# Topology Optimization of Engine Mounting Bracket using Altair Inspire

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# Faculty of Mechanical and Manufacturing Engineering Technology

## Topology Optimization of Engine Mounting Bracket using Altair Inspire

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**Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours**

**2021**

**Topology Optimization of Engine Mounting Bracket using Altair Inspire**

**CHAI TAO ZHE**

**A thesis submitted**
**in fulfillment of the requirements for the degree of**
**Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours**



**Faculty of Mechanical and Manufacturing Engineering Technology**



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2021**

## DECLARATION

I declare that this Choose an item. entitled “Topology Optimization of Engine Mounting Bracket using Altair Inspire” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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|---|---|---|
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| Date | : | 18/JAN/2022 |

## APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

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Universiti Teknikal Malaysia Melaka

# DEDICATION

I would like to express my sincere gratitude to Encik Ahmad Zul Husni Bin Che Mamat, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), for all of his help, guidance, and inspiration. His unwavering patience in mentoring and offering invaluable insights will be remembered by everyone who have supported my path. Prof. Madya Ts. Dr. Lau Kok Tee, the chairman of the PSM 1 and PSM 2, deserves special appreciation for all of his assistance and guidance with Chapters 1, 2, 3,4 and 5.

Take this opportunity to thank of my heart to my buddy, Lim Chia Jiang, who has selected the same supervisor as me for his encouragements and has been a pillar of strength during all of my projects. He constantly explains and advises me about my work and compares us because we have the same study concept but different themes. Finally, I'd want to express my gratitude to everyone who has helped, supported, and encouraged me to continue my education.

## ABSTRACT

A car's and its components' weight is an important aspect in its performance and economy. As a vehicle's weight grows, its fuel efficiency and performance suffer. To increase an automobile's performance, parts should be less in weight and have the necessary strength. The weight of the engine mounting brackets might be reduced by changing the material of the brackets and enhancing the material removal for manufacturing the brackets. To optimise the removal of materials, a topological method was applied. In the age of the vehicle, there is a greater emphasis on decreasing fuel consumption and increasing pollution reduction, which necessitates the use of light-weight structural elements. Manufacturing operations have always been subjected to high demands due to the magnitude of output numbers. Manufacturers place a high priority on cost since there is a demand for components that improve material performance while remaining affordable. Through optimization, the objective is to reduce weight while boosting strength and stiffness. With around 95 percent of the same weight, a CAD model of the base model engine mounting bracket was recreated and constructed using CATIA V5. Altair SIMSOLID and Altair INSPIRE are used to evaluate the analysis of maximum stress and displacement to identify the ideal optimization of the engine mounting bracket utilising strong material. When compared to a based model engine mounting bracket, the researcher determined that Al6061-T6 may be used back as an engine mounting bracket material with a 10% weight reduction and the percentage of maximum stress on the engine mounting bracket has been reduced by 16.94%. The expected result of weight reduction, maximum stress and displacement were achieved in this project.

# *ABSTRAK*

Berat kereta dan komponennya adalah faktor kritikal dalam prestasi dan kecekapannya. Ekonomi dan prestasi kenderaan berkurang apabila berat badannya meningkat. Bahagian kenderaan mestilah lebih rendah dan memiliki kekuatan yang diperlukan untuk meningkatkan prestasi kenderaan. Oleh itu, dengan mengubah bahan pendakap dan meningkatkan penyingkiran bahan untuk pembuatan pendakap, pengurangan berat pendakap pemasangan mesin dapat dicapai. Pendekatan topologi digunakan untuk mengoptimumkan penyingkiran bahan. Keperluan untuk bahan struktur ringan semakin meningkat di zaman mobil, kerana ada penekanan yang lebih besar untuk mengurangi penggunaan bahan bakar dan meningkatkan pengurangan pencemaran. Ukuran kuantiti pengeluaran secara historis meletakkan tuntutan yang ketat terhadap ketahanan proses pembuatan. Pengilang meletakkan nilai yang tinggi pada kos, kerana ada keinginan untuk komponen yang akan meningkatkan prestasi bahan dan menawarkan bahan-bahan ini dengan biaya yang berpatutan. Melalui pengoptimuman, objektifnya adalah untuk mengurangkan berat badan sambil meningkatkan kekuatan dan kekakuan. Dengan kira-kira 95 peratus daripada berat yang sama, model CAD pendakap enjin model asas telah dicipta semula dan dibina menggunakan CATIA V5. Altair SIMSOLID dan Altair INSPIRE digunakan untuk menilai analisis tekanan dan anjakan maksimum untuk mengenal pasti pengoptimuman ideal pendakap pemasangan enjin menggunakan bahan yang kuat. Apabila dibandingkan dengan pendakap enjin model berasaskan, penyelidik menentukan bahawa Al6061-T6 boleh digunakan kembali sebagai bahan pendakap pemasangan enjin dengan pengurangan berat badan 10%, dan peratusan tekanan maksimum pada pendakap pemasangan enjin telah dikurangkan sebanyak 16.94%. Hasil yang dijangkakan daripada pengurangan berat badan, tekanan maksimum, dan anjakan dicapai dalam projek ini.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The engine mounting bracket is one of the important components of an engine mount assembly. Light vehicle performance has its engine supported by a bracket and this engine mounting bracket assembly is used in the chassis' front frame, which has been designed as a framework to support the engine along with the transmission member. The main function of the engine mount bracket is to properly balance the engine and transmission on the vehicle's chassis. The engine mount is an important part of the vehicle because it reduces vibration and noise, allowing for a smooth ride.

Engineers always aim at improvement in each and every part of the automobile system. The automobile industry has continued to improve for many years, with efforts conducted for the purpose of modification of the mechanical parts of vehicles in order to improve their performance response. These characteristics have a vital impact on the mechanical performance of the overall system balance. Furthermore, redesigning the mechanical models plays an important role in improving the system's sustainability against the resulting stresses and displacement, so engineers should take this into account when designing.

As a result, engineers are investigating ways to reduce the weight of the engine mounting bracket while maintaining performance. As a result, the engine mounting bracket can be made at a lower cost than the original. An optimization will be carried out to reduce the weight of the engine mounting bracket by using the topology method and improve the maximum stress and displacement.

## 1.2 Problem Statement

Vehicles are our primary mode of transportation for this generation. So, the quality of vehicle spare parts also needs to be taken seriously. Engine mounts have an important function of containing firmly the power-train components of a vehicle. Correct geometry and positioning of the mount brackets on the chassis ensures good ride quality and performance. To be a high-performance vehicle, the brackets on the frame that support the engine undergo high static and dynamic stresses as well as a huge number of vibrations. Hence, dissipating the vibrational energy and keeping the stresses under a predetermined level of safety should be achieved by careful design and analysis of the mount brackets. Keeping this in mind, the current paper discusses the modeling, Finite Element Analysis and mass optimization of the engine mount brackets for a car.

The main problem in engine mounting design is that of ensuring that the motions of the engine and the forces transmitted to the surroundings, as a result of unavoidable forces, are kept to manageable levels. In the case of vehicle engines, it is sometimes practice to make use of the same flexible mounts and the same location points as in the vehicle. All of these factors alter the dynamics of the system when compared with the situation of the engine in service and can cause fatigue failures of the engine support brackets.

In this project, static structural analysis was used to determine the characteristics of the engine mounting bracket. To obtain a comprehensive design, the existing model is. The modified bracket was subjected to the same analysis procedure as the original bracket, and the results were compared to both designs.Analysis of the stresses and deformations of brackets that affect engine mounting brackets, and optimization of the design to reduce the weight of the rib of the engine mounting models.

## 1.3 Research Objective

The main aim of this research is to examine the structural design and the materials used. The objectives are as follows:

a) To remodel the 3D design of the engine mounting bracket in the local market into a Computer-Aided Design (CAD) format.

b) To analyze the maximum stress and displacement response of the engine mounting bracket.

c) Comparison study of weight, maximum stress and displacement between the optimized engine mounting bracket and the model engine mounting bracket.

## 1.4 Scope of Research

This scope of this research are as follows:

a) To study the engine mounting bracket that is used in the C-segment in the local market.

b) To remodel the actual engine mounting bracket into a CAD format by using CATIA V5.

c) To analyze the maximum stress and the displacement of the engine mounting by using different materials, including gray cast iron, aluminum alloy and magnesium alloy materials, by using ALTAIR SIMSOLID.

d) Weight is reduced by 10% to 20% to optimize the engine mounting bracket.

e) To reduce the percentage of maximum stress of engine mounting bracket by 15%.

f) To perform organic shape comparison between 10% to 20% weight reduction.

## 1.5 Rational of Study

The rational of study of this research are about:

a) To optimize the structural design and the material used for the engine mounting bracket.

b) The engine mounting bracket structural architecture needs to be improved in order to strengthen maximum stress and displacement, which is better than the model engine mounting bracket.

c) Able to achieve a light weight with good performance in terms of maximum stress and displacement.

d) To make the product more cost-effective

## 1.6 Expected Result

At the end of the research, the expected result must be achieved as follows:

a) Reverse engineering close to 95 - 100% actual product.

b) A better maximum stress and displacement light weight material which gives between 10% to 20% weight reduction compared to the based model engine mounting bracket.

c) The percentage of maximum stress on the engine mounting bracket has been reduced by 15%.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In a society with advanced science and technology, science and technology play a role in life. For example, cars are a necessary means of transportation for everyday use. Because of the limited resources for vehicle growth, many automakers design a wide variety of cars, but the main goal is to reduce fuel consumption and air pollution. Not only that, the need for light weight structural materials in automotive applications is increasing as the pressure for improvement in emissions. The most effective way of increasing automobile mileage while decreasing emissions is to reduce vehicle weight. Because of the emphasis on cost, component manufacturers have been forced to improve the performance of their materials and find ways to deliver these materials at a lower cost.

## 2.2 History of the Engine Mounting Bracket Mechanism



The engine mounting bracket plays an important role in reducing engine noise, vibration, and harshness, and thus plays an important role in improving vehicle comfort.The first and foremost function of an engine mounting bracket is to properly balance the power pack on the vehicle's chassis for good motion control as well as good isolation. A longitudinal system that protects other elements of a physical structure is an engine mounting bracket. One of the most important phases in the creation of a modern vehicle is design. The engine mounting bracket is the vehicle's front assembly, which must hold all of the parts and sustain all of the motor and transmission loads.

These loads include the weight of each component and the forces which manifest during acceleration, deceleration and cornering. Therefore, the engine mounting bracket is considered to be the most important element of the vehicle as it holds all the parts and components together. Having a well-designed engine mounting bracket is important to ensure safety and good performance.

## 2.3 Types of Engine Mounting

### 2.3.1 Solid Engine Mounting

Figure 2.1 Solid Engine Mounting

Since these all-metal mounts don't have any rubber or polyurethane, solid engine mounting is the least accommodating. Because solid engine mounting allows for metal-on-metal interaction, it allows for the most vibration and noise.However, since solid engine mounting bends very little under load, solid engine mounting often passes the most strength to the wheels. (David Fuller, 2016)

### 2.3.2 Hydraulic Engine Mounting

Figure 2.2 Hydraulic Enigne Mounting

Hydraulic engine mounts have an empty area filled with hydraulic oil, which is normally a glycol/water mixture. The mounts must withstand two types of vibration in comparison to supporting the engine:

- Low frequency vibration is caused by shock oscillation, such as fast acceleration or stopping and driving on rough surfaces.
- Unbalanced engine forces, such as firing pulses or other mass imbalances between rotating or exchanging engine components, cause high frequency vibration.

(David Fuller, 2016)



### 2.3.3 Rubber Engine Mounting

Figure 2.3 Rubber Engine Mounting

Rubber engine mounts, such as those supplied by the manufacturer, have the best friction and noise dampening properties. The old rubber-style mounts, on the other hand, have a few disadvantages. After a while, rubber engine mounting is sensitive to cracking and breaking, and rubber engine mounting also makes the most movement under load. This ensures that less power is transmitted from the engine to the rear wheels through the driveline. Rubber mounts are suitable for stock or lightly adapted street engines, but as horsepower increases, it will be necessary to update them. (Bright Hub Engineering, 2019)

## 2.4 Application of Engine Mounting Bracket

A component of an automotive engine is the engine mounting bracket, which is separated into two parts. The first is the torsional bracket, and the second is the engine mounting rubber, which is important for shock absorption. Torsion brackets are a type of engine fastener that is always attached to the engine on the vehicle's front axle. The mounting foot is a rubber pier directly inserted into the bottom of the engine, and the torsional bracket looks like an iron bar inserted into the side of the engine, which distinguishes it from the regular engine mounting rubber. On the bracket, there is also a torsional bracket rubber that acts as a damper. (Bright Hub Engineering, 2019)



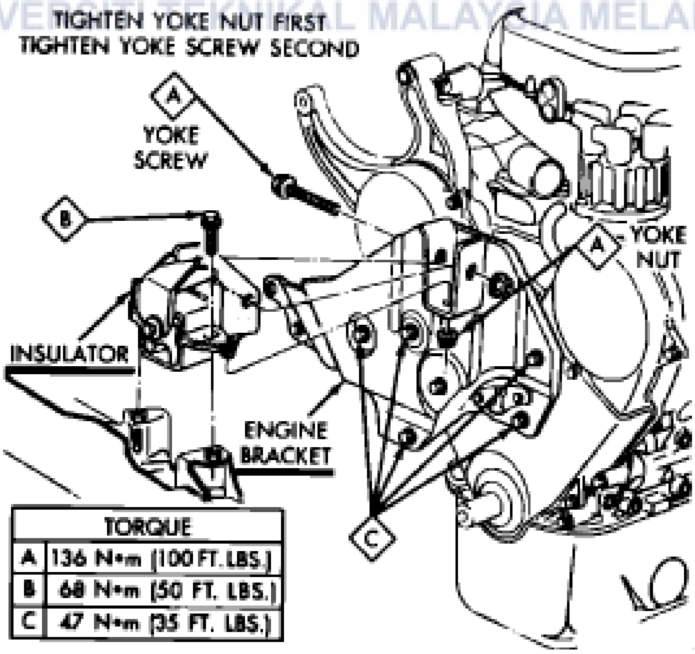



Figure 2.4 Engine Mounting Bracket Assembly

## 2.5 Materials Selection

The materials selection process already described is more closely associated with the activities of technical design. There are many systematic methods, most numerically based, with some implemented as computer software tools, for matching material properties with technical design requirements. There is also relatively easy access to a lot of detailed and verifiable technical information available from many different sources. (Sahil Naghate, 2018)

| PROPERTIES | MATERIALS | | |
|---|---|---|---|
| | Aluminum Alloy (Al 6061 -T6) | Magnesium Alloy (AZ31B - Extruded) | Gray Cast Iron (A536) |
| Possion's ratio | 0.33 | 0.35 | 0.30 |
| Density (kg/�$^{3}$) | 2700 | 1770 | 6640 |
| Yield Strength Stress (MPa) | 276 | 200 | 345 |
| Ultimate Tensile Stress (MPa) | 310 | 260 | 490 |

Table 2.1 Materials and its Physical and Mechanical Properties



### 2.5.1 Von Mises Stress

The Von Mises stress is an equivalent stress number based on distortion energy that may be used to determine whether a ductile material will fail (yield or fracture) under a certain loading scenario. According to the Von Mises failure hypothesis, a material will fail if its Von Mises stress or effective stress under load is equal to or greater than the yield limit of the same material in a basic uniaxial tension test. (University of Notre Dame, 2017)

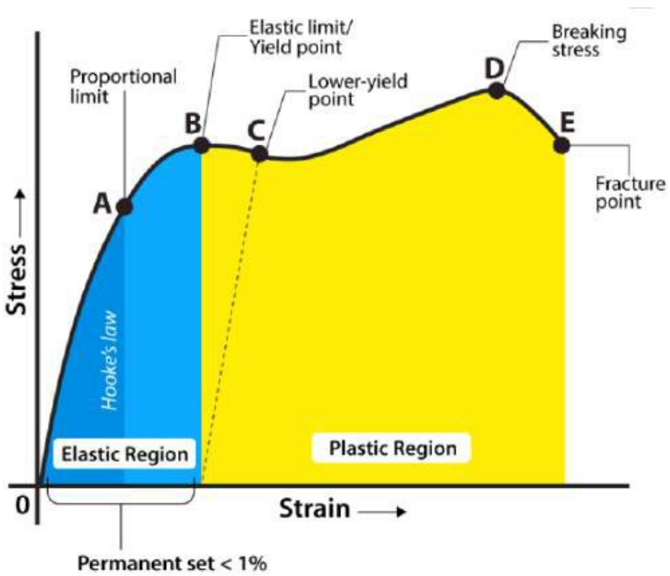


Figure 2.5 Stress-strain curve

- **Proportional Limit**

  Hooke's Law is obeyed in this section of the stress-strain curve. The ratio of stress to strain provides us with the proportionality constant known as Young's modulus at this limit. The proportional limit is the point OA in the graph.

- **Elastic Limit**

  When the load acting on the material is totally eliminated, the material returns to its previous position up to this point in the graph. The material does not return to its original position beyond this point, and a plastic deformation appears.

- **Yield Point**

  The yield point of a material is defined as the point at which it begins to distort plastically. Permanent plastic deformation happens after the yield point is crossed. The yield points are the B higher yield point and the C lower yield point.

- **Upper yield and lower yield**

  When the metal is in the plastic range and hits a critical point known as the upper yield limit, it will rapidly descend to the lower yield limit, where deformation occurs under continual stress until it begins to resist deformation again.

- **Fracture or Breaking Point**

  It is the point on the stress-strain curve when the material fails.

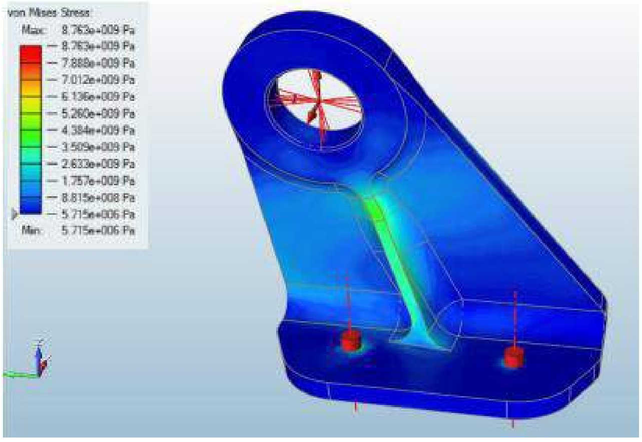



Figure 2.6 Von Mises Stress

### 2.5.2 Deformation

Deformation, like numerous other structural geological words, is employed in a variety of ways and under a variety of conditions. The phrase most commonly refers to the distortion (strain) that is exhibited in a (deformed) rock, especially in the field. A change in form or shape is also what the word literally signifies. During deformation, however, rock masses can be translated or rotated as rigid units with no interior shape change. Fault blocks, for example, can move without collecting any internal distortion during deformation.

When deformation occurs, internal intermolecular forces resist the applied force, according to the University of Notre Dame in 2017.If the applied force is not too strong, these forces resist the applied force and allow the material to return to its original state after the load is removed.A stronger applied force may result in permanent deformation of the material or even structural failure. Different types of deformation may result from variations in the type of material, size and the forces applied. Types of deformations include:

- **Elastic deformation**

  This is a reversible deformation. Rubber, like polymeric materials and type memory metals like nitinol, has a large elastic deformation range.

- **Plastic deformation**

  This might be permanent. Soft thermoplastic materials, as well as ductile metals like copper, silver, and gold, have a high plastic deformation variance.

- **Metal fatigue**

  This is a phenomenon that occurs mostly in ductile metals. Metal fatigue was a prevalent cause of failure in the past, particularly before the process was fully understood.

- **Compressive failure**

  This is a term that refers to the shortening of bars, columns, and other structures. The compressive stress of a structural item or specimen can be increased by loading it until it exceeds its compressive strength.

- **Fracture**

  This might be permanent. If enough force is given to any material, it will ultimately fracture.



