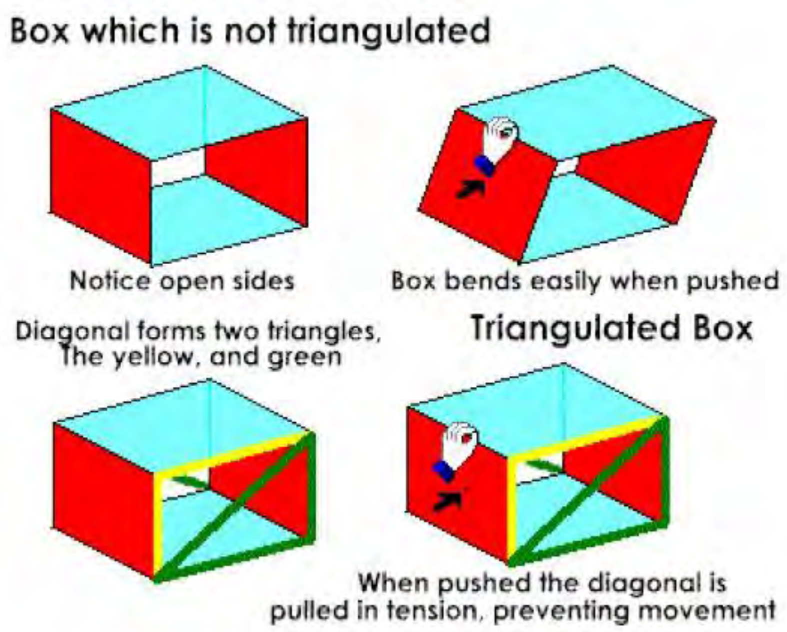


Figure 2.3: Comparison between untriangulated box (top) and triangulated box (bottom) (Dardinski and Norcross, n.d.).

As shown in Figure 2.3, addition of triangle shape in the box provides extra strength to its structure. This concept is applied to optimise the strength of the Space Frame chassis.

2.3.1.1 Chassis structure

Study by Marzuki, Bakar, and Azmi (2015) classified Space Frame chassis for race car is consist of four segments which are the Front Hoop, Main Hoop, Crush Zone, and Side Impact Protection. Figure 2.4 below shows the example of Space Frame race car chassis structure based on Formula Society of Automotive Engineers (SAE) specification.

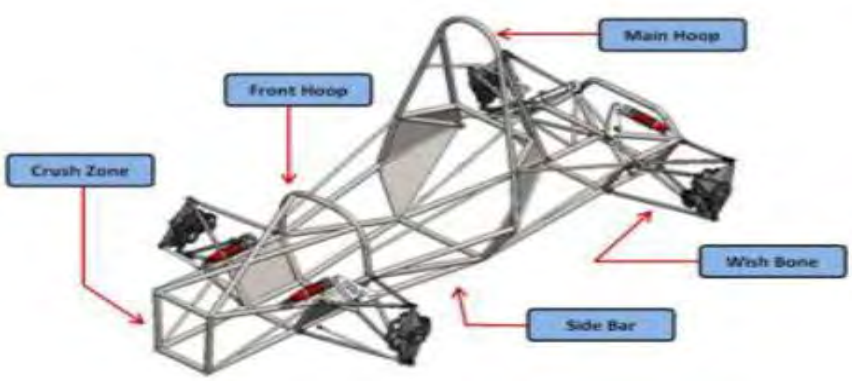


Figure 2.4: Space Frame race car chassis structure (Marzuki, M., et al, 2015).

Every segment of the chassis has their own respective function. Table 2.3 shows the function of each segment.

Table 2.1: Function of chassis segments.

Segment	Function
Front Hoop	Protects the drivers arm and hand if rollover occurs
Main Hoop	Protects the upper part of the driver's body
Crush Zone	Absorb energy in case of a head-on collision
Side Impact Protection	Protect the driver from side in the event of any collision from the either side of the car

As mentioned by Dardinski and Norcross (n.d.), Space Frame chassis apply the"triangulation" method to provide extra strength to the whole structure. Das, A (2015) also stated that torsional stiffness of a frame can be increased by "triangulation" method. Figure 2.5 shows the example of frame triangulation for Space Frame race car chassis.

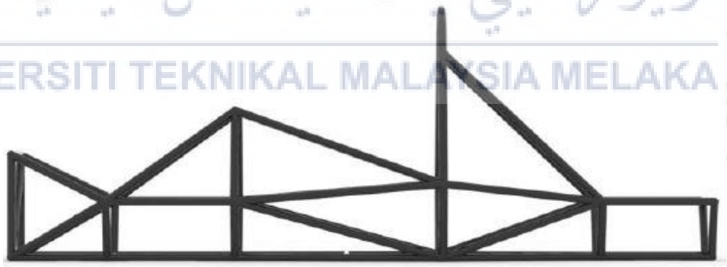


Figure 2.5: Example of frame triangulation (Das, A., 2015).

2.3.2 Monocoque chassis

Monocoque chassis is a chassis that is integral with the vehicle body (MacLeish et. al., 1993). The chassis acts as the main support for the vehicle body and other parts of the frame just been added to make the vehicle whole. Other than automobile, application of

Monocoque chassis has been implemented to the structure of airplanes and boats (Dardinski and Norcross, n.d.).

For racing car, it is required to perform under extreme conditions. It has to be light weight and rigid to give the optimum performance of the racing car. To compromise with these needs, carbon fiber monocoque can optimize the aspect of light weight and high rigidity (Dardinski and Norcross, n.d.). The first car to implement the carbon fiber monocoque chassis was the McLaren MP4/1 Formula 1 race car. Figure 2.6 (a) and (b) shows the McLaren MP4/1 Formula 1 race car.

(a)

(b)

Figure 2.6: (a) MP4/1 Formula 1 race car (top) and (b) carbon fiber monocoque chassis alone (Dardinski and Norcross, n.d.).

2.3.3 Ladder Frame Chassis

The history of the ladder frame chassis starts during the times of the horse drawn carriage. It was used for the construction of the body on chassis vehicles, which meant a separately constructed body was mounted on a rolling chassis. This frames were used in car construction until the 1950’s but in racing only until the mid1930’s (Waterman, B. J., 2011).

The ladder frame consisted of two parallel beams interlinked by several cross members is the oldest and simplest forms of all automotive chassis designs. In the perimeter frame, the middle section of the longitudinal beams was displaced outboard of the front and rear rails. This design allows for a lower floor pan, and therefore a lower overall vehicle height. A perimeter frame design offers more comfortable seating positions and higher safety in case of a side impact. On the other hand, the transition areas from front to center and center to rear reduce the beam and torsion stiffness of the chassis (Waterman, B. J., 2011). The perimeter frame is still used today on full frame cars, like SUVs.

Figure 2.7: Example of ladder frame (Waterman, B. J., 2011).

2.3.4 Backbone Chassis Frame

The backbone chassis frame has a rectangular tube like a backbone that is used to join the front and rear axle. The backbone usually has a rectangular cross section. The body of the vehicle will place onto of the structure This type of automotive chassis is easy to make and cost effective, but it provides little or no protection against a side impact and so requires the body to be designed to accommodate the problem for passenger protection. However, it is still strong and powerful enough to provide support for small sports cars.

Figure 2.8: Example of backbone chassis.

2.4 Design

The design process of the chassis consists of many steps and it is started with fixing of suspension mounting position and engine hard points. The design of a racing car chassis, or any racing chassis for that matter, is going to be based on suspension points, powertrain layout, driver position controls, and most importantly is the safety. These important points must come together to form an effective package for the car to perform.

2.5 Materials

Chassis structure will undergo many kinds of forces during movement, so it has to maintain intact without yielding, stiff to absorb vibrations and lastly, it should resist high temperatures. The material selection is an important criterion while designing and manufacturing a car. The two very commonly used materials for making the space frame chassis are Chromium Molybdenum steel which known as Chromoly 4130 steel and SAE-AISI 1018. SAE 1018 grade steel is better in terms of thermal properties but weaker than Chromoly in terms of strength. But the main preference of design is the safety of the driver. Hence, the material with better stiffness and strength must be chosen. The material should not cause any failure even under extreme conditions of driving. Chromoly steel 4130 exhibits better structural property than SAE 1018 Grade steel. Even though the cost of Chromoly is marginally higher than that of SAE 1018 grade steel, the safety of the driver remains the utmost priority (M.P, et al., 2014). Table 2.2 shows the comparison of material properties between SAE AISI 1018 steel and Chromoly 4130 steel.

Table 2.2: Material properties (M. P, et al., 2014).

Properties	**SAE AISI 1018**	**Chromoly 4130 Steel**
Density (g/cc)	7.8	7.8
Young's Modulus (GPa)	210	210
Elongation at break (%)	19	19
Brinell Hardness	120	200
Strength to weight ratio at Yield (kN.m/kg)	38	100
Yield Strength (MPa)	360	480
Ultimate Strength (MPa)	420	590
Thermal Conductivity Ambient (W.m/K)	50	42
Thermal Expansion: 20°C to 100°C (µm/m.K)	11	12
Specific Heat Capacity Conventional (J/kg.K)	370	370

A composite material is defined as a material composed of two or more elements combined on a microscopic scale by mechanical and chemical bonds. Fibre reinforced composites material has a high internal damping capacity which results to a better absorption of vibration energy within the material. The excellent of fatigue strength weight ratios and fatigue damage tolerances of many composite laminates leads to exchange with metal in many weight-critical components in aerospace, automotive and other industries (Chandra, et al., 2012).

Aluminium is a light, conductive, corrosion-resistant metal with a strong affinity for oxygen. This combination of properties has made it a widely used material, with applications in the aerospace, architectural construction and marine industries, as well as many domestic uses. It is also the second most widely used in the world today. Plus, it is also one of the most important metals used in modern societies. Aluminium's strength, light weight, and workability have led to increased use in transportation systems, including light vehicles, railcars, and aircraft in efforts to reduce fuel consumption. The choice of a material will depend on its price, its mechanical properties and its impact on vehicle production costs. Many of vehicle manufacturers must constantly improve their performance at minimum costs. Due to its low weight, good formability and corrosion resistance, aluminium is the material of choice for many automotive applications, such as the chassis, auto body and many structural components. Lastly, Considering the entire life-cycle of an automobile, from the extraction of materials to the final disposal, including recycling and reuse applications, aluminium proved to be a potential alternative to steels in future automotive applications (Gandara, 2012).

Another material is titanium, which is hard to fabricate and is expensive material, but it also has some similarities with aluminium which are lightweight and quite easy to manufacture but troublesome in welding process. Next is carbon composite; usually it is lightweight in structure and defies fatigue phenomenon but however, it is also quite expensive and it can break under huge impact. Lastly, Aluminium 6061 T6 is the best choice of materials selection. It is strong, lightweight aluminium alloy which contains magnesium and silicon, and smooth for tungsten inert gas (TIG) welding (Porter, et al., 2014). Table 2.3 shows the material properties for typically used frame design materials. Meanwhile, Table 2.4 shows the material properties of a standard steel, fibre and aluminium.

Table 2.3: Material properties for typically used frame design materials (Porter, et al., 2014).

Material	**Elastic Modulus (psi)**	**Yield Stress (psi)**	**Density (lb/ft3)**
Aluminum 6061 T6	10 to 11 x 10^6	11 to 59 x 10^3	168.5
Chromoly 4130 Steel	30 x 10^6	46 to 162 x 10^3	490
Titanium	15 to 16.5 x 10^6	40 to 120 x 10^3	280

Table 2.4: Comparison of material properties (Kamaruddin, et al., 2016).

TYPE OF MATERIAL		
Steel	Fibre reinforced plastic	Aluminium
• Not affected by welding heat and do not require post-welding heat treatment. • 4130 chromyl grade, while stronger than mild steel, does require post-welding heat treatment to restore its mechanical properties. • Good from a metal fatigue perspective and due to the vibration and oscillating loads. • Long chassis life and dependable strength.	• The fibre can be anything from fiberglass to carbon fibre, depending on the requirement to save weight.	• It can provide weight savings. • It may or may not be weld able (Cannot assemble & dissemble after welded). • Expensive material.

2.6 Chassis Loading

Chassis is a fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures. The first step to designing a chassis is to understand the various loads acting on the structure and the main deformation modes occurring on the chassis. These will be described further in the following sections.

2.6.1 Global Load Cases

The load cases can be divided into global and local cases, where the global focus on load cases affecting the whole chassis whilst the local focus on certain points like mounting points and brackets. The global load cases consist of four cases as described below.

2.6.1.1 Torsional Stiffness

Torsional stiffness is often seen as the most important consideration during the construction of a chassis. Torsional loads attempt to twist one end of the chassis in relation to the other end, Figure 2.9, negatively affecting the handling of the car. One can simplify the chassis to a spring model that connects the front and rear suspension units (Riley and George 2002). The role of the suspension is to ensure that all four tires always remain flat on the ground, but if the chassis torsional spring is too weak the chassis tries to take control of the lateral load transfer and obstructs the possibility of optimizing the suspension performance. The easiest way to tackle this problem is to make a chassis with high torsional stiffness.

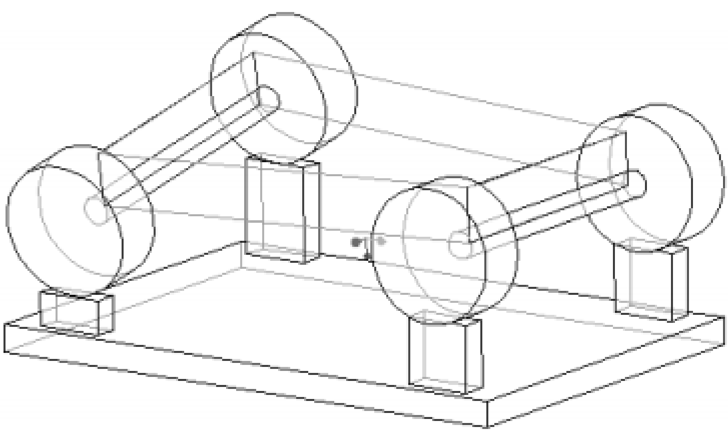


Figure 2.9: Reaction of chassis when torsional loads are exerted units (Riley and George 2002).

Torsional loads arise in different situations. The most common case of torsional load is when one wheel hits a bump while the other three remain at their original vertical orientation. This applies a torque to the chassis, due to the upward movement of the wheel that hits the bump. This load case is also the standard way to measure the torsional stiffness of a chassis in both reality and computer simulations. The resistance to torsional deformation is expressed in Nm/deg. (Milliken and Milliken., 1995)

2.6.1.2 Vertical Bending

Vertical bending means that the chassis either squats or dives under acceleration or deceleration. These two behaviours are a result of the longitudinal load transfer that occurs during the sudden change of speed.

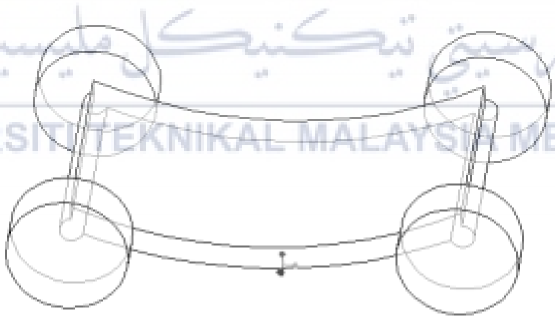


Figure 2.10: Squatting of chassis when accelerating heavily (Riley and George 2002).

