DEVELOPMENT OF A REMOTE CONTROL CAR CHASSIS LIKE THE SWINCAR E-SPIDER

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This report is submitted
in fulfillment of the requirement for the
Bachelor of Mechanical Engineering

Faculty of Mechanical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JULY 2024

DECLARATION

I declare that this project report entitled "Development of Remote-Control Car Chassis Like The Swincar E-Spider" is the result of my own work except as cited in the references.

Signature	:
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Date	: JULY 2, 2024

APPROVAL

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.

Signature	: ....
Name of Supervisor	: DR. SHAMSUL ANUAR BIN SHAMSUDIN
Date	: JULY 2, 2024

DEDICATION

This project report is dedicated to my parents Azlan Bin Abdul Zawawi and Ropidah Binti Kamaruddin, whose unwavering love, encouragement, and sacrifices have provided me with the foundation and strength to persevere and succeed. I extend my deepest gratitude to my supervisor as a mentor, whose wisdom, patience, and guidance have been instrumental in my academic and professional development. I am also grateful to my friends and teammates for their camaraderie and collaboration, which have enriched this journey. Finally, I wish to acknowledge and thank all those who believed in me and contributed to this project, whose support has been invaluable to the successful completion of this work.

ABSTRACT

The purpose of this final year project is to study and build an electric vehicle called the Swincar E-Spider. This 4-motor-powered battery vehicle is designed for hilly areas and areas with uneven terrain, such as mountains and beaches. In relation to that, in this project, students must build a small-scale Swincar E-Spider prototype like a remote-controlled car. Next, this entire research report focuses on the type of chassis or frame that is suitable for making prototypes, the type of material, and the finite element analysis of the chassis design before starting the fabrication process. After that, the fabrication process of the chassis structure also needs to be implemented to see the true capabilities of this prototype. The fabrication process of this prototype is divided by the project supervisor into three parts. A total of three students are involved in one section, among which are the chassis structure design section, automotive section, and system design. Next, these three parts will be put together to complete a prototype called the Swincar E-Spider concept. The function of this prototype can be seen in whether it achieves the characteristics of the Swincar E-Spider or not.

ABSTRAK

Tujuan asal projek tahun akhir ini adalah untuk mengkaji dan membina sebuah kenderaan elektrik yang berkosepkan Swincar E-Spider. Kenderaan bateri yang berkuasakan 4 motor ini adalah dicipta untuk kawasan bukit dan juga Kawasan yang mempunyai bentuk muka bumi yang tidak rata seperti pergunungan dan pantai. Sehubungan dengan itu, di dalam projek ini pelajar perlu membina prototaip berkongsepkan Swincar E-Spider yang berskala kecik seperti kereta kawalan jauh. Seterusnya, keseluruhan laporan penyelidikan ini adalah mengfokuskan pada jenis casis ataupun rangka yang sesuai dalam pembikinan prototaip, jenis bahan, dan analisis unsur terhingga terhadap reka bentuk casis sebelum melulakan proses fabrikasi. Setelah itu, proses fabrikasi struktur casis tersebut juga perlu dilaksanakan untuk melihat kebolehan sebenar prototaip ini. Proses fabrikasi prototaip ini dibahagikan oleh penyelia projek kepada tiga bahagian. Sebanyak tiga orang pelajar terlibat dalam satu bahagian antaranya ialah bahagian rekabentuk struktur casis, bahagian automotive, dan rekabentuk system. Seterusnya, ketiga tiga bahagian ini akan disatukan untuk melengkapkan sebuah prototaip yang berkonsepkan Swincar E-Spider. Fungsi prototaip ini akan dillihat sama ada mencapai ciri- ciri Swincar E-Spider ataupun tidak.

ACKNOWLEDGEMENT

I would like to extend my heartfelt gratitude to all those who have provided me with the guidance, support, and encouragement necessary to complete this final year project. First and foremost, I am deeply grateful to my project supervisor, Dr. Shamsul Anuar Bin Shamsudin, for their invaluable advice, continuous support, and patience throughout the duration of this project. Their expertise and insightful feedback have been instrumental in shaping the direction and quality of this work.

I would also like to thank the Faculty of Mechanical Technology and Engineering for providing me with the necessary resources and a conducive environment to carry out my research. Special thanks to the Lab Technicians and Administrative Staff for their assistance with equipment and logistics. My sincere appreciation goes to my fellow teammates and friends, Muhammad Ammar Faiz Bin Amiruddin and Goh Xue Li, for their camaraderie, encouragement, and constructive discussions that have greatly enriched this experience. I am particularly indebted to my family for their unwavering support, patience, and understanding throughout my academic journey. Their encouragement has been a constant source of strength and motivation.

Finally, I would like to acknowledge everyone who, directly or indirectly, has contributed to the successful completion of this project. Your support and contributions are deeply appreciated.

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LIST OF ABBEREVATIONS

FEA	Finite Element Analysis
CAD	Computer Aided Design
EVs	Electric vehicles
PEVs	Pure Electric Vehicles
HEVs	Hybrid Electric Vehicles
BEVs	Battery Electric Vehicle
FCEVs	Fuel Cell Electric Vehicles
SUVs	Sports Utility Vehicle
LiPo	Lithium-Polymer Battery
ESC	Electronic Speed Control
N/A	Not Available
RC	Remote control

LIST OF SYMBOLS

σ_V	=	von-Mises stress
σ_y	=	Yield stress
σ_{vmax}	=	Maximum Von-mises stress
τ	=	Shear stress
τ_{max}	=	Maximum shear stress
n	=	Factor of safety
N	=	Newton
Mpa	=	Mega Pascal
mm	=	Millimeter
R	=	Percentage of Reduction
C_0	=	Original cost
C_1	=	New cost

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CHAPTER 1

INTRODUCTION

1.1 Background

Electric vehicles (EVs) represent a significant achievement in the vehicle industry. This technology provides a sustainable and ecologically beneficial alternative to typical internal combustion engine automobiles. The growing number of internal-combustion cars that utilize nonrenewable conventional fuels has resulted in both energy and environmental challenges. (Sun, 2019). EVs have gained considerable attention and popularity due to their potential to reduce greenhouse gas emissions, decrease dependence on oil, and improve air quality.

Moreover, in comparison between steam and gasoline engines of the time, electric vehicles were quiet, easy to operate, and did not generate foul-smelling pollution (Rajashekara, 1994). Electric vehicle technology began about 1884. In England, inventor Thomas Parker assisted in the deployment of electric trams and constructed prototype electric automobiles (Guarnieri, 2012). Electric cars are classified into three types which are pure electric vehicles (PEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs). A traction battery powers a pure electric vehicle, often known as a battery electric vehicle (BEV) (Evgo, 2023). Battery-electric cars do not operate on petrol, but rather on energy stored in a battery pack, which powers one or more electric motors and emits no exhaust emissions. These vehicles may be charged practically anywhere, at any time, and at a far cheaper cost than petrol (Zhengguo, 2019).

This project focuses on electric vehicles, specifically Swincar E- Spider chassis prototype which is a BEV. Actual EV cannot move smoothly in uneven roads, hills, and slopes. To overcome all the problems, we plan to design and fabricate the Swincar which is operated with pendulum mechanism (Redd, 2020). The driver's compartment or nacelle and the wheels are articulated on a longitudinal axis, which allows the nacelle to tilt on turns or a slope (Swincar, 2017).

The vehicle's chassis structure, often referred to as the chassis, is the framework that provides structural support and forms the foundation for the entire vehicle. Chassis design and construction can vary substantially depending on the type of vehicle, but the basic elements and functions remain relatively consistent. An automotive chassis is a skeleton frame upon which different mechanical components such as the engine, suspension, and steering are mounted. (Prasad,2020). However, this prototype chassis carries electronic components such as Electronic Speed Controller (ESC), Servo motor, battery and so on. The chassis is the most significant component of an automobile (Sun, 2019). The development of EV chassis prototypes involves the creation and testing of innovative chassis designs to improve the performance, efficiency, and safety of electric vehicles chassis. The maximum shear stress and deflection under maximum load constitute essential design and analytical requirements for chassis (Rajnish, 2014). These prototypes serve as the foundation for future EV models, especially Swincar.

Apart from that, in the production of automobile body sheets and chassis, most vehicles nowadays use a combination of three basic materials which are steel, aluminum alloys, and composite materials. Various grades of the materials are available for usage, each with its own set of benefits, and the best approach to choose material for chassis design is based on application and load distribution (Shiva, 2020). Lightweight materials like aluminum, high-strength steel, and carbon fiber are frequently used in EV chassis prototypes.

Reducing the chassis' total weight is crucial to enhance energy efficiency and extend the vehicle's range. Then, a strong and rigid chassis is necessary to ensure the safety of the vehicle's occupants. Chassis prototypes are engineered to withstand various forces, including torsional and bending stresses. Furthermore, the process to fabricate the chassis will be started with analysis and design from computer-aided design (CAD) and finite element analysis (FEA) to optimize structural integrity.

1.2 Problem Statement

The main challenge in designing and fabricating a new chassis is to study the actual concept and function of Swincar chassis from the others research. A comprehensive study is to identify the most suitable chassis for Swincar and implement targeted improvements by analysis of the overall strength, and safety of the structure. This process requires in-depth learning about structure analysis by using software.

The structural analysis of the prototype chassis is to ensure the factor of safety and the strength of the prototype chassis design. Besides, the selection of appropriate materials in the chassis structure fabrication process is also important to ensure that the chassis produced is safe and has high durability. Lack of in-depth finite element analysis leaves uncertainties about the chassis prototype ability to withstand diverse stresses. This study aims to conduct a comprehensive finite element analysis to validate the design and identify areas for improvement.

Furthermore, the fabrication process also needs to consider the in-depth study of Swincar design. As a result, the study can determine the improvements that need to be made for the chassis fabrication process. From the study, the types of materials and methods for chassis fabrication need to be identified. This is because the wrong choice of materials and parts can cause losses. Moreover, this process can also take a lot of time. The fabrication process can be completed within the specified time by having good planning.

1.3 Objective

The objectives of the project are:

1. To design and fabricate the concept of electric vehicles chassis specifically Swincar chassis prototype.
2. To analyze the finite element of the chassis.
3. To strengthen the structure based on the study conducted.

1.4 Scopes

The scopes of this project are:

1. Literature review
   Research and study focusing on electric vehicles chassis and prototype.

2. Design and analysis
   The chassis prototype of electric vehicles specifically Swincar will designed and continue with finite element analysis using Ansys software.

3. Fabrication
   Fabricating the prototype of chassis down scale from the actual size.

4. Testing
   The test focuses on finishing product function.

1.5 Organization of The Report

This report is separated into 5 chapters and each chapter will go into detail about the information of the project. In Chapter 1, it will cover the project introduction, objectives, problem statement, and scope of the study. Then, Chapter 2 is the literature review of the remote-control car chassis fabrication process. Chapter 3 will include the methodology used in this project such as the design of the chassis, FEA and the method that we used in fabrication process. After that, Chapter 4 will show the result and discussion from the analysis and the functional of remote-control car like Swincar concept. Lastly, Chapter 5 will conclude and provide recommendations for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Swincar

The SWINCAR concept developed from architect and inventor Pascal Rambaud's shared interests in mountain adventure, mechanical sports, and applied physics. Swincar's e-Spider is the culmination of years of development, prototyping, testing, and patent filing**.** The driver's compartment or nacelle and the wheels are articulated on a longitudinal axis, which allows the nacelle to tilt on turns or a slope (Swincar, 2017)**.** Actual EV cannot move smoothly on uneven roads, hills, and slopes. Moreover, to overcome all the problems, we plan to design and fabricate Swincar which is operated with pendulum mechanism (Mohan, 2020).

Figure 2.1 Swincar model (Sincar, 2017).

2.2 Type of Vehicles Chassis

An automotive chassis is a skeleton frame onto which different machine elements such as the engine, tires, axle assemblies, brakes, and steering are mounted. Under various situations, the chassis provides the vehicle with strength and stability (Abhishek, 2014). Typically, the chassis is built to be strong and sturdy. In the traditional design approach, the design is focused on strength, and then emphasis is placed on increasing the rigidity of the chassis, with little regard for the weight of the chassis (Vishal, 2014).

2.2.1 Ladder Chassis

Ladder chassis are one of the earliest types of vehicle chassis and are still utilized in a wide range of SUVs today. The ladder chassis, as the name implies, is shaped like a ladder, with two longitudinal rails interconnected by lateral and cross beams (Abhishek, 2014). Ladder chassis are heavy, often built of steel, and extremely sturdy. The steel mixture absorbs shocks well, providing a more forgiving ride over pebbles and ruts. If you damage a ladder chassis, it is significantly easier to repair, which is critical for long-lasting workhorses. The ladder chassis favors simplicity. It reduces the cost of designing and mass-producing them. Ladder chassis is commonly found in trucks, SUVs, and some off-road vehicles (Kimberley, 2018).

Figure 2.2 Ladder chassis (Diwan, 2014).

2.2.2 Monocoque Chassis

A monocoque chassis is a one-piece construction that uses the body as a load-bearing element. A monocoque chassis is a one-piece structure that uses the body as a load-bearing element. The chassis serves as a foundation for the suspension system, steering system, drive system, and other components. Effective chassis performance is dependent on preserving bending and torsion stiffness, providing effective load absorption, and minimizing total chassis weight (Denny, 2018). A monocoque has a low weight and a high rigidity (Danielsson, 2013). Monocoque chassis design became essential due to its properties of lightness, stiffness, and strength, making it suitable for high-performance and racing vehicles (Leon, 2020). The inherent rigidity of a monocoque structure can contribute to improved safety in the event of a crash by better distributing and absorbing impact forces. Road vehicles are unquestionably better suited to apply a monocoque due to their reduced weight, enhanced handling, and increased packing possibilities (Kimberley, 2018).

Figure 2.3 Monocoque Chassis (Kartik, 2020).

2.2.3 Spaceframe Chassis

A spaceframe chassis is a structure made up of interconnected struts and braces arranged in triangular or pyramidal designs, providing a strong yet lightweight framework. This design ensures uniform weight distribution in all directions, enhancing vehicle performance by improving rigidity and reducing weight. The spaceframe chassis functions similarly to a unibody or monocoque chassis by serving as both the body and the frame of the vehicle (Shingada, 2024). A space-frame chassis is located between the ladder chassis and the monocoque, and it is made from a series of small, basic elements that form a bigger frame (Brendan, 2011). Furthermore, in the case of space frame chassis, the chassis is widely utilised for high-end road vehicles and some race cars, where weight reduction is also an essential feature that contributes to the vehicle's improved handling (Shiva, 2020).

Figure 2.4 Spaceframe chassis (Shiva, 2020).

2.3 Materials of Chassis

Most manufacturers of vehicle chassis nowadays employ three basic materials to manufacture sheets of the automobile body and chassis. Steel, aluminum alloys, and composites are used. Various grades of the materials are available for usage, each with its own set of benefits, and the best approach to choose material for chassis design is based on application and load distribution (Shiva, 2020).

2.3.1 Steel

Steel, in different forms, has traditionally been the most common material used to manufacture vehicle chassis. Steel is inexpensive, and the technology needed to handle it is likewise inexpensive. There are several steel grades that may be utilized for sheet preparation of automobile chassis and bodywork (Shiva, 2020). Besides, In the automobile industry, most stainless-steel needs are for crashworthiness. Therefore, the steel and functional elements may be recycled and reused while also providing reliable safety. Because of its chemical composition, SS 304 can readily cover both parts, with the added benefit of reduced noise and vibration (Vishwa Stainless, 2022).