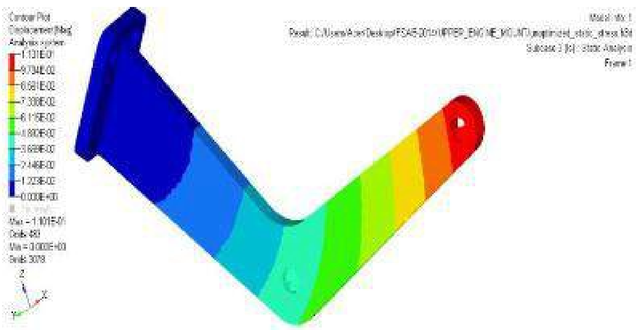


Figure 2.7 Deformation

## 2.6 Engine Mounting Bracket Designing Process

Design is a common word with elaborate meanings close to fashion, aesthetics, culture, so on. Basically, it is the process of translating an idea into a product or system. Mechanical design is referred to as the design explained in the context of this course. The role of materials in mechanical design will be elaborated on in the following courses. The selection of materials is as important in mechanical design as the selection of function, shape and process. Because of the vast number of materials developed in the modern era, designers can be as creative and open-minded as possible when creating innovative designs based on a wide range of material properties.Regarding the material collection, the process moves on to developing a CAD model, which is then refined using optimization methods. (Sahil Naghate, 2018)



| Software | Developer | Characteristic features |
|---|---|---|
| FUSION 360° | Autodesk | Files are stored in the cloud on this cloud-based network. Users have access to their files from virtually any place. User-friendly, organic geometry, surface simulation. Manufacturability and other technical modelling functionality are missing. (Ostrem, n.d, 2018) |
| SolidWorks | Dassault Systémes | Manufacturing software, as well as robust modelling tools. Simple to use with a fast-learning curve. (Cali, 2019) |
| AutoCAD Inventor | Autodesk | Professional-grade 3D mechanical modelling and production equipment are available. Designed for practitioners. (Ooin, n.d, 2019) |
| CATIA | Dassault Systémes | In the automotive and aerospace industries, seamless collaboration between departments is used to simulate products and production processes. Concept design |

| | | |
|---|---|---|
| | | must be able to replicate the whole production process of the component. For newcomers, it's difficult to get started and there's a steep learning curve. (Aaltonen, 2013) |

Table 2.2 Comparing different CAD software

### 2.6.1 Computer Aided Design (CAD) Model Designing

Cad modelling is the process of creating a basic model based on the engine's location on the chassis. CREO Parametric is used throughout the modelling process. Because the design called for a lengthy bracket, material selection became a priority owing to the bracket's weight. To save weight, the mount bracket was designed to be made up of two bolted-together components. The chassis would be welded to one section, while the engine would be fastened to the other. Creo, short for Creo Parametric, is a powerful and intelligent 3D CAD software improved to deal with the challenges organizations face as they design, analyze, and share information. Using the CATIA V5 software, the engine mounting bracket was developed and sketched to create a CAD file. The CAD file is necessary for the subsequent processes, such as the analysis and optimization processes.



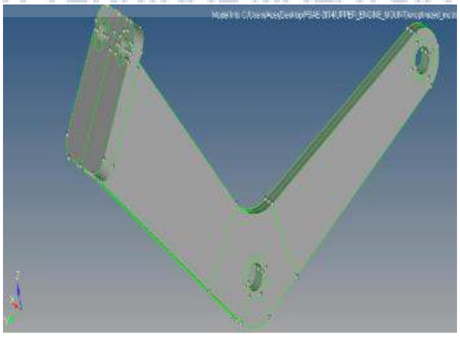


Figure 2.8 Engine Mounting Bracket in CATIA V5

### 2.6.2 Finite Element Analysis (FEA) Method

The basic concept behind Finite Element Analysis (FEA) is to do computations at a small number of locations and then interpolate the results throughout the whole domain, which includes both surface and volume. Continuous objects have an infinite degree of freedom, making it impossible to solve the issue in this manner. As a result, the degree of freedom may be decreased from infinite to finite utilising the FEA approach with discretization or meshing (nodes and elements). According to Nitin S Gokhale's book "Practical Finite Element Analysis," published in 2008, these lines are correct.

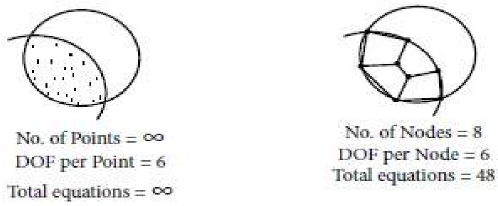



Figure 2.9 Degree of freedom before and After FEA

#### 2.6.2.1 Load Cases on Engine Mounting Bracket

These duties are assigned to various mounts in the engine mount system, largely based on the engine's location and orientation. Because the gear ratio of the differential at the rear axle has no effect on the mounts in conventional drive cars, the mounts must sustain the engine's transmitted torque. The torque that needs to be sustained in front-, rear-, and all-wheel drive vehicles, especially with transversely positioned engines, is that acting on the drive shafts as communicated by the axle drive. As a result, torque rods, such as the one illustrated in Figure 2.8 are introduced into the engine mount system, which are particularly built and installed to sustain torque rotating the powertrain. (Master of Science Thesis Stockholm, 2018)

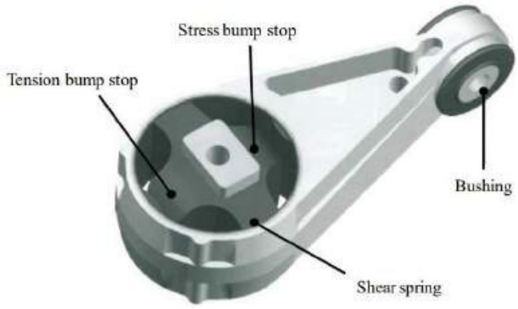



Figure 2.10 Example of a torque rod

Figure 2.11 depicts a typical engine mount system constellation in a front-wheel drive vehicle with a transversely positioned engine for better understanding. A four-point mounting mechanism is seen in the image. The mounts are usually named depending on their position in the engine mount system for further clarity. As a result, the mount closest to the engine is referred to as the ‘engine mount,' while the one closest to the transmission is referred to as the ‘transmission mount.' (Master of Science Thesis Stockholm, 2018)

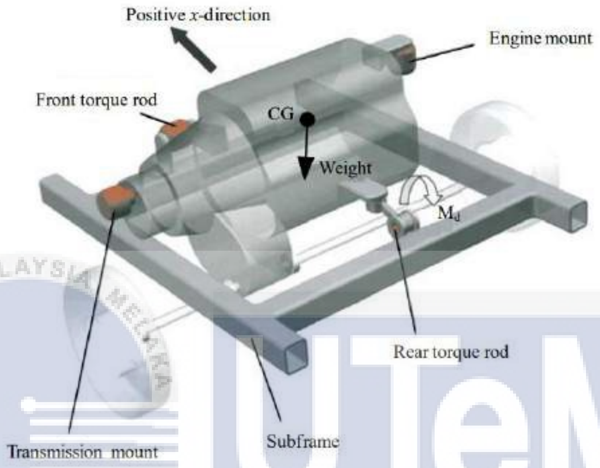



Figure 2.11 Schematic example of an engine mount system in a front-wheel drive vehicle



### 2.6.2.2 Load Calculation

According to Master Katrin Engel's article "Predicting the design relevant loads in the engine mount system at an early stage of the development process," published in the journal "Predicting the design relevant loads in the engine mount system at an early stage of the development process" in 2013. To determine the load of the engine operating on the engine mounting, the weight of the engine must be distributed across the vehicle that has so many engine mounts. For example, because the Audi A3 has three engine mountings, the engine's weight must be distributed evenly among them.

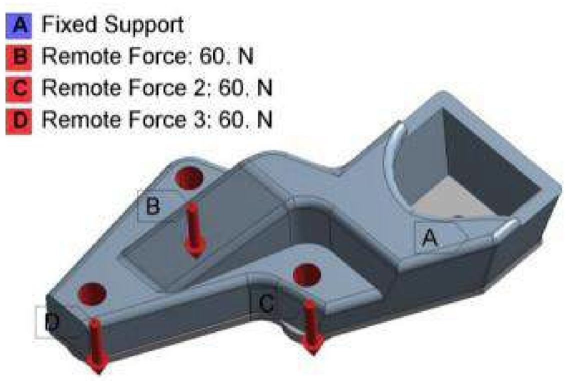



Figure 2.12 Boundary conditions of Engine Mounting Bracket

(Prof. D.S.Chavan, 2018)

### 2.6.3 The Meshless Analysis (SIMSOLID)




Figure 2.13 Altair SIMSOLID software

SIMSOLID is a structural analysis programmer developed exclusively for engineers. SIMSOLID greatly decreases the amount of time and experience needed for even complex FEA by avoiding geometry meshing and simplification. The terms meshless and finite element analysis are rarely used together. For decades, the general consensus has been that fine-tuning a mesh requires 80% of your attention in order to get a successful FEA result. This approach is based on fundamental mathematics and computational methods for predicting how a component or assembly will perform under different conditions.

The imported geometry is transformed into a faceted representation of a geometric hierarchy on the inside. For various feature forms, such as bolts, thin shells, and so on, the geometry is tested. Potential communication surfaces are assessed at the interfaces between components. The normal FEA emphasis on sufficient mesh regulation is bypassed since no supporting mesh is used. (Tony Abbey)

With the Altair SIMSOLID, an alternative to the conventional FEA methodology is available. There is no need for meshing or model simplification for this program. Furthermore, SIMSOLID employs a proprietary mesh-free approach that works specifically on CAD geometry. SIMSOLID also has the advantage of being able to run on a normal desktop or laptop without the need for costly GPU hardware, and it also delivers reliable results with fewer errors, according to Dr. Richard King, who conducted simulations on 18 different models in Simsolid and static simulations on some SolidWork models in 2019




Figure 2.14 Von Mises Stress and Deformed Shape for nonlinear vertical load

### 2.6.4 Optimization Software (Altair INSPIRE)

INSPIRE
solidThinking / WHERE IDEAS TAKE SHAPE

Figure 2.15 Altair INSPIRE

For design engineers, Altair Inspire software is the industry's most powerful and user-friendly Generative Design/Topology Optimization and quick simulation solution. It improves the idea creation process by allowing simulation-driven design, which improves the efficiency, strength, and manufacturability of your product. Costs, development time, material consumption, and product weight may all be decreased as a result. SIMSOLID's capabilities are listed in the table below (Altair, 2019).

#### 2.6.4.1 Geometry Creation and Simplification

| | |
|---|---|
| Sketch Tools | Build or modify parts by sketching lines, rectangles, circles, and arcs |
| Trim/Break | Cut and remove sketch curves at the point of intersection |
| Boolean Operations | Add, subtract, or intersect solid parts to create more complex geometry |
| De-feature | Remove imprints, rounds, fillets, holes, and pockets, or plug holes |
| Mid-surfacing | Mid-surfacing tools allow users to find and extract 2D sheets from single thickness thin solid geometry |

Table 2.3 Geometry Creation and Simplification

#### 2.6.4.2 Optimization Options

| | |
|---|---|
| Optimization Objectives | When running an optimization, can choose to either maximize stiffness or minimize mass |

| | |
|---|---|
| Stress Constraints | global stress constraint can be applied to limit the maximum stress in the model during optimization |
| Displacement Constraints | Displacement constraints can be applied to a model to limit deflections in desired locations and directions |
| Acceleration loads | Angular velocity and acceleration tools allow to define the speed of rotation of the entire model and the axis about which it rotates |
| g-Loads | g-Loads tool allow users to simulate a model undergoing acceleration, which imparts a force on all parts of the model |
| Displacement Constraints | Displacement constraints can be applied to a model to limit deflections in desired locations and directions. |
| Temperature Loads | Temperature tool allows to simulate the effects of temperature changes in a model |
| Export to OPTISTRUCT | Can export OPTISTRUCT input files for advanced simulations |

Table 2.4 Optimization Options

#### 2.6.4.3 Contacts and Assemblies

Optimization and analyze full parts and assemblies inside of Inspire.

- The Contacts tool allows you to locate nearby pieces and decide whether they should be bonded, contacting, or not.
- To add bolts, screws, pins, or sliding pins to many elements in a model, use the Fastener and Joints tools.



#### 2.6.4.4 Manufacturing and Shape Controls

Generate design concepts that are not only structurally efficient but also manufacturable using Inspire's shape controls:

| | |
|---|---|
| Symmetry Planes | Force asymmetric design spaces to generate symmetric optimized shapes |
| Cyclic Repetition | Create cyclically repeating shapes like propellers or wheels |

| | |
|---|---|
| Draw Directions | Generate shapes that can be easily molded or stamped by applying single or split draw directions |
| Extrusion Shape Control | Generates constant cross-section topologies in a specified direction |

Table 2.5 Manufacturing and Shape Controls

#### 2.6.4.5 Analysis

Visualize displacement, factor of safety, percent of yield, tension and compression, von Mises stress, and major primary stress using linear static and normal modes analysis on a model.

#### 2.6.4.6 Shape Controls & Design Constraints

| | | |
|---|---|---|
| Min/ Max Size | Draw Direction | Symmetry |
| Pattern Repetition | Cyclic Repetition | Stress Constraints |
| Frequency Constraints | Displacement Constraints | Overhang Angle |

Table 2.6 Shape, Controls & Design Constraints



### 2.6.5 Optimization Methods

The design purpose in optimization of a design might simply be to reduce manufacturing costs or to increase production efficiency. An optimization algorithm is a process that compares numerous solutions iteratively until an optimum or satisfying one is identified.

#### 2.6.5.1 Topology Optimization

Topology optimization is an iterative method that identifies the most effective configuration based on a collection of constraints or characteristics, often by eliminating content. It refers to the domain's total number of associated components/boundaries. Users may use topological optimization methods to get around the disadvantages of pure form optimization. The traditional with formulation evaluates design output using the finite element method (FEM). The architecture is optimised using gradient-based mathematical programming techniques like the optimality criterion algorithm and the process of moving asymptotes, or non-gradient-based formulas like numerical methods. (J.G. Korvink, 2021)

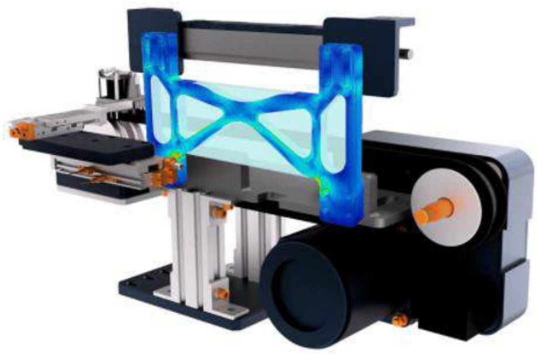


Figure 2.16 Topology Optimization

The most of topology optimization procedures are carried out by integrating the principles of Computer Aided Design (CAD), Finite Element Analysis (FEA), and various optimization algorithms in view of diverse production processes, as shown in the topology optimization phase in Figure 2.11. CAD is used in topology optimization to produce a rough or initial model of the product to be optimised, while FEA is used to see how stresses and displacements are distributed across the product, according to A W Gebisa. & H G Lemu, 2017. Topology optimization is also utilised to remove parts of the component that are not properly managing the imposed loads, are not undergoing significant deformation, and hence do not contribute to the overall outcomes of the part.

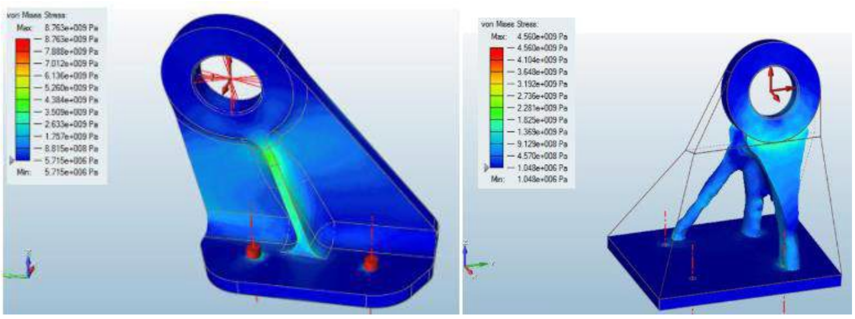


Figure 2.17 Engine Mounting Bracket of Topology Optimization

#### 2.6.5.2 Shape Optimization

The area of optimal control theory includes shape optimization. The most common challenge is to find the form that is optimal in terms of minimizing a given cost function while satisfying those constraints. In certain cases, the solution of a partial differential equation defined on the variable domain is required to solve the functional.

The shape of a structure can be improved by manipulating its boundary. A typical shape optimization task may be to reduce effective tension in certain local regions. Parametric and non-parametric shape optimization methods are the two kinds of shape optimization methods. (Robin Larsson, 2016)

A parametric shape typically represents CAD parameters like the radius of a fillet or the distance between geometry parts. The majority of commercial CAD applications use parametric form representation. The parametric forms, on the other hand, have no clear information about the structure or topology of the boundary.

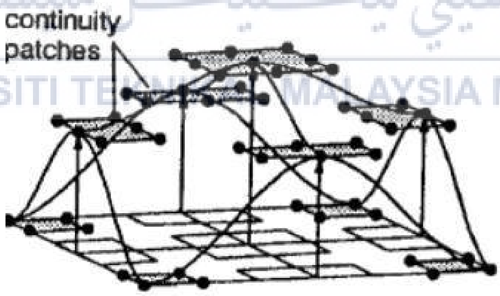



Figure 2.18 Parametric Shape

In non-parametric form optimization, non-parameters are defined from a set of selected surface nodes from the FE model. The nodes that are labelled as design nodes are those that are labelled as such. Non-parameters are scalar displacements along the optimization vectors belonging to the design surface nodes. The natural vector to the adjacent surface of the design node is often used as the optimization vector. (Robin Larsson, 2016)

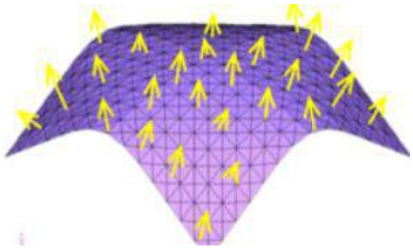


Figure 2.19 Non-Parametric

#### 2.6.5.3 Size Optimization

Size Optimization transforms existing revenue data into size-demand intelligence using advanced analytics. The solution estimates potential revenue and inventory demands based on scale, then calculates the best case pack supply to satisfy the need. It provides intelligence for ordering and allocation workflows when combined with current merchant systems. (Yi et al, 2016)

The optimum relationship between weight, stiffness, and dynamic behaviour is achieved by sizing optimization. It makes for material savings as well as improved convenience and environmental quality. The aim of using this optimization method is to get the component's thickness to the ideal level. Most automatic systems are programmed to deal with standard sheet thicknesses. As a result, if no custom unique thicknesses are needed, producing optimised parts is less costly. This means that in the context of sizing optimization, the optimised values of design variables must equate to values from a given set of potential values. (Tejani et al, 2017)

An asymmetric bottle is modelled across 120° as an example to show the size optimization. At first, all 1.500 shell parts are the same thickness, and a vertical force distribution is applied to the top of the bottle. Some element classes' shell thicknesses clearly approach their maximum or lowest limits, such as in the transition from the bottle ground to the bulb or from the bulb to the collar.

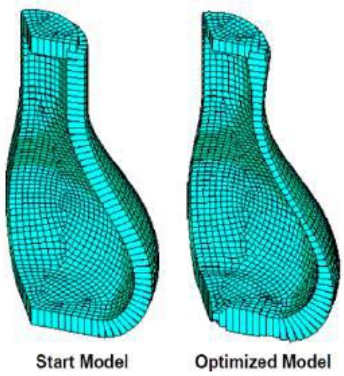



Figure 2.20 FE-model of bottle

## 2.7 Summary or Research Gap

The material used in the engine mounting bracket must be much more precise because the weight of the engine mounting bracket should be considered with the same or equivalent maximum stress and displacement as the dependant model when load is introduced to the engine mounting bracket for the use of a light weight engine mounting bracket to reduce vehicle weight. The most widely utilised materials in the industry, according to the literature research, are magnesium alloy and aluminium alloy, both of which have a greater total stress and displacement but add a substantial amount of weight to the engine. (David C. Barton, 2018).