During acceleration, the front of the car rises, causing a vertical bending in the middle of the chassis. The chassis dips, bending down as in Figure 2.10. To resist this squat behaviour it is possible to use anti-squat suspension linkages that reduce the impact. The opposite behaviour is to dive, which is caused by braking. This is because load is transferred from the centre to the front (Smith, 1978). The middle of the chassis rises, resulting in vertical bending. Using optimized suspension linkage can reduce diving.

When designing a chassis, vertical bending is not a top priority to consider, as the vertical deflection will not affect wheel loads. It has also been shown that a chassis with good torsional stiffness has adequate bending stiffness (Milliken and Milliken 1995).

2.6.1.3 Lateral Bending

Lateral bending is typically a result of the centrifugal forces that occur when cornering. These lateral forces tend to throw the car out of its intended path in the corner. When cornering the tires follow their intended path, giving rise to a torque which transfers some of the load from the inner to the outer tires (Riley and George 2002). The load transfer not only results in lateral chassis bending, Figure 2.11, but also makes the car roll.

Figure 2.11: Lateral bending of chassis when cornering (Riley and George 2002).

The amount of roll depends on several factors, for example the weight and height of the car, the roll centre height and the resistance that the suspension and anti-roll bars offer (Smith, 1978). Chassis roll should be restricted as it causes unfortunate wheel camber, affecting tire adhesion. Additionally, roll should be restricted because the more stable the car is, the better it responds to direction changes.

2.6.1.4 Horizontal Lozenging

Horizontal lozenging typically occurs when one side of the vehicle has better traction than the other. What happens then is that the left and right sides endure an unequal horizontal force, causing the chassis to disfigure into a more parallelogram-like shape, Figure 2.12 (Riley and George 2002). The lozenging typically occurs under heavy braking, when one tire locks up and skids, while the others continue rolling. It can also be caused by vertical variations on the driving surface. Compared to vertical bending and torsional stiffness, horizontal lozenging is often considered to be less of a concern (Broad and Gilbert 2009).

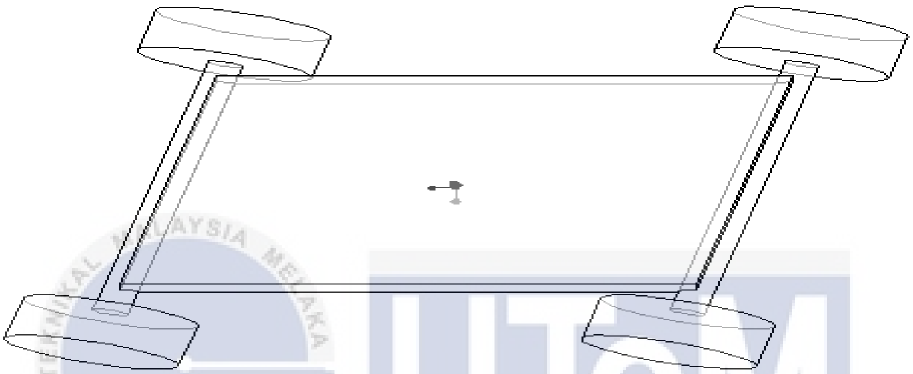


Figure 2.12: Parallelogram-like deformation of chassis (Riley and George 2002).

2.6.2 Local Load Cases

The chassis absorbs all the loads from the suspension, engine and other parts of the car. It is important to construct the chassis in a way that allows for efficient load absorption. Ensuring that the attachment points of the car components are placed in stiff portions of the chassis can sometimes be very difficult (Gaffney and Salinas 2004). For example, when designing a space frame, one may be forced to place a pick-up point of a wishbone in the middle of a tube, thus resulting in bending loads in the tube. Even though this would be bad for the performance of chassis, it might be a compromise that is necessary, given the circumstances (Costin and Phipps 1966).

In general, the main aspect to have in mind when designing where the suspension mounting points, engine brackets and other components attach to the chassis is to optimize the load paths for the resulting local loads. The design must also account for and prevent crack propagation and stress concentration when subjected to local loads.

2.7 Finite Element Analysis of ANSYS Software

Finite Element Analysis (FEA) is a type of computer program that uses the finite element method to analyze a material or object and to find how applied stresses will affect the material or design. The FEA can help determine any points of weakness in a design before it is manufactured. Besides that, it is an effective way of determining the static performance of structures for three reasons which are saving in design time, cost effective in construction and increase the safety of the structure. ANSYS Workbench software is one of the tool for FEA. ANSYS Workbench combines the strength of their core product solvers with the project management tool necessary to manage the project workflow.

In ANSYS, analyses are built as systems which can be combined into a project. ANSYS Workbench also consists of many analyses; explicit dynamic, static structural, fluid flow, random vibration and others (Southpointe, 2009). In static structural analysis; ANSYS Workbench is capable of producing von-mises stress and total deformation of the structure (Choubey, 2016). Graphic Processing Units (GPU) are effective accelerators to diagnose the compute-intensive parts of a program. Their huge number of cores, speed memory and improved programming models allow researchers to study their use for linear algebra. The highest degree of the runtime of a direct sparse solver is used in the factorization of dense matrices and their assembly and for this caused; this decomposition was transmitted to GPUs. For ANSYS's case, the matrices are symmetrical and factorized by using generalized Cholesky decomposition (Krawezik & Poole, 2009). Plus, the sparse solver is real and complex, symmetric and non-symmetric, positive definite and indefinite, support block Lanczos and others. For torsional stiffness, FEM simulations are done in order to estimate the value of torsional stiffness for the body-in-white, vehicle body's sheet metal parts without any other sub-assemblies, doors, fenders and others. An estimation range can be set between 17kNm/deg to 40kNm/deg for most common car manufacturers and vehicle segments (Danielsson & Cocana, 2015).

CHAPTER 3

METHODOLOGY

3..1 Introduction

This chapter describes the methodology used in this project to obtain the design of the chassis frame. All the steps that had been taken during the project will be explain in this segment. The working flow for this project is shown as the flow chart in Figure 3.1. This project starts by studying some single seater chassis frame design and draw several propose design. The designing of the chassis frame was doing using CATIA V5 software. The design including all the chassis specifications. All the analysis on the chassis frame are also investigated to get the best chassis frame. The main Finite Element Analysis method for this project will be using ANSYS Workbench software to analyze the chassis. Various materials, dimensions and parameters will be analyzed and using ANSYS Workbench in order to get desired results.

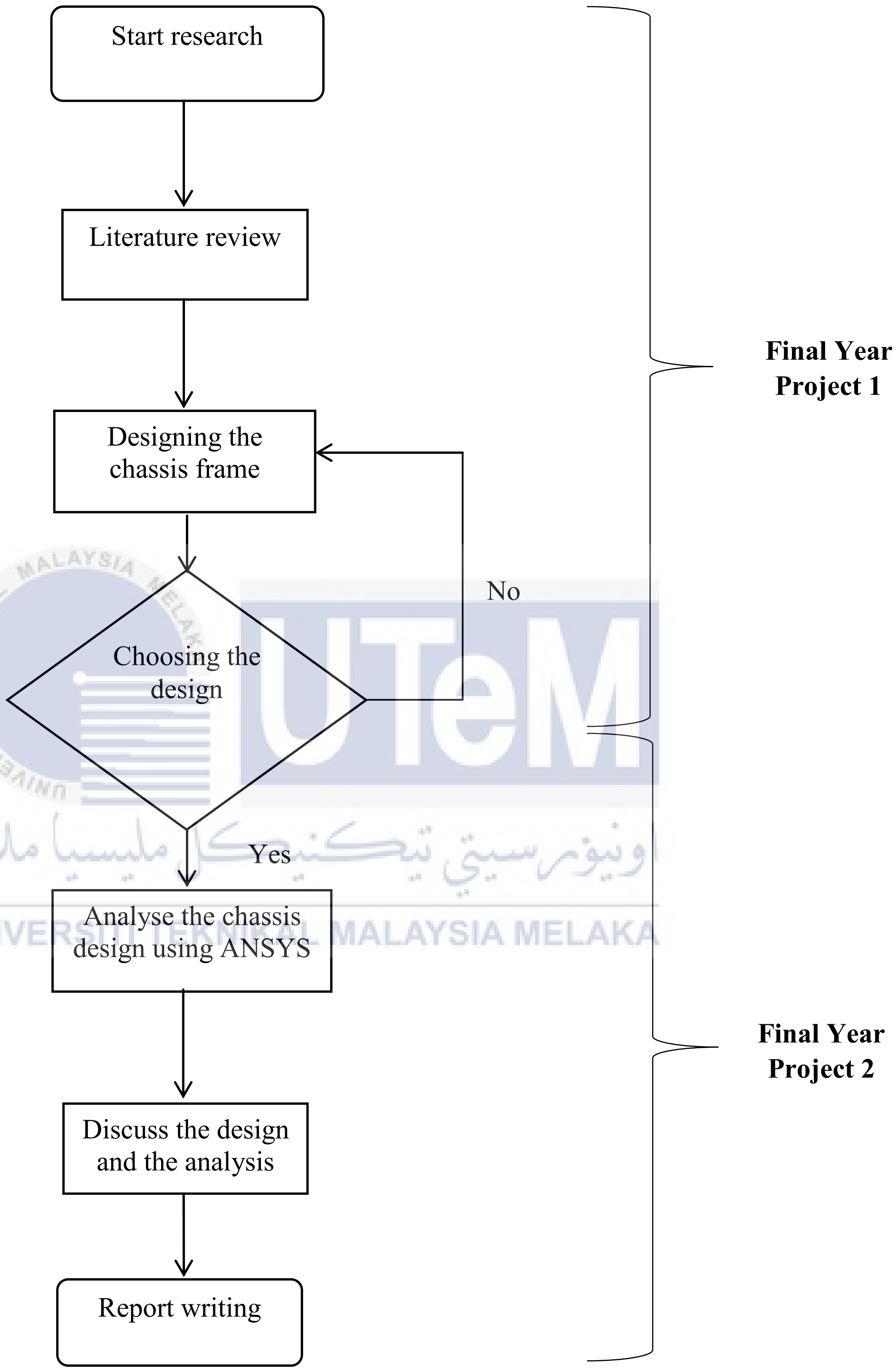


Figure 3.1: Flow chart of the project.

3.2 Design Process

For this project, the computer aided design software is heavily used to design chassis frame. The design is based on the specifications that has been set for all educational racing vehicle.

3.2.1 CATIA Software

Computer aided design is the process of using computer technology to assist in the design of a component or model. A CATIA V5 R21 software will allow a to create a digital 2 or 3 dimensional model that can then be used for further analysis without the need of making costly physical models.

3.2.2 Chassis Frame Design

The designing process of the chassis frame is fully by CATIA software. The process starting with reviewing some of the chassis design that already designed before. Thus, the design had been taken as a reference for this project. All about the about is refer to the reference design.

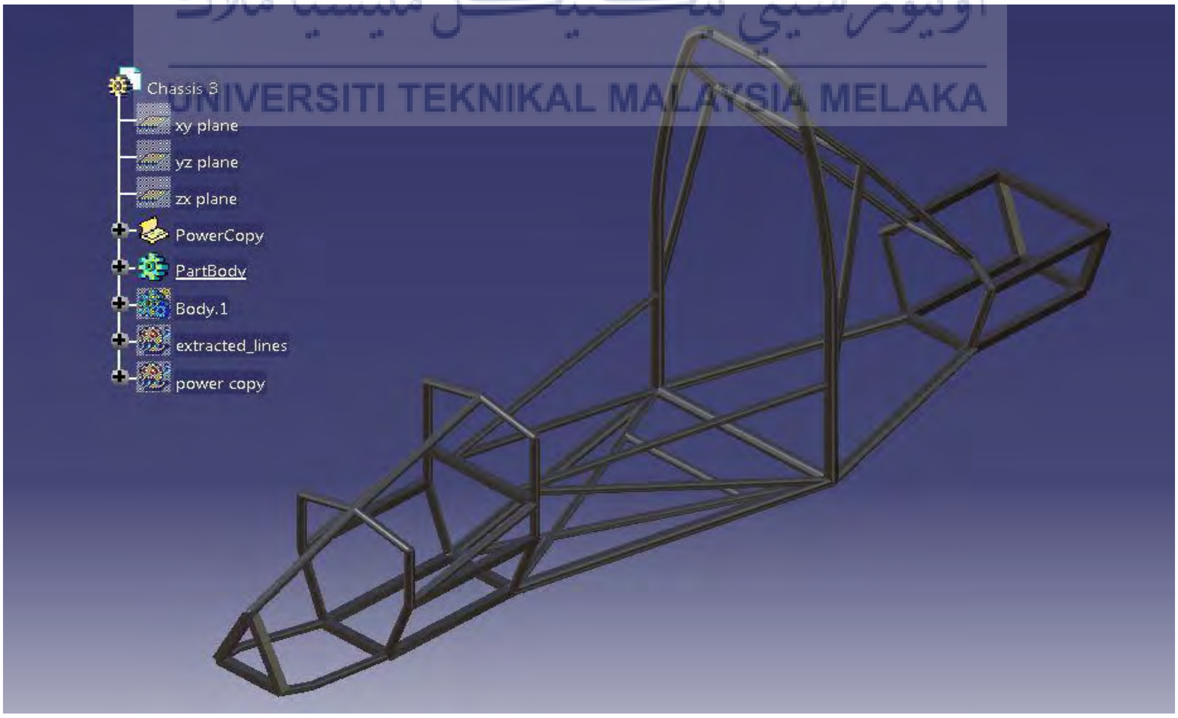


Figure 3.2: Isometric view of the simplified race car chassis model in CATIA.

Figure 3.3: The main hoop that design to protects the driver during roll over.

Figure 3.4: Front section of the chassis.

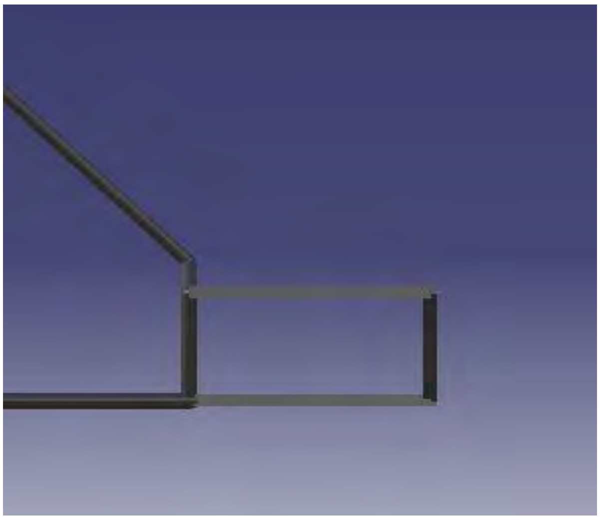


Figure 3.5: Rear section, housing the engine and transmission of the race car.

3.2.2.1 Propose Designs

For this project, there are several designs that had been proposed. Design for all chassis frame to focus on single-seater racing car. The design actually had been referring to some references for the parts on the chassis like the main hoop, the front section and the rear section.