2.3.2 Aluminum Alloys

Aluminum alloys have an elastic modulus of about 70 Gpa, which is about one-third that of typical steels and steel alloys. Space frames consisting of extruded profiles are used in automobile engineering to maintain stiffness in cars made of aluminum alloys. This is a dramatic departure from the existing paradigm for steel automobile construction, which relies on the body shells for rigidity, known as unit-body design (Shiva, 2020).

2.3.3 Composite materials

The production and application of composite materials is a straightforward notion. A composite is essentially the combination of several components used to make one substance (Shiva, 2020). Carbon fibers can be used in various parts of a vehicle. Carbon fiber reinforced plastic offers superior specific stiffness, specific strength, and fatigue qualities when compared to widely used metals. In the automobile industry, the advantages of carbon fiber reinforced plastic include weight reduction, component integration and reduction, crashworthiness, durability, toughness, and aesthetic appeal (Ahmad, 2020).

2.3.4 Materials Properties

Table 2.1 Materials properties (MatWeb,2024).

Materials properties	Stainless Steel (304)	Aluminium Alloys (6016)	Carbon Fiber 290
Yield Strength (MPa)	215	210	-
Ultimate Tensile Strength (MPa)	505	280	3500
Poisson's ratio	0.29	0.33	0.468
Shear Modulus (GPa)	74	26	54.580
Young's Modulus (GPa)	190	69	70

2.4 Finite Element Analysis (FEA)

FEA is the use of calculations, models, and simulations to predict and understand how an object might behave under various physical conditions. Engineers use FEA to find vulnerabilities in their design prototypes (Brush, 2019). There are three main steps involved in finite element analysis. The process will start with pre-processing followed by solution, and post-processing. The pre-processing stage involves defining the geometric domain of the problem, selecting the type of elements to be used, followed by specifying the material properties of the elements. Then, determining the geometric properties of the elements, establishing the element connectivity through meshing the model, defining the physical constraints as boundary conditions, and specifying the applied loadings.

The next process is the solution. This process focuses on the algebraic equations that regulate in matrix form and the unknown values of the primary field variable are assembled. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses, and heat flow. In post-processing, the analysis and evaluation of the result are conducted. The examples of operations that can be accomplished include sorting element stresses in order of magnitude, check equilibrium, calculate factors of safety, plot deformed structural shape, animate dynamic model behavior, and produce color-coded temperature plots (Yagyansh, 2020).

2.4.1 Static Structural Analysis

Regarding the Roziqin finding, finite element method simulation of static load on the chassis structure was employed for the test. In general, static load is used to determine the distribution of stress that occurs in the chassis. In this study, the load that given to the chassis structure uses the field testing conditions approach, where the conditions in countryside areas do not always have good road facilities, some are still in dirt and rock road conditions, so in this test a specific approach is carried out in testing the chassis structure.

Moreover, FEA enables engineers to optimize and stress test designs prior to actual prototyping, which saves time and money. By introducing additional loads, engineers can uncover possible weaknesses or areas for improvement in a design, resulting in more efficient and cost-effective solutions (Don, 2018).

Loads	Support	Normal (N)	Extreme (normal x 3) N
Engine & Transmission	Bracket engine & transmission	1260	3780
Body & Passenger	Bracket body	4100	12300
Pickup & Cargo	Bracket pickup	7000	21000

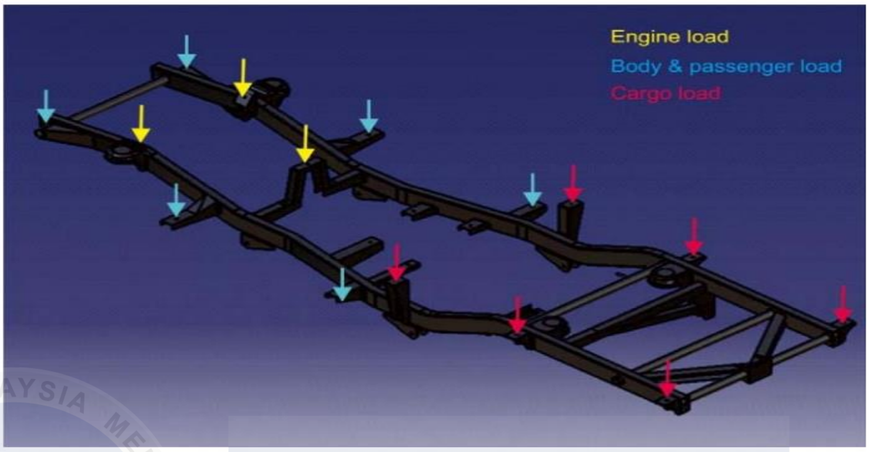


Figure 2.5 The position of load applied on the chassis (Roziqin, 2021).

2.4.2 Size of Mesh

Meshing is the process of creating finite elements and connecting those elements to produce a collection of functions. Finite elements are produced by splitting known geometry with imaginary lines, and the elements are then connected to each other by specifying nodal connection at the element borders (Jiacheng, 2022). Finite element models with coarse mesh (large element size) may lead to less accurate results but smaller computing time. Small element size will increase the finite element model's complexity which is only used when high accuracy is required (Bindu, 2015).

2.4.3 Total Deformation

Total deformation and directed deformation are the two forms of deformation in ANSYS Workbench. Both deformations are used to determine displacement due to stress. Directional deformation occurs in X, Y, and Z directions. In the case of complete deformation, it is the square root of the sum of the squares of the X, Y, and Z directions (Kaur, 2020).

$$\delta_{total} = \sqrt{(x^2 + y^2 + z^2)} \tag{2.1}$$

where the total deformation is δ_{tota} and X, Y & Z are directional deformation.

2.4.4 Von-Mises Stress, σ_v

According to von Mises stress theory, material yields when a critical distortion value is reached. Von Mises stress is the combination of all stress components such as tensile, compression, and shear at all points, whereas yield strength is the maximum amount of stress that an object can withstand before permanently deforming or fracturing. Von Mises stress may be applied in finite element analysis models by first determining the total stresses encountered at a given place. Tensile, compression, and shear stresses must all be considered when calculating how a structure will perform under load. Once these stresses are estimated, the von Mises stress may be calculated and compared to the material's yield strength to determine whether a structure would fail under the specified loading conditions. The data may then be utilized to predict model failure and make suitable design revisions (Ishchuk, 2024).

2.4.5 Maximum Shear Stress, τ

Maximum shear stress is the maximum amount of shear force in a small region. When an outside force acts in the opposite unaligned direction as internal forces, shear force arises across any structural part. These forces create shear stress on the structure materials. According to max shear stress theory, the material can take a maximum amount of shear stress focused on limited parts of the member. Shear forces and shear stress are simply two of many engineering aspects that must be considered. The maximum bending moment, tensile stress, compression force, and other factors must also be evaluated. After these evaluations, a good design for the structural member can be determined (Benjamin, 2023).

2.4.6 Factor of Safety, n

In engineering, the safety factor or factor of safety is defined as the ratio of a structure's ultimate strength to the applied load it experiences. This ratio serves as an indicator of design and manufacturing reliability. Furthermore, the following principle can be used to determine the safety factor of a structure to be developed. Firstly, n = 1.25 to 2.0 for the design of structures that withstand static loads with a high level of confidence for all design data. Then, n = 2.0 to 2.5 for the design of machine elements that withstand dynamic loads with average confidence level for all design data. Thirdly, n = 2.5 to 4.0 for designing static structures or machine elements receiving dynamic loads with uncertainty regarding load, material properties, stress analysis, or environment; Fourthly, n = 4.0 or more for designing static structures or machine elements that are subjected to dynamic loads with uncertainty regarding some load combination, material properties, stress analysis, or environment (Roziqin, 2021).

$$n = \frac{\sigma y}{\sigma v \ max} \qquad (2.2)$$

where the factor of safety is n, yield stress is σ_y, and maximum von Mises is $\sigma_{v\ max}$. If the safety factor is greater than 1, then the design is safe.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will describe the methodology used for this predictive study of the Swincar chassis structure before fabricating the chassis prototype in PSM2. The first section of this study provides an overview of actual vehicles chassis and prototype vehicles chassis specifically Swincar. Before the fabrication process of prototyping begins, the suitable types of the Swincar chassis design must been studied. The outlined actions to achieve project objectives encompass a literature review to identify relevant articles on vehicle chassis and prototype chassis. The step is followed by the creation of a 3D model using SolidWorks software.

The step is followed by finite element analysis to determine the chassis total deformation, von-mises stress, maximum shear stress, and factor of safety for the static structure of the chassis. For PSM 2, the cost of fabrication and timeline to running this project also need to be considered. The flow chart of the project is shown below. This project needs to be done based on the flow chart to ensure there are no mistakes and errors during the progress.

3.2 Flowchart

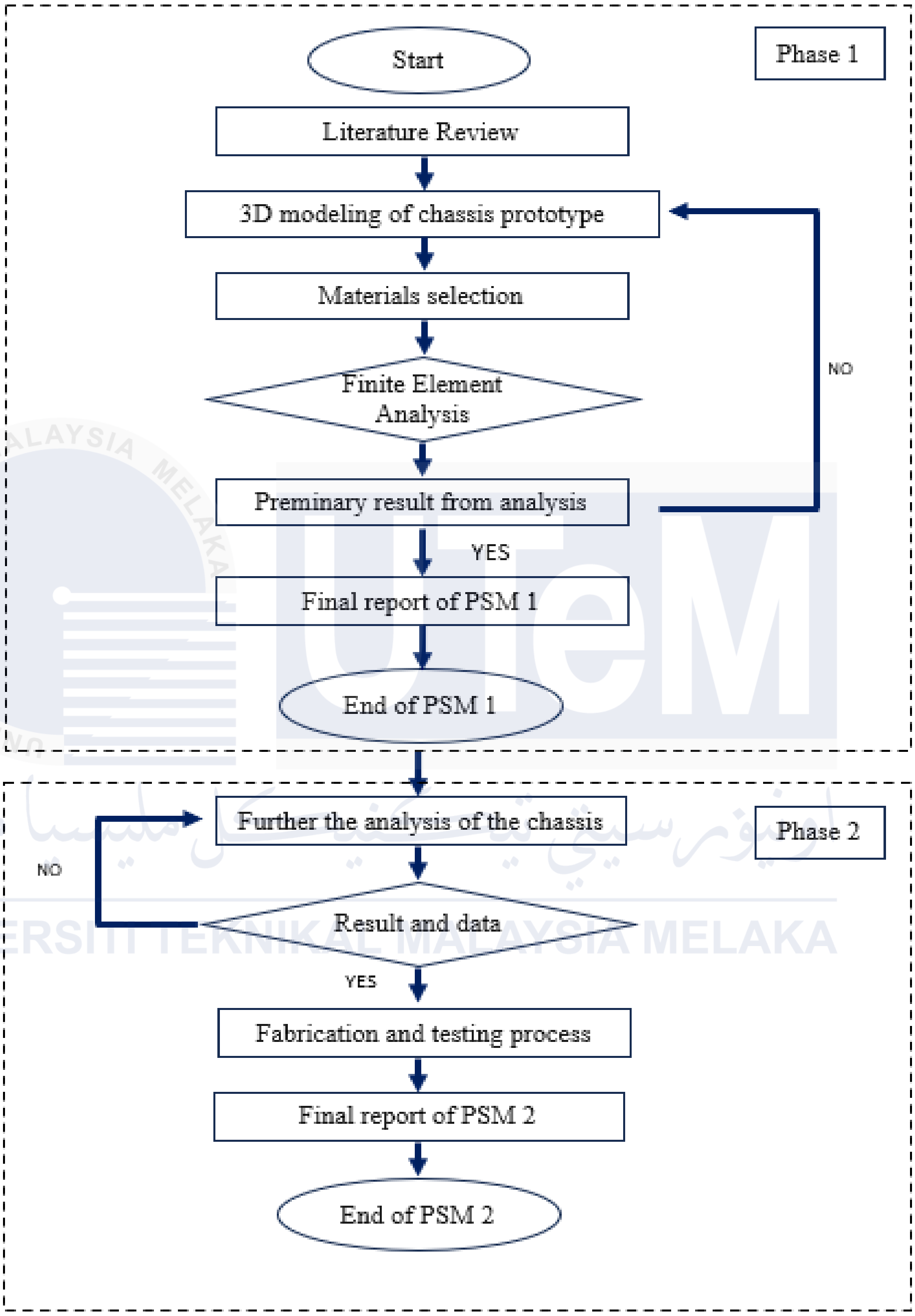


Figure 3.1 Research Flowchart.

3.3 Selected Chassis and 3D Solid modelling of The Chassis

The ladder chassis has been selected for the Swincar chassis prototype. This is because the purpose of the Swincar development is to overcome all the problems of actual electric vehicles that cannot move smoothly on uneven roads, hills, and slopes. According to my research the ladder chassis is the most suitable chassis for off road purposes. A ladder chassis is significantly easier to repair if it is damaged, which is vital for long-lasting workhorses. Moreover, based on the research, a ladder chassis is commonly found in Trucks, SUVs, and some off-road vehicles.

3.3.1 3D Modelling of Ladder Chassis

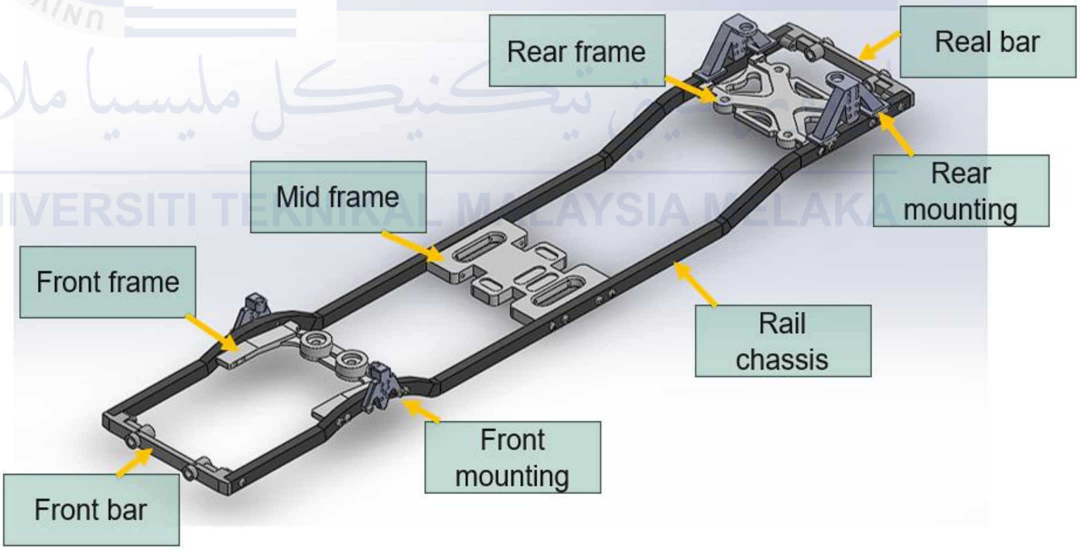


Figure 3.2 3D Modelling of ladder chassis.

3.4 Materials Selection

Nowadays, most automotive chassis are produced from three basic materials. According to the study, these materials are used to make sheets of the automotive body and chassis. Steel, aluminum alloys, and composites are among the materials available. Different grades of these materials are available, each with its own set of benefits. The best method for selecting the material for chassis design is determined by the application and load distribution.

Figure 3.3 Materials applied on finite element analysis.

3.4.1 Materials Properties

Table 3.1 Materials properties.