The Altair SIMSOLID programme has been developed as a substitute or alternative to classical finite element analysis (FEA). SIMSOLID by Altair is a mesh-free programme that eliminates the requirement for meshing. As a result, it saves a significant amount of time and effort while analysing the model, such as the load analysis for maximum stress and displacement, as mentioned by Roopinder Tara, 2019. According to Dr Richard King, 2019, as mentioned in the subtopic above, the accuracy of the analysis utilising SIMSOLID is somewhat greater than that of FEA such as SOLIDWORK and OPTISTRUCT. According to the literature analysis, classical FEA has various drawbacks, such as a high use of the graphic processing unit (GPU) and a long time to interpret the results.

The model must first start the topology optimization process, which optimises the material placement and structure within a specified 3D geometrical design space. Later, proceed to shape optimization to improve its form by changing a structure's border and reducing stress at a specific region. Aside from that, sizing optimization results in the best weight, stiffness, and dynamic behaviour. Both the form and size optimization processes provide material savings as well as greater comfort and environmental efficiency.

| No. | Literature Title | Strength | Weakness | Notable Features | Reference |
|---|---|---|---|---|---|
| 1. | Optimization of engine mounting bracket by topology technique for reduction in weight | - CATIA V5<br>- ANSYS 19 | Doesn't describe detail about the topology technique | It had use clearly picture to demonstrate the topology technique | Mr. Shridhar R. Kothawale (2019) |
| 2 | Static Structural and Modal Analysis of Engine Bracket Using Finite Element Analysis | - ANSYS 19 | It doesn't describe detail software use | It had use table clearly to show the result for analyze | Prof. M.V. Kavade (2019) |
| 3 | Optimization of engine truss mounting bracket | - CATIA V5R20<br>- ANSYS 15.0 | It doesn't describe the detail for topology optimization | It had described for each picture | Yadu Krishnan S Professor (2020) |
| 4 | Design of Engine Mount Bracket for a FSAE Car Using Finite Element Analysis | - HYPERMESH<br>- CREO | It doesn't do comparison for material selection in detail | It had described the detail for each analyze | Jasvir Singh Dhillon (2014) |
| 5 | Finite Element Analysis of engine mounting bracket by considering pretension effect and service load | - HYPERWORKS<br>- CATIA | It doesn't describe the detail for topology optimization | It had clearly shown the detail for data analysis | Sandeep Maski (2015) |
| 6 | A Review on Optimization of Engine Mounting Bracket | - CATIA<br>- ANSYS | It doesn't describe detail software use | It has scope for the optimization of engine bracket | Sanket Vinchurkar (2016) |
| 7 | Modal Analysis of Engine Mounting Bracket Using FEA | - CATIA | It doesn't mention any software that it use for analysis I just refer from photo only know | It has clearly shown the comparison the materials by using the graph | Sahil Naghate (2012) |

Table 2.7 Summary of previous researches findings

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

The specifics of the approach that will be used in this study are discussed in this chapter. To show the topology optimization procedure, a standard engine mounting bracket was chosen. The method's approach is to study the behavior of the dependent model (engine mounting bracket) using Altair SIMSOLID, which includes physical and mechanical properties. In addition, Altair INSPIRE is used in the optimization process to remodel the construct (engine mounting bracket). In Figure 3.1 a research flowchart is created and shown to have a seamless and reliable research procedure as well as the flow to complete the research step by step.

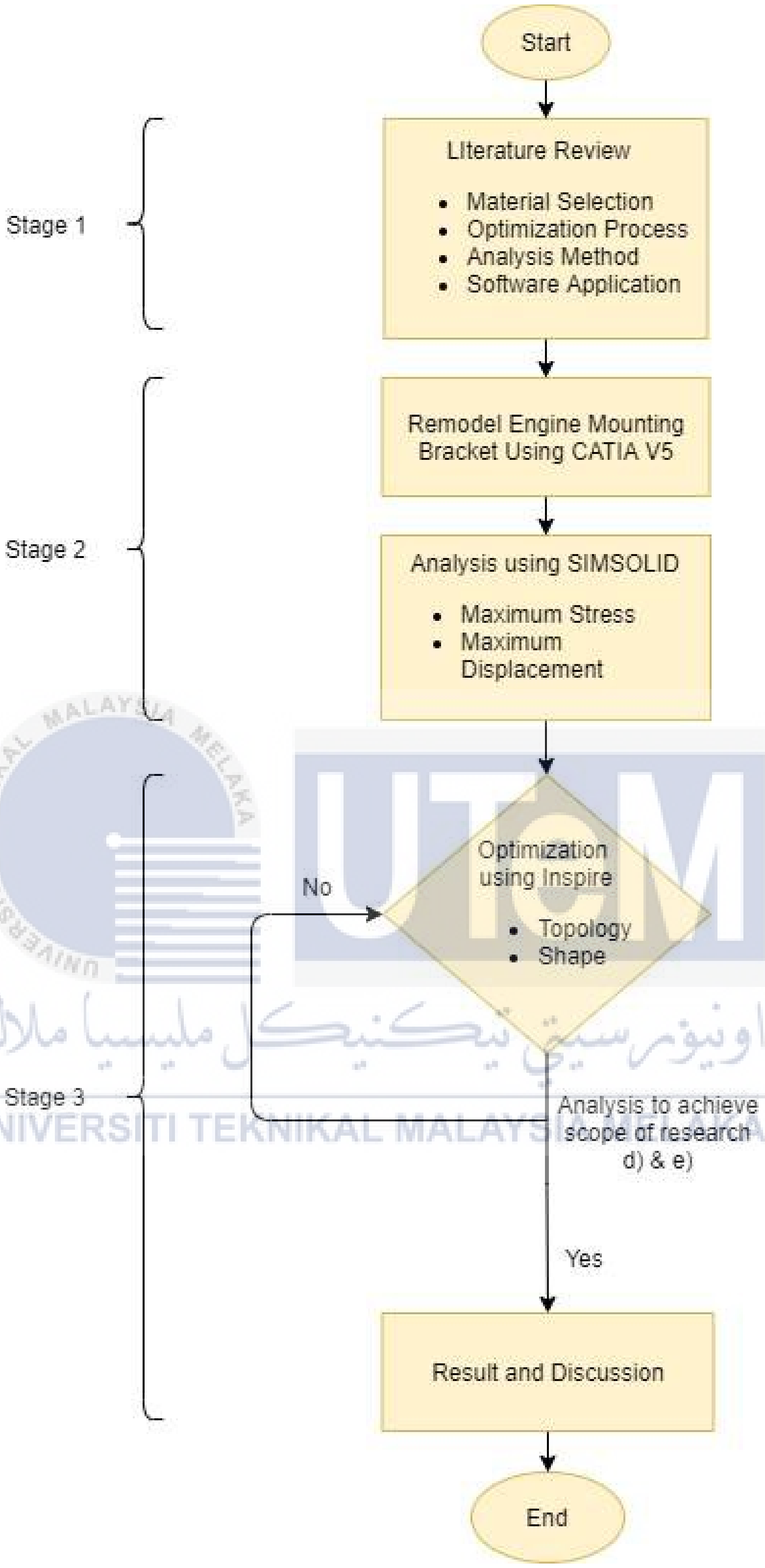



Figure 3.1 Flowchart of the research methodology

## 3.2 Remodel Design

To produce a reverse engineering on remodeling the based model engine mounting bracket, the researcher will prepare the engine mounting bracket (Figure 3.2) bought from the market.

Figure 3.2 Engine Mounting Bracket

The equipment that the researcher used are the Vernier caliper (Figure 3.3) to measuring the length and diameter of the circle and the model Radius Gauge (Figure 3.4) for measuring the radius of the fillet. Following the completion of the measurements, the reverse engineering will be converted into a CAD file using CATIA V5 software for drawing in the first stage, followed by the addition of a pad and the removal of unneeded components using the pocket function. The fillet will be added to the model to complete it. On the basis of Figure 3.5 a nearly identical engine mounting bracket is created.



Figure 3.3 Vernier caliper

Figure 3.4 Radius Gauge

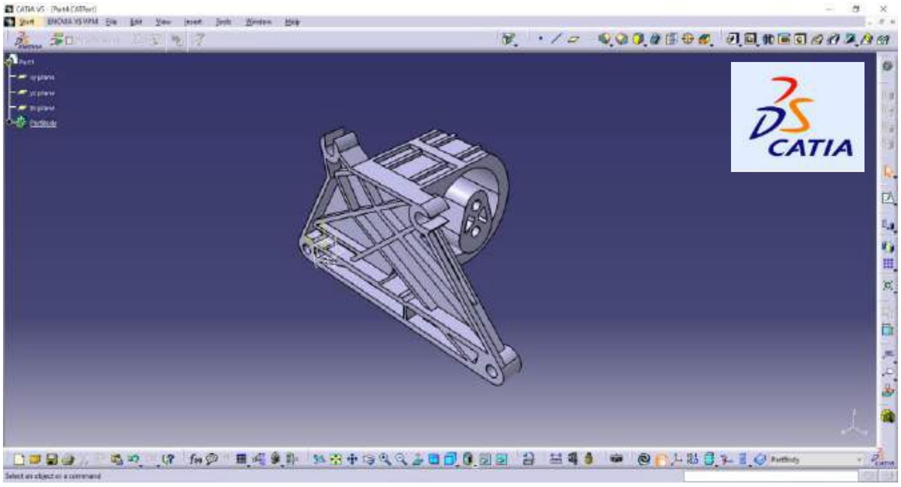



Figure 3.5 CATIA V5 software

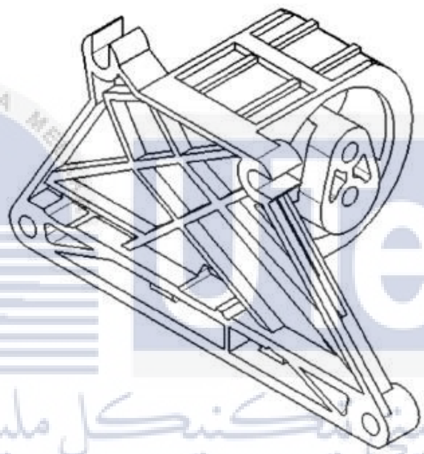


Figure 3.6 Isometric View of Engine Mounting Bracket



## 3.3 Weight Calculation of Engine Mounting Bracket

### 3.3.1 Actual Engine Mounring Bracket

The engine mounting bracket for one of the vehicles (Audi A3) was purchased off the shelf. Only a weighing scale will be used to determine the weight of the actual engine mounting bracket. According to the scale (in kg), the weight of the real engine mounting bracket is 1.10 kg, as indicated in the diagram below.

Figure 3.7 Weighing of Based Model Engine Mounting Bracket

### 3.3.2 In CAD data

CATIA V5 is used to create a CAD file for the actual engine mounting bracket. Then, in CATIA V5, click the apply materials button to attach the material to the engine mounting bracket. Add aluminum to the model, making sure the material is visible in the tree diagram. Then, in the tree diagram, click measure inertia and select the mass of the engine mounting bracket based on the model of the engine mounting bracket. The engine mounting bracket for the standard model weights 1.193kg.




Figure 3.8 Applying Aluminum materials

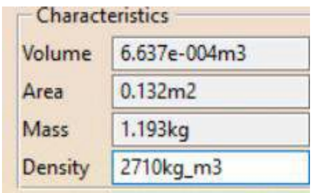



Figure 3.9 Mass Information

### 3.3.3 Percentage of Error of Reverse Engineering

The correctness of the CAD-based model knuckle as compared to the actual engine mounting bracket, as calculated below.

� = ����� ����� ���i�� �����i�� �������, � = ������ ���i�� �����i�� �������

$$\text{������������} \quad \frac{|W_{�} - W_{�}|}{W_{�}} \times 100\ \%$$

$$\text{�����},\% = \frac{|1.10 - 1.193|}{1.10} \times 100\ \%$$

$$= 8.45\ \%$$

The percentage of error between the CAD data and the actual engine mounting bracket is 1.193kg, which is acceptable when reverse engineering is near to the researcher's objective of 95-100 percent.



## 3.4 Test Analysis and Optimization

The methodology's procedure entails optimizing the basis model engine mounting bracket by utilizing the materials that have been chosen. To get the greatest outcome from the chosen materials, the model engine mounting bracket must go through a series of steps. The flowchart in Figure 3.1 illustrates the technique utilized in this study. Before discussing the findings acquired for the best material and design utilized, the model engine mounting bracket should go through a step-by-step procedure to achieve the results (maximum stress and displacement). CATIA V5 is used to create the CAD file for the engine mounting bracket.

All of the aforementioned steps are collected and used after doing a literature review using journals, papers, books, or online reference materials. However, in this study, the researchers employed a different technique of analysis and optimization than the research discovered in all of the resources.

### 3.4.1 Calculation of Force act on Engine Mounting Bracket

Engine weight (Audi A3) is 89.5kg citation by Audi Service Training, 2019, therefore 89.5/4 = 22.38kg on one engine mounting.

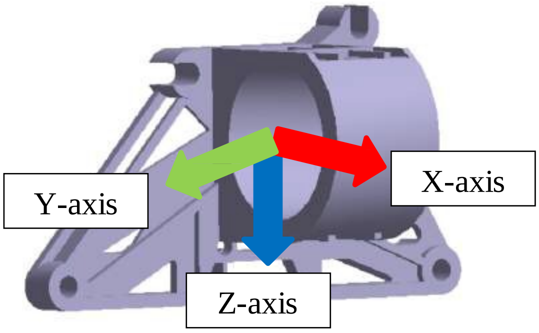



Figure 3.10 Free Body Diagram of Engine Mounting Bracket

1. Braking Force, $F_r = 1.5 \times mg = 1.5 \times 22.38 \times 9.81 = 329.32\ N$
2. $F_x = F_y = F_z = 3 \times mg = 3 \times 22.38 \times 9.81 = 658.64\ N$
3. Resultant Force, $F_R = \sqrt{(F_x{}^2 + F_y{}^2 + F_z{}^2)}$

$$F_R = \sqrt{(658.64^2 + 658.64^2 + 658.64^2)}$$

$$= 1140.80\ N$$



### 3.4.2 Experimental Setup

#### 3.4.2.1 Altair SIMSOLID

SIMSOLID by Altair is a mesh-free technology that eliminates the requirement for meshing (Altair, 2018). It saves a lot of time because SIMSOLID takes care of everything for the researcher. Its purpose is to do a stress and displacement study (forces operating on the engine mounting bracket). The SIMSOLID software is available for download on the Altair website.

The procedure of using SIMSOLID is provided below:

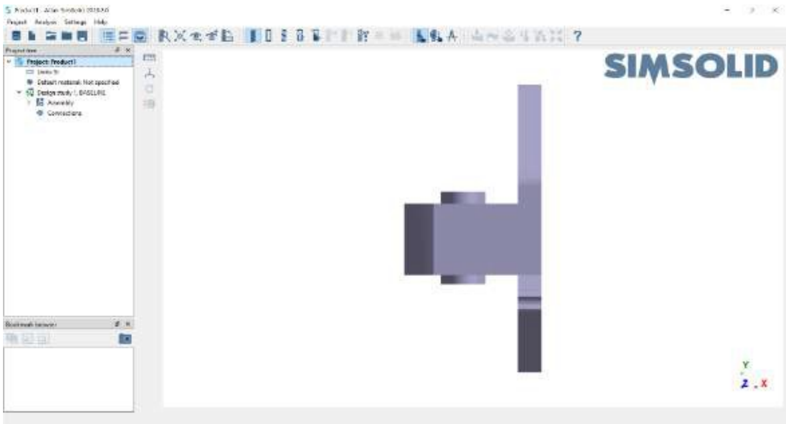



Figure 3.11 Altair SIMSOLID

1. Click icon  in desktop to open SIMSOLID software, then click  to select the CAD file and open.

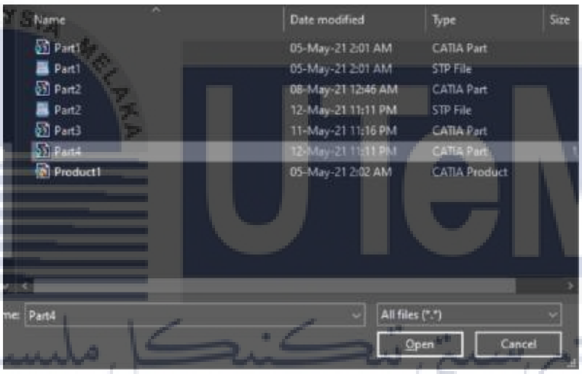



Figure 3.12 Selection of the CAD file



2. The CAD file is imported and information in project tree is shown (Figure 3.7).

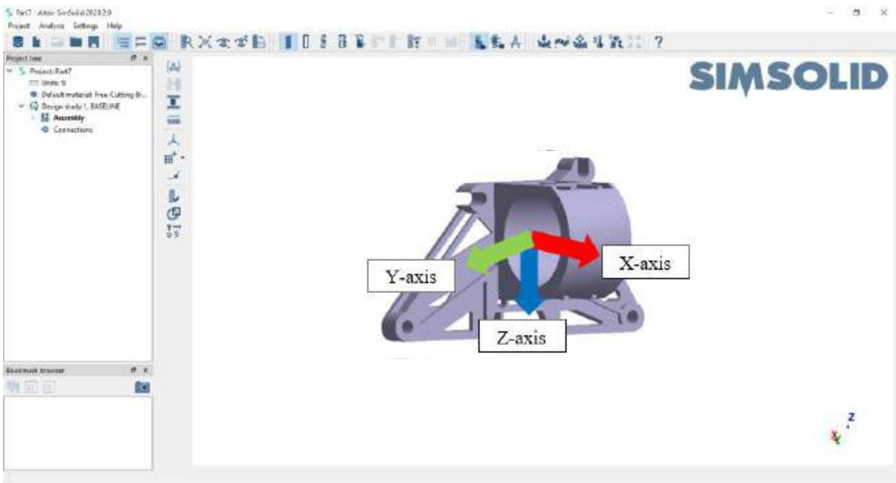



Figure 3.13 CAD file imported in SIMSOLID

3. Click the Assembly in project tree and then will show the function at beside the project tree is shown in Figure 3.8.

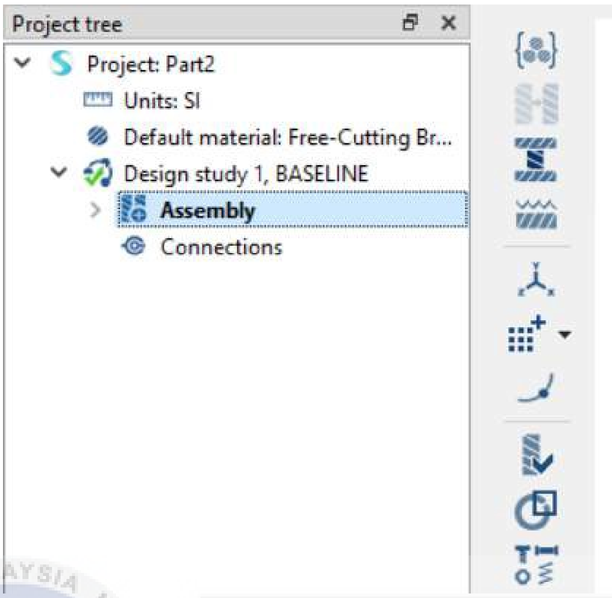



Figure 3.14 To set up the apply materials

4. Click to apply  materials such as Aluminium Al6061-T6 and Magnesium alloy > apply to all parts > click ok to proceed.

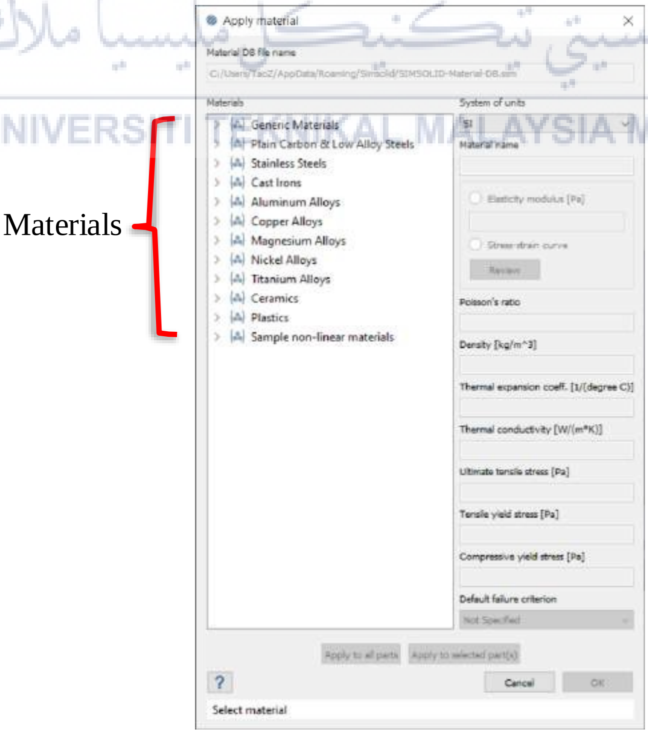



Figure 3.15 Apply Material

5. After applying material, click then select structural linear for analysis. The Structural 1 is shown in the project tree > solution setting change to Adapt to stress