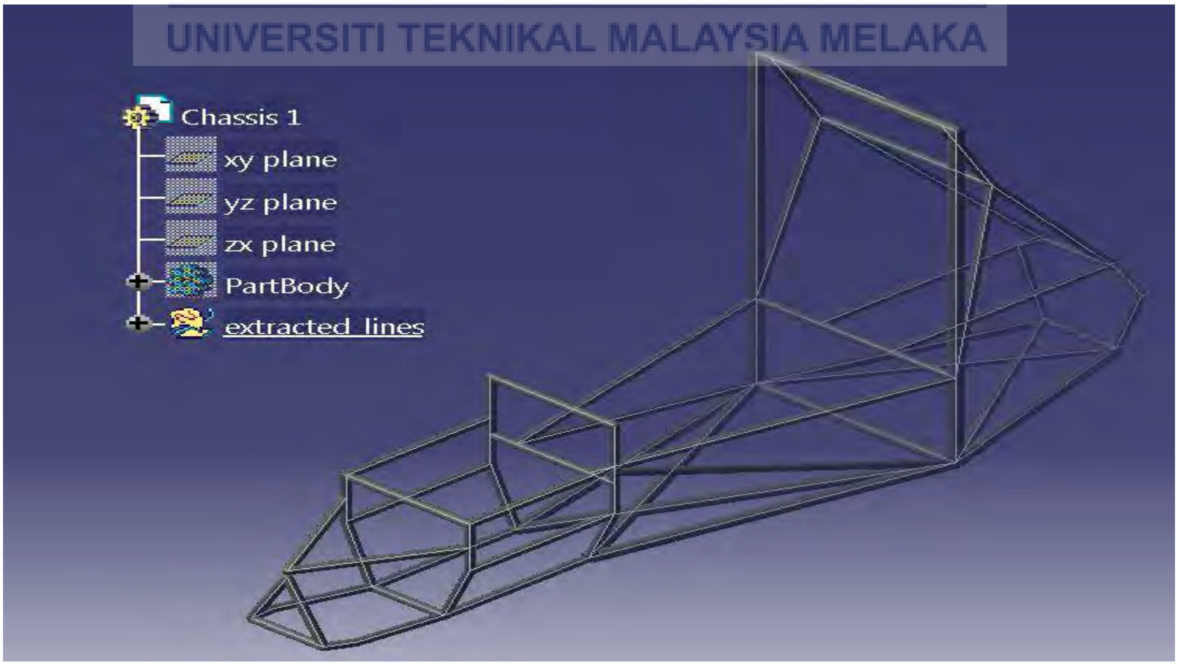


Figure 3.6: Propose design 1.

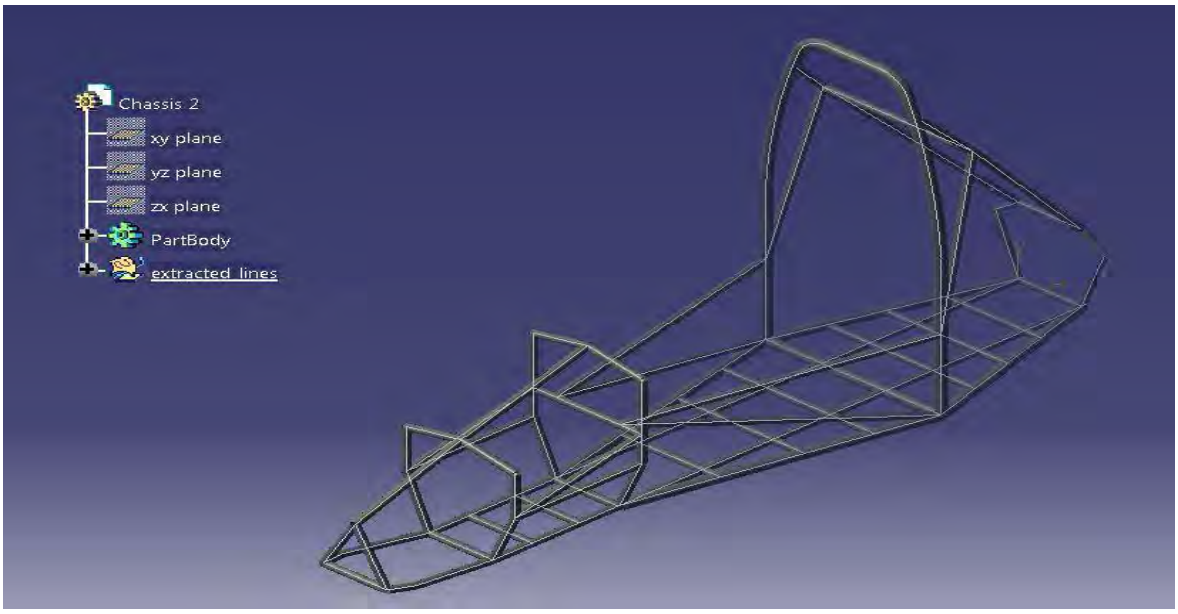


Figure 3.7: Propose design 2.

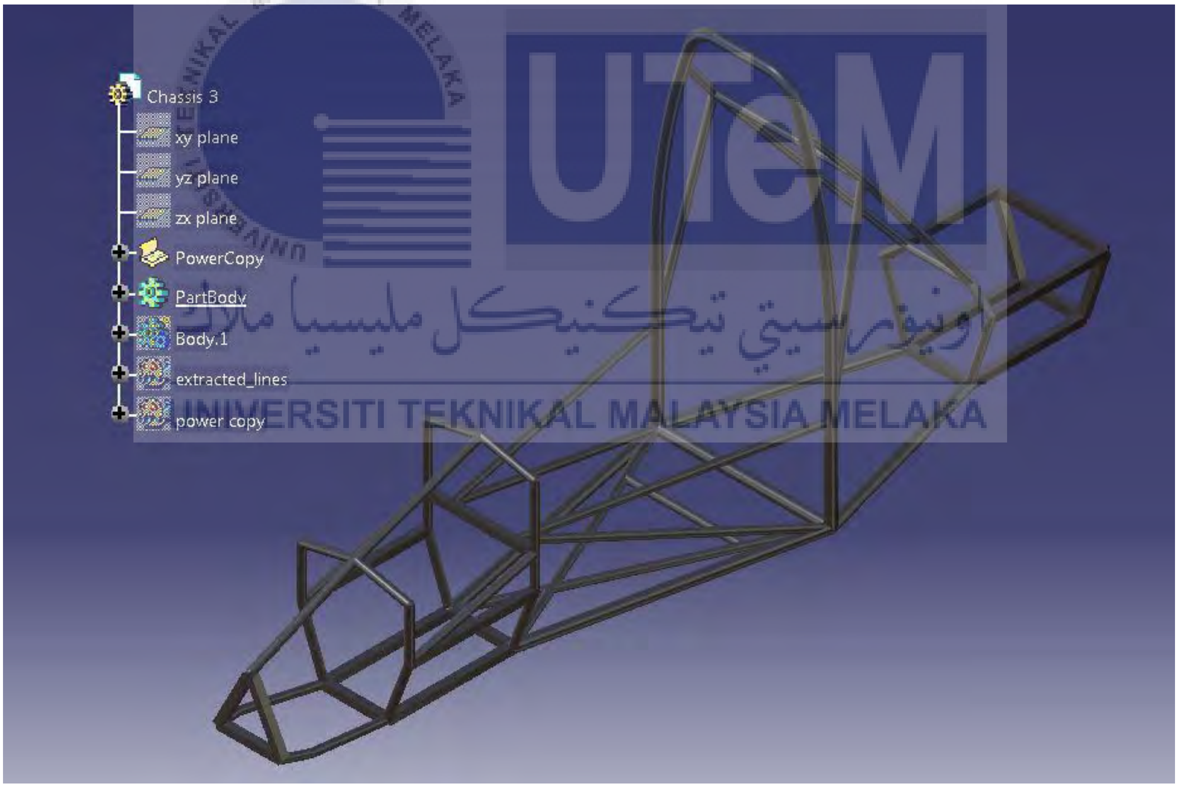


Figure 3.8: Propose design 3.

3.3 Analysis of the chassis

The chassis is subjected to four different types of loads that shows how it would react under different conditions, these are bending, braking and cornering loads and will all be experienced by the chassis at some point.

The total mass of the car chassis plus its components and with the driver mass that in average 70 kg is about 270.3 kg (Abdullah, M. A. et. al., 2013). This value is used in the Von Mises stress analysis. Figure 3.10 to 3.13 show the location of the forces exerted and clamps for static analysis, acceleration analysis, braking analysis and cornering analysis.

3.3.1 ANSYS Software

ANSYS Workbench is the chosen software for this project to evaluate the Finite Element Analysis process. This software utilizes FEA method to solve the underlying governing equations and the related problem-specific boundary condition. In addition, ANSYS is also able to import CAD data and build geometry with its pre-processing abilities. Besides that, it can also run out advanced engineering analyses safely, quickly and practically by its variety of contact algorithms, time based loading features and nonlinear material models.

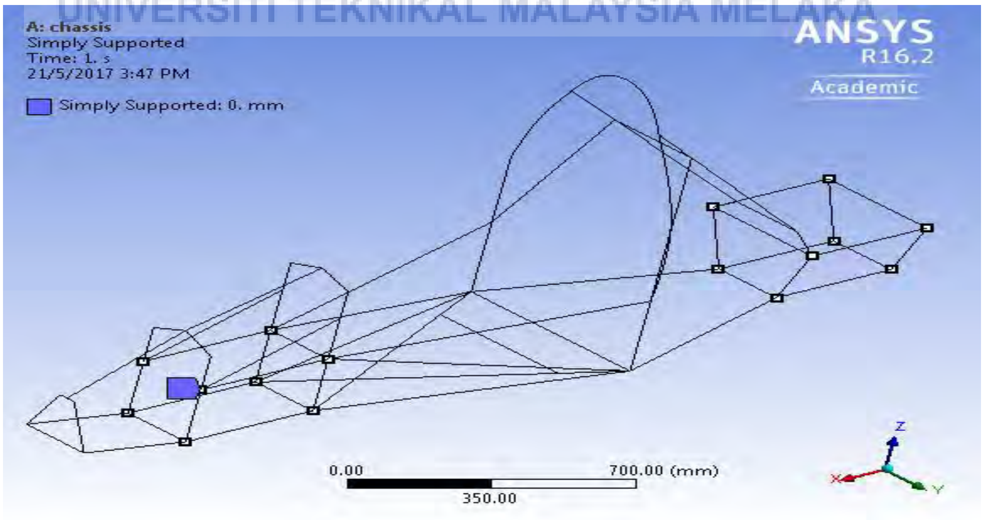


Figure 3.9: Idealization of the chassis using line element.

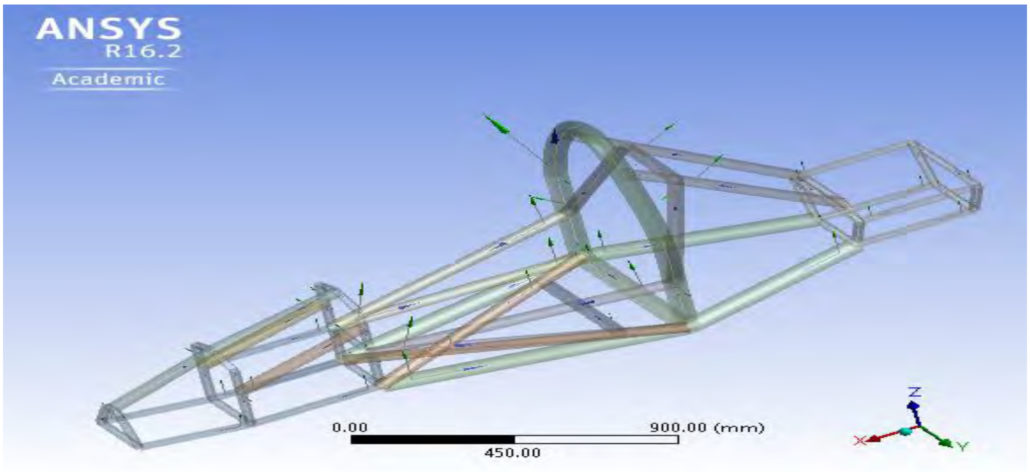


Figure 3.10: Model visualization with cross-sections.

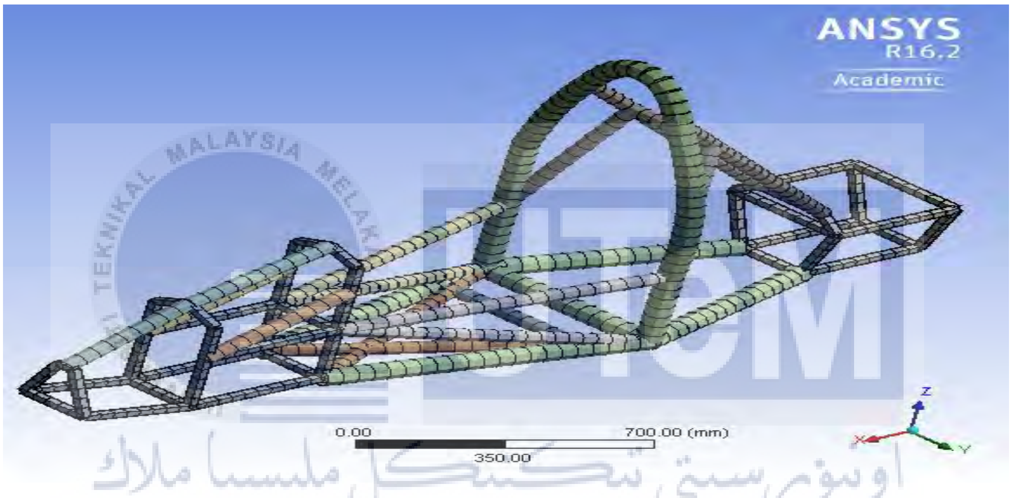


Figure 3.11: Computational model featuring elements.

3.3.2 Static Analysis

The loads that are caused by the weight of the components on the chassis and being applied normal to an axis that will produce a bending moment. To simulate these loads, forces will be applied in the vertical plane to simulate the bending force cause by the weights of the various components and the driver

For the static analysis, it just the main components that will placed inside the chassis are considered. The weight components that are considered exerted on the chassis were the weight of the engine and the weight of the driver. The clamps were set at all the parts of the chassis where the brackets were attached as shown in Figure 3.10. The weight of the driver was distributed to the seat mountings while the weight of the engine was distributed to the engine mountings. Each of the loads were directed downwards.

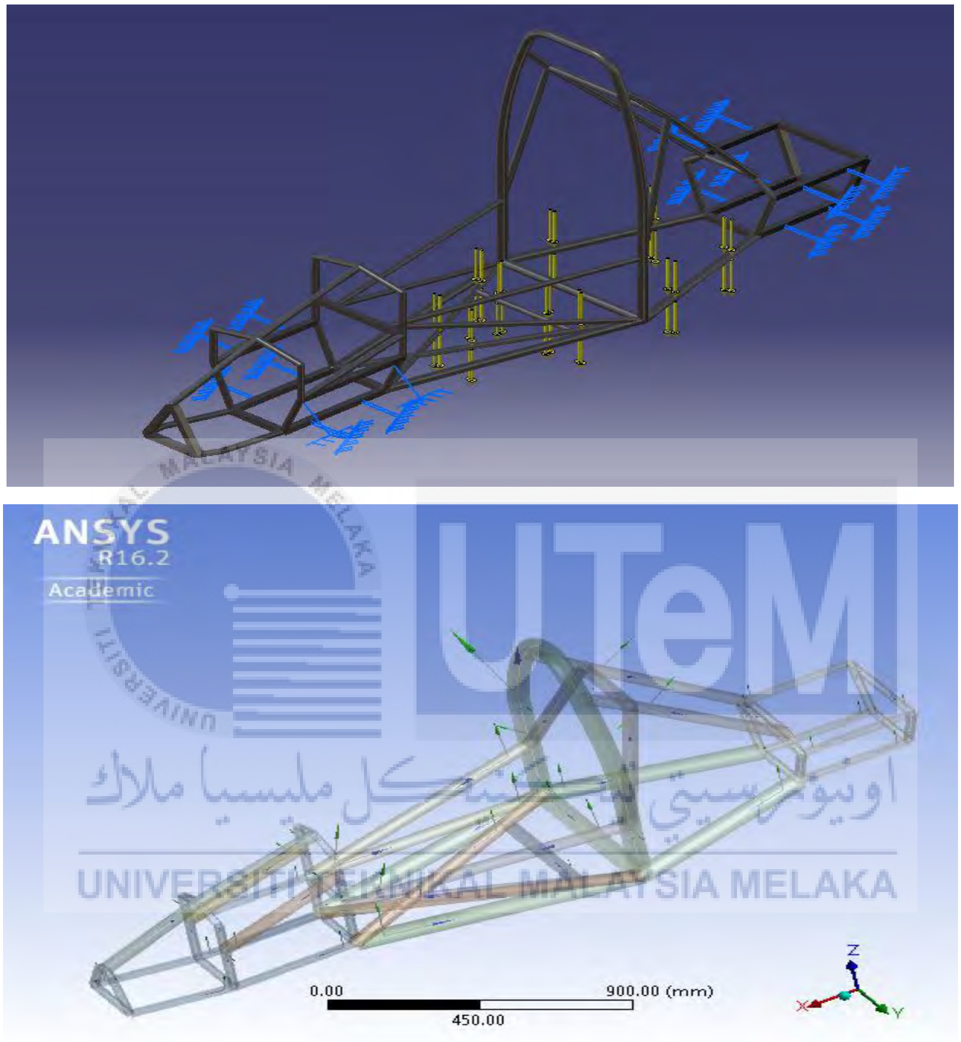


Figure 3.10: Static analysis.