Chassis parts	Materials selection	Materials properties	
Chassis rail	Carbon fibre	**Yield Strength (MPa)**	**3000**
		Ultimate Tensile Strength (MPa)	**3500**
		Poisson's ratio	**0.74**
		Shear Modulus (GPa)	**15**
		Young's Modulus (GPa)	**70**
Front frame	Aluminium alloy (6016)	**Yield Strength (MPa)**	**210**
Rear frame		**Ultimate Tensile Strength (MPa)**	**280**
Middle frame		**Poisson's ratio**	**0.33**
		Shear Modulus (GPa)	**26**
		Young's Modulus (GPa)	**69**
Front bar	Stainless steel	**Yield Strength (MPa)**	**215**
Rear bar	(304)	**Ultimate Tensile Strength (MPa)**	**505**
Rear mounting		**Poisson's ratio**	**0.29**
Front mounting		**Shear Modulus (GPa)**	**74**
		Young's Modulus (GPa)	**190**

3.5 Finite Element Analysis (FEA)

Regarding to the research, after the suitable type of chassis for this project was selected and 3d modelling of the chassis have been done, the finite element analysis needs to be done to analyze the total deformation, von-mises stress, maximum shear stress, and factor of safety of the chassis. Besides, for PSM1 the load apply for the chassis is based on the component weight on the chassis. Moreover, for PSM 2 the adding additional load must the middle part of chassis to determine the maximum load that can stand by the chassis. The software used for the analysis is Ansys Workbench 2022R.

3.5.1 Size of Mesh

In Ansys, the size of the mesh refers to the resolution or density of the mesh elements used to discretize the geometry. The mesh size plays a crucial role in the accuracy and efficiency of simulations. Mesh sizing is important because it determines the level of detail and accuracy in capturing the physics of the problem being simulated. Regarding this analysis, the mesh applied on the chassis in 5mm.

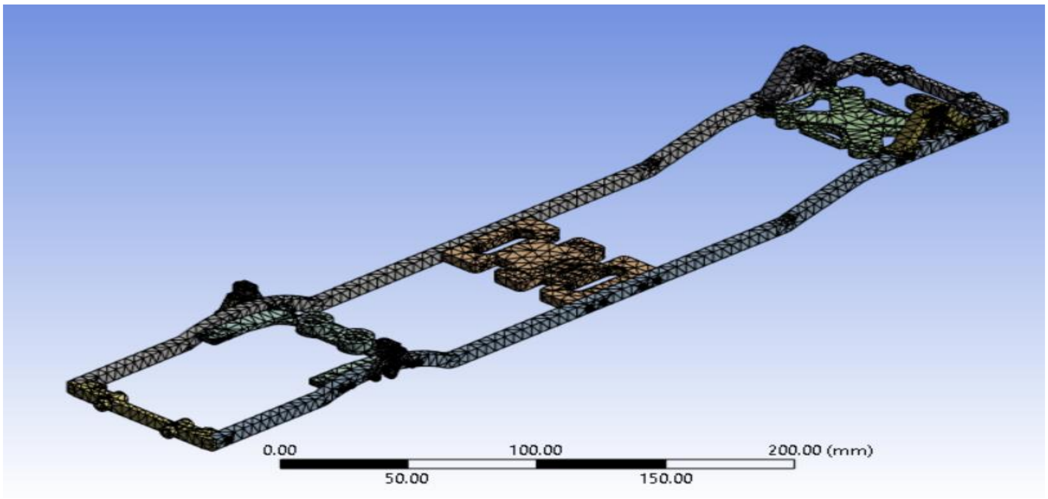


Figure 3.4 Mesh applied on the chassis.

3.5.2 Estimation Load

Based on the literature review, it was discovered that the chassis was built to support significant force from the body itself under both static and dynamic conditions. To get an accurate load for the analysis, the component load will be applied on the prototype chassis. From this test, the load applied for analysis with estimated load 4 has high accuracy result.

Table 3.2 Approximate load of main component.

Component on the chassis	**Support**	**Estimated load 1 (N)**	**Estimated load 2 (N)**	**Estimated load 3 (N)**	**Estimated load 4 (N)**
Servo motor	Front frame	0.35	1.05	3.15	9.45
Power source, LiPo(3000mAh)	Mid frame	0.57	1.71	5.13	15.39
Receiver		0.06	0.18	0.54	1.62
Electronic Speed Control (ESC)	Rear frame	0.16	0.48	1.44	4.3

3.5.3 Load Applied on Chassis

Figure 3.5 and 3.6 below shows some of the loads that have been applied to the chassis. The chassis structure is supported by fixed supports such as mounting, front bar and rear bar.

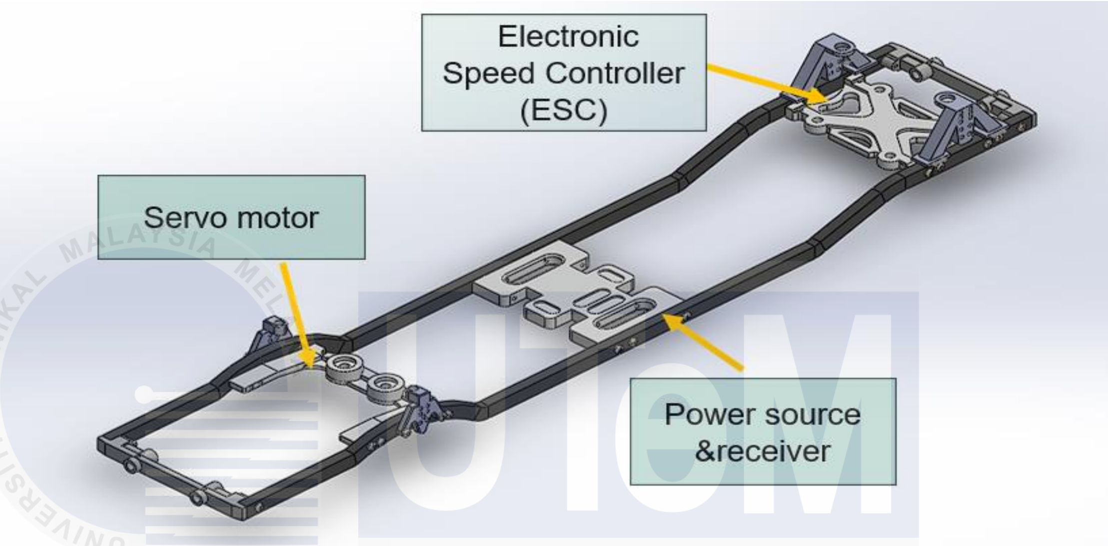


Figure 3.5 Component on the chassis.

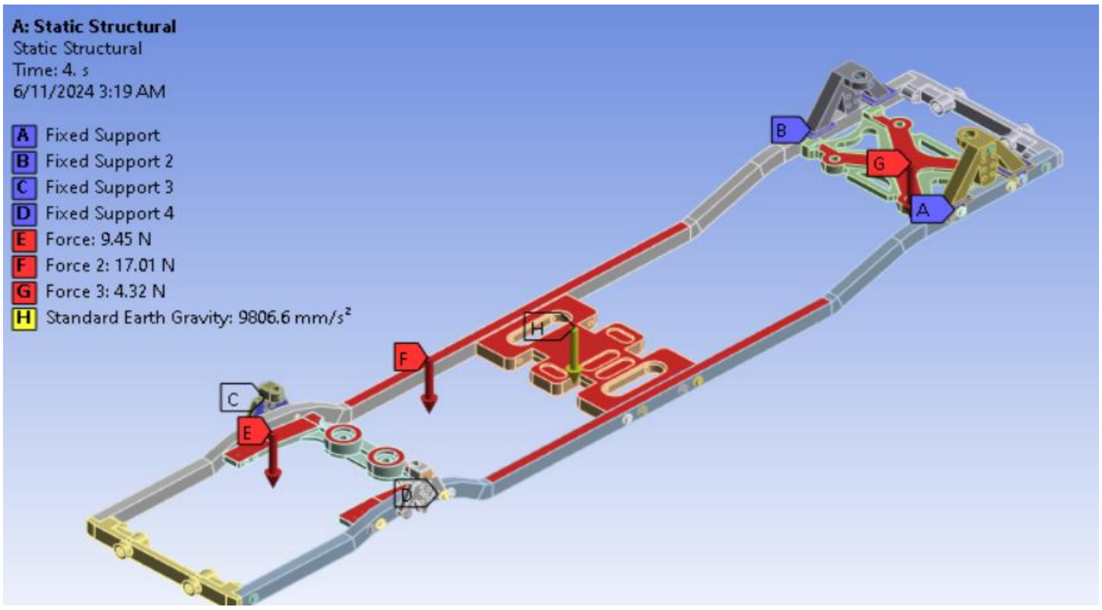


Figure 3.6 Load applied on the chassis.

3.5.4 Additional Load Applied on The Middle of The Chassis

During Final Year Project 2, the analysis continued by adding additional loads allows engineers to simulate real-life scenarios and understand how objects interact with physical forces. By considering various types of loads such as static loads, engineers can accurately predict the behavior and performance of structures or components. The additional loads assist students or engineers in identifying probable failure models and predicting the lifespan of a building or component. Furthermore, by simulating extreme or worst-case scenarios, students and engineers may analyse structural durability and plan maintenance plans to avoid catastrophic failures. Table 3.3 shows the load has been added to the chassis structure incrementally by 5 N using the Ansys software. Following that, in this analysis, the maximum load that we can apply on the chassis is around 150 N. For the maximum load we get the result for total of deformation is about 0.7280 mm, equivalent elastic strain is 0.0022923, Equivalent (von mises) stress is 165.61Mpa, Maximum shear stress is 92.202Mpa, and the factor of safety is 1.51. Regarding the research, firstly, n = 1.25 to 2.0 for the design of structures that withstand static loads with a high level of confidence for all design data. Then, n = 2.0 to 2.5 for the design of machine elements that withstand dynamic loads with average confidence level for all design data. Thirdly, n = 2.5 to 4.0 for designing static structures or machine elements receiving dynamic loads with uncertainty regarding load, material properties, stress analysis, or environment; Fourthly, n = 4.0 or more for designing static structures or machine elements that are subjected to dynamic loads with uncertainty regarding some load combination, material properties, stress analysis, or environment (Roziqin, 2021).

Table 3.3 Additional load applied on the chassis.

1	Additional load (N)	Parts load (N)	Total load (N)	Total deformation (mm	Equivalent elastic strain	Equivalent (von mises) stress (Mpa)	Maximum shear stress (Mpa)	Factor of safety
2	5	17.01	22.01	0.0983	0.000309	22.375	12.457	11.175
3	10	17.01	27.01	0.1201	0.000378	27.311	15.207	9.154
4	15	17.01	32.01	0.14181	0.00044607	32.251	17.957	7.752
5	20	17.01	37.01	0.16353	0.00051445	37.19	20.707	6.722
6	25	17.01	42.01	0.18524	0.00058282	42.129	23.456	5.934
7	30	17.01	47.01	0.20695	0.0006512	47.069	26.206	5.311
8	35	17.01	52.01	0.22866	0.00071958	52.008	28.956	4.809
9	40	17.01	57.01	0.25037	0.00078796	56.947	31.706	4.39
10	45	17.01	62.01	0.27208	0.00085634	61.886	34.456	4.04
11	50	17.01	67.01	0.29379	0.00092472	66.82	37.205	3.741
12	55	17.01	72.01	0.3155	0.00099309	71.765	39.955	3.483
13	60	17.01	77.01	0.33721	0.0010615	76.704	42.705	3.259
14	65	17.01	82.01	0.35892	0.0011298	81.643	45.455	3.062
15	70	17.01	87.01	0.38063	0.0011982	86.583	48.205	2.887
16	75	17.01	92.01	0.40234	0.0012666	91.522	50.955	2.732
17	80	17.01	97.01	0.42405	0.001335	96.461	53.704	2.591
18	85	17.01	102.01	0.44576	0.0014034	101.4	56.454	2.466
19	90	17.01	107.01	0.46747	0.0014717	106.34	59.204	2.351
20	95	17.01	112.01	0.48918	0.0015401	111.28	61.954	2.247
21	100	17.01	117.01	0.51089	0.0016085	116.22	64.704	2.151
22	105	17.01	122.01	0.5326	0.0016769	121.16	67.453	2.063
23	110	17.01	127.01	0.55431	0.0017453	126.1	70.203	1.983
24	115	17.01	132.01	0.57602	0.0018136	131.04	72.953	1.908
25	120	17.01	137.01	0.59773	0.001882	135.98	75.703	1.839
26	125	17.01	142.01	0.61944	0.0019504	140.91	78.453	1.774
27	130	17.01	147.01	0.64115	0.0020188	145.85	81.202	1.714
28	135	17.01	152.01	0.66286	0.0020871	150.79	83.952	1.658
29	140	17.01	157.01	0.68457	0.0021555	155.73	86.702	1.605
30	145	17.01	162.01	0.70628	0.0022239	160.67	89.452	1.556
31	150	17.01	167.01	0.728	0.0022923	165.61	92.202	1.51

3.6 Actual Lab Test for RC Chassis

Regarding the research, the method of the lab test that is suitable for the preprocessing stage is load test. This is because load testing is a crucial evaluation process designed to assess the structural integrity and load-bearing capacity of a component or system. In the context of an RC ladder chassis, load testing involves subjecting the chassis to various static and dynamic loads to simulate real-world conditions and determine its ability to support the weight of the vehicle and any additional payloads. By applying controlled forces and measuring the corresponding responses, such as deflection and stress distribution, we can identify potential weaknesses in the chassis design and make necessary adjustments to ensure optimal performance and durability. Load testing provides valuable insights into the chassis' ability to withstand the rigors of off-road driving, ensuring it meets safety standards and delivers a reliable platform for RC enthusiasts. However, the lab test cannot be in PSM2 because there are some constraints such as lack of test apparatus. In relation to that, to do the test, we need a lot of funds to buy test equipment such as strain gauges, connectors, copper, and so on. The cost to buy this equipment is more than the funds allocated for students to run PSM 2. As a result, after discussing with the supervisor, we only use data from analysis with finite element analysis. Table 3.4 shows the test procedure for additional load test of the RC chassis.

Table 3.4 Load test procedure.

working step	Process	Description
1	Define Load Conditions	Identify specific points on the chassis where loads will be applied. These may include suspension mounting points, chassis braces, and other structural components.
2	Select Load Points	Identify specific points on the chassis where loads will be applied. These may include suspension mounting points, chassis braces, and other structural components.
3	Instrumentation	Install load sensors or load cells at the designated load points to measure the forces applied to the chassis accurately.
4	Apply Static Loads	Gradually apply static loads to the chassis and measure the corresponding forces at each load point. This can be done using weights, hydraulic or pneumatic systems.
5	Record Data	Record the load values at each load point along with any observations regarding chassis deflection or deformation.

6	Evaluate Performance	Analyze the data collected during load testing to determine if the chassis meets design specifications and performance requirements. Look for any signs of structural weakness, excessive deflection, or failure.
7	Iterative Testing	If any issues are identified during initial testing, make necessary design modifications, and repeat the load testing process to verify improvements.

3.7 Fabrication Process for The Chassis

Before starting the fabrication process, we need to study the design to identify the improvements that can be applied to the RC chassis structure to avoid losses and wasted time. Cost planning and types of goods are very important in the fabrication process so that we can plan what goods need to be bought. Other than that, we also must determine the most suitable process for fabricating. According to the diagram below, we identify that we can trim the parts that are not so important for this Swincar prototype, and we change the design for the front and rear bars.