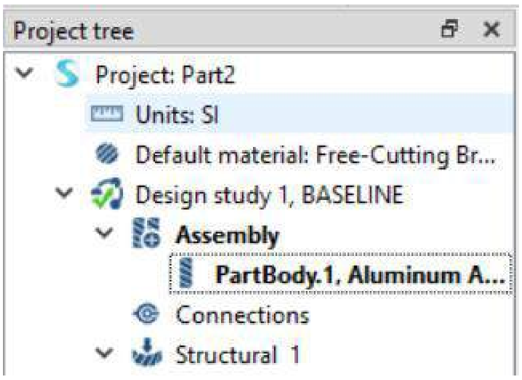



Figure 3.16 Project Tree

6. Apply the immovable support by clicking and apply force to the engine mounting bracket model as shown below.

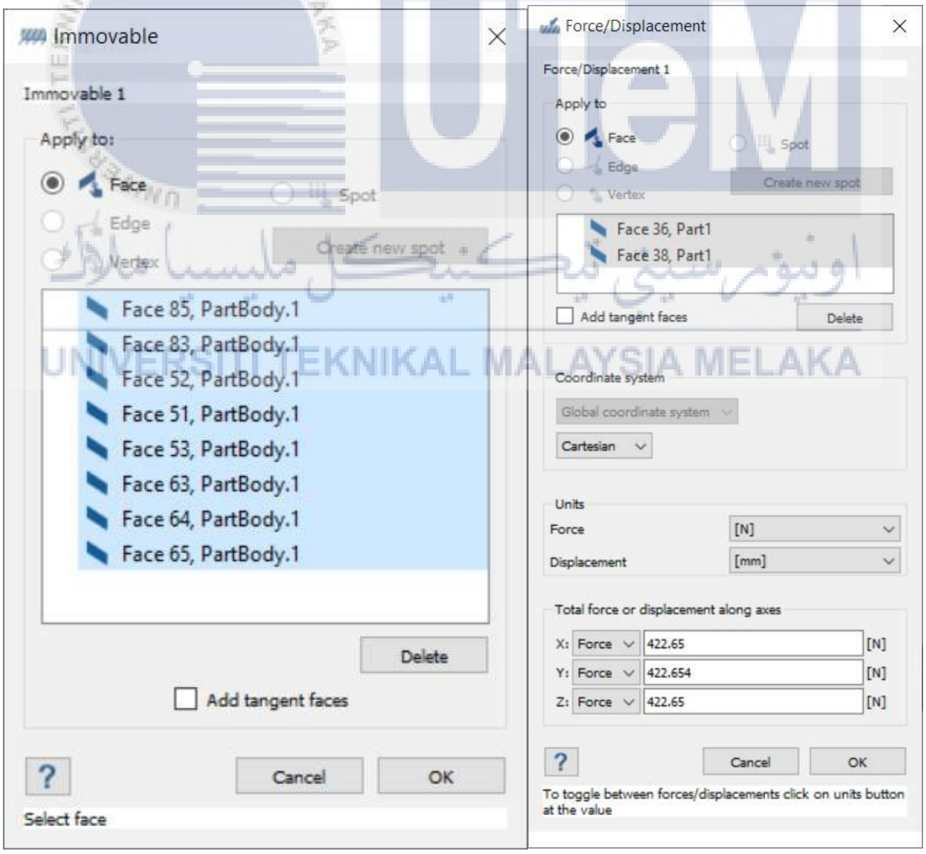




Figure 3.17 Load & Constraints

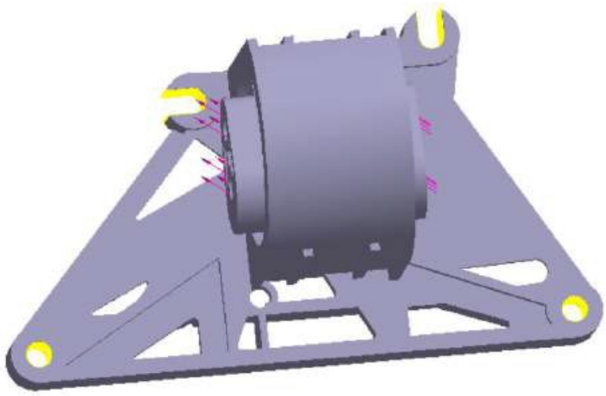


Figure 3.18 Fixed Support on Engine Mounting Bracket

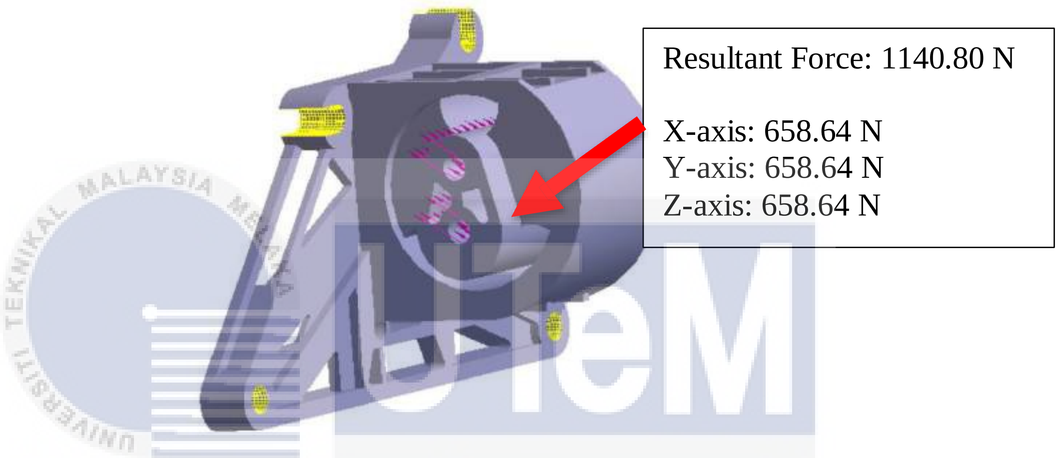



Figure 3.19 Loads in X, Y and Z direction on Engine Mounting Bracket

7. Run Analysis by clicking , the result of maximum stress and displacement will be shown by clicking

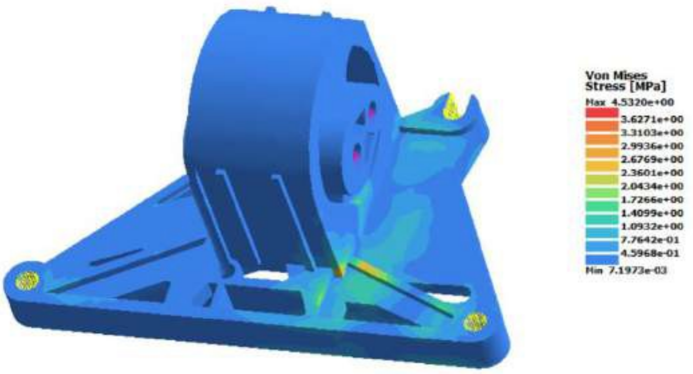



Figure 3.20 Result of Von Mises Stress

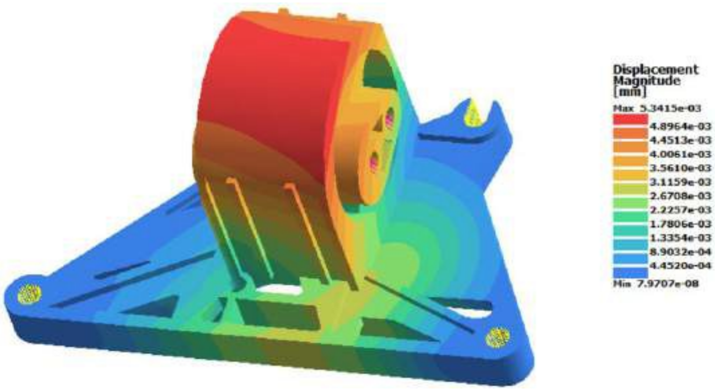



Figure 3.21 Result of Displacement

### 3.4.2.2 Altair INSPIRE

Altair solidThinking Inspire 2019 is a simulation-driven modelling application that enables designers and engineers to create and simulate prototypes (Altair, 2019). It saves a lot of time because the Inspire will take care of everything for the researcher. To minimise weight and raise maximum stress and dispalcement, the based model should go through an optimization procedure with the specified research materials. The Inspire software is available for download on the Altair website.

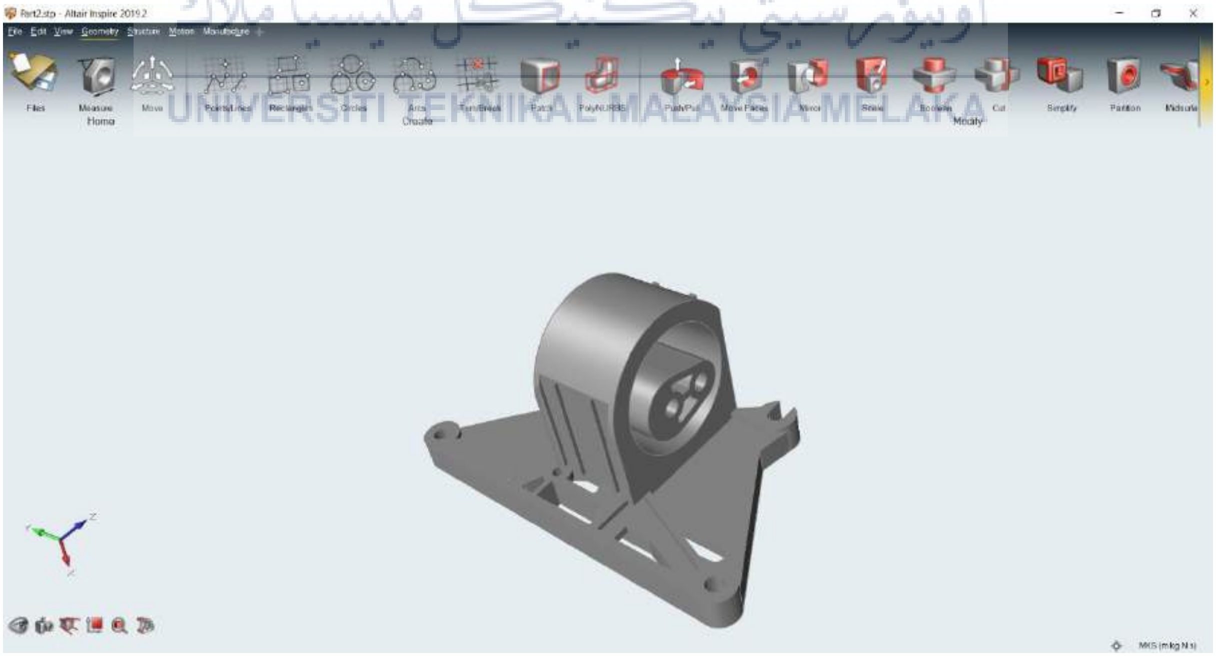


Figure 3.22 Altair INSPIRE

The procedure of using Inspire is provided below.

1. Open Altair INSPIRE software downloaded in the desktop > click  to open the desired file.

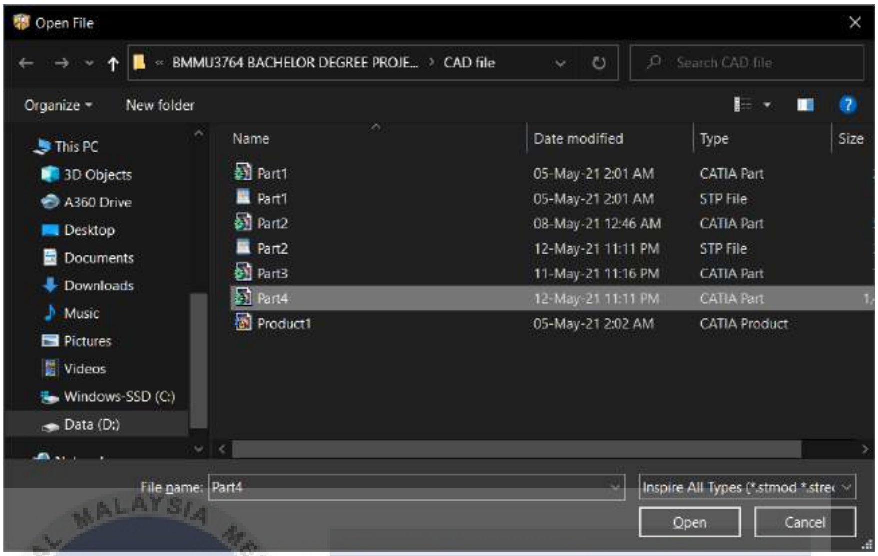



Figure 3.23 Selection of the CAD file

2. Click structure and select material on the top side of the software, then add desired material such as Aluminium alloy (Al6061-T6) to the model,

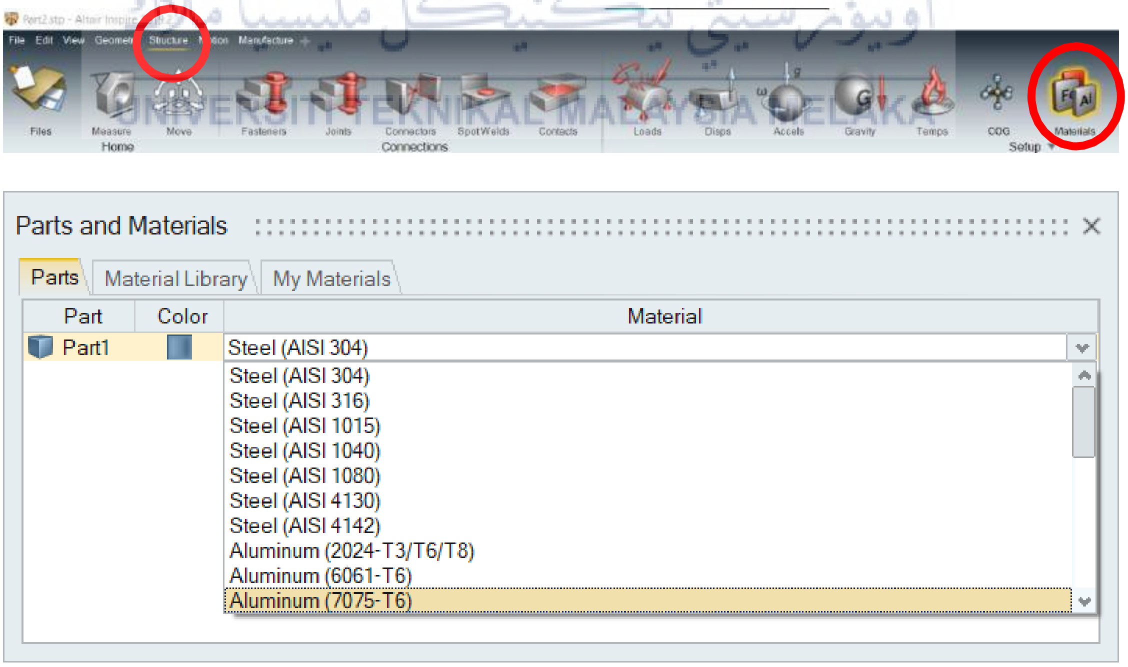



Figure 3.24 Selection of Material

3. Press F2 to show the Model Browser shown on the left side for further checking of load applied, modification and mass. Right click the object and click mass after that click OK then the mass of product will be appear. The mass is reduced as compared to based model engine mounting bracket.

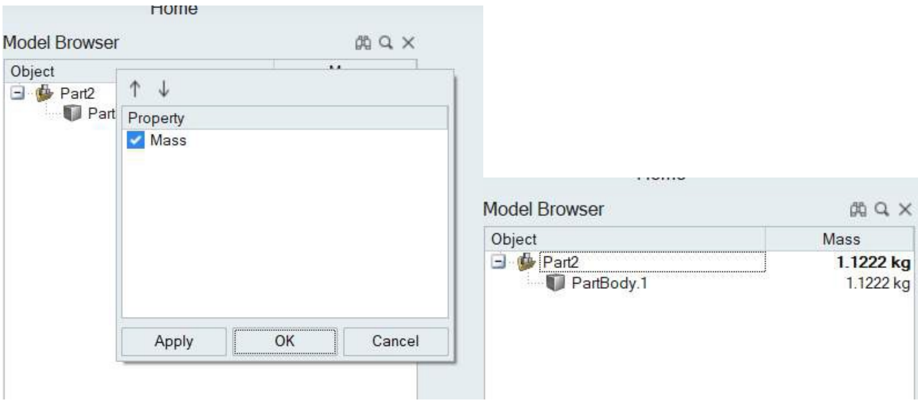



Figure 3.25 Model Browser

4. Select all the screw holes to apply partition, to make sure doesn't effect after the optimization then right click the model to create design space.

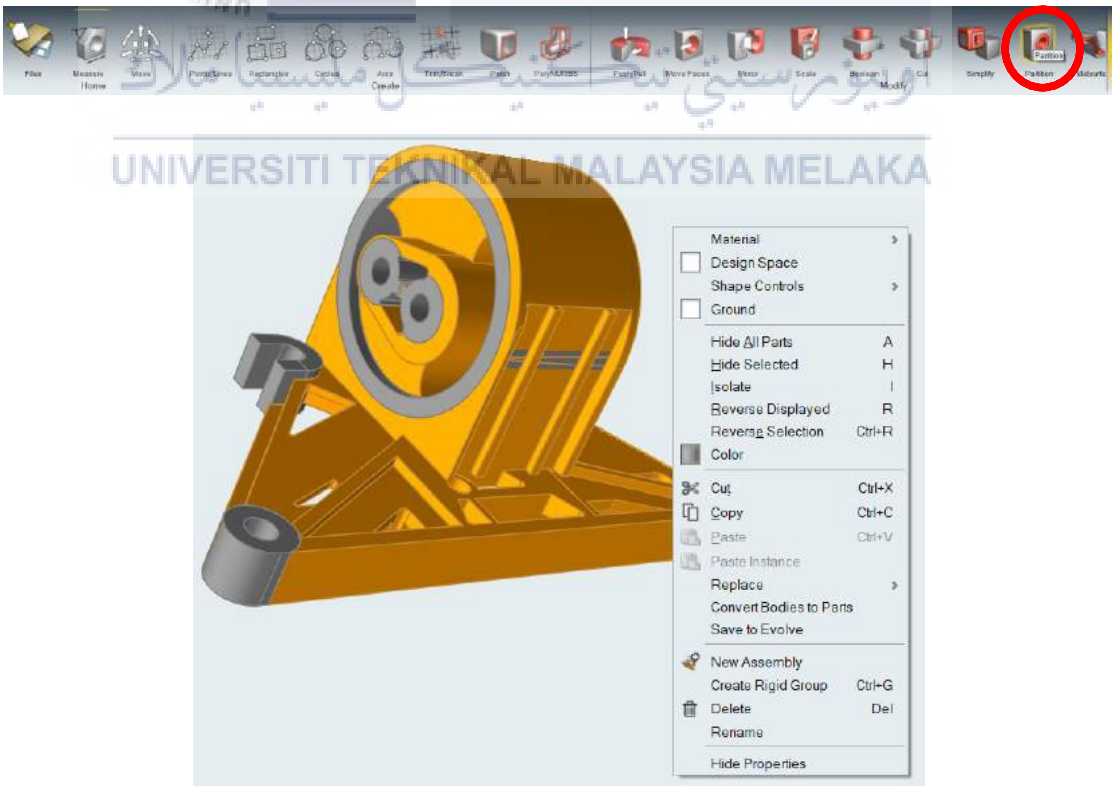



Figure 3.26 Partition to All Holes

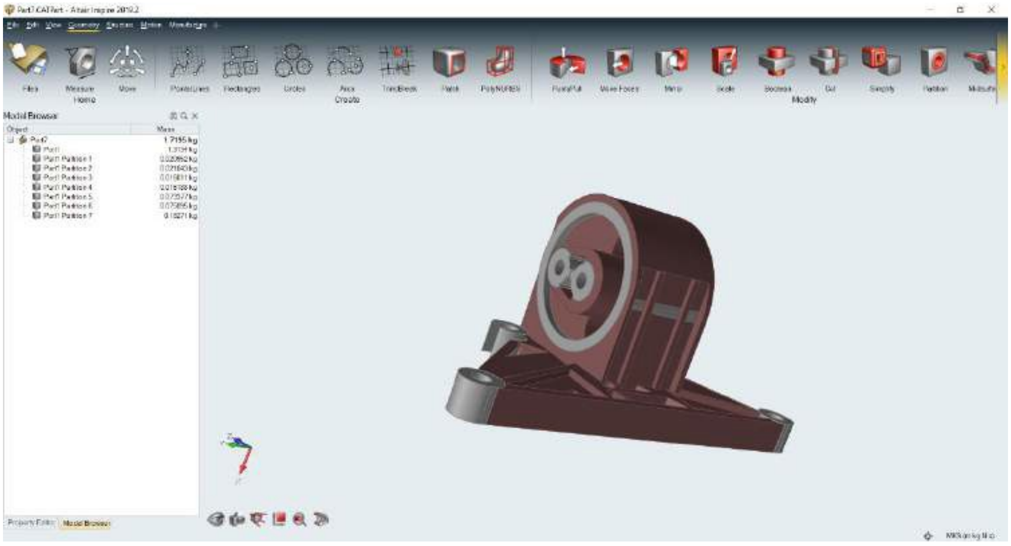


Figure 3.27 Design Space

5. Apply load such as forces on X, Y, Z axes moment to the engine mounting bracket to check for the maximum stress and displacement for modification later.