3.3.3 Acceleration Analysis

For the acceleration analysis that shown in Figure 3.11, all weight is still set inside the chassis and for the loads and clamps were still placed at the same parts of the chassis as in the static analysis. However, during acceleration the loads were directed backwards, the engine and driver experience inertia to the backwards when the car was moving forward.

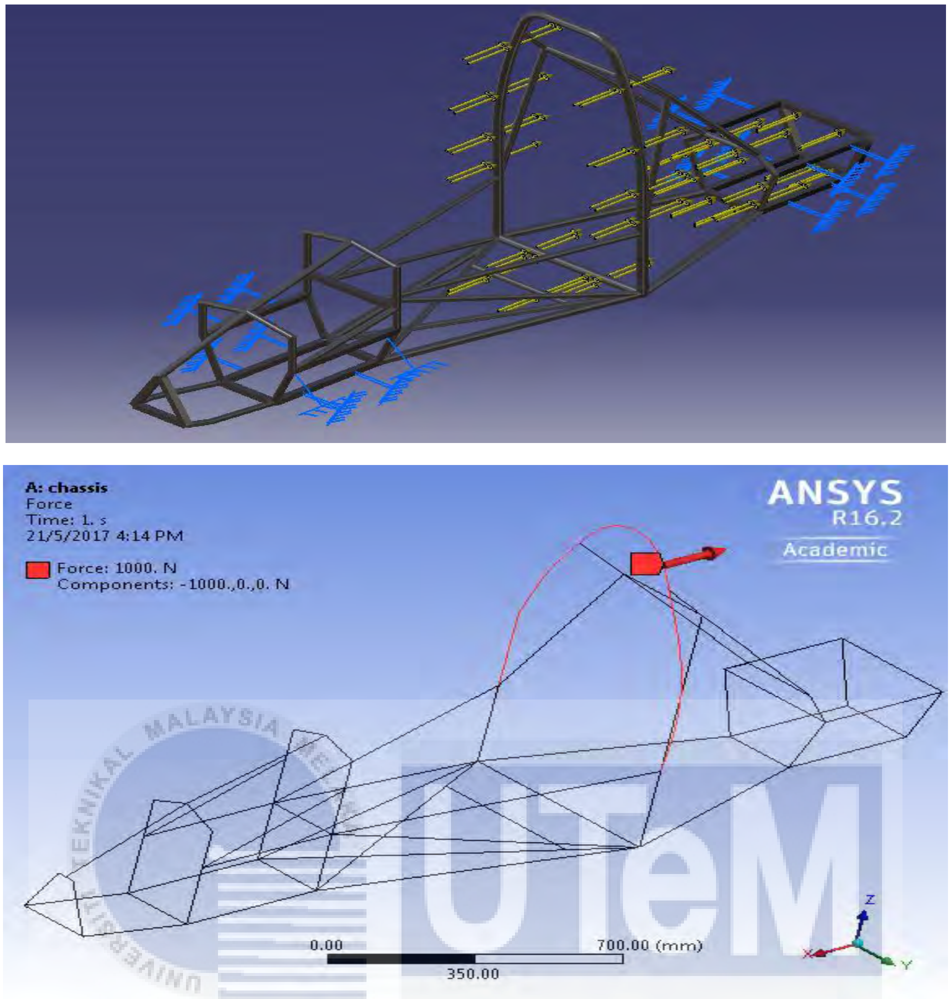


Figure 3.13: Acceleration analysis.

3.3.4 Braking Analysis

Braking loads are those experienced by the car during deceleration. The loads originate at the surface of the road where the tyres are in contact with the tarmac. The forces are transferred through the suspension struts onto the chassis of the vehicle through the mounting points.

In Figure 3.12, for braking analysis, the loads and clamps were still placed at the same parts of the chassis. Nevertheless, the loads were directed forward as during braking. When this situation occurs, the engine and driver experience inertia as the mass of the engine and the driver tends to continue moving forward when the car is being stopped from moving forward.

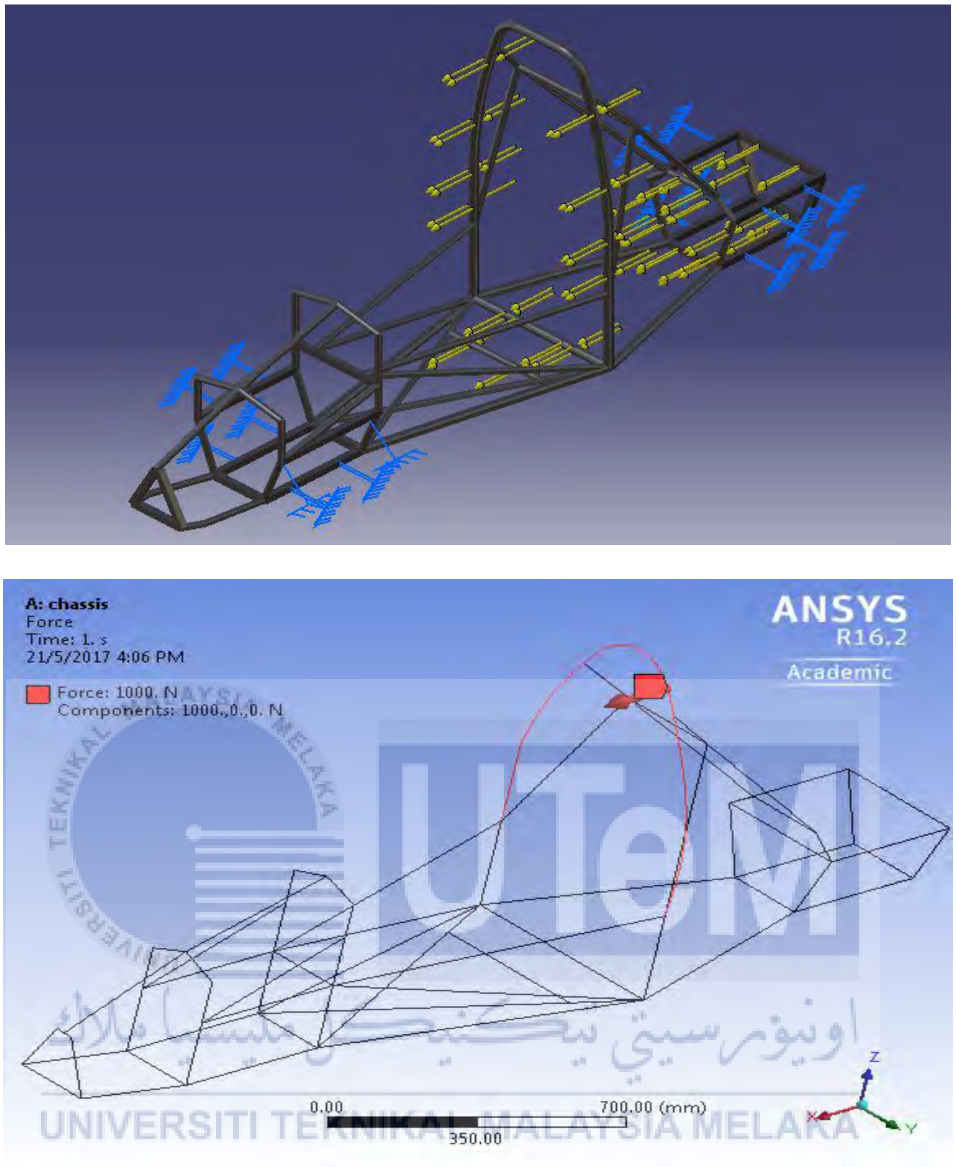


Figure 3.14: Braking analysis.

3.3.5 Cornering Analysis

When the car travels around a bend, cornering loads are imposed on the car body. Cornering loads originate from the contact patch between the tyre and the road surface. During cornering manoeuvres loads act on the wheels mainly on the outside of the corner depending on the roll of the car.

In Figure 3.13, the clamps at the chassis is still at the same place and the loads was distributed to the same parts in the cornering analysis. However, the loads direction was to the side, as during cornering. The driver and the engine will still experience the inertia whereby when the car turns to the other way, the mass of the driver and the mass of the engine will to stay where it was (pushing to the side way).

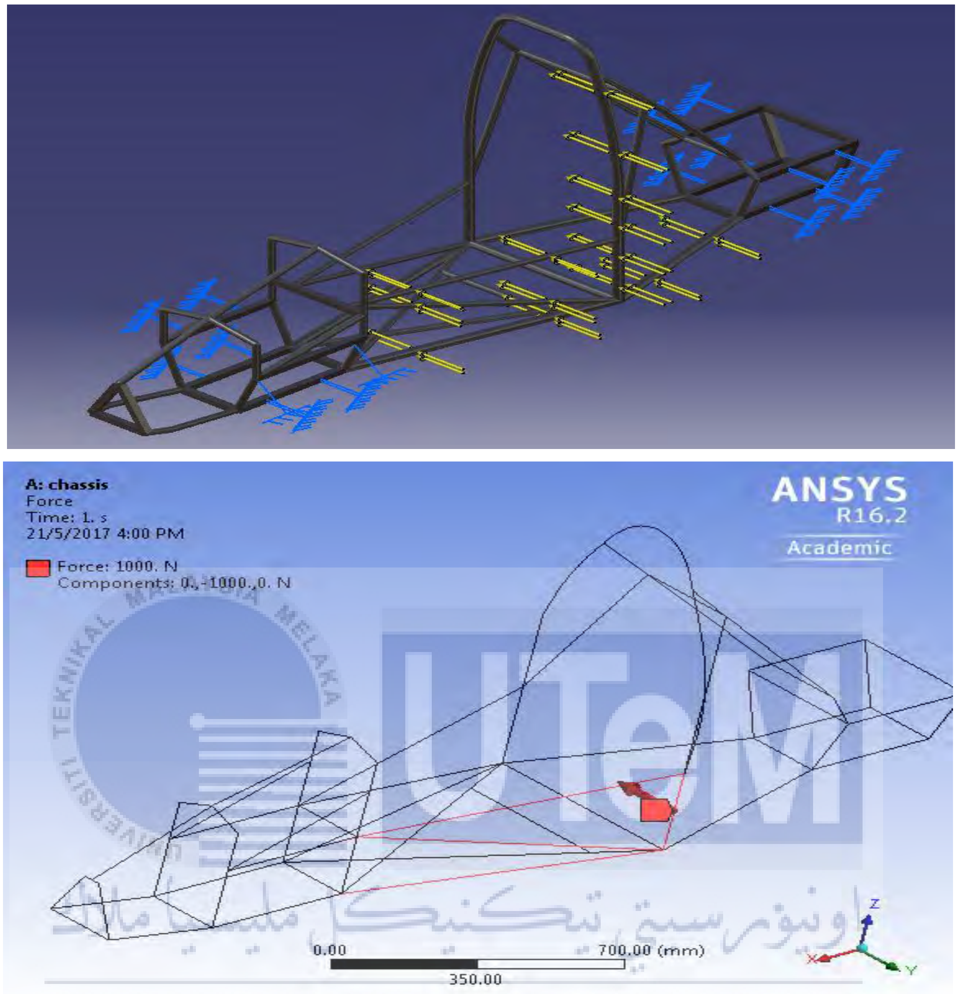


Figure 3.15: Cornering analysis.

3.3 Material Selection

For this project, the material that had been selected to fabricate the chassis frame is mild steel. This material had been chosen as the main material because of some properties of it. In reference to Marzuki, Bakar, and Azmi (2015), the material properties of steel used for the race car chassis are 200 GPa of Young’s Modulus, 7860kg/m^2 of material density, and Poisson’s Ratio of 0.3. According to Das, A (2015), another common type of steels used in Space Frame chassis are SAE-AISI 1018 and Chromium Molybdenum steel (Chromoly). This material also is one of the material with low cost and the other important point is steel easily to be weld.

The chassis undergoes various kinds of forces during locomotion, it has to stay intact without yielding, and it should be stiff to absorb vibrations, also it should resist high temperatures. The material property of the chassis is an important criterion while designing and manufacturing the car. A tubular space frame chassis was chosen over a monocoque chassis despite being heavier because, its manufacturing is cost effective requires simple tools and damages to the chassis can be easily rectified. The two very commonly used materials for making the space frame chassis are Chromium Molybdenum steel (Chromoly) and SAE-AISI 1018. Both these materials were analyzed for different parameters and finally decided on to use Chromoly steel 4130 for making the tubular space frame chassis because of several reasons.

SAE 1018 grade steel is better in terms of Thermal properties but weaker than Chromoly in terms of strength. But the main priority of design is safety for the driver hence the material with better stiffness and strength was chosen. The material should not cause any failure even under extreme conditions of driving as defined in the rule book. Chromoly steel 4130 exhibits better structural property than SAE 1018 Grade steel hence the former was considered as the basic material for building a tubular space frame chassis. Even though the cost of Chromoly is marginally higher than that of SAE 1018 grade steel, the safety of the driver remains the utmost priority for the team.

Table 3.1: Steel properties

Properties	SAE AISI 1018	Chromoly 4130 Steel
Density (g/cc)	7.8	7.8
Young's Modulus (GPa)	210	210
Elongation at break (%)	19	19
Brinell Hardness	120	200
Strength to weight ratio at Yield (kN.m/kg)	38	100
Yield Strength (MPa)	360	480
Ultimate Strength (MPa)	420	590
Thermal Conductivity Ambient (W.m/K)	50	42
Thermal Expansion: 20°C to 100°C (µm/m.K)	11	12
Specific Heat Capacity Conventional (J/kg.K)	370	370

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter describes the analysis and the result of the studies that have been conducted. Among the items discussed in the analysis, the result included several phases. Starting from the concept drawing, the design using CATIA software and analysing the chassis frame design using ANSYS software

4.2 Design

Designing the chassis frame for educational racing vehicle is based on Formula SAE specification. The specification is really important because the design specification covers all aspect for a chassis frame especially the safety of the driver. After some discussion and research had been made, Design 3 had been chosen as the main design for this project. This design had fulfilled the part that needed on chassis frame. It has space for the engine, transmission and importantly the for the main hoop will protect the driver when the situation of roll.