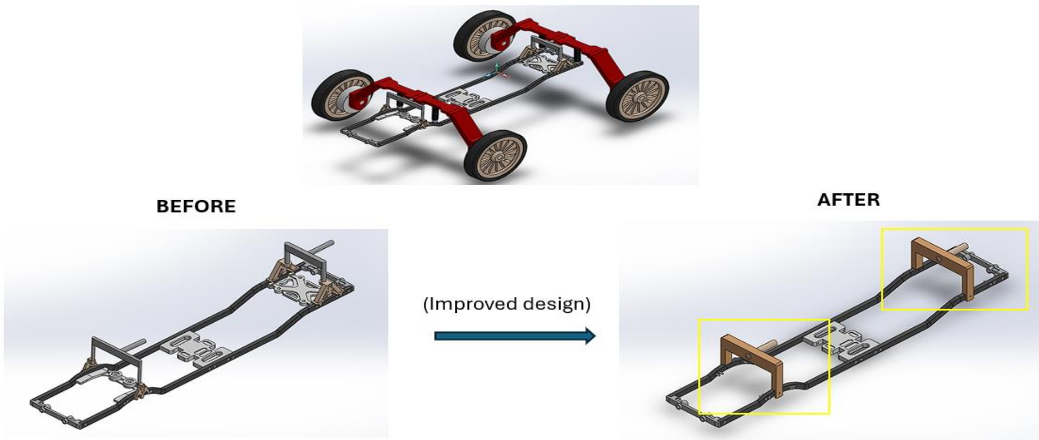


Figure 3.7 Updated drawing

3.8 Considering Cost for Fabrication Process

Table 3.5 Considering cost for fabrication process.

Parts (Before)	Cost (RM)	Parts (After)	Cost (RM)
Chassis rail carbon fibre x 2pices	25.43	Chassis rail carbon fibre x 2pices	25.43
Aluminium plate 10mm (80x50)	15.47	Aluminium plate 10mm (80x50) x 2pcs	30.93
Aluminium road	6.00	Aluminium road	6.00
Mid frame	28.77	Mid frame	28.77
Front frame	33.87	Front frame	N/A
Rear frame		Front frame	N/A
Front bar & Rear bar	34.60	Front bar & Rear bar	34.60
Mounting x 4PCS	40.83	Mounting x 4PCS	N/A
Total	184.97	**Total**	125.73

$$R=\frac{C0-C1t}{C0}\times 100\% \qquad \textbf{(3)}$$

where percentage of reduction represented as R the original cost is represented $C_{0,}$ and the new cost is represented as C_1. Given the original cost RM 184.97 and the new cost RM125.73, plug these values into the formula:

$$R=\frac{184.97184.97-125.73}{184.97}\times 100\%$$

$$R=\frac{59.24}{184.97}\times 100\%$$

$$R = 0.3202\times 100\%$$

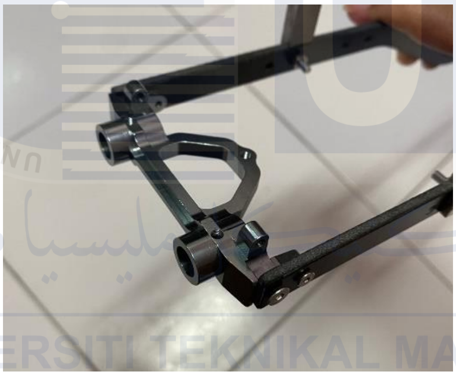
Therefore, the cost has reduced by approximately 32.02% from RM184.97 to RM125.73.

3.9 Fabrication Process

3.9.1 List of Chassis Parts

Table 3.6 List of chassis parts.

No.	Chassis parts	Description
1	 Carbon fiber chassis rail	Chassis rails provide the main structural framework for the RC vehicle. They support the weight of the vehicle, including the battery and electronics components. This ensures that all components remain securely attached and properly aligned during operation. The chassis rails offer rigidity and durability, which are essential for maintaining the structural integrity of the RC vehicle, especially during high-speed maneuvers and impacts. This is crucial for the performance and longevity of the vehicle. Despite being lightweight, carbon fiber is exceptionally strong and rigid. This provides the necessary structural support to the RC vehicle while keeping the weight to a minimum.

2	 Front bar	The primary function of the front bar is to absorb and dissipate energy during a frontal collision. This helps to reduce the impact force transmitted to the occupants and other critical components of the vehicle. Moreover, like the front bar, the rear bar is designed to absorb energy during rear-end collisions, thereby protecting the occupants and reducing damage to the vehicle's rear components. In addition to providing protection, the rear bar contributes to the vehicle's overall aesthetic and may be designed to enhance its visual appeal. The front and rear bars of a vehicle's chassis play crucial roles in safety, protection, and functionality. They are engineered to absorb impacts and protect critical components. For RC vehicles, these components also enhance durability and handling during operation.
3	 Rear bar	

4

Mid frame

The mid frame provides essential support to the entire vehicle structure. It connects the front and rear sections of the vehicle, ensuring that the chassis remains rigid and capable of withstanding various stresses and loads during operation. In RC chassis, mid frame often houses the battery pack and electronic components, ensuring they are securely mounted and protected from impacts. Moreover, A well-designed mid frame in an RC vehicle can significantly improve stability and handling, especially important for high-speed racing or off-road conditions.

5

Front conner bar

Rear conner bar

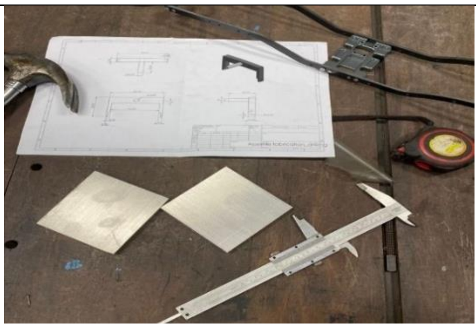
The front conner bar and rear conner bar were designed to fulfill the E-spider stability concept. The parts are made from aluminum bar and aluminum rod. For cornering, the cornering parts will be assembled with the front corner bar and rear conner bar. The main function for cornering system in Swincar e-spider concept is to plays a crucial role in maintaining stability and handling.

3.9.2 Fabrication Process Flow

Beginning the fabrication process, we just order some parts from supplies for example carbon fiber chassis rails, mid frame, front frame, and rear frame. After the parts was receive, we just assemble the parts using the screw. Our purpose in doing such things is to reduce time and cost. Furthermore, there are also parts that we fabricate ourselves, such as the front corner bar and rear corner bar. The fabrication process started with buying a 10 mm aluminum plate. Based on the drawing, we have trimmed the aluminum plate based on the drawing we planned. We use wire cut EDM machines to make the cutting process more accurate and save time.

Next, we made a 3 mm-diameter hole on the side of the front corner bar and rear corner bar to insert the screw in the connection process between the part and the chassis rail. After that, we insert an 8-mm-diameter aluminum rod into the hole that has been drilled. Finally, combine the front corner bar and rear corner bar with the chassis rail. fasten the two parts using screws and nuts so that it is stronger and neater. Table 3.6 shows the fabrication process on making front conner bar and rear conner bar.

Table 3.7 Fabrication process for front conner bar and rear conner bar.

NO.	Process	Description
1	 Planning the process.	Study the design and determine the best process to fabricate the parts.
2.	 Method for cutting the aluminum plate.	For the cutting process, the EDM Wire cutting machine has been used to cut the aluminum plate following the design. Before the cutting process begins the aluminum plate needs to be tied to a vise. Then, X and Y cutting axes need to be reset to zero.
3	 Wire cut controller	Draw the line to be cut using AutoCAD and determine the cutting direction. After that, turn on the coolant and motor than started the cutting process.

4.

Cutting process finished

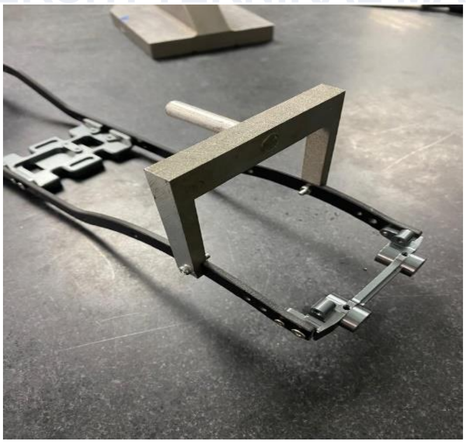
After the cutting process has been finished repeat the same step for the next aluminum plate. Finally clean the machine after finishing all the process.

5

Make a hole based on the drawing.

By using the bench drill machine, drill an 8mm hole to insert the aluminum rod and 3mm on both sides for the screw.

6



Insert insert the aluminum rod into the hole 8mm and combine the parts with the chassis.

Tap the aluminum rod into the 8-mm hole that has been drilled and fasten the two parts with the chassis rail using a 3mm screw and a nut in the 3mm hole on the side of the parts.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Result for Static Structure Analysis

FEA is utilized because it allows engineers to predict and evaluate the structural behavior of a design under various conditions before fabrication. This predictive capability helps identify potential issues, optimize the design for performance and safety, and reduce material costs and development time. By using FEA, engineers can ensure that the final product meets all specifications and regulatory requirements, ultimately leading to more reliable and efficient structures while minimizing the risk of failure and costly post-production modifications.

4.1.1 Total Deformation

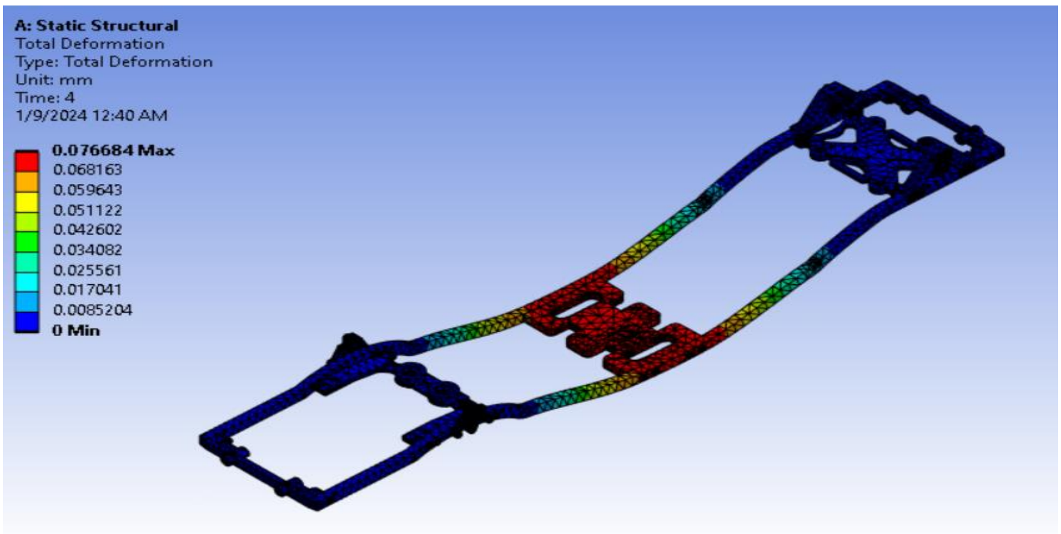


Figure 4.1 Total Deformation.

Figure 4.1 shows the total deformation of the chassis during the static structural analysis by using the ANSYS software. The maximum deflection of the chassis when a force of 17.01 N in y direction was 0.077 mm. This result indicates that the chassis exhibits a high degree of rigidity under the applied load, ensuring minimal deformation and maintaining structural integrity.

4.1.2 Equivalent Von Mises Stress

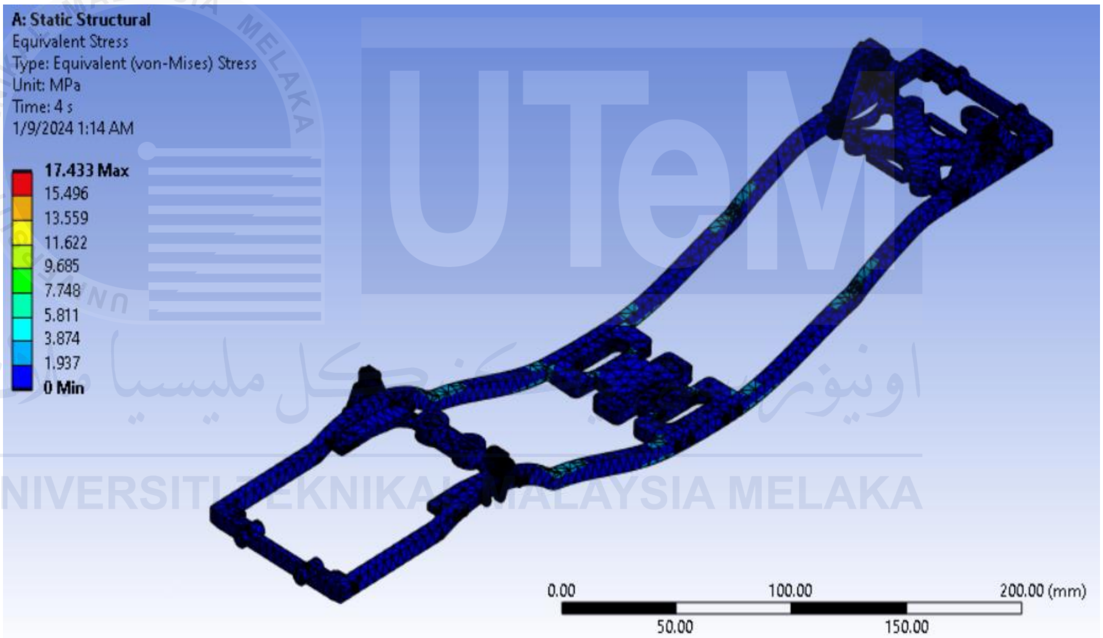


Figure 4.2 Equivalent Von Mises Stress.

Equivalent Von Mises stress is a way to measure the combined effect of different types of stress on a material. Instead of looking at each type of stress individually. The Von Mises stress considers the overall stress on the material. Von Mises stress is widely used in engineering simulations and analyses to evaluate the safety and strength of structures. According to this analysis, the result is not achieving the maximum value of Equivalent Von-Mises Stress.

4.1.3 Equivalent Elastic Strain

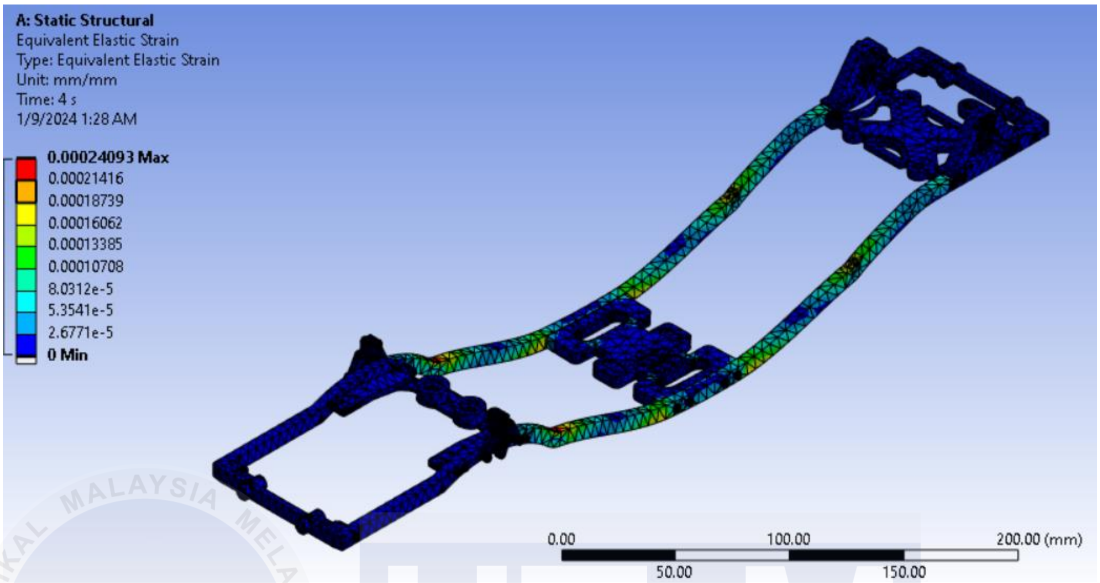


Figure 4.3 Equivalent Elastic Strain.