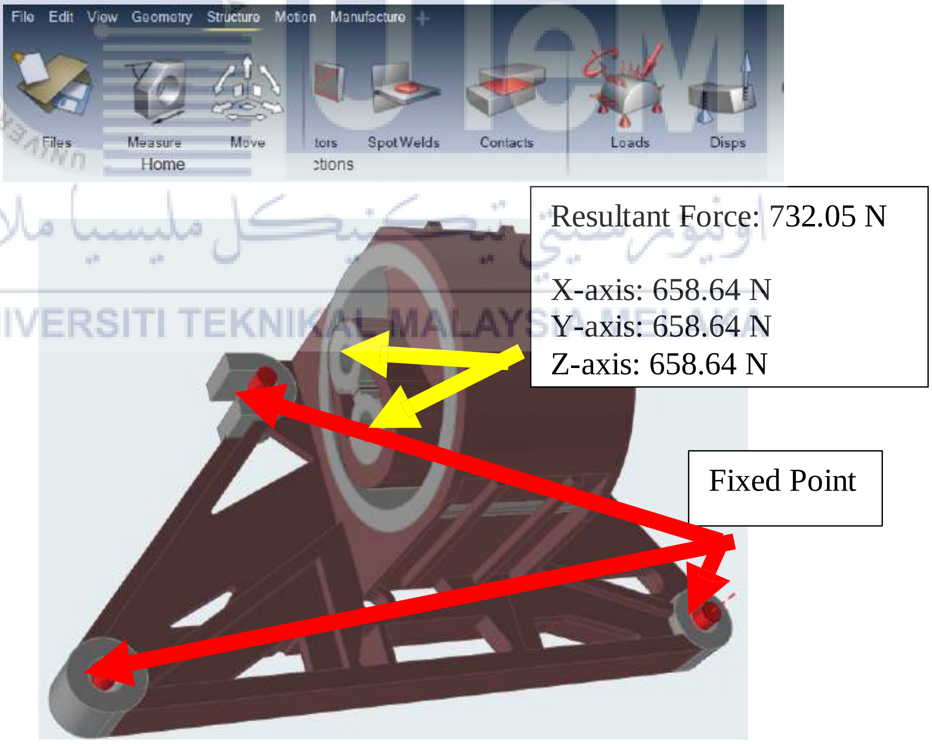



Figure 3.28 Load on the Engine Mounting Bracket

6. Apply Shape Control to the engine mounting bracket.

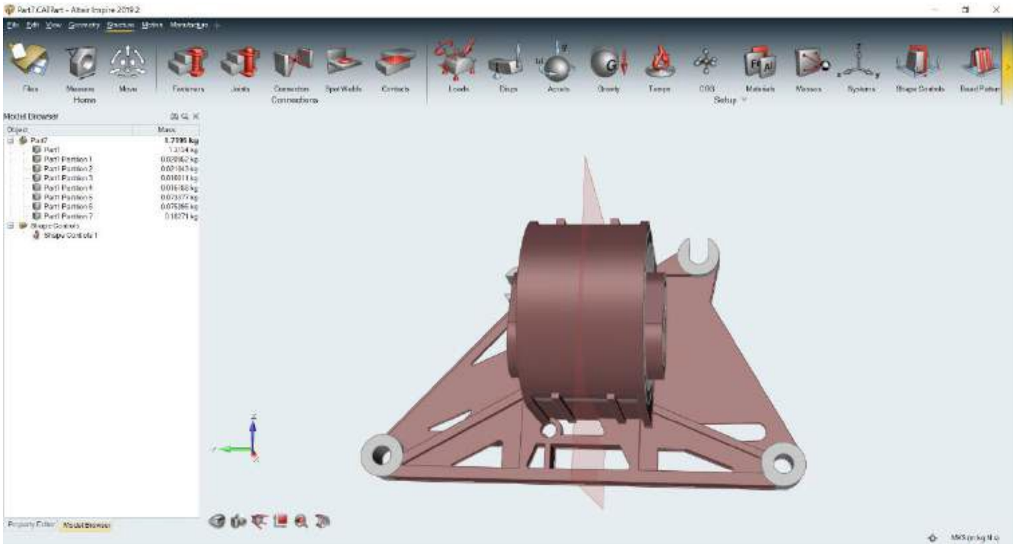


Figure 3.29 Shape Control

7. Select the Optimize tool and then rename the model part before starting the optimization process. Next, choose the maximum stiffness for topology and then choose the percentage of weight reduction. Last, click the run button to run the optimization.

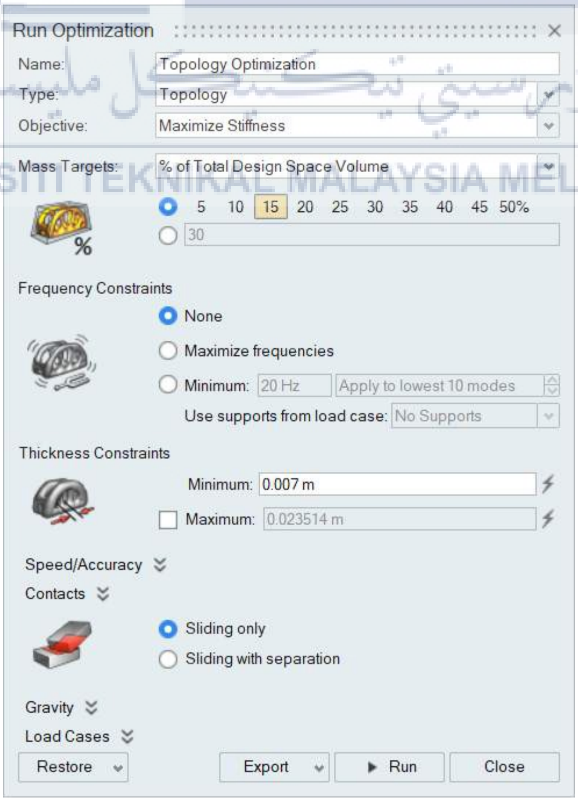



Figure 3.30 Optimize Tool

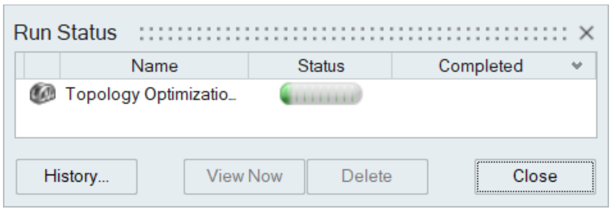



Figure 3.31 Topology Optimization Run Status

8. The optimize model is shown and the weight is reduced.

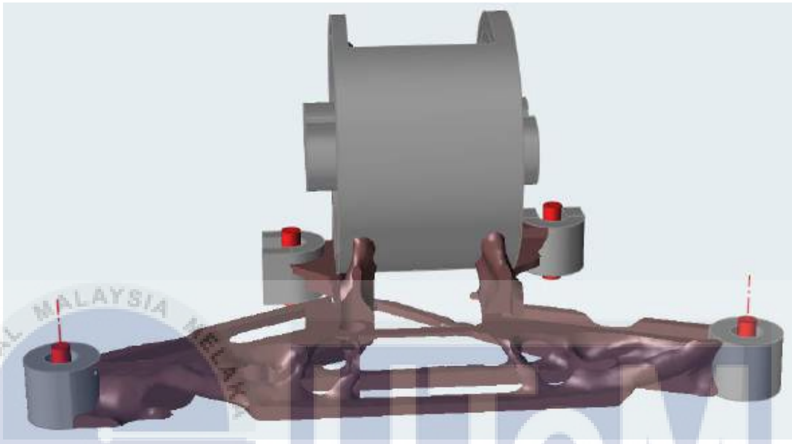


Figure 3.32 Optimize Model

9. Select fit polyNURBS to wrap the model for manufacture ability and aesthetic value. The weight of the optimized model is shown and compared to the based model.



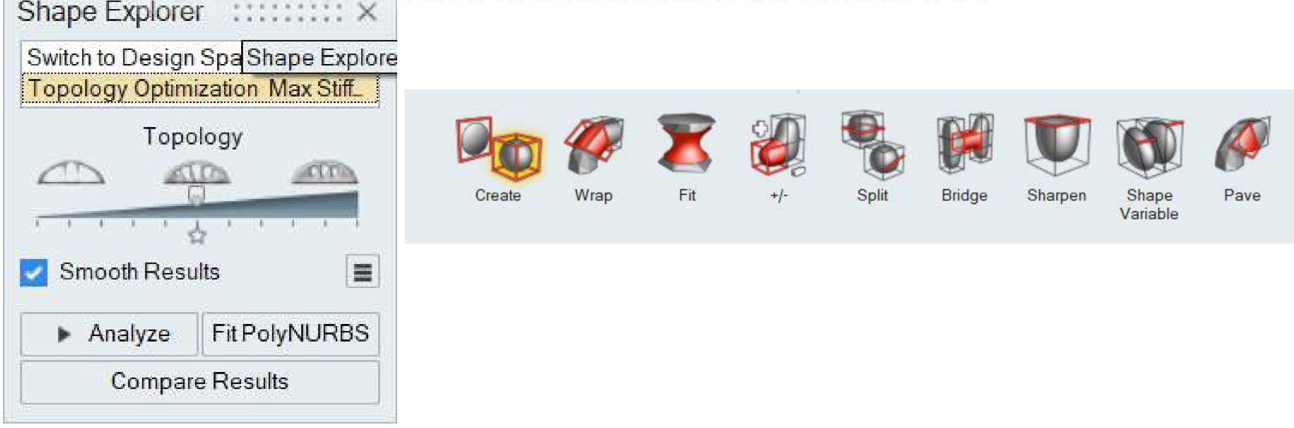



Figure 3.33 Fit PolyNURBS

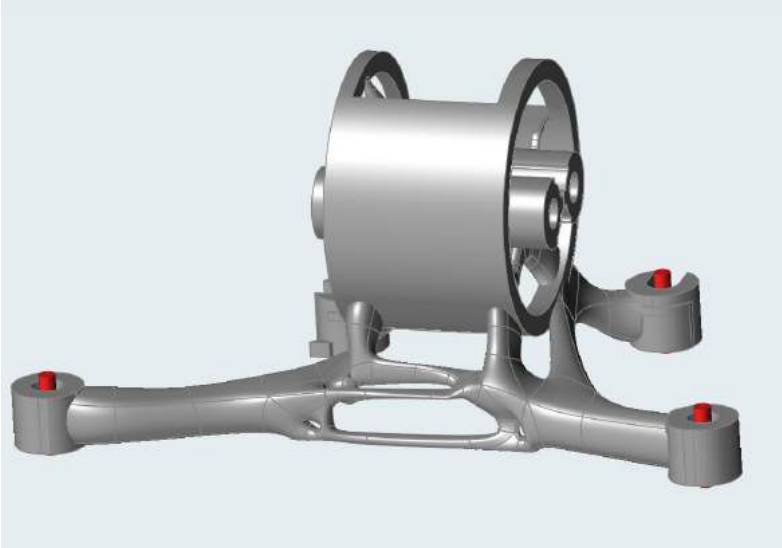


Figure 3.34 Optimized model after wrapping process

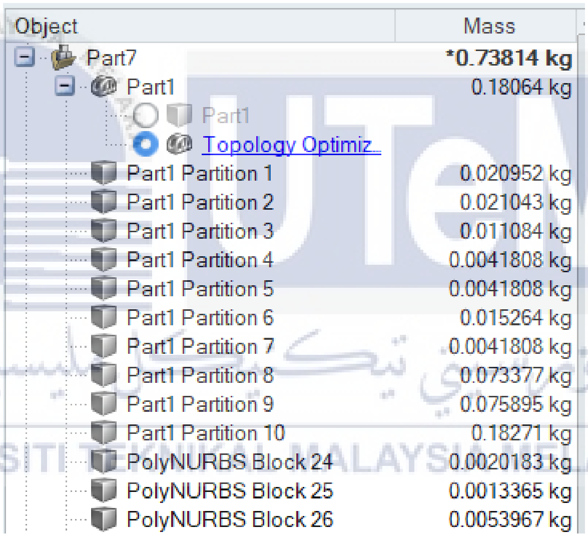



Figure 3.35 Weight of Optimized Model

| Engine Mounting Bracket | Weight |
|---|---|
| Based Model | 1.122kg |
| Optimized Model | 0.738kg |

Table 3.1 Weight Comparison

10. After optimization, the optimized model must analyze again using Altair SIMSOLID to get the result on maximum stress and displacement and compare it with the based model engine mounting bracket.

11. In case the based model engine mounting bracket did not meet the requirement of the objective then need to repeat the step 7 to manipulate variable such as the percentage of weight reduction.
12. If the result is meet the research objective requirement, step 1 to 10 is repeat to change the material to magnesium alloy.

## 3.5 Result Data Comparison

The maximum stress and displacement, as well as the weight of the basic model engine mounting bracket and another improved engine mounting brackets, are gathered after the optimization and test analysis procedure. The information gathered will be compared in the below table 3.2 and a more optimised engine mounting bracket will be chosen to replace the basis model engine mounting bracket that meets the researcher's expectations.

| **Material** | **Weight** (kg) | **Weight Reduction (%)** | **Maximum Stress (Mpa)** | **Maximum Displacement (mm)** |
|---|---|---|---|---|
| **Aluminum Al6061-T6 (Based model)** | | | | |
| **Aluminum Al6061-T6 (Optimized)** | | | | |
| **Magnesium AZ31B (Optimized)** | | | | |

Table 3.2 Sample of Result Data

## 3.6 Summary

In a word, the technique employed by the researcher in this thesis began with the remodelling of a market-based model engine mounting bracket. The based model engine mounting bracket was then transferred into a CAD file using the CATIA V5 software, and the maximum stress and maximum displacement were tested using the Altair Simsolid software. The CAD file is then imported into the Altair Inspire software for further optimization and customization of the based model engine mounting bracket as well as the application of various materials. Finally, the optimised engine mounting bracket gets the test analysis stage, which involves using the Altair Simsolid software to determine maximum stress and maximum displacement. These findings will be discussed in order to determine which design and material are best to apply to the engine mounting when compared to the market-based model engine mounting bracket. The flowchart in Figure 3.1 contains all of the stages for the whole process.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Introduction

The results and analyses of the development of topology optimization of vehicle engine mounting bracket are presented in this chapter. The real engine mounting bracket purchased on the market is rendered into CAD format using the CATIA V5 software, with a design pattern and weight that are 95% identical to the genuine item. The first stage involves creating a CAD model of the engine mounting bracket with CATIA software and integrating it into the Altair SIMSOLID geometry. The Altair SIMSOLID software was used to analyze the engine mounting bracket. Later, the optimization procedure for the based model engine mounting bracket was carried out using Altair Inspire using two alternative types of materials: magnesium alloy AZ31B and aluminum alloy Al6061-T6. If the results and analysis from the Altair SIMSOLID are suitable for usage, the optimum optimization will be chosen. In Figure 4.2, the result and analysis of the based model engine mounting bracket, as well as the optimized engine mounting bracket, are displayed.

## 4.2 Result and Analysis of Optimization Engine Mounting Bracket

### 4.2.1 Based Model Engine Mounting Bracket (Al-6061 T6)

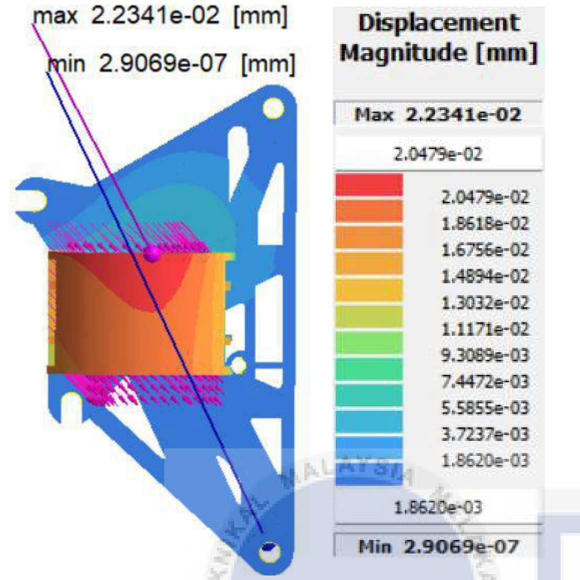
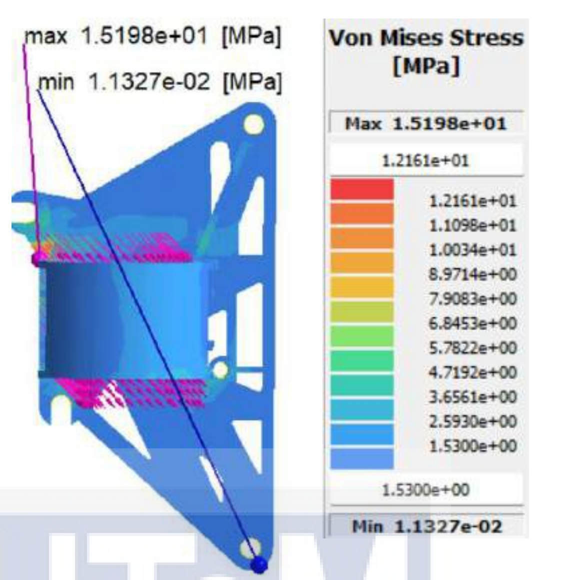
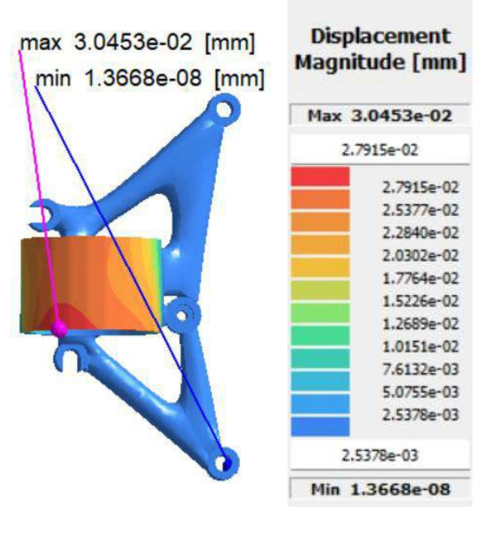
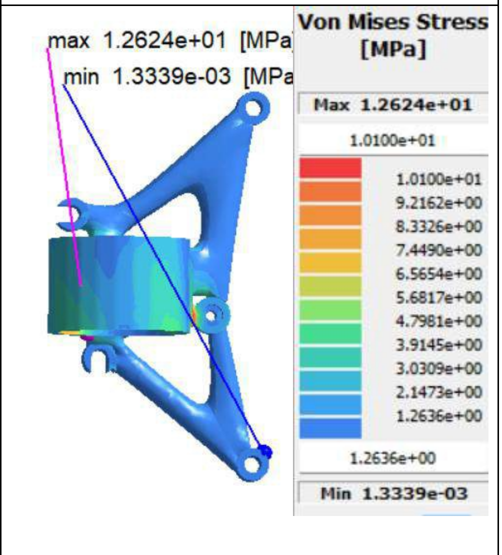
| Displacement | Stress |
|---|---|
|  |  |