Table 4.1: Design selection. (more details)

	Design 1	Design 2	Design 3
Advantages	-Able to withstand very strong impact. -Meets safety regulations. -Fulfil component layout	--Meets safety regulations. -Able to withstand very strong impact.	-Less number of structure. -Fulfil component layout. -Meets safety regulations.
Disadvantages	-Difficult to fabricate. -Heavyweight	-Does not fulfil component layout. -Heavyweight	-Difficult to fabricate.

Figure 4.0: Design 3

4.3 Analysis Result of the Chassis

The analysis of the chassis contains total deformation for cornering, acceleration, braking and torsional analysis, bending stiffness and torsional stiffness and lastly the safety factor. The results are obtained from ANSYS software with various type of materials. Some calculations are performed to obtain bending stiffness and torsional stiffness as well as the safety factor. The overall results are combined and grouped into tables. Graphical visualizations of the combination and comparisons based on the tables are illustrated. Next, the results are discussed in the last section based on the result from the analysis.

4.3.1 Vertical Bending Analysis

Total deformation of a static structural may present the strength and toughness of a chassis with material and design. This can be shown by finding the stiffness of the structure. The analysis of the chassis structure was to get the value of the deformation on the structure when a force is applied on it. Figure 4.1 until Figure 4.3 are shown the analysis of vertical bending.

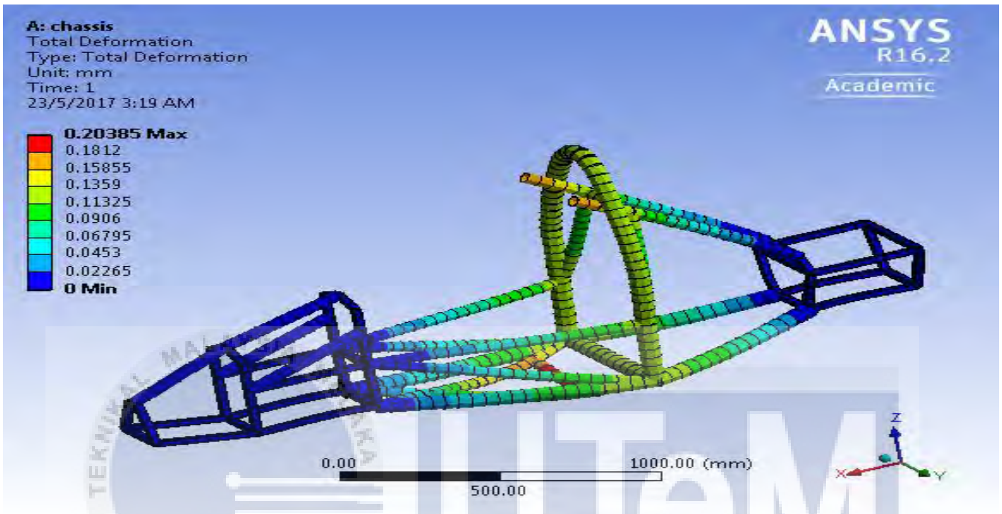


Figure 4.1: Vertical bending analysis on stainless steel for Design 3.

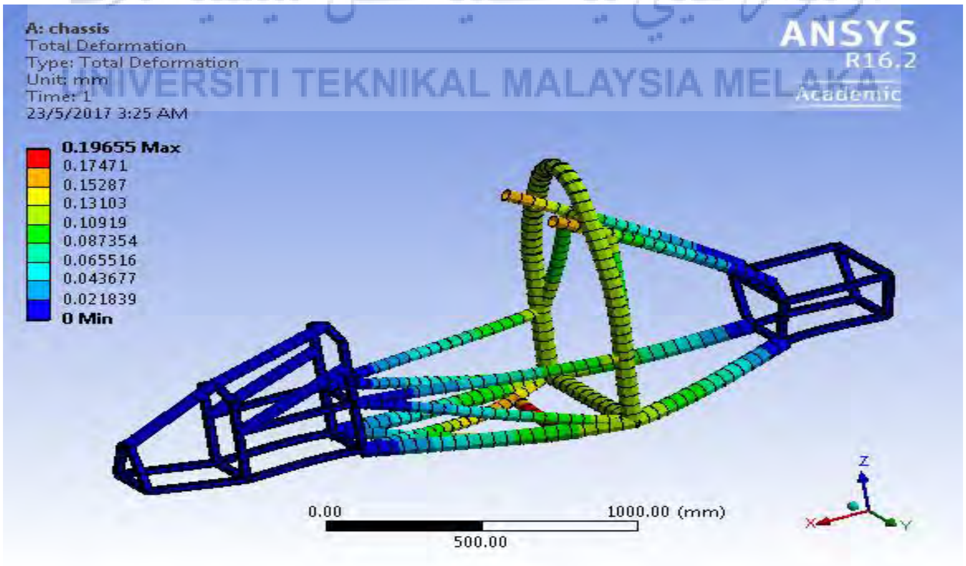


Figure 4.2: Vertical bending analysis on structural steel for Design 3.

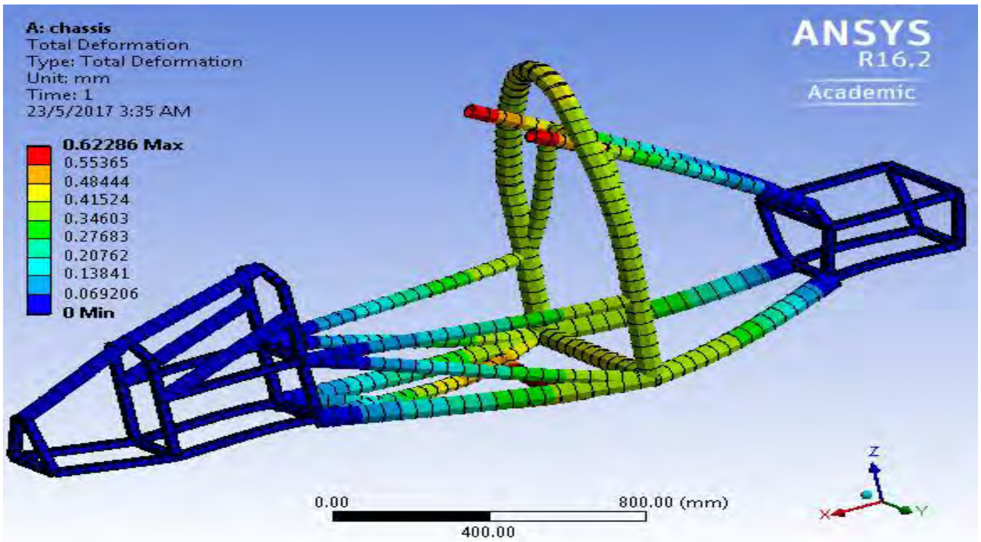


Figure 4.3: Vertical bending analysis on aluminium alloy for Design 3.

Material	Deformation(mm)
Structural steel	0.19655
Stainless steel	0.20385
Aluminium	0.62286

Table 4.2: Maximum total deformation for vertical bending analysis of Design 3.

4.3.2 Torsional Analysis

Total deformation of Design 3 of aluminum alloy, structural steel and stainless steel chassis for torsional analysis are shown in **Figure 4.4**, **Figure 4.5** and **Figure 4.6** respectively. Finally, **Table 4.3** shows overall total deformation for torsional analysis.

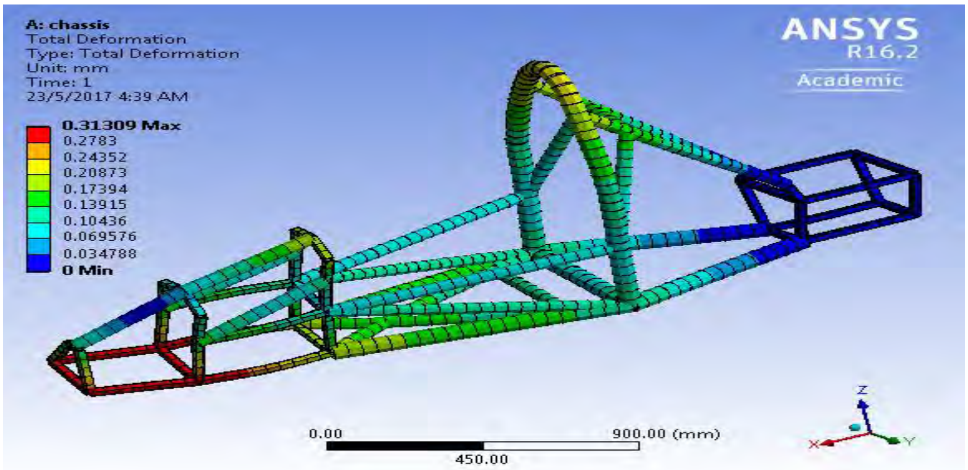


Figure 4.4: Torsional analysis on stainless steel for Design 3.

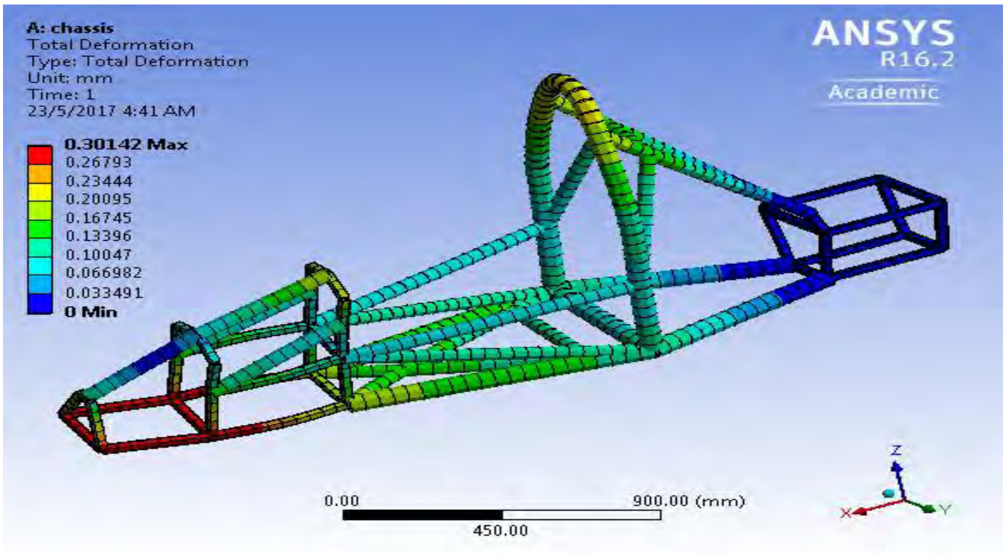


Figure 4.5: Torsional analysis on structural steel for Design 3.

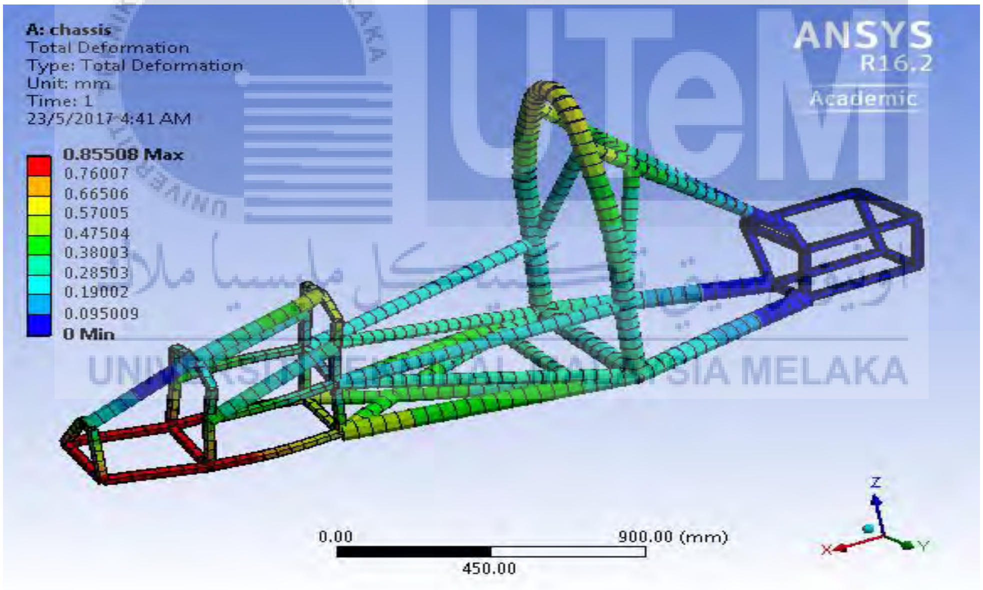


Figure 4.6: Torsional analysis on aluminium alloy for Design 3.

Material	**Deformation(mm)**

Table 4.3: Maximum total deformation for torsional analysis of Design 3.

Structural steel	0.30142
Stainless steel	0.31309
Aluminium	0.85508

4.3.3 Acceleration Analysis

This section shows the total deformation for acceleration analysis of chassis design for aluminum alloy, structural steel and stainless steel including an overall table and a graph illustration. Figure 4.7, Figure 4.8 and Figure 4.9 show the total deformation of forth design of aluminium alloy, structural steel and stainless steel chassis respectively for acceleration analysis. Last but not least, Table 4.3 shows overall total deformation for acceleration analysis.

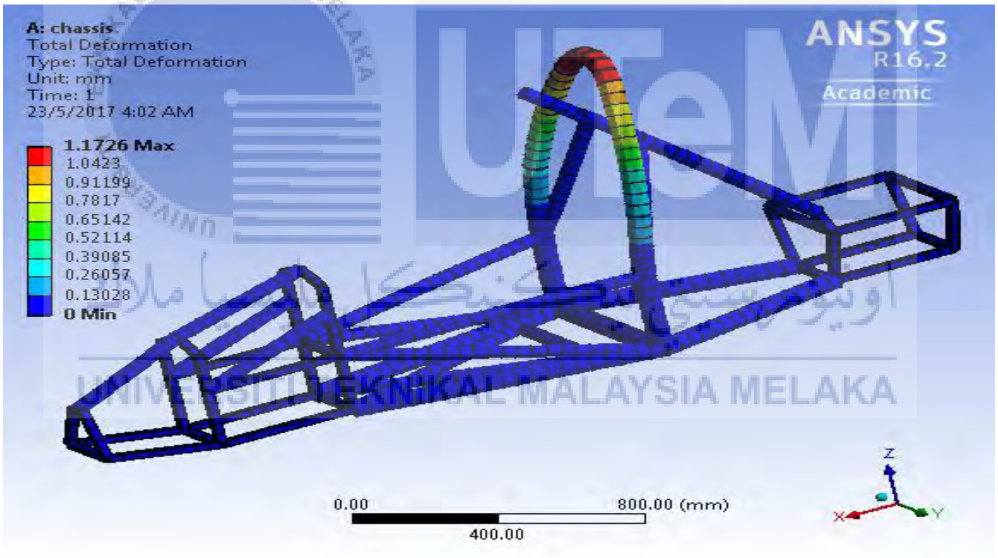


Figure 4.7: Acceleration analysis on structural steel for Design 3.