Equivalent elastic strain refers to the amount of deformation or stretching that a material undergoes when subjected to stress, while still being able to return to its original shape once the stress is removed. When a material is subjected to external forces or loads, it experiences stress, which is the internal resistance to deformation. This stress causes the material to deform or strain. Elastic strain specifically refers to the reversible deformation that occurs within the elastic limit of the material. The maximum equivalent elastic test for this analysis resulted in 0.00024093.

4.1.4 Maximum Shear Stress

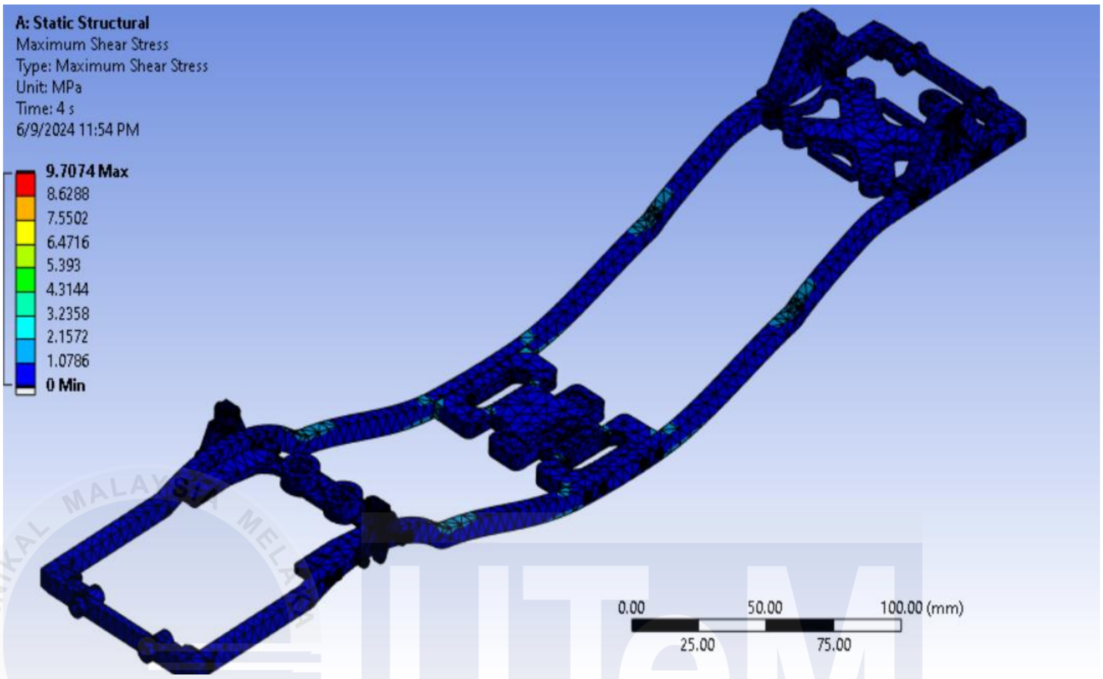


Figure 4.4 Maximum shear stress.

The result for maximum shear stress in this analysis is 9.7074 Mpa. Shear stress is defined as the internal force per unit area that acts parallel to the plane of interest within a material. It is a measure of how much a material can withstand sliding forces before failure occurs. Maximum shear stress, specifically, refers to the highest value of shear stress experienced at a particular point within the material, which often dictates the design limits and safety considerations in engineering applications. This parameter is critical in determining the structural integrity and durability of materials under various loading conditions.

4.1.5 Factor of Safety

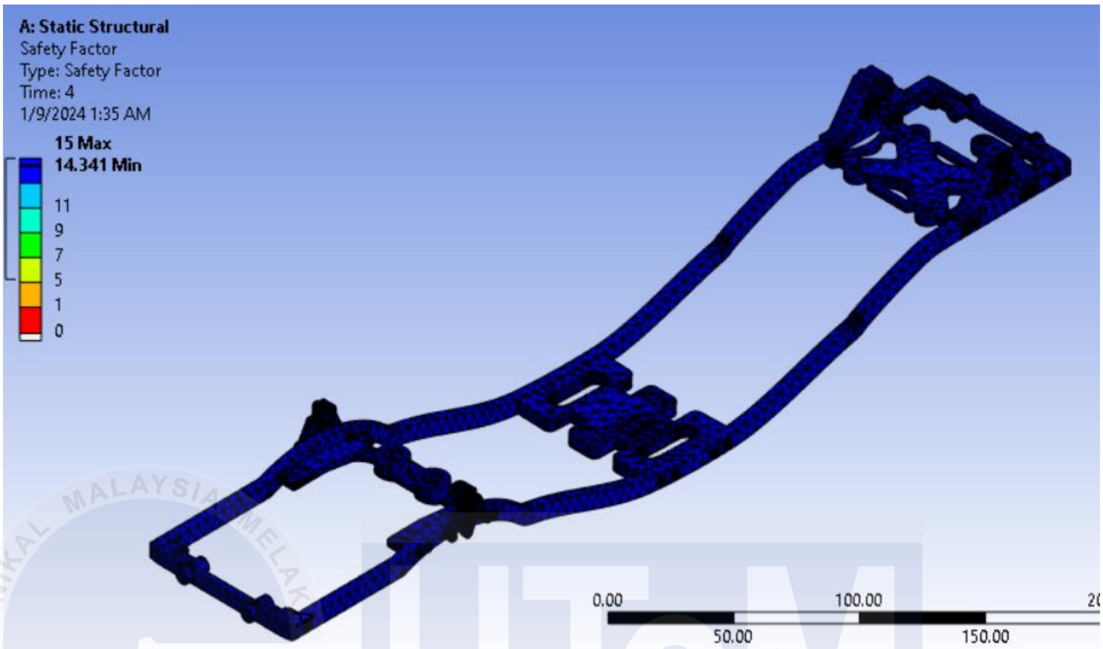


Figure 4.5 Factor of safety.

The result of safety factor shows that the design and analysis is pass. The factor of safety is typically defined as the ratio of the ultimate strength or load-carrying capacity of a structure or component to the working or design load. It represents the level of redundancy or margin of safety built into the design. A higher factor of safety indicates a greater level of safety and reliability.

4.2 Result for Additional Load Analysis

Adding additional loads in FEA is crucial to ensure the structure can withstand unexpected or extreme conditions that may occur in real-world scenarios. By simulating these extra loads, engineers can assess the structure's safety margin, identify potential weaknesses, and make necessary design adjustments to enhance durability and reliability. This comprehensive approach helps prevent failures, ensures compliance with safety standards, and provides confidence that the structure will perform effectively under all expected and unforeseen loads.

4.2.1 Total Deformation After Adding Additional Load

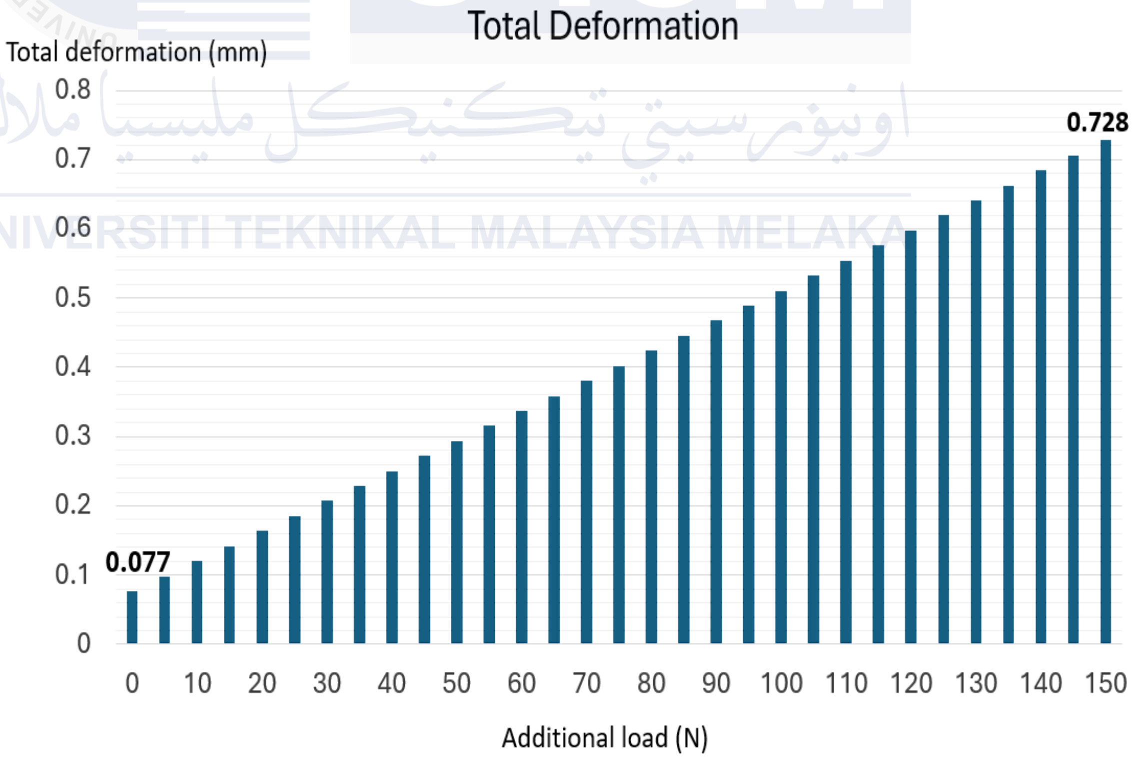


Figure 4.6 Graph of total deformation after additional load.

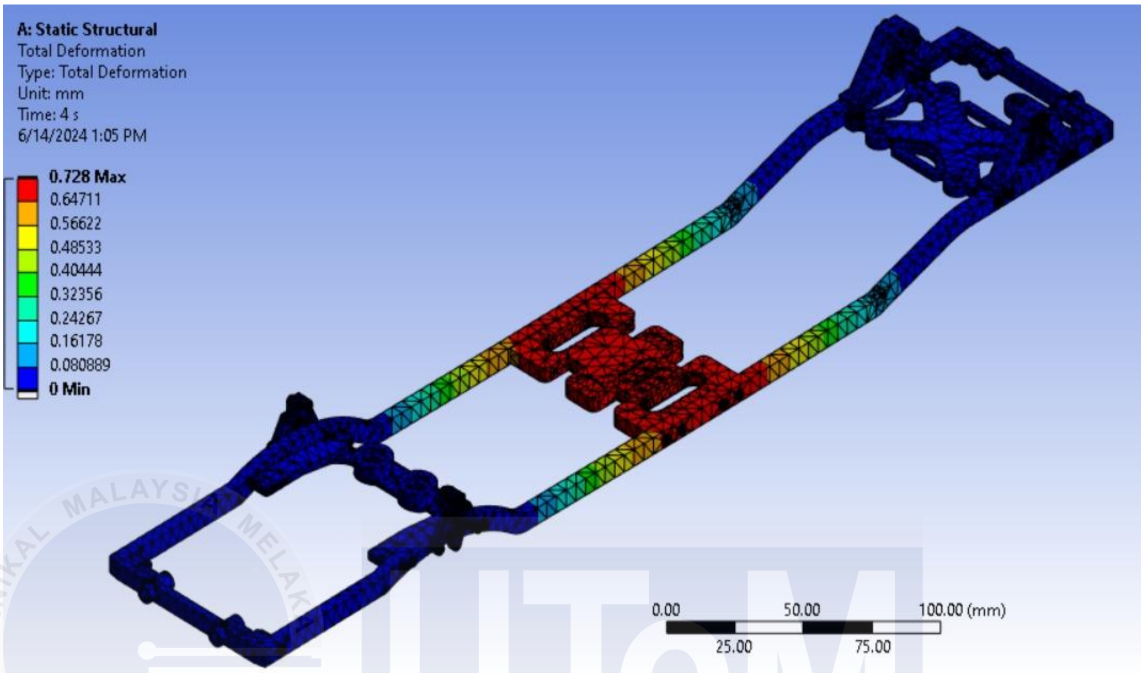


Figure 4.7 Total deformation after adding maximum load.

Based on the maximum load applied to the middle part of the structure during the analysis, we found that the maximum total deformation for the chassis is 0.728mm. This result indicates that the chassis maintains a high level of structural integrity under load, ensuring minimal flex and deformation, which is critical for maintaining handling and stability. Additionally, the small deformation value suggests that the chassis can effectively distribute and withstand operational stresses, enhancing the overall durability and performance of the vehicle.

4.2.2 Equivalent Elastic Strain After Adding Additional Load

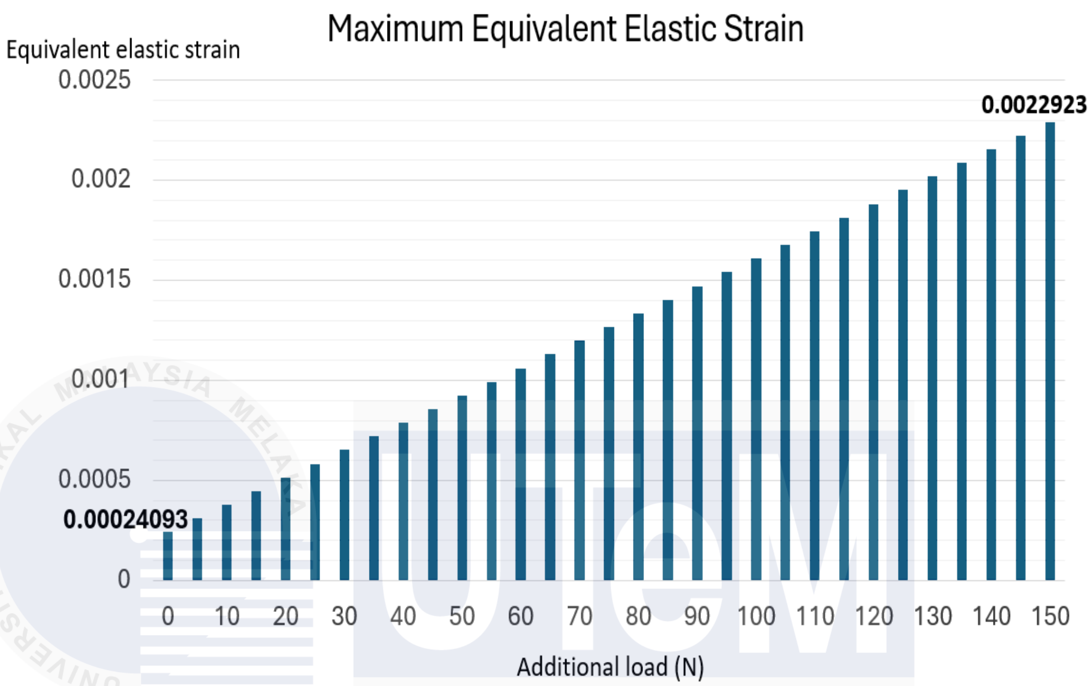


Figure 4.8 Graph of equivalent elastic strain after additional load.