Table 4.1 Maximum Stress and Displacement of Based Model Engine Mounting Bracket (Al6061 - T6)

### 4.2.2 Result of Optimization Engine Mounting Bracket

**a) Weight Reduction of Al6061-T6**

| Weight Reduction (%) | Displacement | Stress |
|---|---|---|
| 10 |  |  |

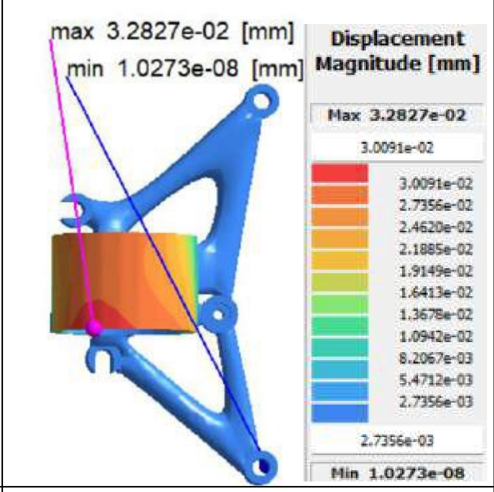
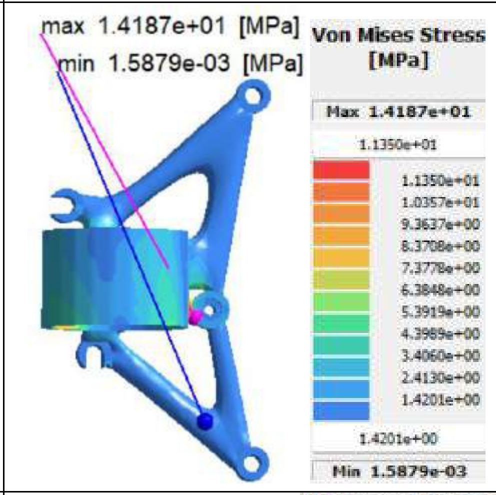
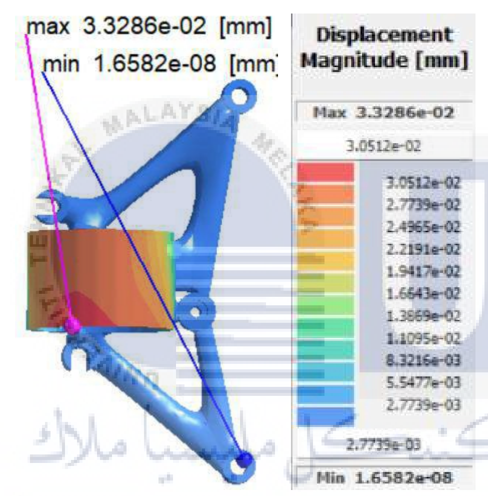
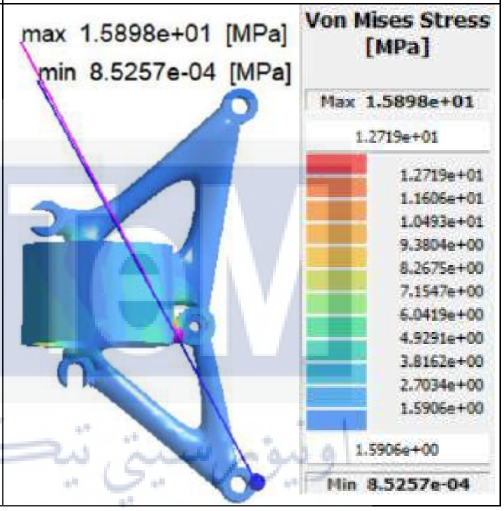
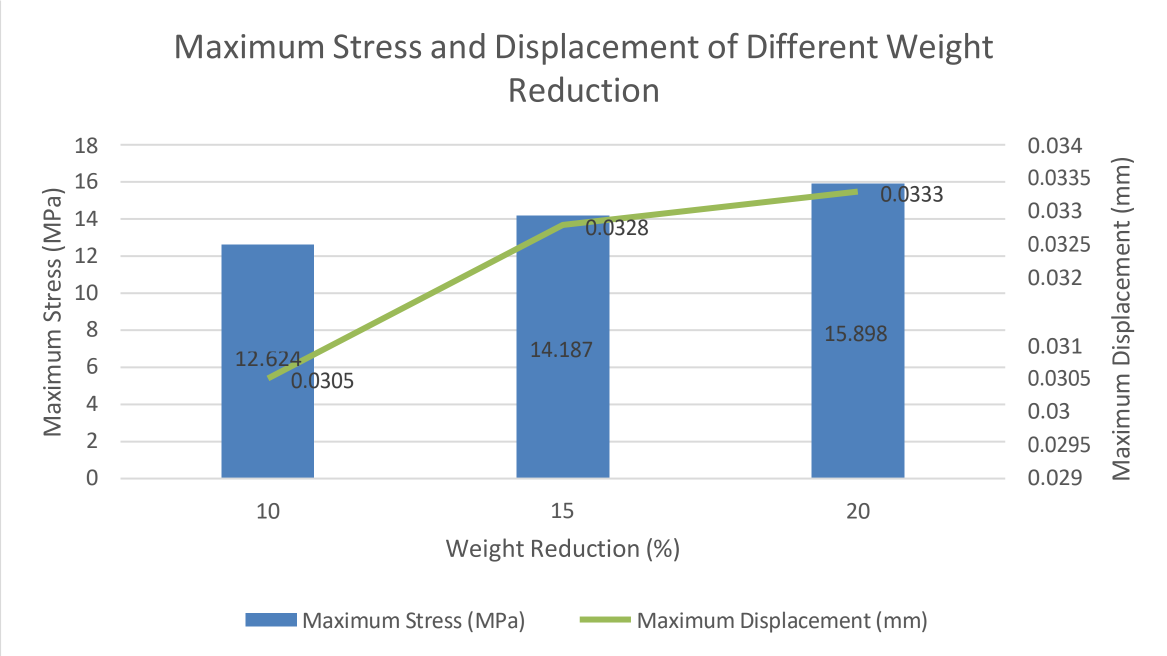
<table>
<tr><th>Weight Reduction (%)</th><th>Displacement</th><th>Stress</th></tr>
<tr><td>15</td><td>
</td><td>
</td></tr>
<tr><td>20</td><td>
</td><td>
</td></tr>
</table>

Table 4.2 Maximum Stress and Displacement of Al 6061-T6 Weight Reduction



| Weight Reduction (%) | Weight (kg) | Maximum Stress (MPa) | Maximum Displacement (mm) |
|---|---|---|---|
| 10 | 0.992 | 12.624 | 3.0453E-02 |
| 15 | 0.935 | 14.187 | 3.2827E-02 |
| 20 | 0.880 | 15.898 | 3.3286E-02 |

Table 4.3 Result of Weight Reduction (Al 6061-T6)



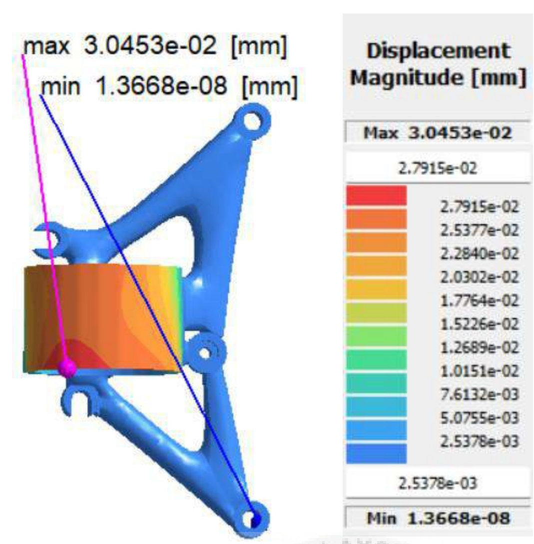

Graph 4.1 Graph of Maximum Stress and Displacement of Different Weight Reduction (Al 6061-T6)

In graph 4.1, the maximum stress for a 10% weight reduction is lower than in the others. The maximum displacement, on the other hand, is larger, suggesting a lengthening of more than 15% and a weight reduction of more than 20%. As a result, weight savings of 15% and 20% in Al 6061-T6 are unacceptably small for comparison. A 10% weight reduction of Al 6061-T6 is used to compare since the maximum displacement is the lowest among the others and the maximum stress is quite comparable to the basic model engine mounting bracket.

## b) 10% Weight Reduction Comparison of Different Materials

Al 6061 – T6

**Displacement**




**Stress**

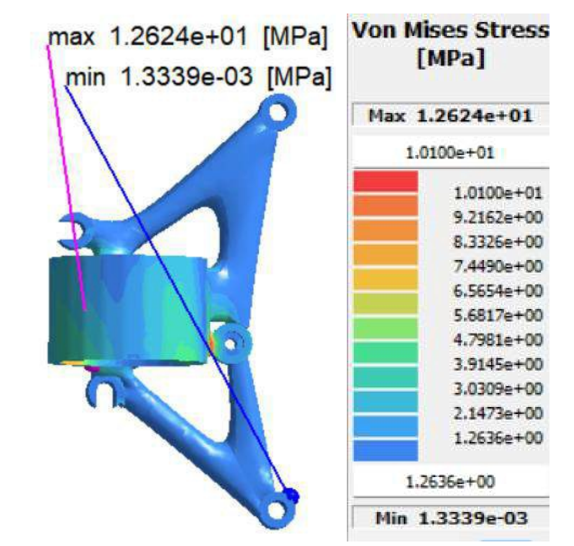
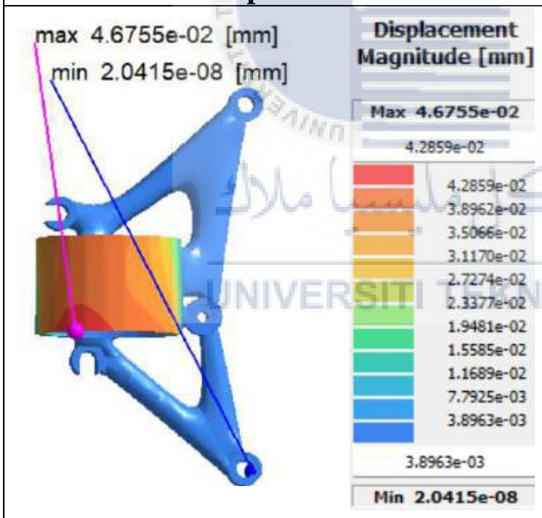



Table 4.4 Maximum Stress and Displacement of Al 6061 - T6 (weight reduction 10%)

AZ31B - Extruded

**Displacement**




**Stress**

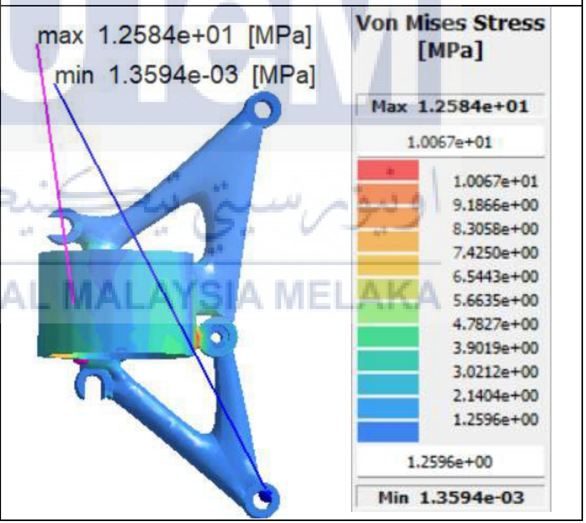



Table 4.5 Maximum Stress and Displacement of AZ31B (weight reduction 10%)

A536

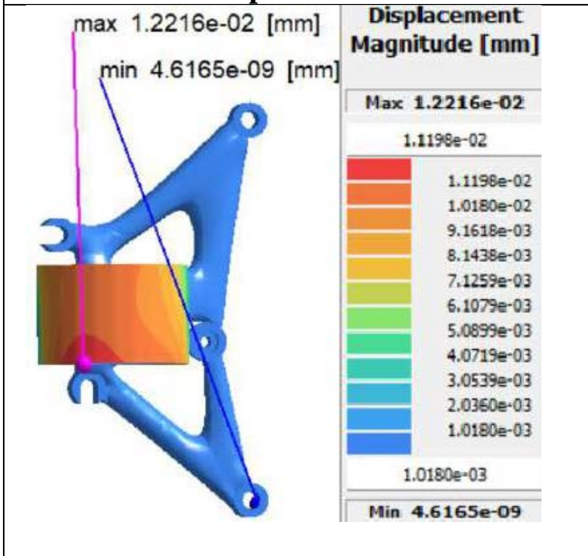
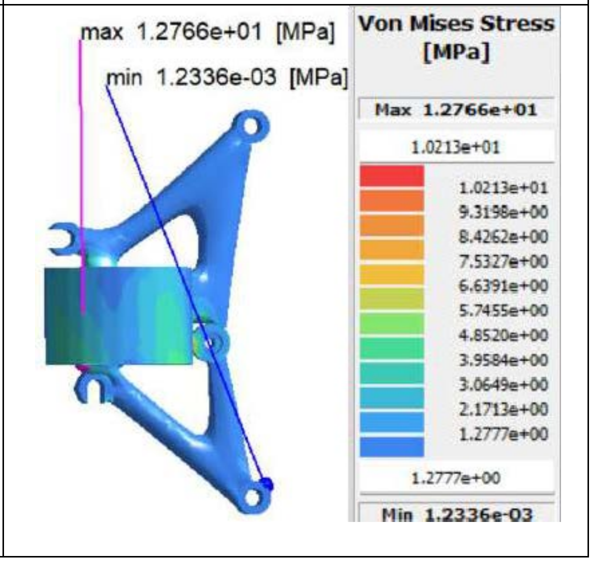
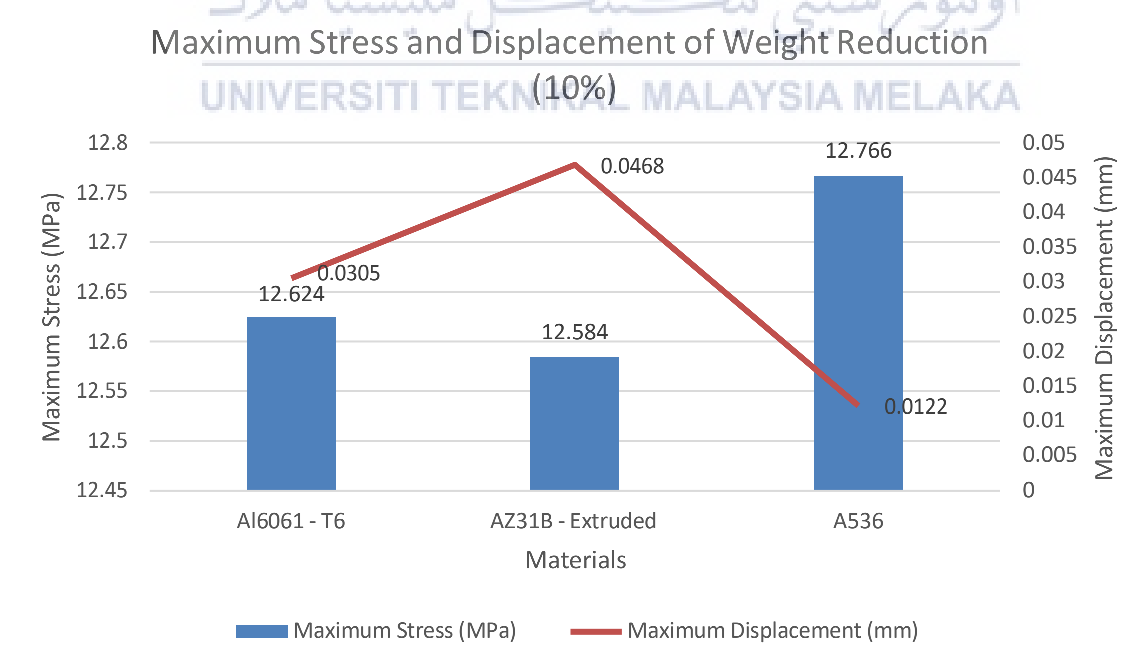
| Displacement | Stress |
|---|---|
|   |   |

Table 4.6 Maximum Stress and Displacement of A536 (weight reduction 10%)

| Material | Weight (kg) | Yield Stress (MPa) | Maximum Stress (MPa) | Maximum Displacement (mm) |
|---|---|---|---|---|
| Al6061-T6 | 0.992 | 276 | 12.624 | 3.0453E-02 |
| AZ31B - Extruded | 0.655 | 200 | 12.584 | 4.6755E-02 |
| A536 | 2.382 | 345 | 12.766 | 1.2216E-02 |

Table 4.7 Result of 10% Weight Reduction






Graph 4.2 Maximum Stress and Displacement of Weight Reduction (10%)

**c) 15% Weight Reduction Comparison of Different Materials**

Al 6061 – T6

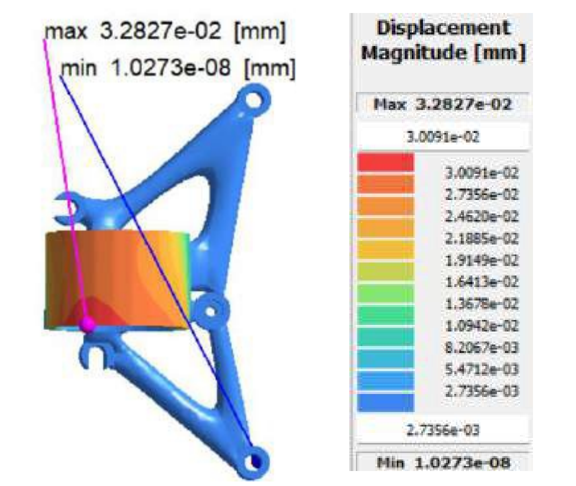
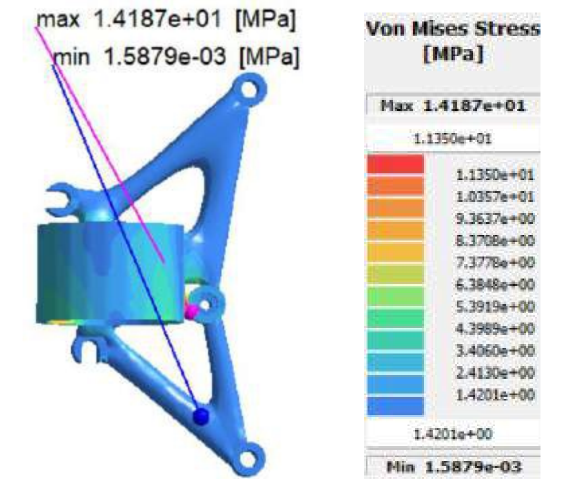
<table>
<tr><th>Displacement</th><th>Stress</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 4.8 Maximum Stress and Displacement of Al 6061 - T6 (weight reduction 15%)