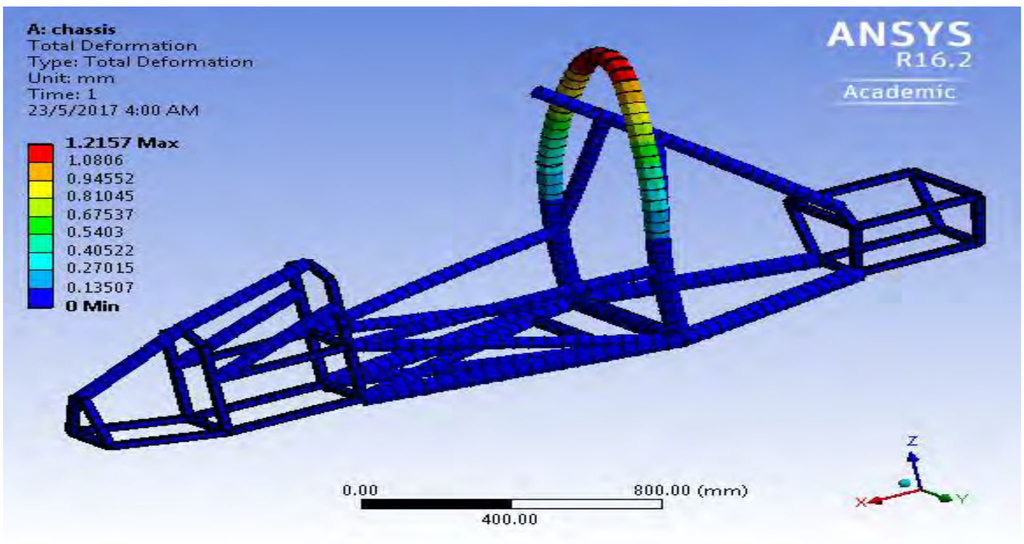
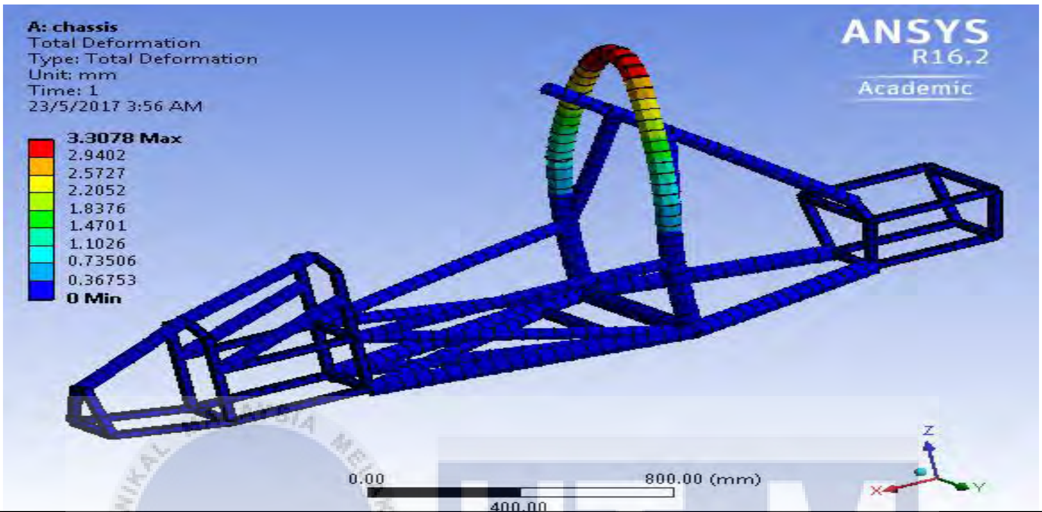


Figure 4.8: Acceleration analysis on stainless steel for Design 3.



Material	Deformation(mm)
Structural steel	1.1726
Stainless steel	1.2157
Aluminium	3.3078

Figure 4.9: Acceleration analysis on aluminium alloy for Design 3.

Table 4.4: Maximum total deformation for acceleration analysis of Design 3.

4.3.4 Cornering Analysis

This section shows the total deformation for cornering analysis with respect to Design 3 of aluminum alloy, structural steel and stainless steel as well as an overall table and a graph illustration. Figure 4.10 Figure 4.11 and Figure 4.112 show the total deformation of Design 3 of aluminium alloy, structural steel and stainless steel chassis respectively for cornering analysis. Lastly, Table 4.5 shows overall total deformation for cornering analysis.

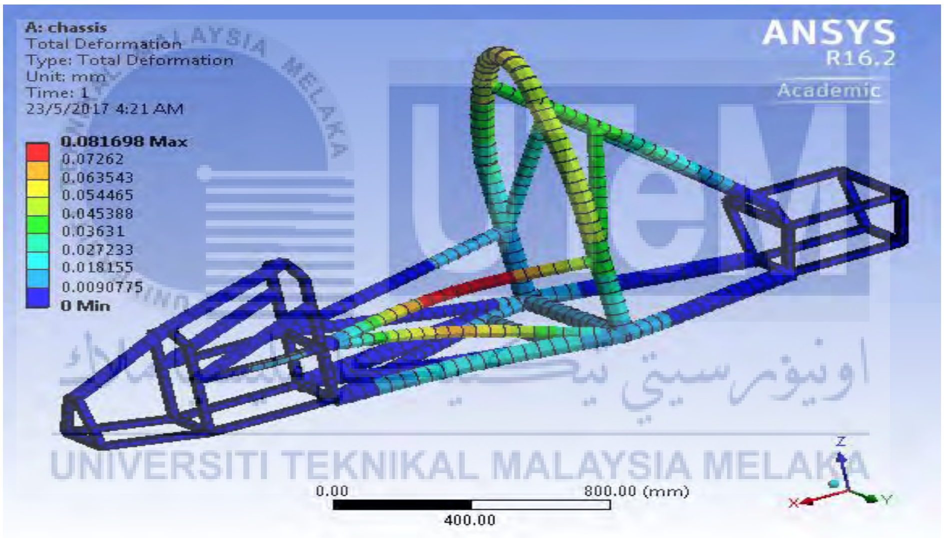


Figure 4.10: Cornering analysis on structural steel for Design 3.

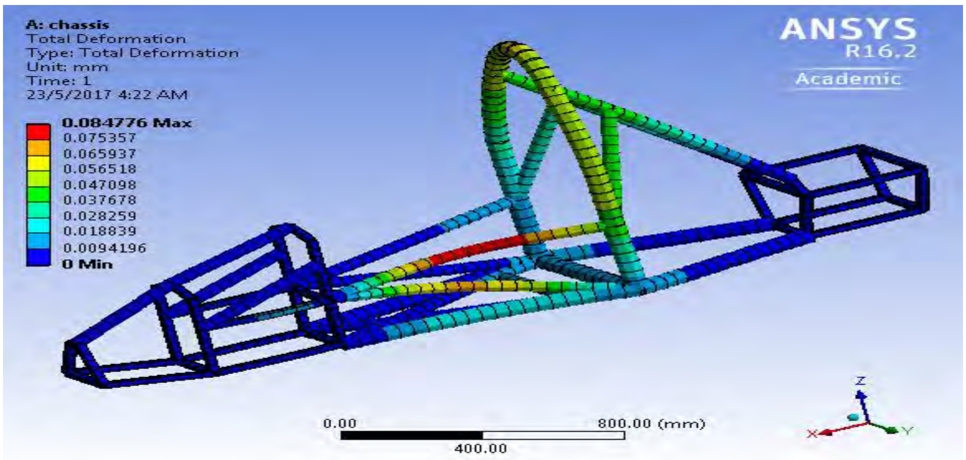
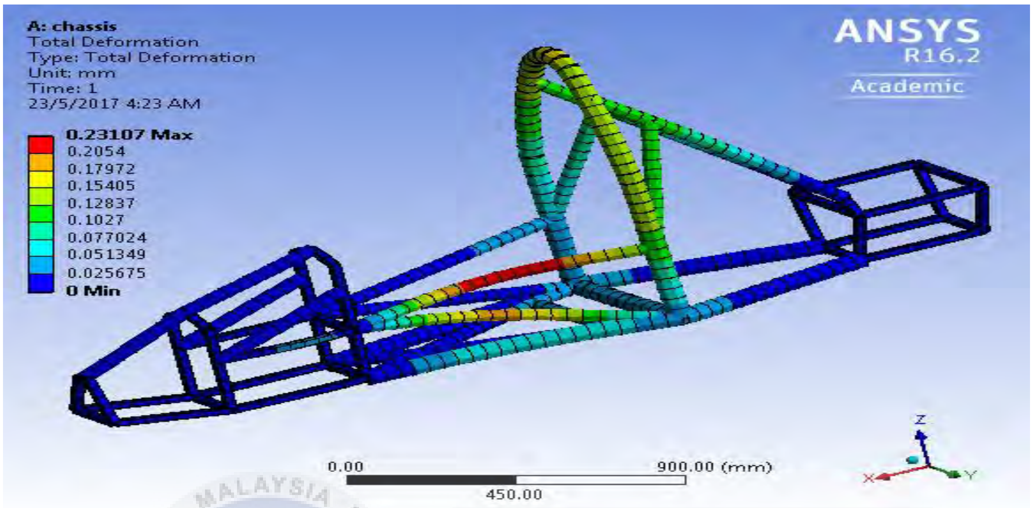


Figure 4.11: Cornering analysis on stainless steel for Design 3.



Material	Deformation(mm)
Structural steel	0.081698
Stainless steel	0.084776
Aluminium	0.23107

Figure 4.12: Cornering analysis on aluminium alloy for Design 3.

Table 4.5: Maximum total deformation for cornering analysis of Design 3.

4.3.5 Bending And Torsional Stiffness

Total deformation of a static structural may present the strength and toughness of a chassis with particular material. This can be shown by calculating the stiffness of the structure. The previous total deformation results are used to calculate the stiffness of the chassis structure. In these cases, materials with a large specific stiffness are the best. The stiffness can be expressed as:

$$k = F / \delta \tag{4.1}$$

Material	Bending Stiffness (kN/m)
Structural steel	5087.76
Stainless steel	4905.57
Aluminium	1605.50

Where,

k = Stiffness (N/m)

Material	Bending Stiffness (kN/m)
Structural steel	852.81
Stainless steel	822.57
Aluminium	302.32

F = Applied Force (N)

δ = Deformation (m)

Material	Bending Stiffness (kN/m)
Structural steel	12240.20
Stainless steel	11795.80
Aluminium	4327.69

Table 4.6: Overall bending stiffness for bending analysis.

Table 4.7: Overall bending stiffness for acceleration analysis.

Table 4.8: Overall bending stiffness for cornering analysis.

Whereas, the stiffness formula for torsional moment can be expressed as:

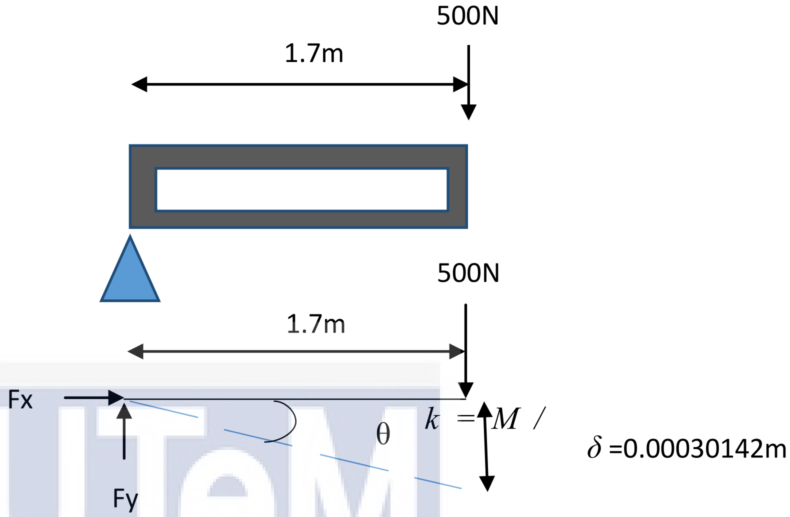
$$k = Mt / \theta \tag{4.2}$$

Where,

Mt = Twisting Moment (Nm)

θ = Angle of rotation (rad)

Sample calculation for torsional stiffness analysis is as follows:



$k = M / \theta$

tan θ = 0.00030142 m / 1.7 m

θ = 10.16x10^{-3} deg

M_t = Fd = 500 x 1.7

= 850 Nm

θ

k = 850 Nm / 10.16x10^{-3} deg

= 83661.42 Nm/deg

Figure 4.13: Free body diagram of the chassis structure with respect to side view.

Material	Torsional Stiffness (Nm/deg)
Structural steel	83661.42
Stainless steel	46145.49
Aluminium	16898.61

Table 4.9: Overall bending stiffness for torsional analysis.

4.3.6 Von Mises Stress Analysis Result

i. Bending

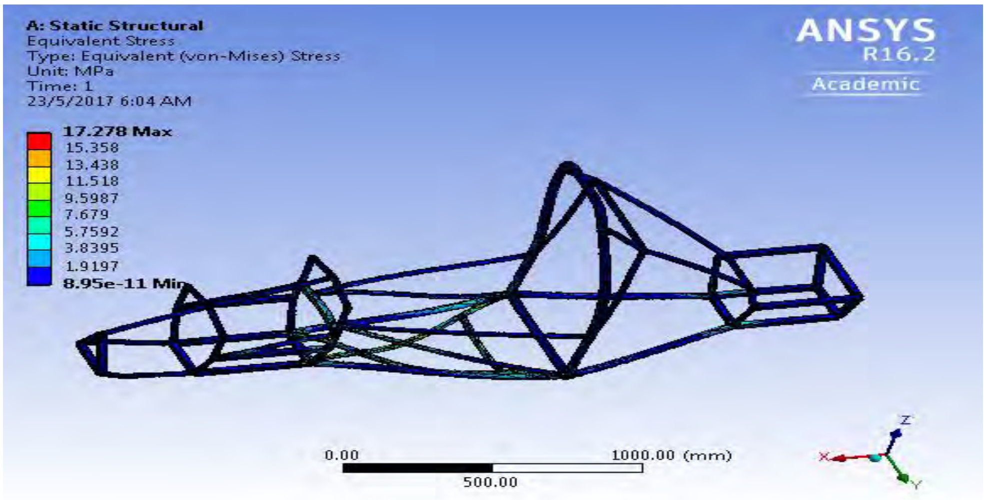


Figure 4.14: Von-Mises stress of stainless steel chassis for bending analysis.

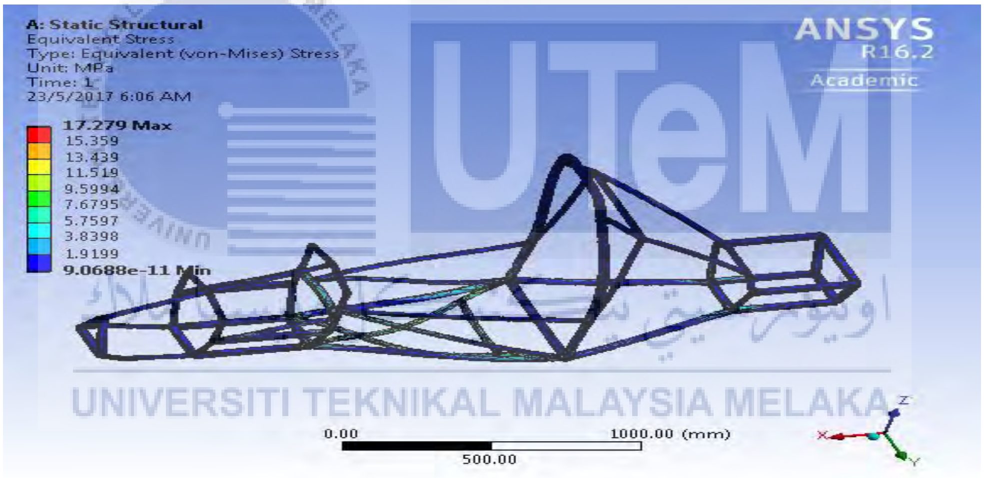


Figure 4.15: Von-Mises stress of structural steel chassis for bending analysis.