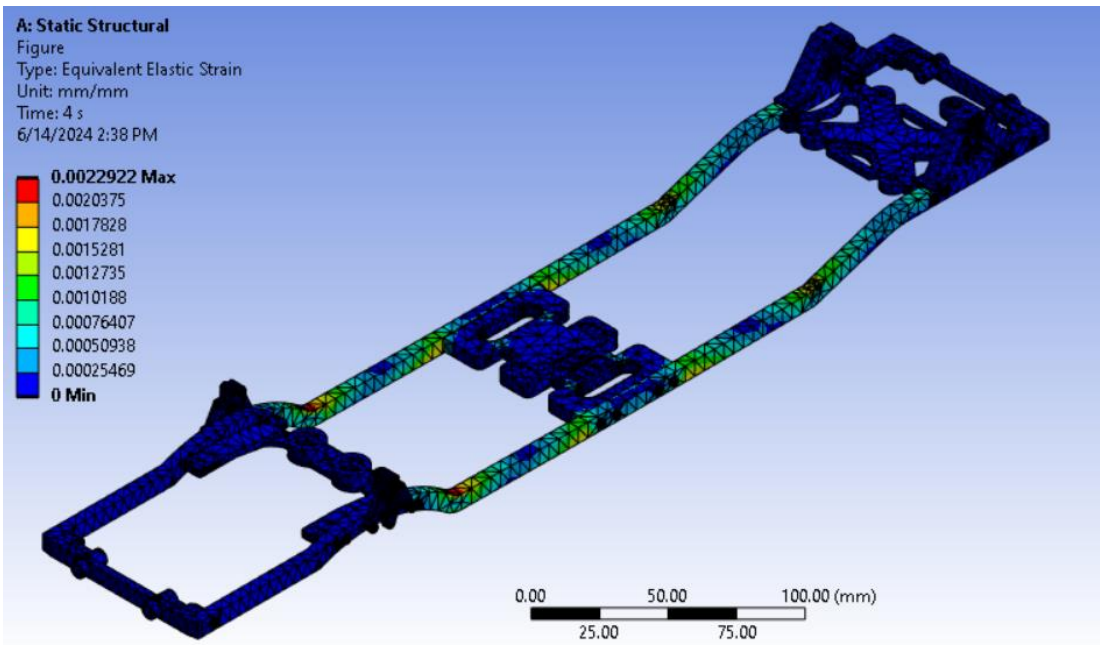


Figure 4.9 Equivalent elastic strain after adding maximum load.

Based on the analysis, the maximum equivalent elastic strain that resulted after applying the maximum load is 0.0022923. This indicates that the material remains well within its elastic limit, ensuring that the chassis will return to its original shape once the load is removed. The low strain value further confirms the robustness of the chassis design, indicating its ability to handle operational stresses without permanent deformation or failure.

4.2.3 Equivalent Von Mises Stress After Adding Additional Load

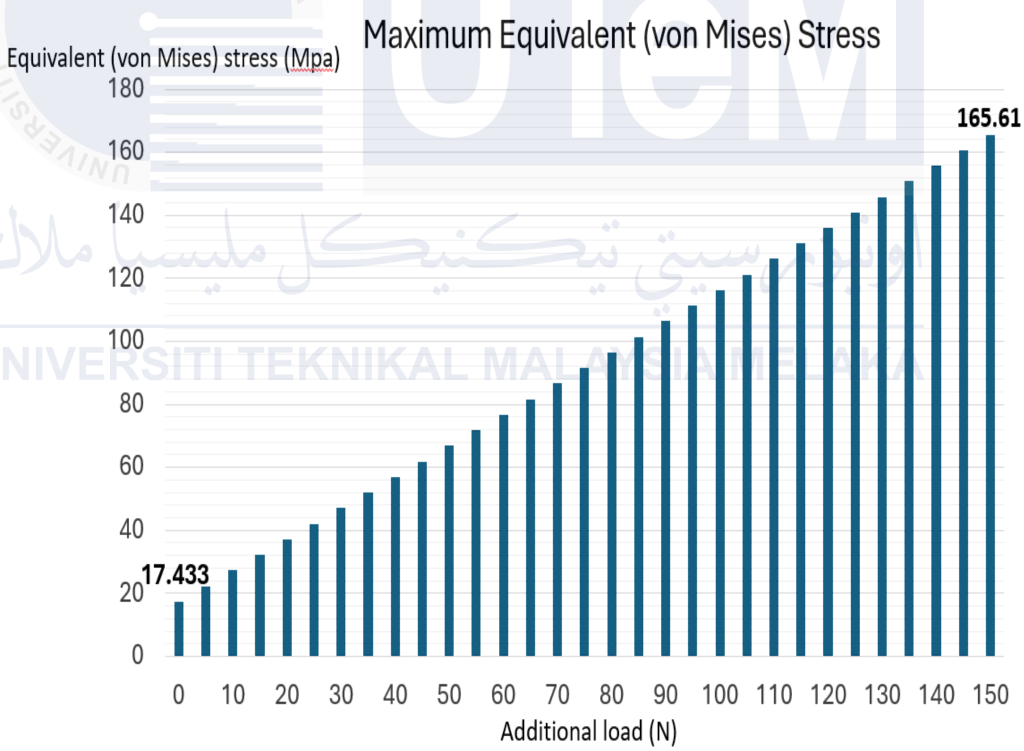


Figure 4.10 Graph of equivalent von mises stress after additional load

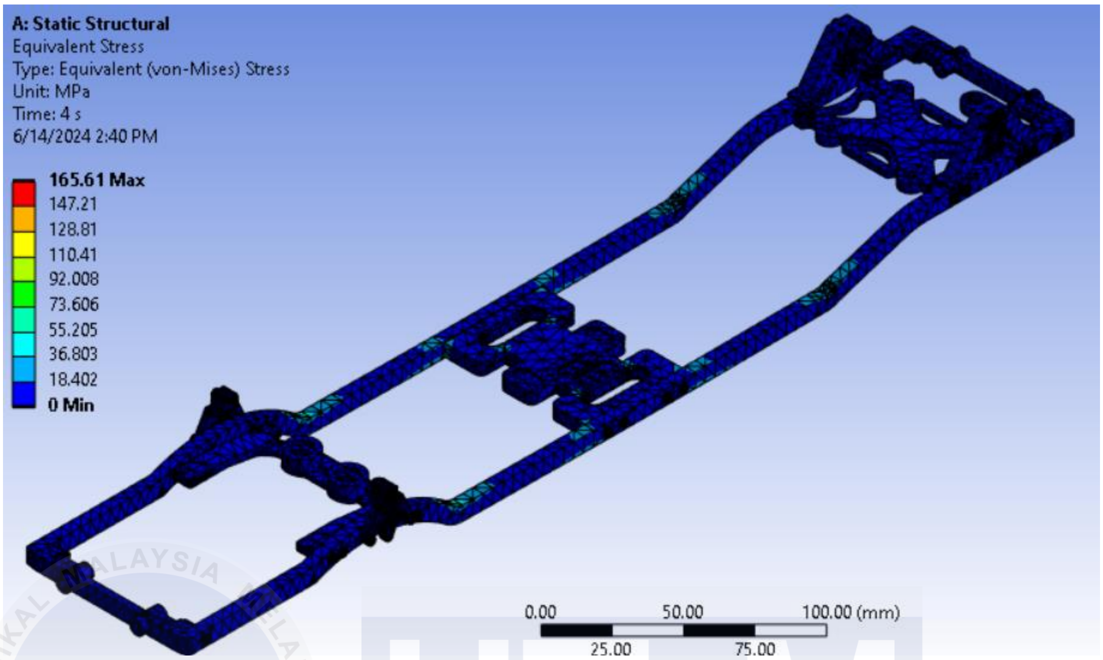


Figure 4.11 Equivalent von Mises stress after adding maximum load.

Based on the analysis, after applying the maximum load to the middle of the chassis, the maximum von Mises stress result is 165.61 MPa. This stress value indicates that the chassis can withstand substantial operational loads without yielding, demonstrating the strength and reliability of the material used in the chassis construction. Von Mises stress is used to assess the overall strength and safety of the structure. If the von Mises stress exceeds the material's yield strength, plastic deformation is expected to occur. Additionally, this analysis underscores the chassis' capability to perform under high-stress conditions while maintaining structural integrity.

4.2.4 Maximum Shear Stress After Adding Additional Load

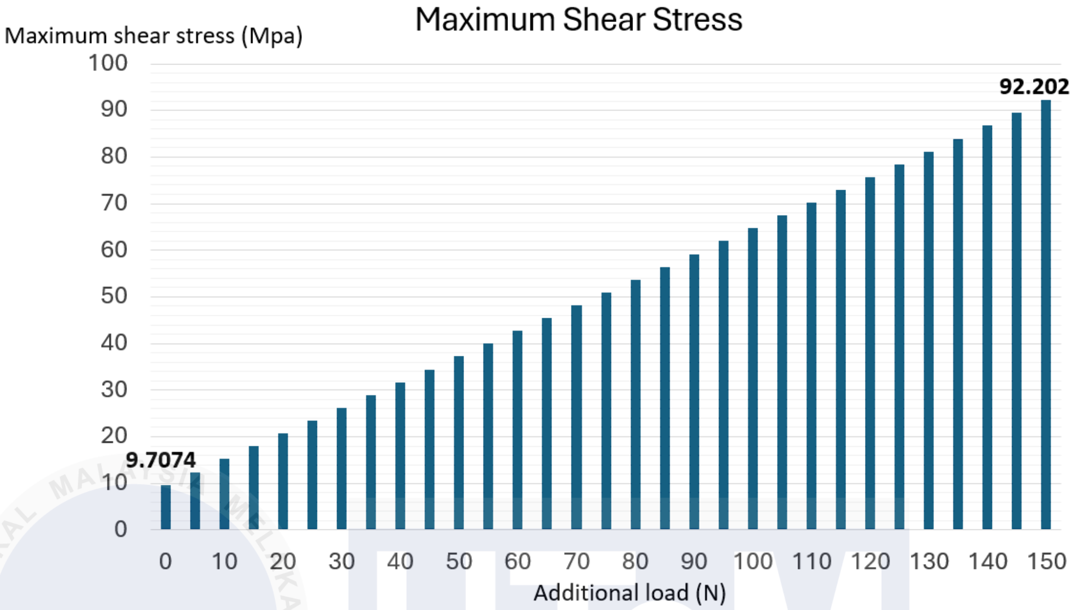


Figure 4.12 Graph of maximum shear stress after additional load.

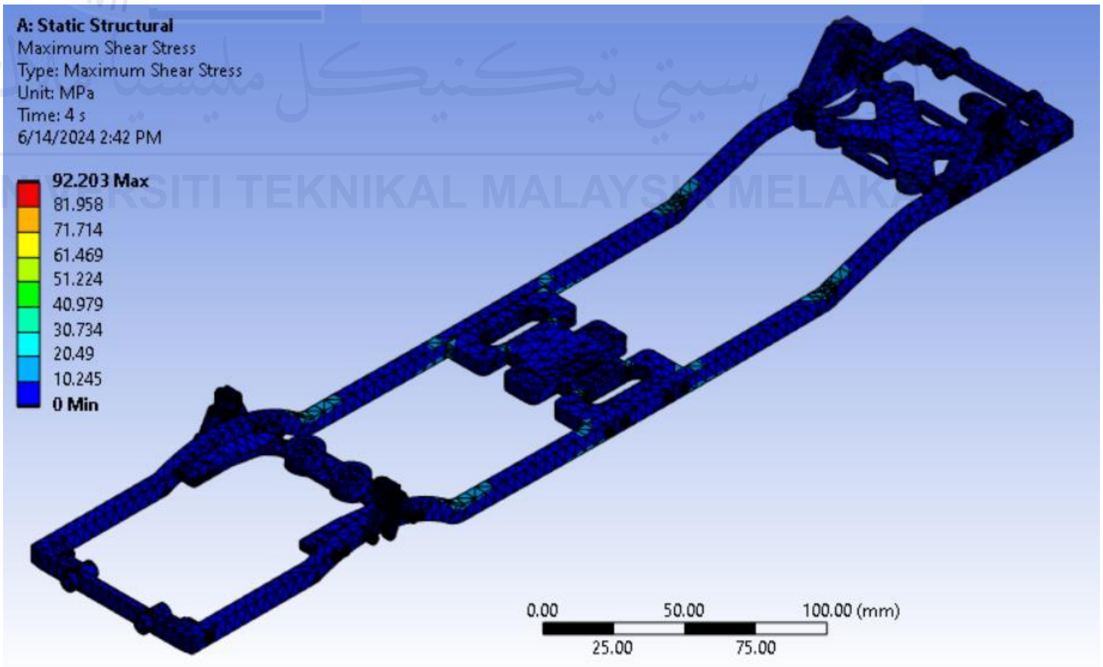


Figure 4.13 Maximum shear stress after adding maximum load.

The maximum shear stress generated in this analysis is 92.202 MPa. This indicates that the chassis can endure significant shear forces without experiencing structural failure. Such a capacity ensures the reliability and safety of the vehicle under operational stresses.

4.2.5 Factor of Safety After Adding Additional Load

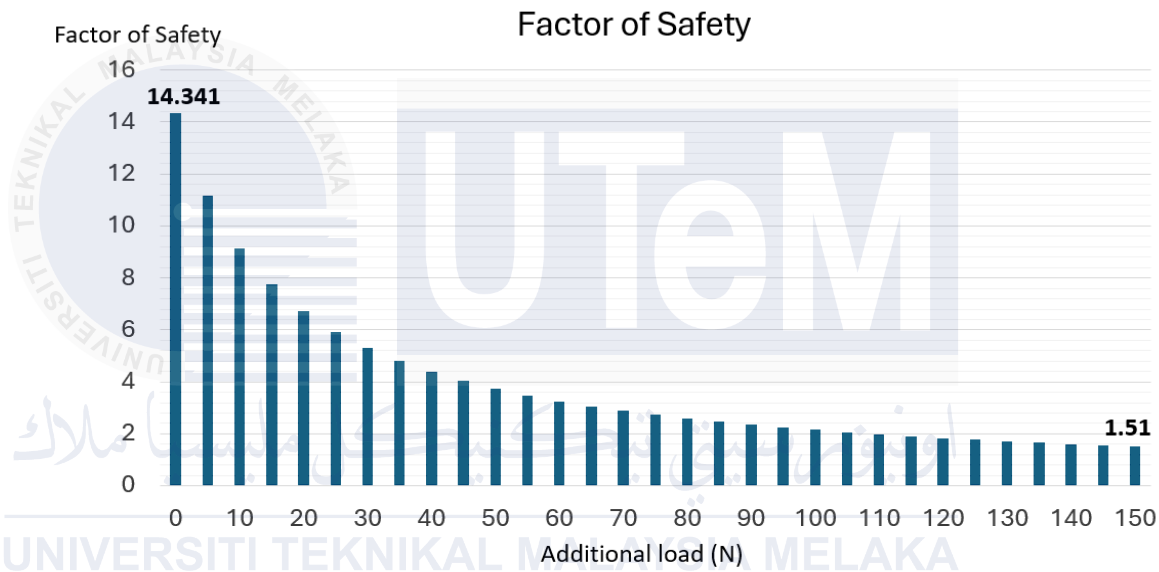


Figure 4.14 Graph of factor of safety after additional load.

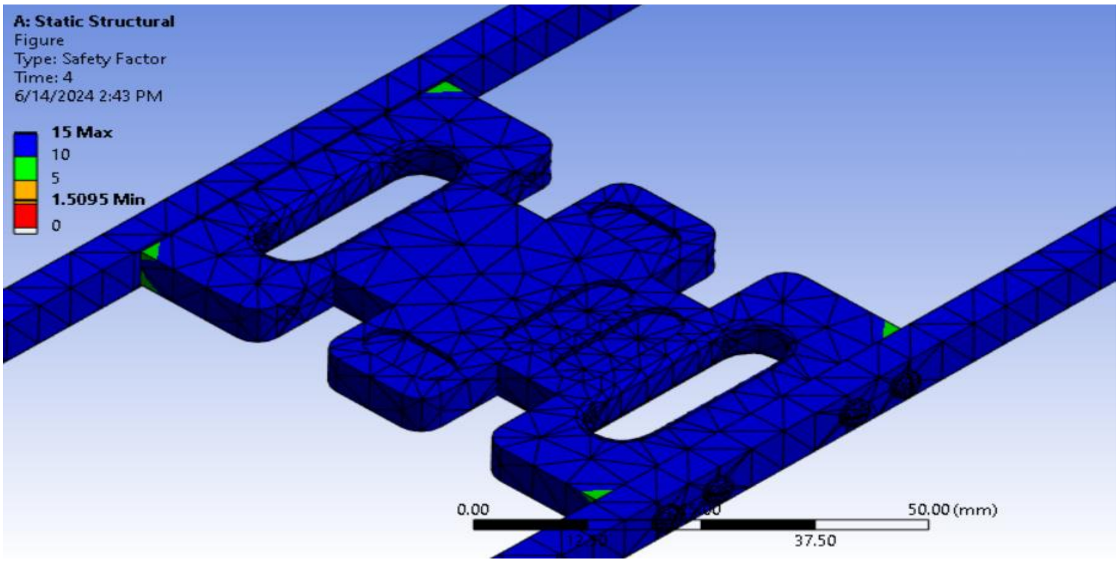


Figure 4.15 Factor of safety after adding maximum load.