Magnesium AZ31B - Extruded

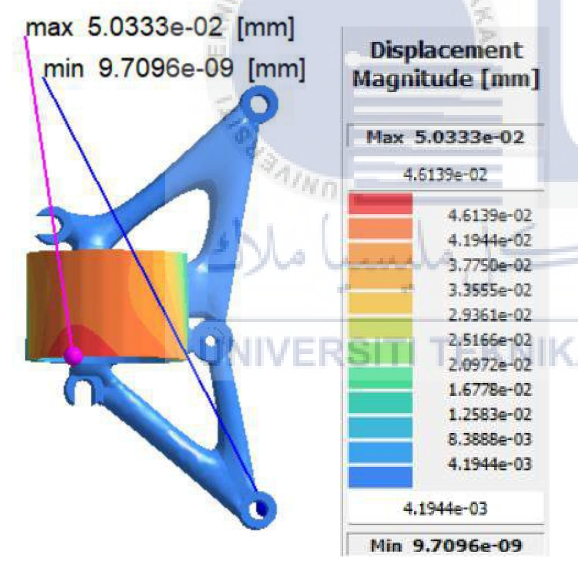
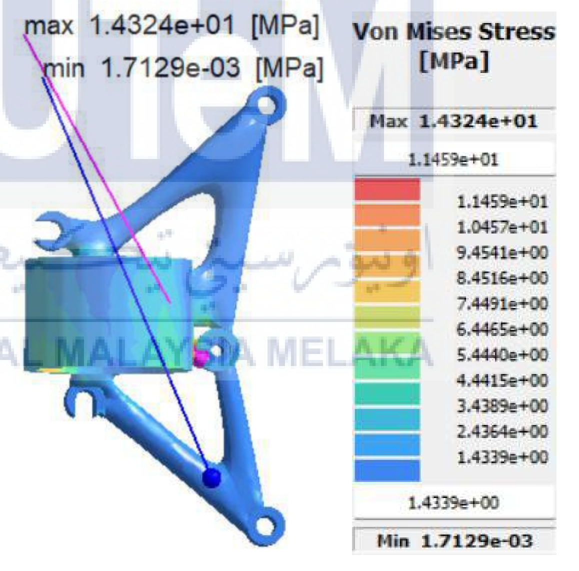
<table>
<tr><th>Displacement</th><th>Stress</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 4.9 Maximum Stress and Displacement of AZ31B (weight reduction 15 %)

A536

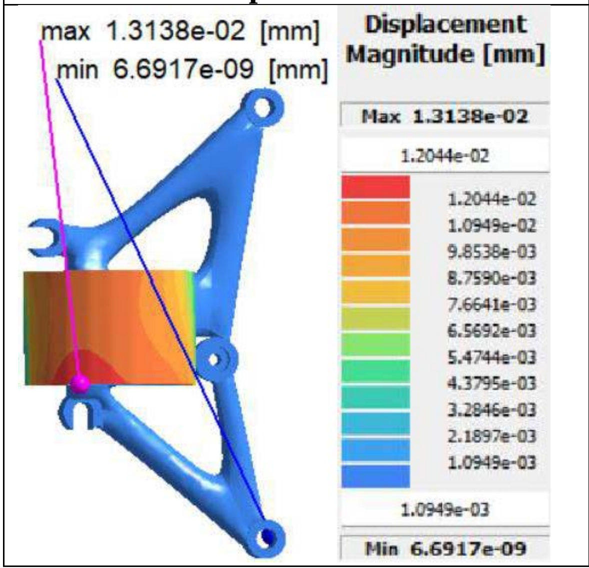
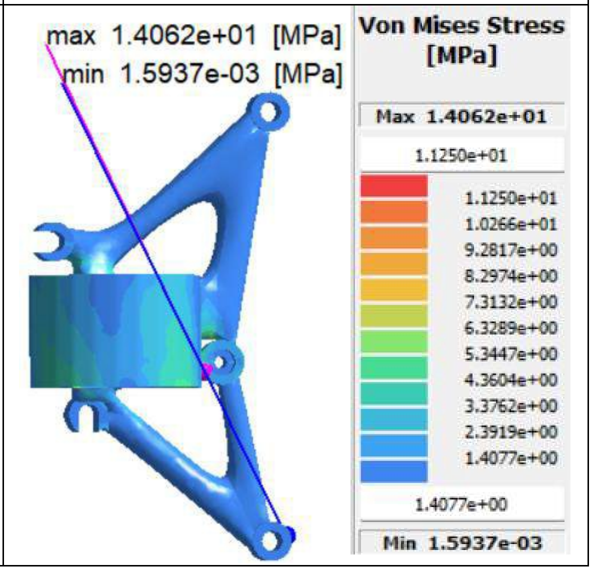
| Displacement | Stress |
|---|---|
|  |  |

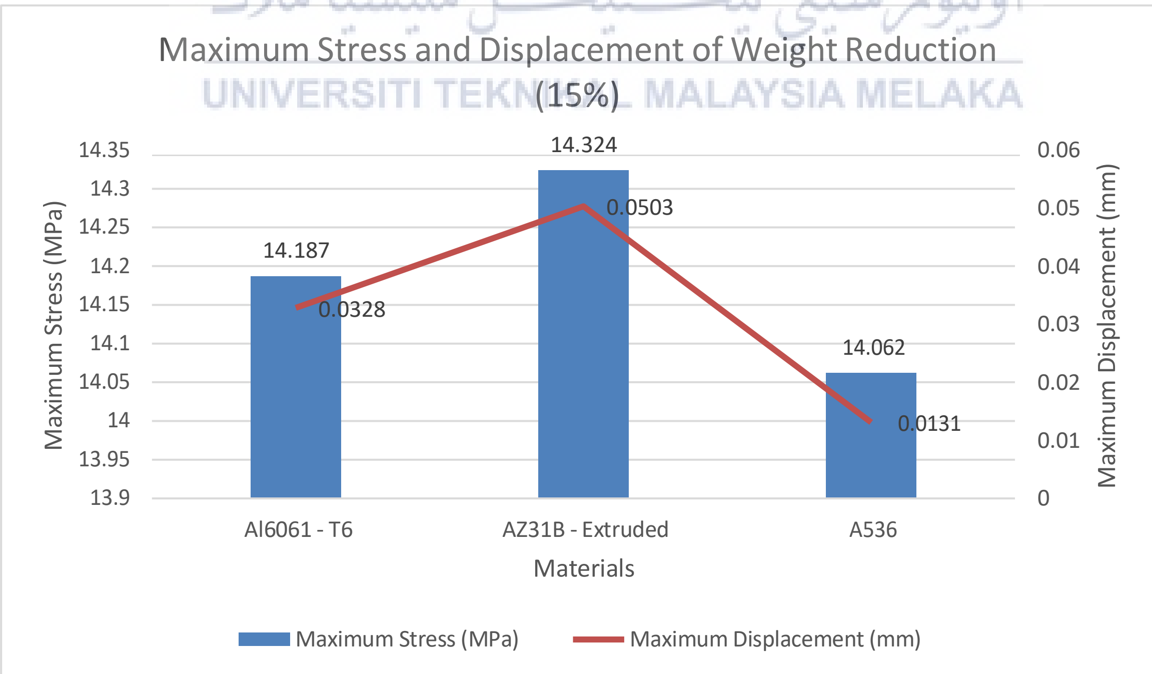


Table 4.10 Maximum Stress and Displacement of A536 (weight reduction 15%)

| Material | Weight (kg) | Yield Stress (MPa) | Maximum Stress (MPa) | Maximum Displacement (mm) |
|---|---|---|---|---|
| Al6061-T6 | 0.935 | 276 | 14.187 | 3.2827E-02 |
| AZ31B - Extruded | 0.613 | 200 | 14.324 | 5.0333E-02 |
| A536 | 2.231 | 345 | 14.062 | 1.3138E-02 |

Table 4.11 Result of 15% Weight Reduction






Graph 4.3 Maximum Stress and Displacement of Weight Reduction (15%)

## d) 20% Weight Reduction Comparison of Different Materials

Al 6061 – T6

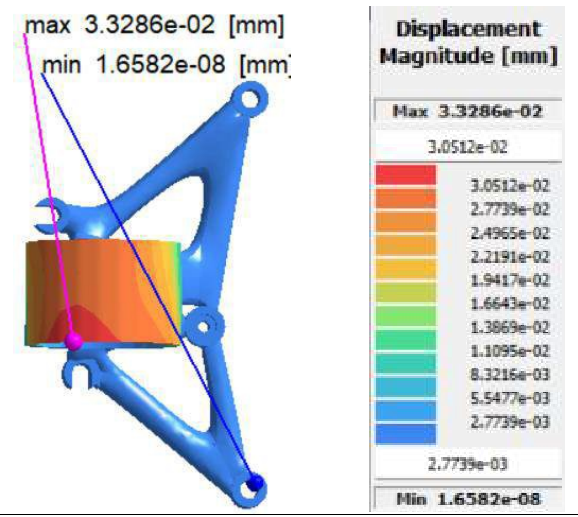
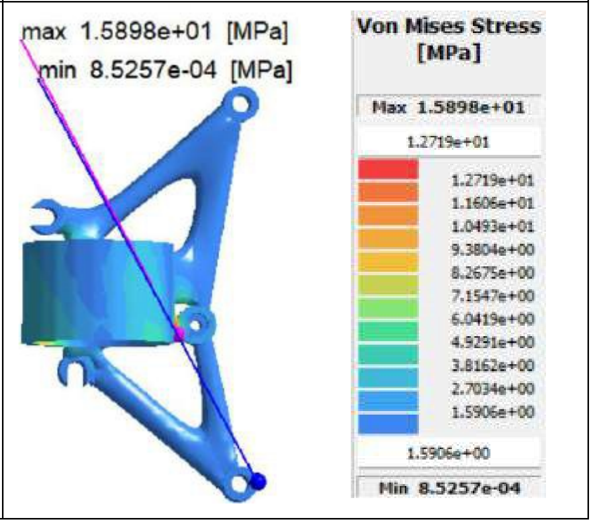
<table>
<tr><th>Displacement</th><th>Stress</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 4.12 Maximum Stress and Displacement of Al 6061 - T6 (weight reduction 20%)

Magnesium AZ31B - Extruded

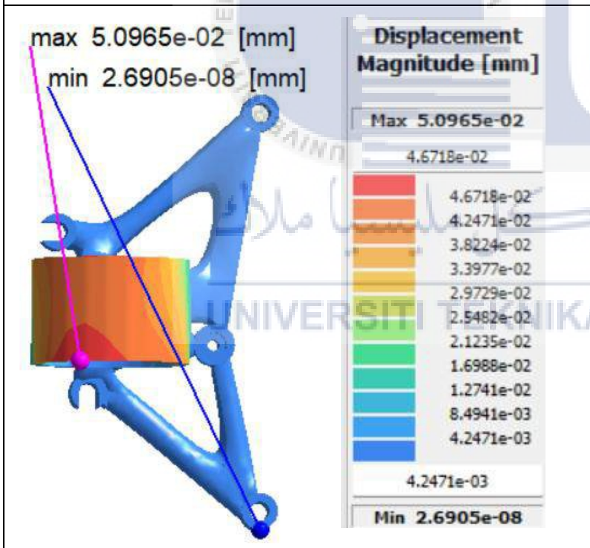
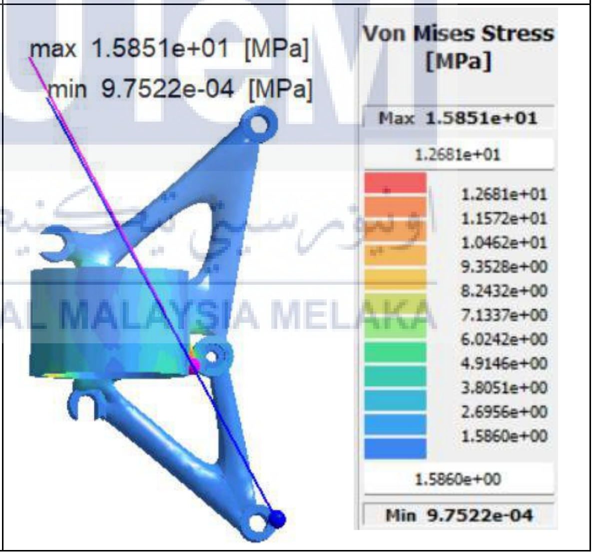
<table>
<tr><th>Displacement</th><th>Stress</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 4.13 Maximum Stress and Displacement of AZ31B (weight reduction 20%)

A536

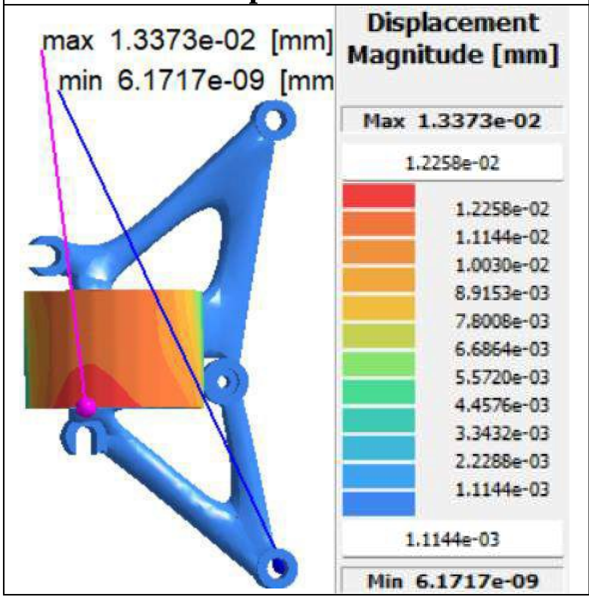
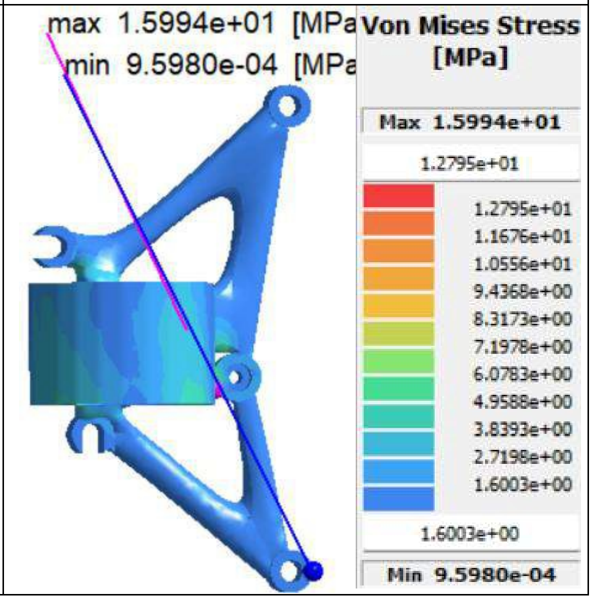
| Displacement | Stress |
|---|---|
|  |  |

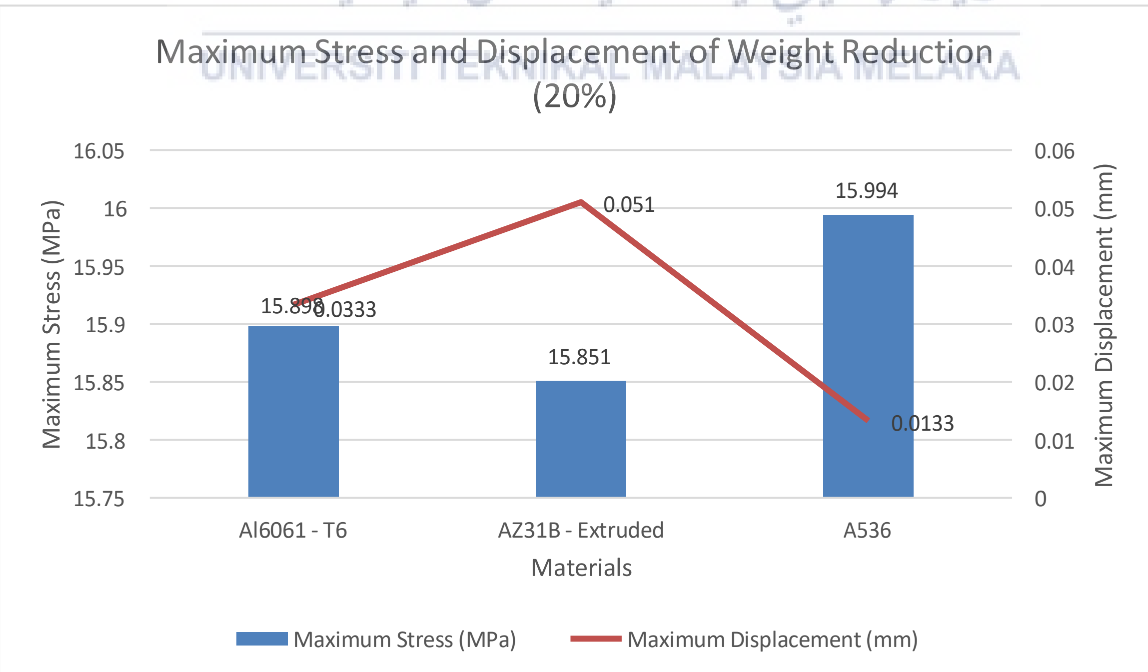


Table 4.14 Maximum Stress and Displacement of A536 (weight reduction 20%)

| Material | Weight (kg) | Yield Stress (MPa) | Maximum Stress (MPa) | Maximum Displacement (mm) |
|---|---|---|---|---|
| Al6061-T6 | 0.880 | 276 | 15.898 | 3.3286E-02 |
| AZ31B - Extruded | 0.576 | 200 | 15.851 | 5.0965E-02 |
| A536 | 2.097 | 345 | 15.994 | 1.3373E-02 |

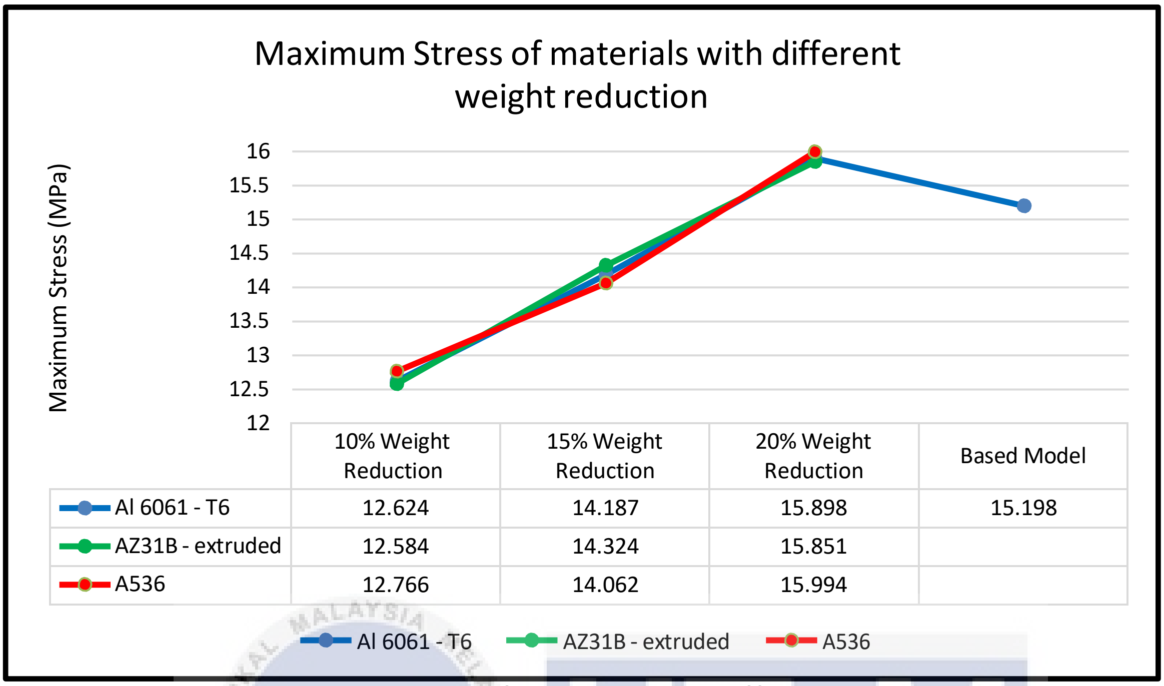
Table 4.15 Result of 20% Weight Reduction






Graph 4.4 Maximum Stress and Displacement of Weight Reduction (20%)