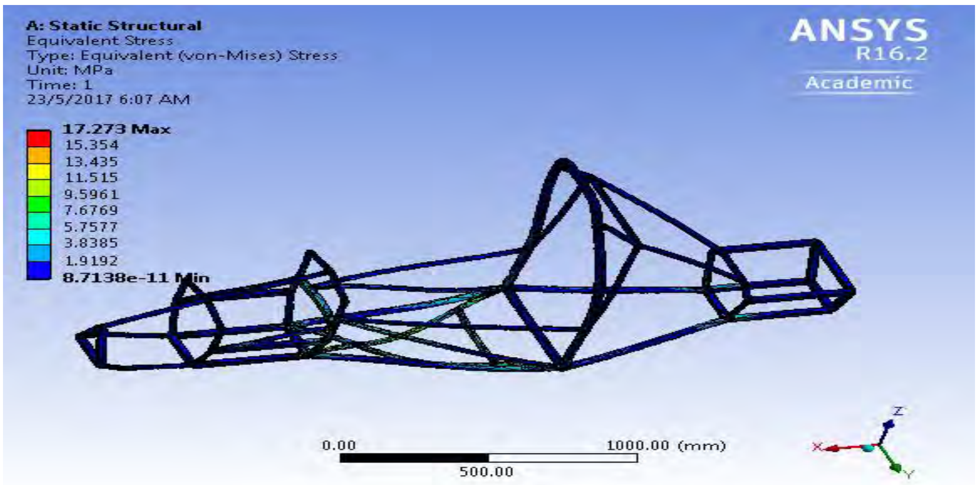


Figure 4.16: Von-Mises stress of aluminium alloy chassis for bending analysis.

Material	Von Mises stress (MPa)
Stainless steel	17.278
Structural steel	17.279
Aluminium alloy	17.273

Table 4.10: Von Mises stress value for bending analysis.

ii. Acceleration

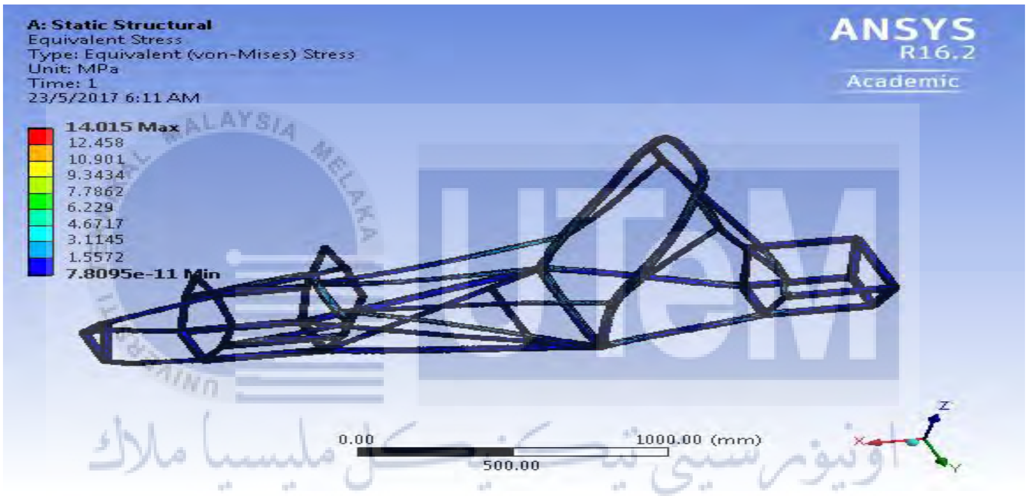


Figure 4.17: Von-Mises stress of stainless steel chassis for acceleration analysis.

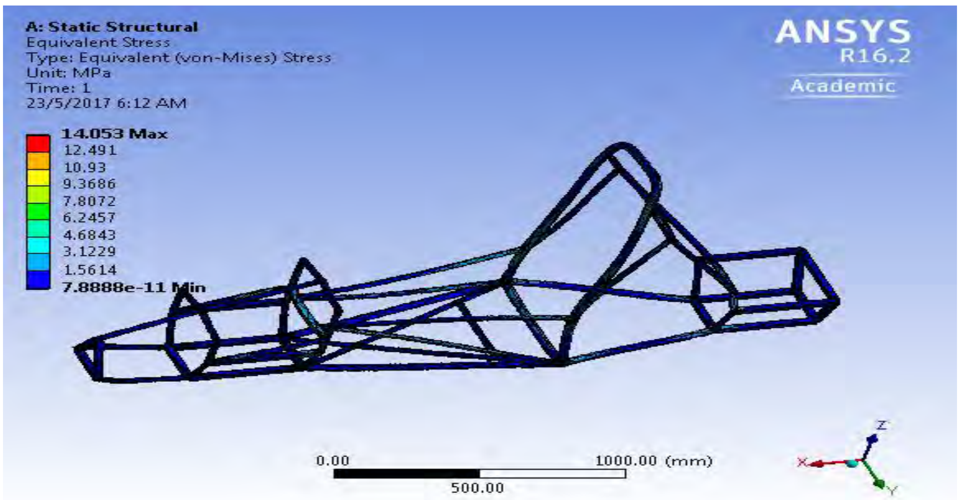


Figure 4.18: Von-Mises stress of structural steel chassis for acceleration analysis.

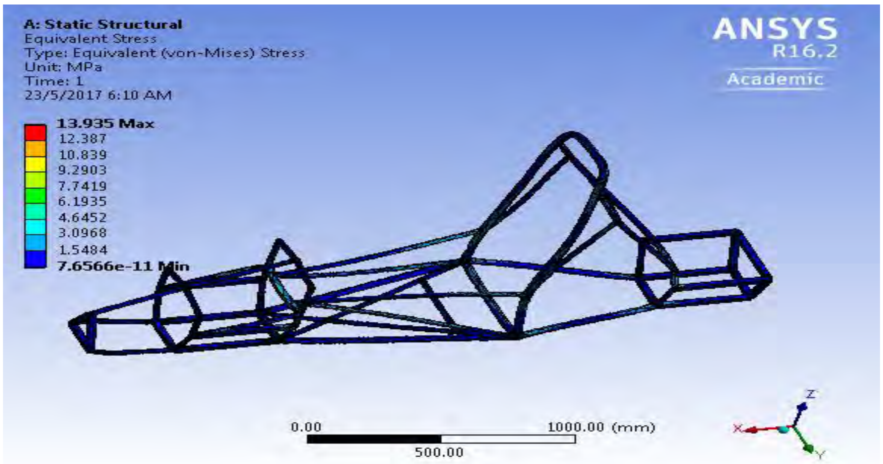


Figure 4.19: Von-Mises stress of aluminium alloy chassis for acceleration analysis.

Material	Von Mises stress (MPa)
Stainless steel	14.015
Structural steel	14.053
Aluminium alloy	13.935

Table 4.11: Von Mises stress value for acceleration analysis.

iii. Cornering

Figure 4.20: Von-Mises stress of stainless steel chassis for cornering analysis.

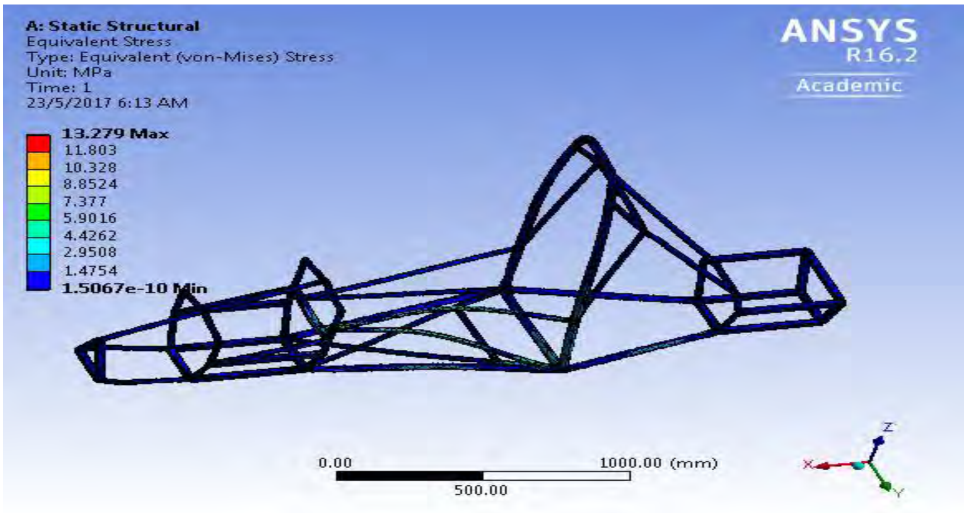


Figure 4.21: Von-Mises stress of structural steel chassis for cornering analysis.

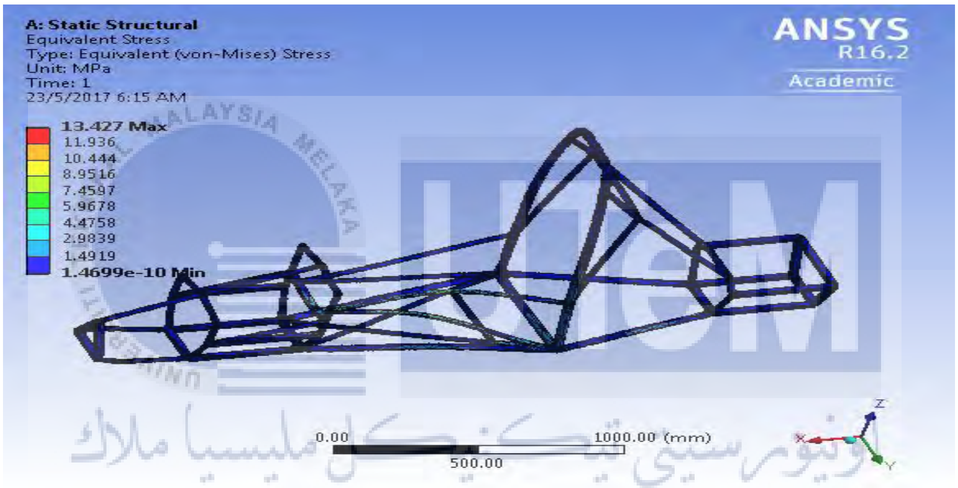


Figure 4.22: Von-Mises stress of aluminium alloy chassis for cornering analysis.

Material	Von Mises stress (MPa)
Stainless steel	13.326
Structural steel	13.279
Aluminium alloy	13.427

Table 4.12: Von Mises stress value for cornering analysis.

iv. Torsional

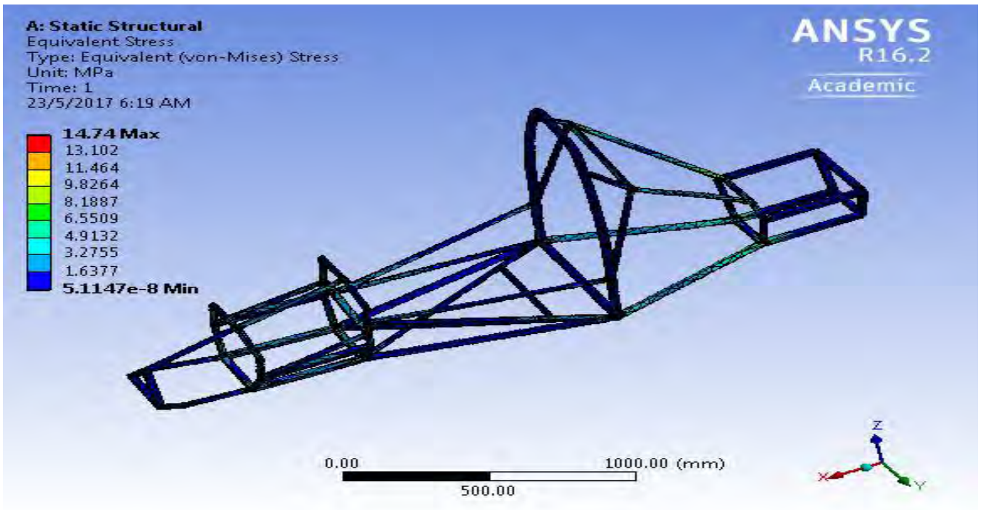


Figure 4.23: Von-Mises stress of stainless steel chassis for torsional analysis.

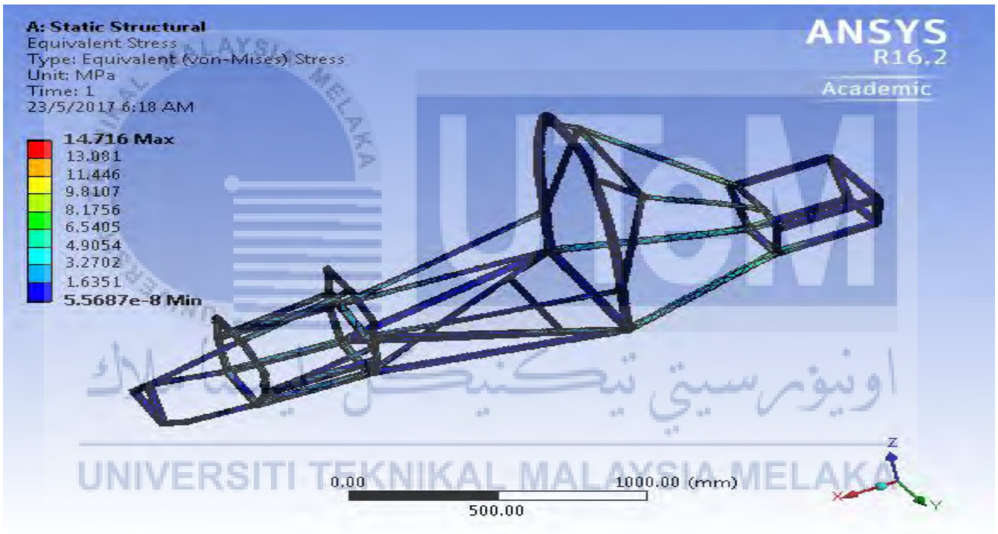


Figure 4.24: Von-Mises stress of structural steel chassis for torsional analysis.

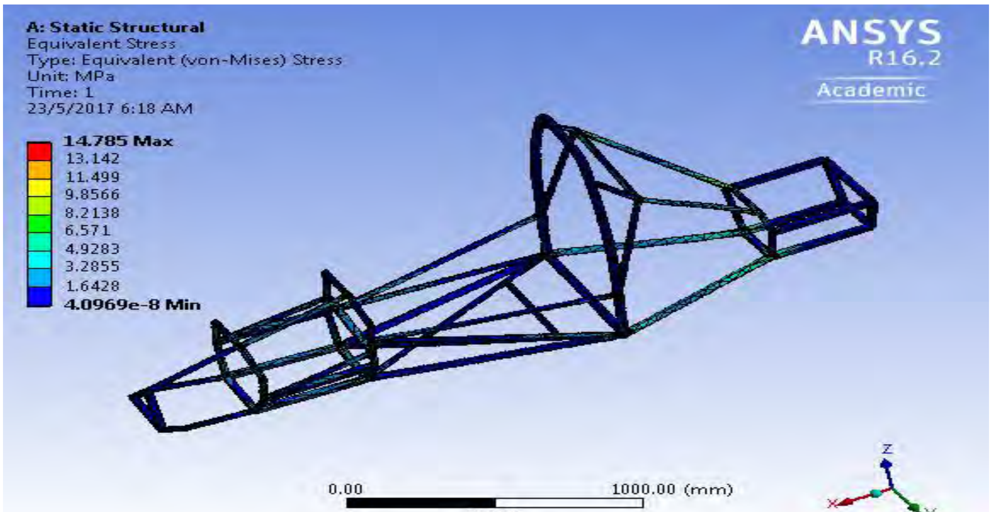


Figure 4.25: Von-Mises stress of aluminium alloy chassis for torsional analysis.