According to the analysis the maximum load applied generates the minimum factor of safety to become 1.5096. Regarding the research, the factor of safety from 1.25 to 2.0 is the range for the design of structures that withstand static loads with a high level of confidence for all design data. Ensuring a safety factor above 1 signifies that the design has a reasonable margin of safety for operational conditions, enhancing the overall reliability and durability of the vehicle.

4.3 Result for Fabrication Process

From the fabrication process stated in the methodology, a ladder chassis was created from carbon fiber and aluminum alloy. This chassis structure will then be combined with other student parts to form a prototype of the Swincar E-spider concept. Figure below shows the prototype of the chassis that has been fabricated.

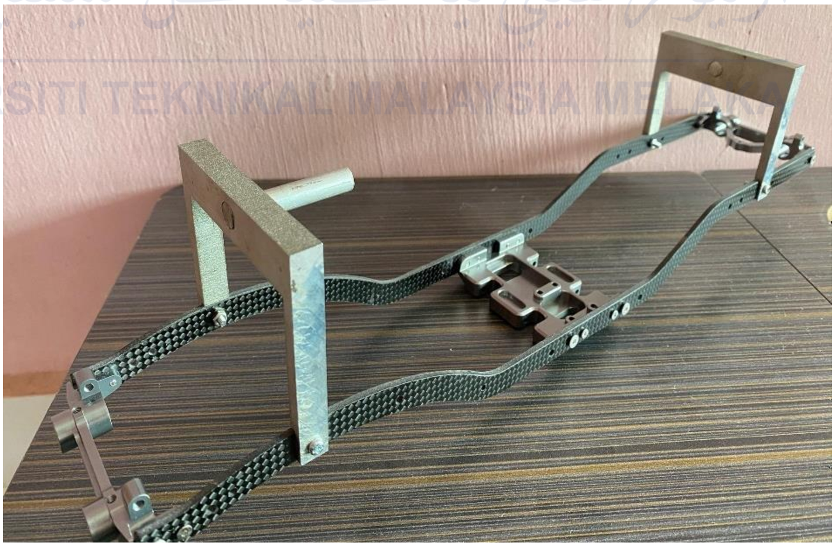


Figure 4.16 Prototype of the chassis.

4.4 Result for Assembly Process

Figure 4.17 shows the results for the assembly process. The chassis of the remote-controlled car that has been fabricated has been combined with other automotive parts and it also attached to electronic components and motors to move this prototype. Furthermore, figure 4.18 shows that the prototype is controlled by a remote-control application in a smart phone.

Figure 4.17 Result for assembly process.

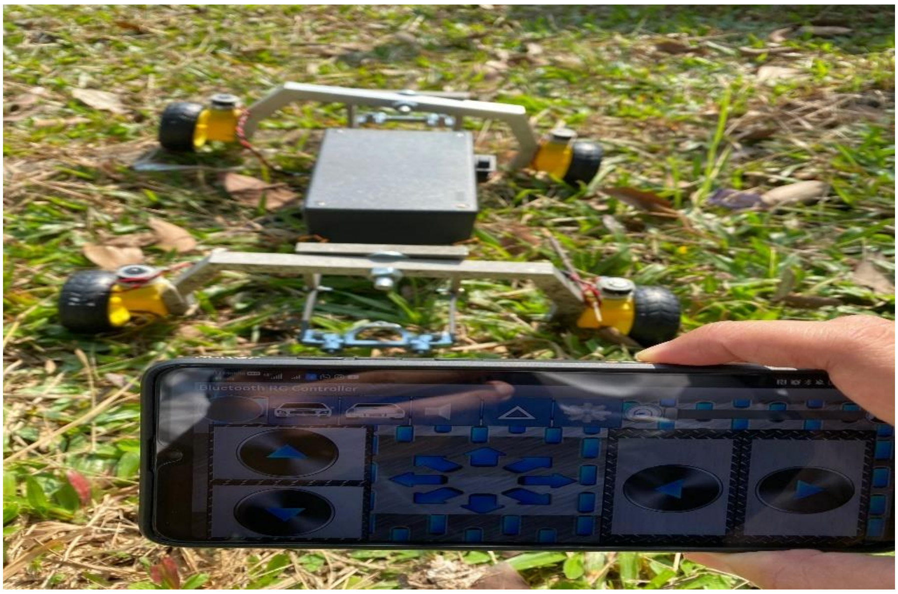


Figure 4.18 Remote control car functional testing.

4.4.1 The Result for The Prototype Achieves Pendulum Concept Like Swincar

According to the results of the study on Swincar, electric vehicles move using four electric motors. Indirectly, this makes the electric vehicle an all-wheel-drive vehicle. Swincar also uses a concept pendulum to ensure the driver is on the x-axis when the vehicle passes through hilly and uneven terrain. From this fabrication process we can see the objective to create a remote-control vehicle with the Swincar concept has been achieved as the prototype that was created can apply the same concept as the Swincar. The position of the chassis on the x axis proves that this prototype conforms to the real Swincar concept. This prototype also uses 4 dc motors to allow it to move. This is also the same as the Swincar concept that uses 4 motors to provide more power to navigate hilly and uneven roads. Figure 4.19 shows the prototype have achieves the pendulum concept like Swincar.

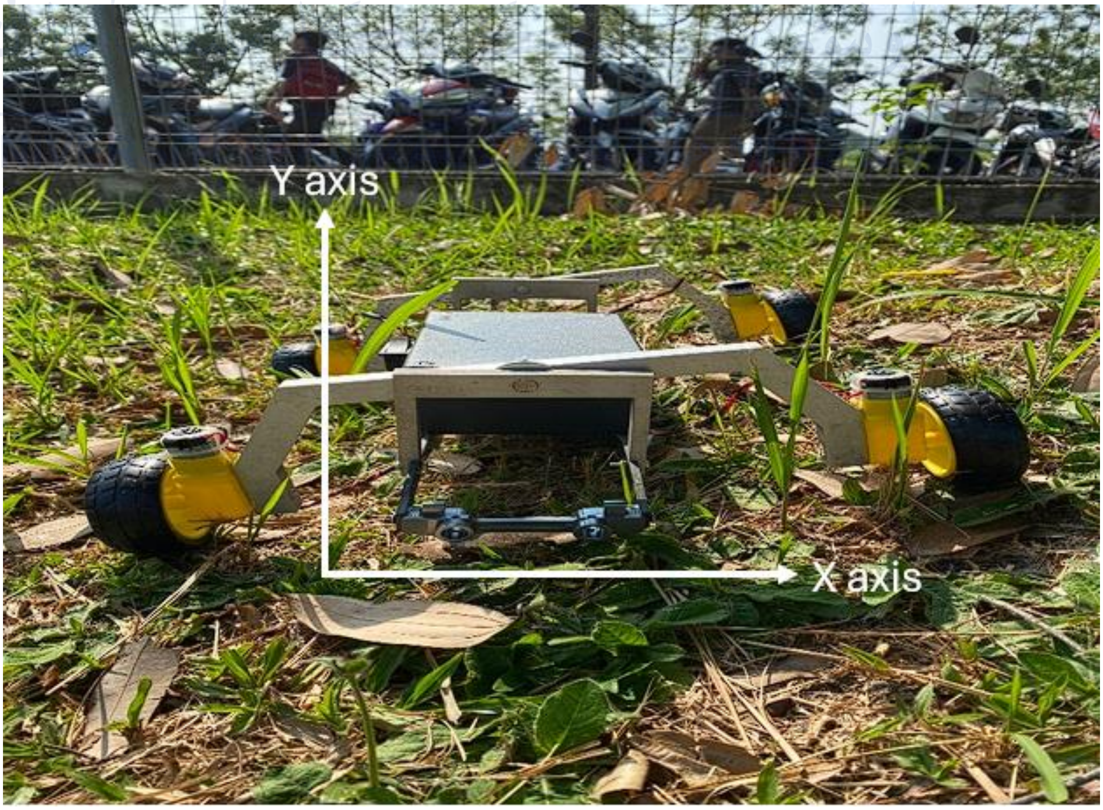


Figure 4.19 The prototype achieves the pendulum concept like Swincar.

CHAPTER 5

CONCLUSION AND RECOMENDATIONS

5.1 Conclusions

In conclusion, the entire task that has been carried out in PSM 1 and 2 achieved every objective. The results of the study found that the ladder chassis is the most suitable type of chassis to be used for this Swincar fabrication project. From the results of the study, the selection of materials to build the chassis structure is correct after doing the FEA analysis. The right choice of materials can produce a chassis that is lightweight and has high durability. Moreover, in PSM 2, 30 loads in multiples of 5 have been applied to the middle part of the structure. This method is to determine the maximum load that can be applied to the chassis. The results of this analysis clearly show that this structure design has a good factor of safety. Furthermore, after finishing the fabrication process on the chassis part, this process continues with the assembly process from other student parts such as cornering part and electrical system. The state of the structure when this Swincar moves the child can be seen to determine whether it can meet the objectives of the study or not.

5.2 Recommendations for Future Study

The recommendation for this project is to make improvements to the cornering part. Apart from that, we can also continue the study related to the mechanism related to the making of this Swincar. Additionally, for the Swincar e-spider prototype development focusing on optimizing the suspension system and enhancing the battery efficiency would significantly improve performance and user experience. A more refined suspension system can offer better stability and comfort during off-road conditions, which is crucial for the Swincar's intended use. Investigating advanced materials and design modifications to reduce weight without compromising strength could further enhance maneuverability and efficiency. Moreover, further the analysis can be continued using the actual chassis measurement scale and the actual driver weight. Lastly, integrating smart technology such as adaptive control systems and real-time monitoring could elevate the functionality of the Swincar e-spider. This could include features like automatic terrain adaptation, enhanced safety systems, and improved user interface for easier operation.

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APPENDIX A

ANSYS FRONT PAGE REPORT

Project*

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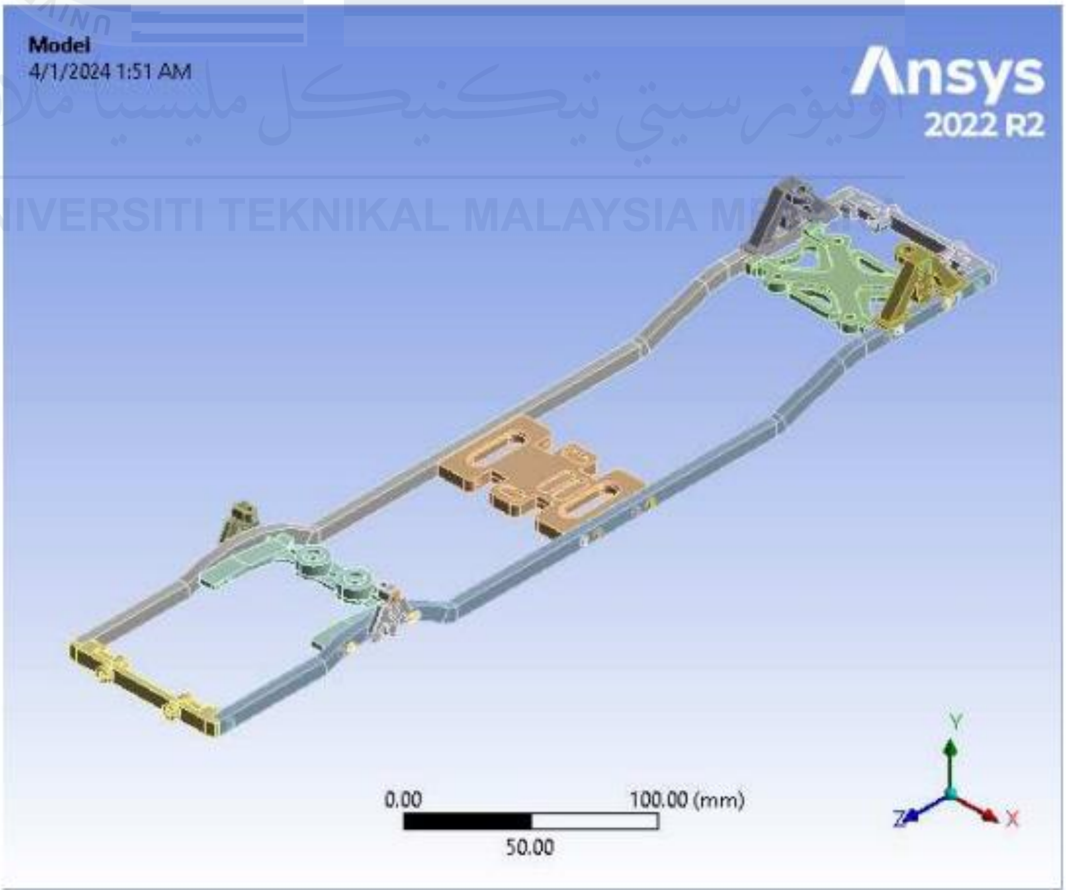
Last Saved	Sunday, March 31, 2024
Product Version	2022 R2
Save Project Before Solution	No
Save Project After Solution	No



APPENDIX B

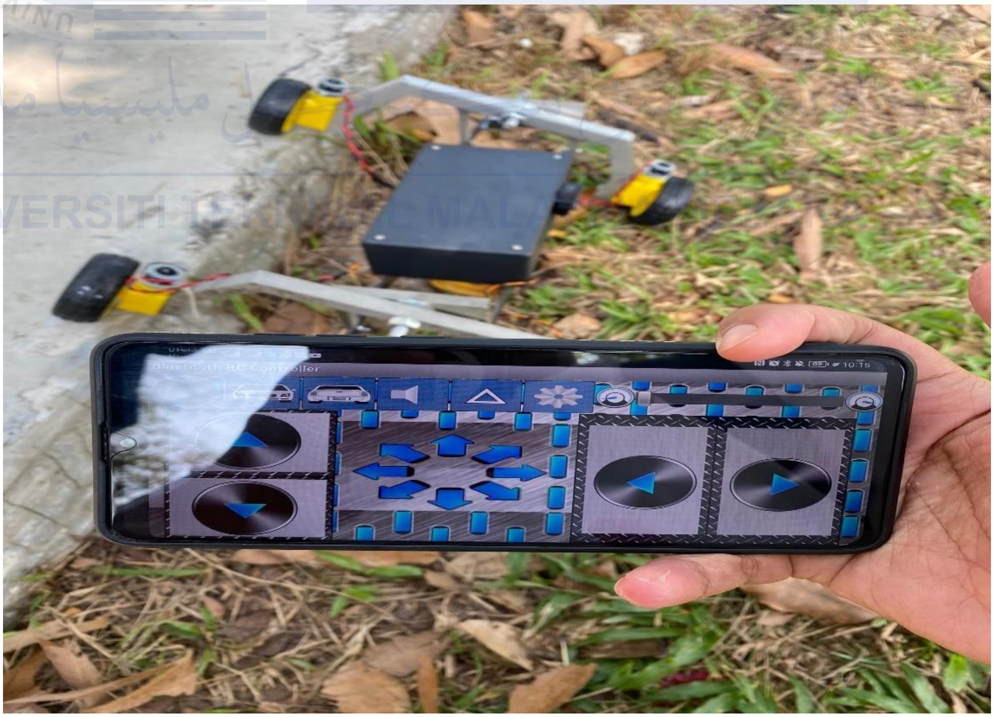
SWINCAR E-SPIDER

APPENDIX C

MARKING AND WIRE CUTTING PROCESS

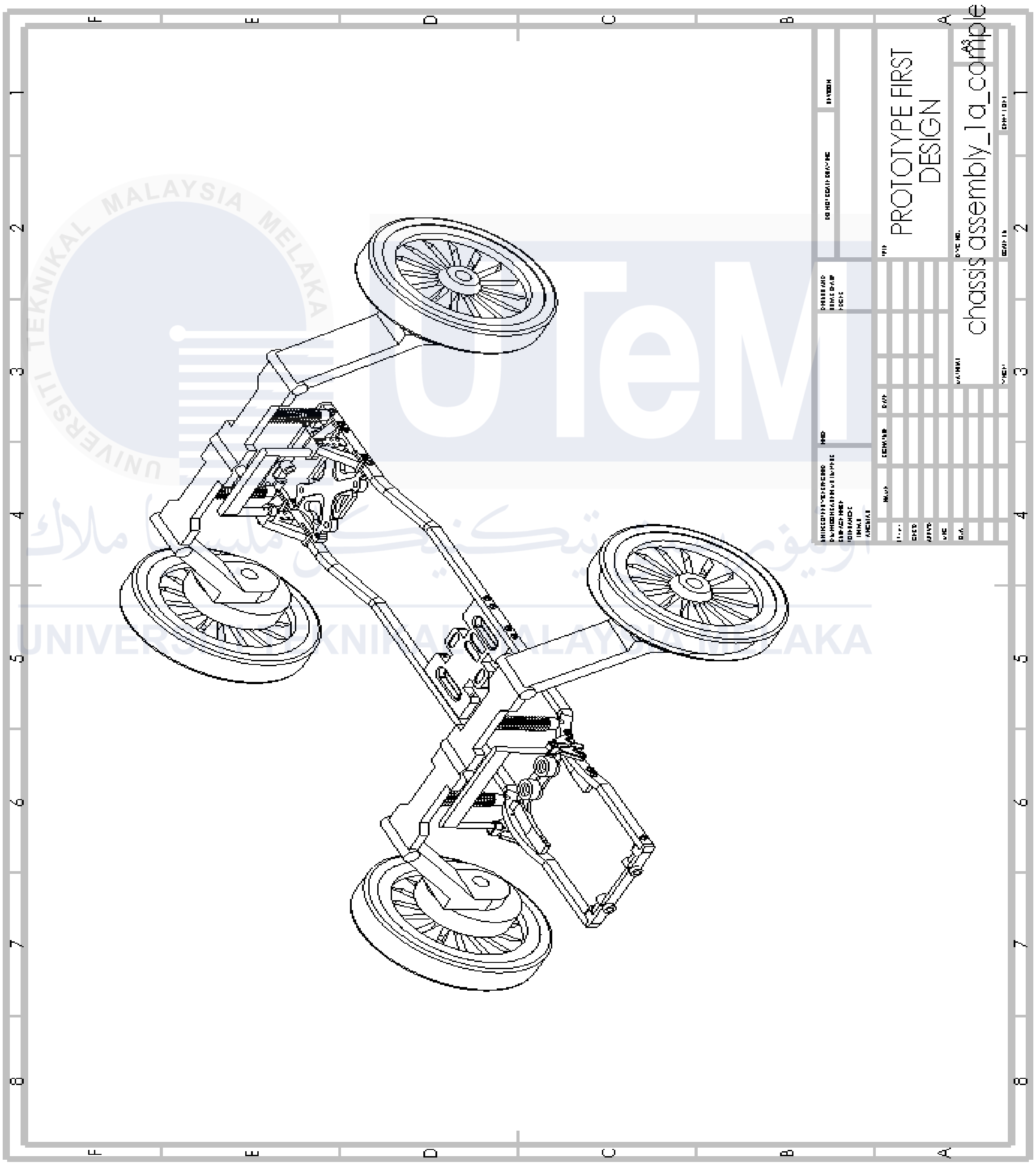
APPENDIX D

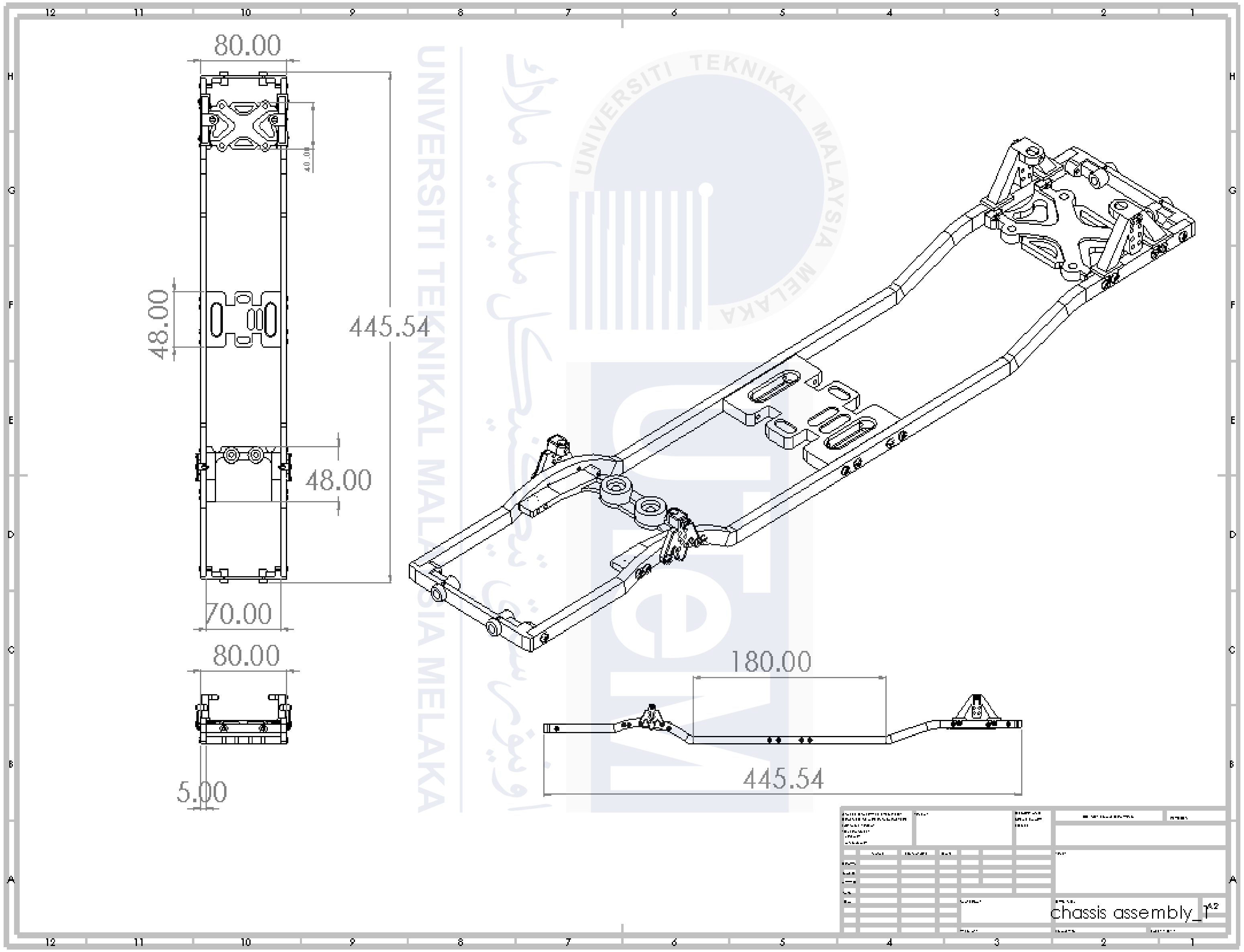
REMOTE CONTROL CAR LIKE SWINCAR FINISH PRODUCT



APPENDIX E

DRAWING AND MESUREMENT

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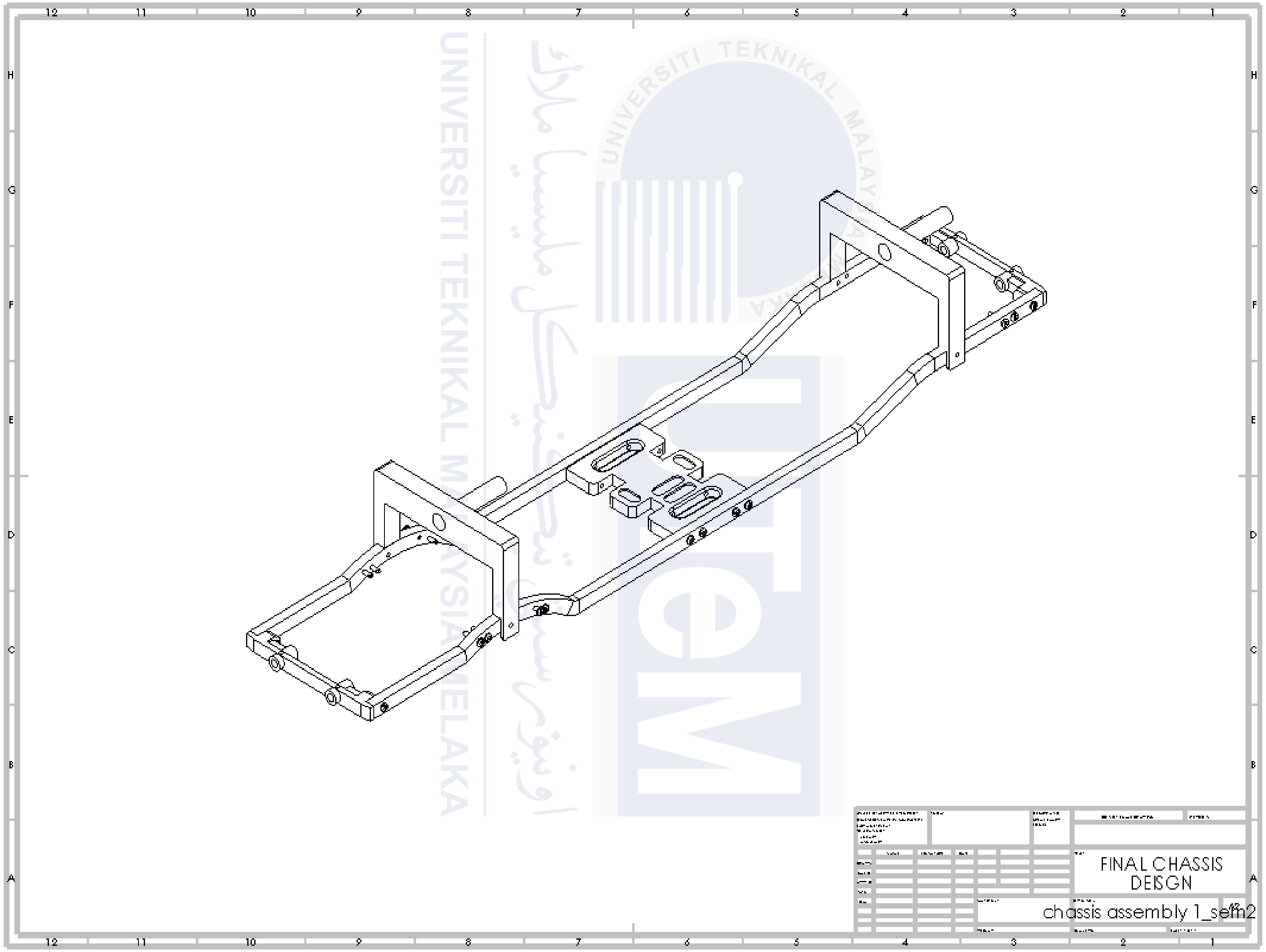
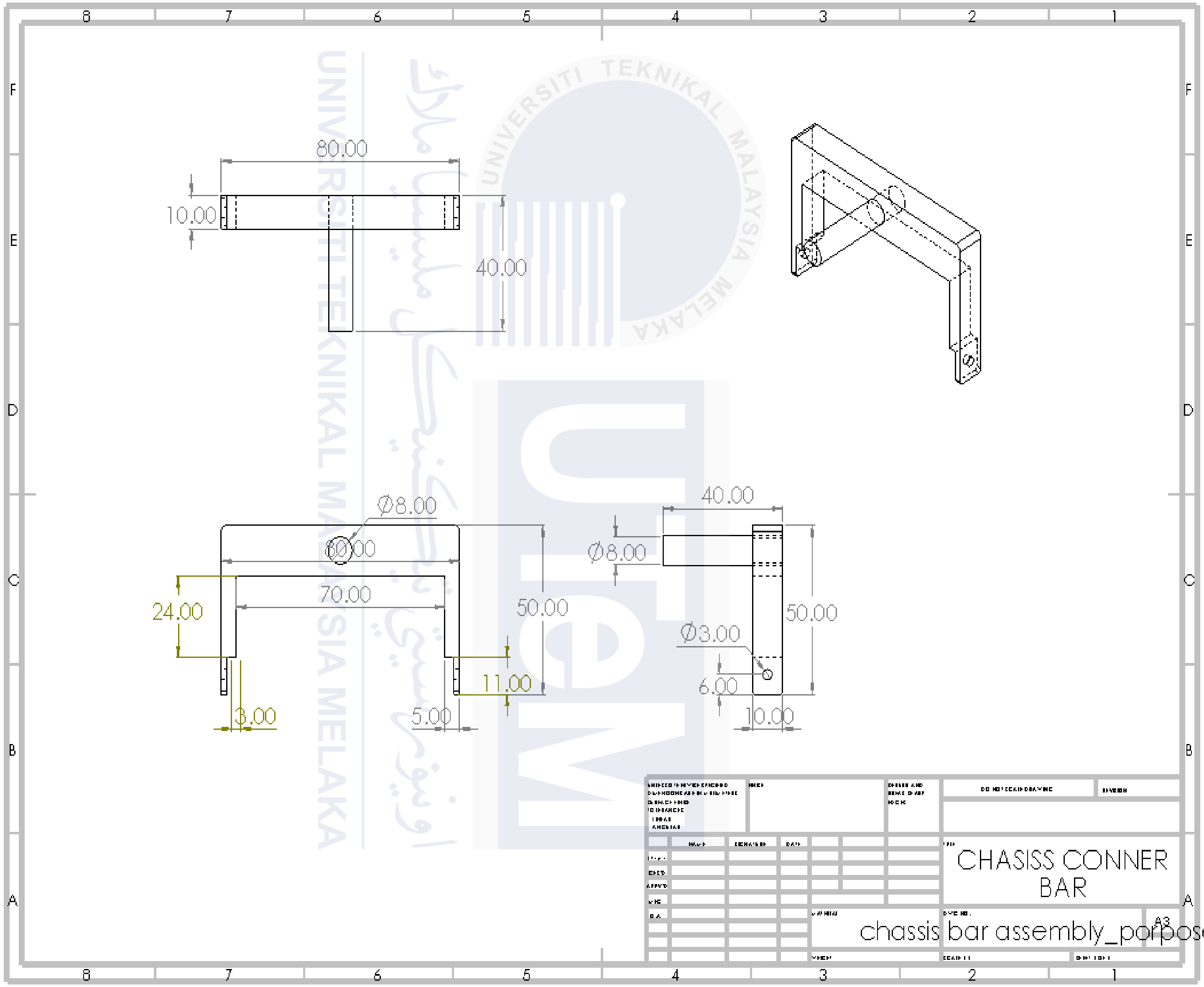
A2


FINAL CHASSIS
DEISGN
chassis assembly 1_sem2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CHASISS CONNER BAR
chassis bar assembly_porpose
A3