Material	Von Mises stress (MPa)
Stainless steel	13.326
Structural steel	13.279
Aluminium alloy	13.427

Table 4.13: Von Mises stress value for torsional analysis.

4.4 Discussion

The design for the chassis frame is based on FSAE specification. Design 3 had fulfilled the part that needed on chassis frame. It has space for the engine, transmission and importantly the for the main hoop will protect the driver when the situation of roll. Furthermore, the advantages of this design it has less number of structures which make the design more lightweight. However, this chassis structure is fulfilling the safety specifications.

For the analysis, the chassis was analysed with 1000N force was exerted on the chassis body. For bending analysis, acceleration analysis, cornering analysis and torsional analysis, the force that exerted on the chassis structure affected the deformation that occurred on the chassis. The smaller deformation value is more better because it will not give a big impact on the chassis structure. As we can see in Table 4.2 until Table 4.5, the deflection that occur on the chassis is highest for aluminium alloy. The deformation values are highest when aluminium alloy was applied on the chassis body than structural steel and stainless steel.

Bending and torsional stiffness is really important for a chassis frame. Stiffness is the ability of a structure to remain at it original condition after deflection occur. So, for a chassis frame the bending stiffness and torsional stiffness are the important values in order to know flexibility of the structure. Table 4.6 until Table 4.9 shows the bending and torsional stiffness values for the chassis structure. The structural steel has highest stiffness values other than stainless steel and aluminium alloy.

Lastly, von Mises stress analysis is important for chassis structure because we will know the maximum stress that can be adapted by a chassis structure. For this chassis design, the maximum von Mises stress occurs when aluminium alloy was applied and this can in the Table 4.10 until table 4.13.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The design of chassis frame for educational racing vehicle is needed to fulfil the specification for every educational racing vehicle. All chassis frame need to be designed with front hoop, main hoop, crush zone and side impact protection which all of these parts are important to protect the driver whenever accident happen. However, the structure of every chassis frame can be reduced to minimum weight. Design 3 of the chassis frame is the most suitable structure as compared to other two proposed. This design has fulfilled the requirement specifications of chassis frame which it has front section, rear section and main hoop with side impact protection. The chassis design also has less number of structures which help the chassis to reduce it weight. Design 3 had been selected as the design for the chassis frame of educational racing vehicle.

As the Design 3 has been selected as the design for chassis frame, the analysis on the structure of the design had been made. For the analysis, the chassis structure had been applied with three types of materials which are structural steel, stainless steel and aluminium alloy. All these materials have different types of properties. The analysis on the chassis frame was focused on static analysis which included vertical bending analysis, acceleration analysis, cornering analysis and torsional analysis. The analysis on the chassis structure is to know the deformation that occur on the structure when a force is exerted on it. The analysis also is to find out the bending stiffness and torsional stiffness of the structure because it important to know the ability of the chassis structure to remain to its original shape after being exerted by any forces.

The deformation that occurred on the chassis is need the smaller value. Chassis structure with aluminium alloy has bigger deformation value and the structure with structural steel has smaller deformation occur which also smaller than the stainless steel material for deformation values for all analysis. Vertical bending analysis is when vertical forces is applied as the force is same with the weight of the driver and the engine is the structure bending downwards. The chassis with aluminium alloy on it has larger deformation value with 0.62286 mm and structural steel has smaller deformation with 0.19655 mm. The acceleration analysis is the force act because of the inertia and the structure with aluminium alloy has 3.3078 mm deformation and the chassis with structural steel has 1.1726 mm deformation. Next, the cornering analysis is applying with the forces were exerted on the side of the chassis frame. The structure with aluminium alloy has 0.23107 mm deformation for bigger value and the chassis with structural steel has 0.081698 mm deformation for smaller value.

Bending and torsional stiffness are important value for a chassis frame. The stiffness is showing the flexibility of the structure for the chassis frame. The stiffness of a structure is help the structure from change its shape as the force is applied on it. Hence, the bending and torsional stiffness are analysed at bending, acceleration, cornering and torsional analysis. The structural steel chassis has a bigger bending stiffness values other than stainless steel and aluminium alloy which 5087.76 kN/m for bending analysis, 852.81 kN/m for acceleration analysis and 12240.20 kN/m for cornering analysis. For torsional stiffness, chassis frame with structural steel also has bigger stiffness which is 83661.42 Nm/deg.

Von Mises stress is the tension of a structural and a chassis frame structure need a maximum value of Von Mises stress before the structure fracture or fail. For this chassis design, the von Mises stress for the structure when all three materials are applied has small different in every value. The structural steel has bigger maximum Von Mises stress value which 17.279 MPa for bending analysis and 14.053 MPa for acceleration analysis. For cornering analysis and torsional analysis, when aluminium alloy is apply on the chassis frame the maximum von Mises stress is 13.427 MPa and 14.785 MPa.

Lastly, all the design selection process and analysis process for the chassis is important process to find a better chassis frame for educational racing vehicle. For the materials, although aluminium alloy has low in weight but based on the analysis this material is not suitable to be the chosen material for chassis frame because despite having good maximum von Mises stress this material causes bigger deformation and has smaller bending and torsional stiffness. Structural steel and stainless steel can be chosen as the material for chassis frame because these two materials have small deformation and bigger bending and torsional stiffness values. For the last, Design 3 of the chassis frame with structural steel materials is the best chassis frame that can be manufacture for the educational racing vehicle.

5.2 Future Work Recommendations

For the recommendation, this project can be continued with more analysis work on the chassis structure like dynamic analysis. More research on material selection also can be do it in the future for better chassis frame structure. This project also can be continued with fabricating the chassis frame and experimental work on the chassis frame can be performed in the laboratory. Lastly, it is hope that this project can be continued or be a reference for the future project of educational racing vehicle.

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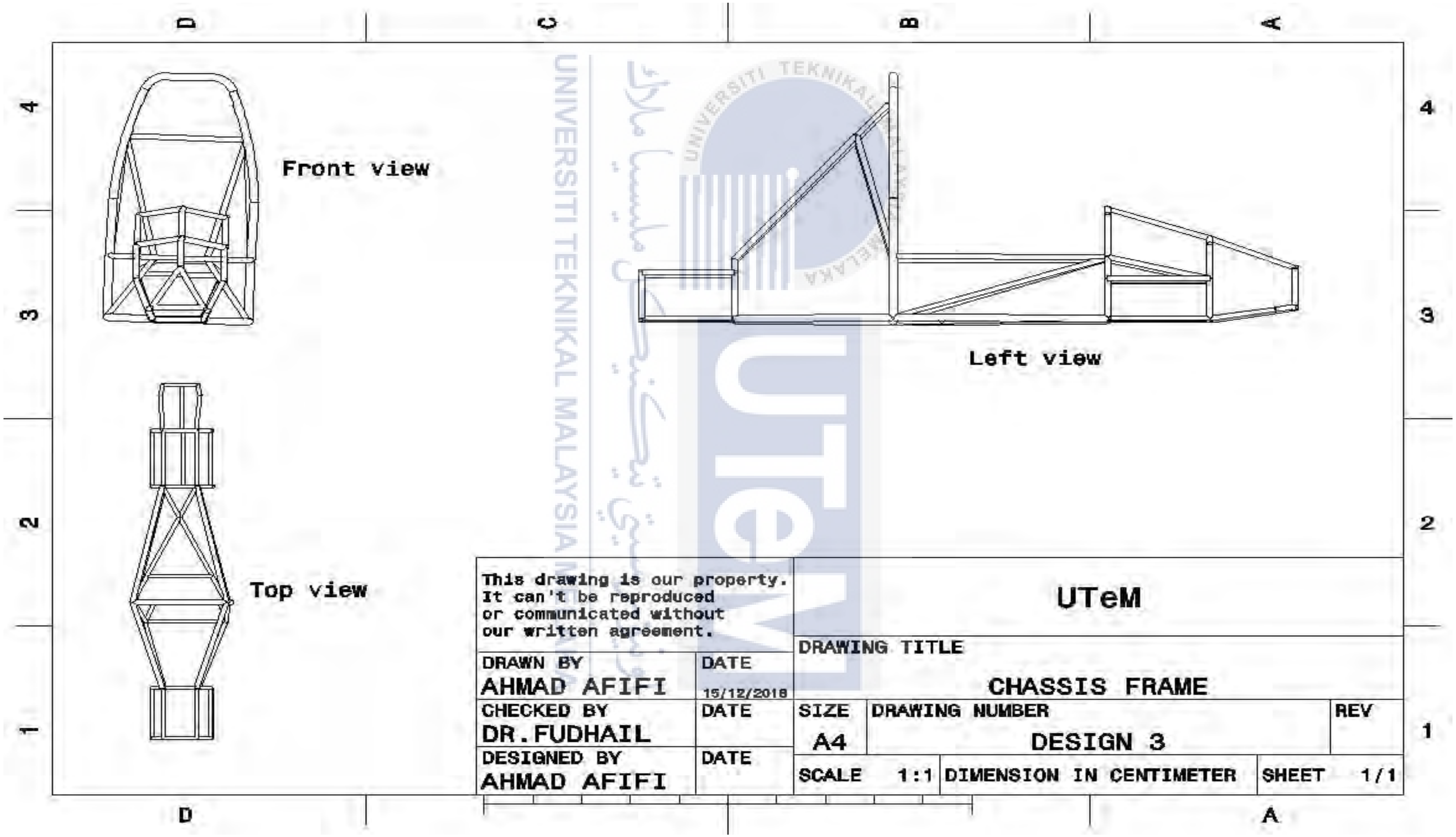
APPENDICES

Activity	Semester 1 Session 16/17															Semester 1 Session 16/17														
	Week															Week														
PSM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Planning	■	■																												
Chapter 1: Introduction			■	■	■																									
Chapter 2: Literature Review				■	■	■	■	■	■	■	■	■																		
Chapter 3: Methodology									■	■	■	■	■	■																
Chapter 4: Preliminary Result											■	■	■	■																
Chapter 4: Result and Analysis																■	■	■	■	■	■	■	■	■	■	■	■			
Chapter 5: Conclusion and Recommendation																												■	■	
Progress report								■															■							
Draft final report																													■	
Final report submission																														■

APPENDIX B


Front view
Top view
Left view
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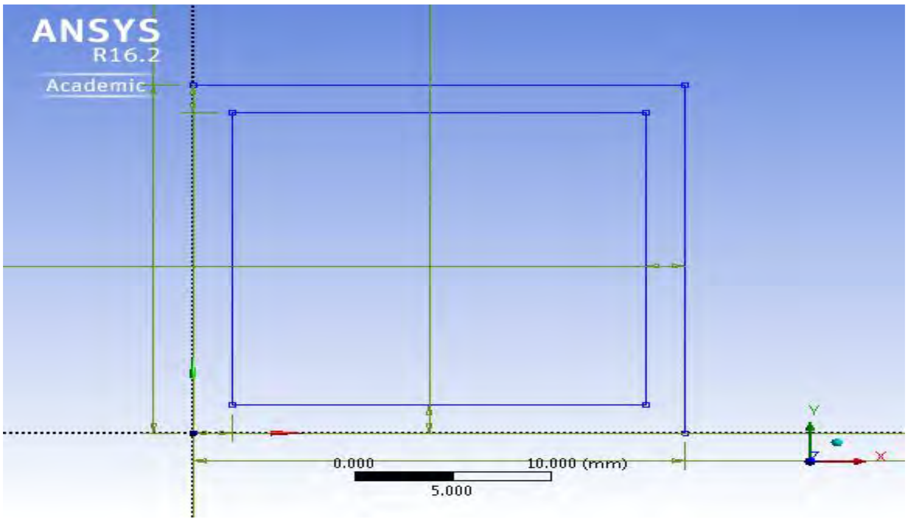
APPENDIX C



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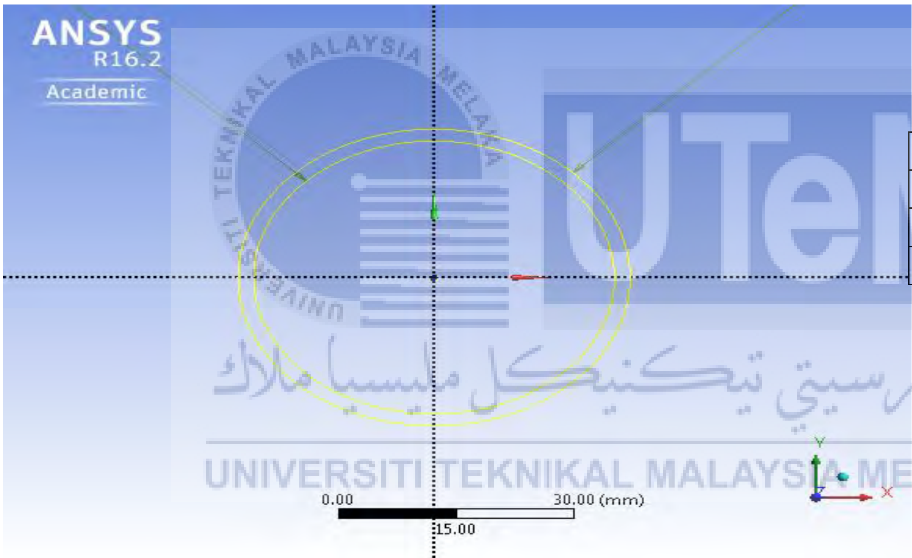

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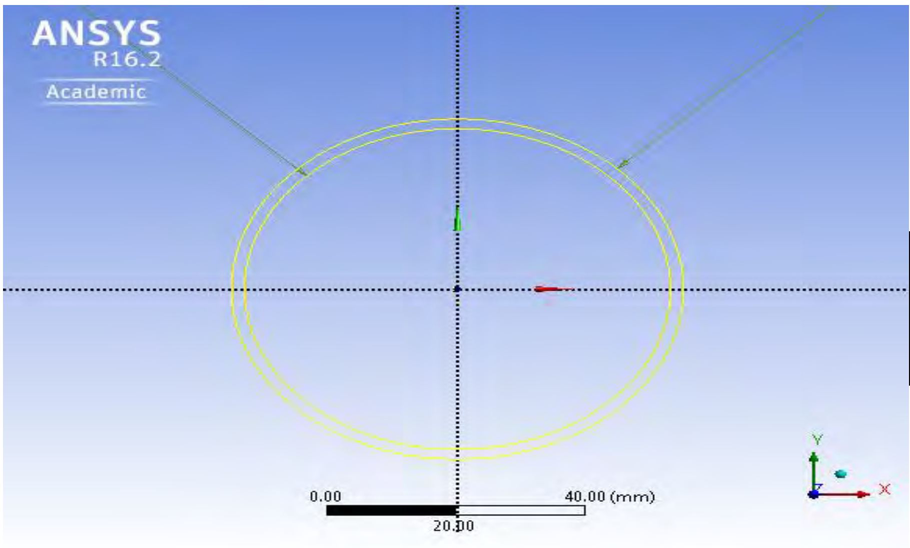

	Dimension(mm)
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Outer radius	35
Thickness	2