### 4.2.3 Comparison Result for 10%, 15% and 20% Weight Reduction




Graph 4.5 Maximum Stress of Materials with Different Weight Reduction

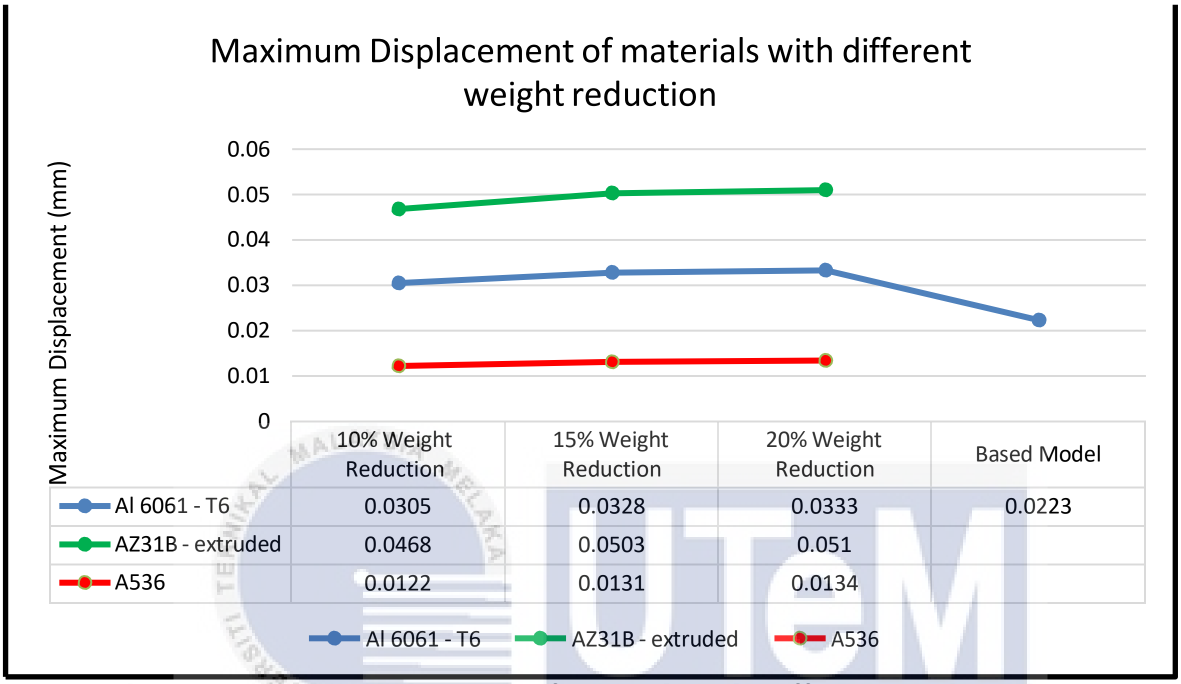
Based on Graph 4.5, the researcher compared the maximum stress of A536, Al6061-T6 and AZ31B-Extruded is approximately identical. But, the maximum stress of Gray Cast Iron A536 is slight higher compare with Al6061-T6 and AZ31B-Extruded. At 10% weight reduction, the maximum stress of Al6061-T6, AZ31B-Extruded and A536 is 12.624MPa, 12.584MPa and 12.766MPa respectively. As a consequence, a 10% weight reduction as the first consideration is the best optimization for three materials.

$$\left| \frac{\text{[illegible]} - \text{[illegible]}}{\text{[illegible]}} \right| \times 100\%$$

$$= \left| \frac{15.198 - 12.624}{15.198} \right| \times 100\% = 16.94\%$$

| Materials | Percentage of maximum stress reduction (%) |
|---|---|
| Al 6061-T6 | 16.94 |
| AZ31B | 17.20 |
| A536 | 16.00 |

Table 4.16 The percentage of maximum stress at 10% of weight reduction for each materials




Graph 4.6 Maximum Displacement of Materials with Different Weight Reduction

When it comes to maximum displacement, as shown in Graph 4.6, for materials AZ31B is slight higher than Al 6061 – T6 and A536. But for materials A536, Al 6061 – T6 and AZ31B is a slight increase after weight reductions of 10%, 15%, and 20%, with the value rising from 0.0305 mm to 0.0333 mm. From a 10% weight loss to a 20% weight loss, the maximum displacement trend continues to rise. A536, Al6061-T6 and AZ31B-extruded optimizations with a 10% weight reduction were chosen as a consequence. As a result, for Al6061-T6 and A536, the ideal optimization is a 10% weight reduction, which has better maximum stress and displacement to the other weight reduction percentages.

### 4.2.4 Shape Comparison

#### 4.2.4.1 Al6061-T6

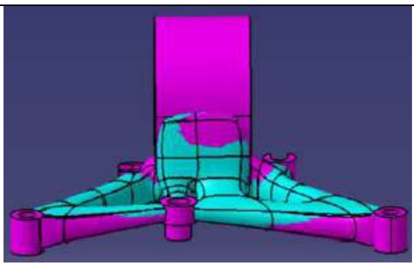
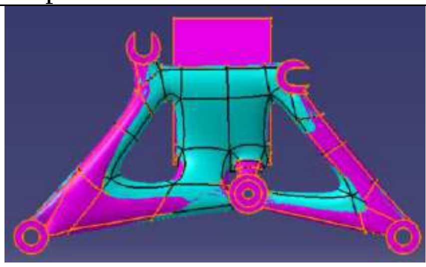
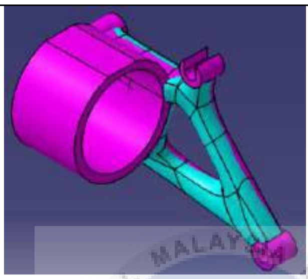
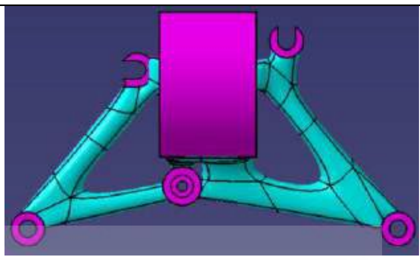
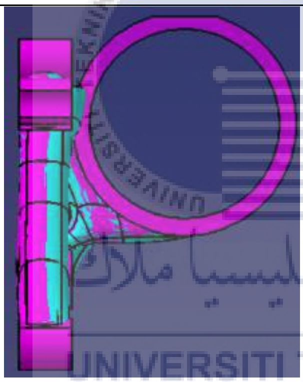
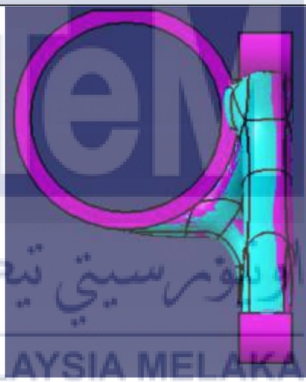
| 10% and 15% Shape Comparison | |
|---|---|
|  Bottom View |  Back View |
|  Isometric View |  Front View |
|  Left View |  Right View |
| 10% of weight reduction – blue color<br>15% of weight reduction – purple color | |

Table 4.17 Shape Comparison of Al6061-T6

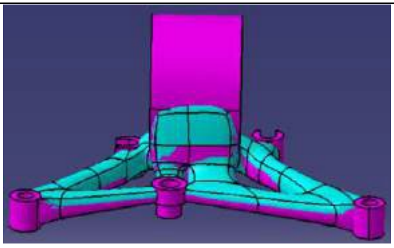
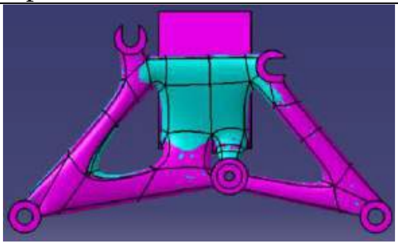
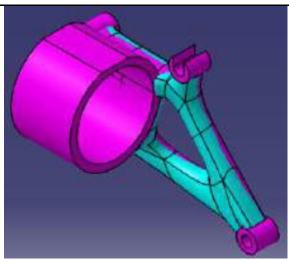
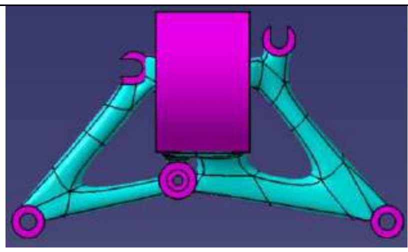
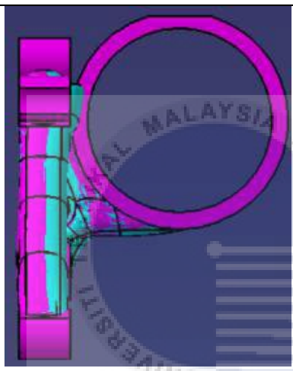
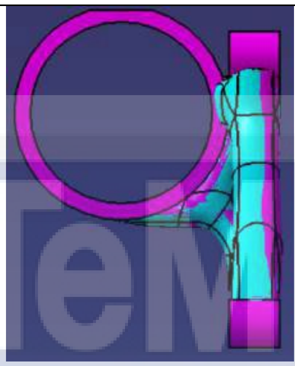
| 15% and 20% Shape Comparison | |
|---|---|
|  Bottom View |  Back View |
|  Isometric View |  Front View |
|  Left View |  Right View |
| 15% of weight reduction – blue color<br>20% of weight reduction – purple color | |

Table 4.18 Shape Comparison of Al6061-T6



Based on above table it clearly show the differences shape betweeen 3 percentages of weight reduction. For example, blue color is lower weight reduction it means need using more materials so that the above table shown the blue is more thicker compare with purple color. So part doesn’t show the blue color is because it overlap with purple color.

#### 4.2.4.2 AZ31B-Extruded

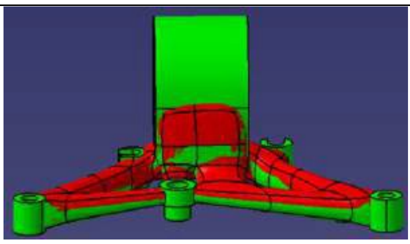
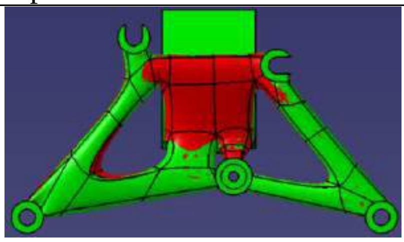
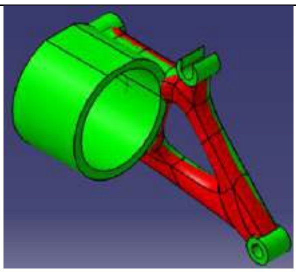
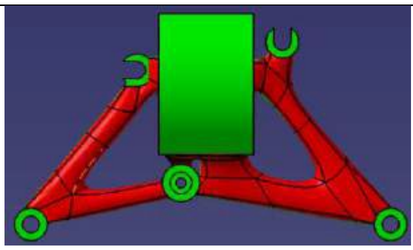
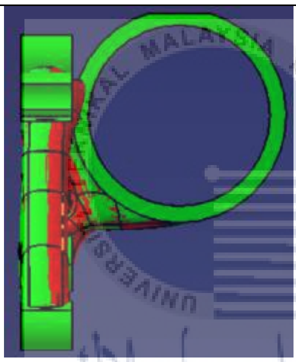
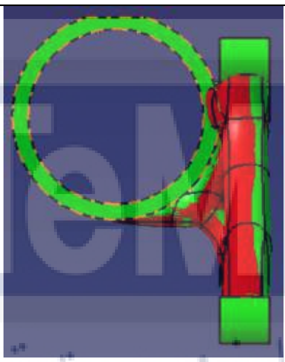
| 10% and 15% Shape Comparison | |
|---|---|
| <br>Bottom View | <br>Back View |
| <br>Isometric View | <br>Front View |
| <br>Left View | <br>Right View |
| 10% of weight reduction – red color<br>15% of weight reduction – green color | |

Table 4.19 Shape Comparison of AZ31B-Extruded

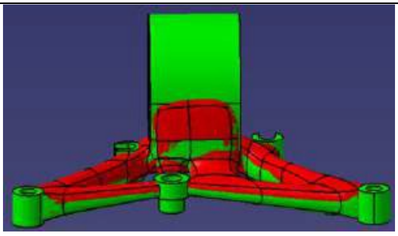
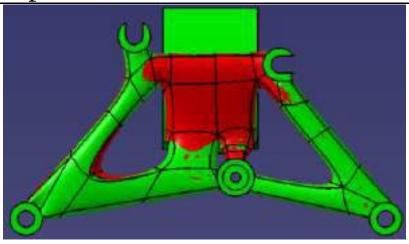
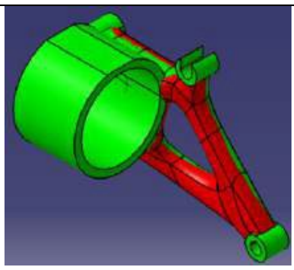
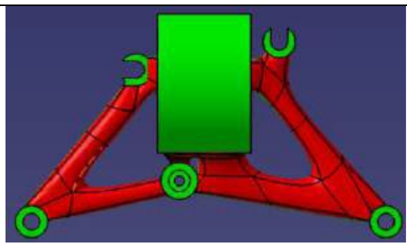
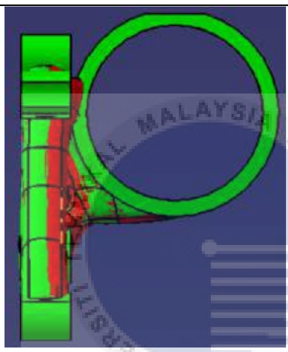
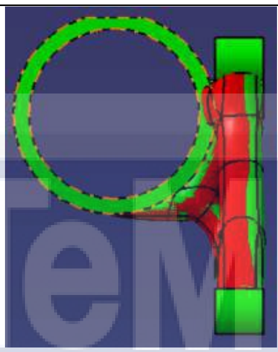
| 15% and 20% Shape Comparison | |
|---|---|
|  Bottom View |  Back View |
|  Isometric View |  Front View |
|  Left View |  Right View |
| 15% of weight reduction – red color<br>20% of weight reduction – green color | |

Table 4.20 Shape Comparison of AZ31B-Extruded 2



Based on above table it clearly show the differences shape betweeen 3 percentages of weight reduction. For example, red color is lower weight reduction it means need using more materials so that the above table shown the blue is more thicker compare with green color. So part doesn’t show the red color is because it overlap with green color.

### 4.3 Summary

The results and analyses of the based model engine mounting bracket and the optimised engine mounting bracket were provided in this chapter through case studies. The weight, maximum stress, and displacement of the based model engine mounting bracket and the optimised engine mounting bracket were recorded using the optimization image, graph, and table for the different types of materials, with 3 percentages of weight reduction used, such as Al6061-T6 and AZ31B-Extruded. The shape of 10%, 15%, and 20% of the materials Al6061-T6 and AZ31B-Extruded changes after optimization. All of the base model and optimised engine mounting brackets are below their material yield stress for maximum stress, ensuring that the engine mounting bracket does not break when the force is applied. The maximum stress of the optimised engine mounting bracket for Al6061-T6 and AZ31B-Extruded is reduced by 10% of weight for all categories of weight reduction thanks to the based model engine mounting bracket. While the optimised engine mounting bracket for Al6061-T6 and AZ31B-Extruded improves maximum displacement by a little amount, maximum displacement rises as weight reduction increases from 10% to 20%. The best optimization is determined for both Al6061-T6 and AZ31B-Extruded at a 10% weight reduction.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

In reality, cutting the weight, reducing maximum stress, and raising maximum displacement are all methods for improving the engine mounting bracket's efficiency. It can assist increase the strength of the engine mounting bracket while minimizing the quantity of material utilized. However, there are other issues that hinder the engine mounting bracket from being optimized, including the time it takes to do so. The topology optimization technique, on the other hand, is now widely used in the automobile industry, not just for engine mounting brackets but also for other parts of the vehicle.

The realistic engine mounting bracket is being transformed into a Computer Aided Design using CATIA V5 software (CAD). The engine mounting bracket remodel, however, does not meet the requirement as completely as the actual engine mounting bracket purchased by the researcher because there is some minor error when measuring the curve, thickness, angle, radius, and length, and some may be difficult to reach for measurement. When compared to the real component, the researcher was able to attain a design pattern and weight accuracy of up to 95%.

Returning to the optimization, the based model engine mounting bracket will be optimized first, using the Altair Inspire for weight reductions of 10%, 15%, and 20%, and then the based model engine mounting bracket will continue to use Al6061-T6 and replace it with AZ31B-Extruded for weight reductions of 10%, 15%, and 20%, as before. The ideal optimization of the engine mounting bracket for the materials Al6061-T6 and AZ31B-Extruded is determined when the maximum stress is analyzed and assessed using Altair

Simsolid without exceeding the materials' yield stress and maximum displacement is not raised significantly. This ensures that the engine mounting bracket is properly set to withstand the force applied without breaking or elongating unduly.

When Al-6061-T6 and AZ31B-Extruded are utilized, the best outcome is reached after topology optimization and analysis, and the researcher receives around a 10% weight reduction. This is due to the fact that the maximum stress of Al-6061-T6 and AZ31B-Extruded has been lowered from 15.198MPa to 12.624MPa and 12.584MPa, respectively. The maximum displacement rises by roughly 0.02mm when compared to the base model engine mounting bracket, which is 0.0304 mm and 0.0468 mm for Al-6061-T6 and AZ31B-Extruded respectively. Not only that, the maximum stress of optimized model with materials Al6061-T6 and AZ31B-Extruded at 10% weight reduction have been reduced by 16.94% and 17.40% respectively as compared to the based model.



Figure 5.1 10% weight reduction of Al 6061-T6

As a consequence, the researcher will choose for Al6061-T6 to save 10% on the weight of the engine mounting bracket used in the based model. There are two explanations for this: Al6061-T6 and AZ31B-Extruded have the same maximum stress and displacement, and Al6061-T6 is less costly than AZ31B-Extruded. As a consequence, with a 10% weight reduction, the optimal optimization and cost for Al6061-T6 is adequate. (Hossein Mahtabpour,2017)

In a nutshell, the topology optimization technique is commonly used in the car industry when a company has to reduce vehicle weight for fuel efficiency and reduce material consumption while maintaining strength. The aluminum alloys, on the other hand, exhibit chemical, mechanical, and physical characteristics that are similar to those of the AZ31B-Extruded. Al6061-T6, which is utilized in engine mounting brackets, is more costly than AZ31B-Extruded. In racing automobiles that require a low weight for greater performance and handling, only magnesium alloy will be utilized.

## 5.2 Recommendation

In the future, the engine mounting bracket estimation findings might be enhanced as follows:

a) To ensure that the optimization is suitable for use, prototype testing of the revised engine mounting bracket is necessary.
b) Make a list of prospective engine mounting bracket materials with superior chemical, mechanical, and physical properties.
c) The engine mounting bracket should be evaluated and tested for any probable road conditions, such as vibration and dynamic motion.
d) Increase the weight reduction percentages to get a better result and maybe save money on supplies.

## 5.3 Project potential

Weight reduction is becoming more popular in the vehicle industry. There are no exclusions in the weight reduction of the engine mounting bracket that the researcher selected to investigate. Weight reduction of the engine mounting bracket has a lot of potential in the future, and there are certain benefits to it, such as decreasing the cost of the parts by lowering the weight of the engine mounting bracket. The quantity of material used to build the engine mounting bracket will be lowered as it is optimized while keeping its mechanical and physical properties, potentially decreasing the cost of updating or replacing the engine mounting bracket.

## REFERENCES


K. J. Bathe, O. Guillermin, J. Walczakt and Heng-Yee Chen,*"advances in nonlinear finite element analysis of automobiles*" Computers & Strucrures (2017) Vol. 64, No. 516, pp. 881-891.

Gonzalez, R.C. and Woods, R.E., 2010. *Digital Image Processing*, 3rd ed., New Jersey: Pearson Education Inc.

.S. Adkine, V. S. Kathavate, G. P. Overikar S. N. Doijode, "*Static Behaviour of Engine Mounting Bracke*t", International Advanced Research Journal in Science, Engineering and Technology Vol. 2, Issue 4, April 2015

Mr.Pramod Walunje,Prof.V.K.Kurkute, "*Engineering Optimization of Engine Mounting Bracket Using FEA*" Indian Journal of Research ISSN-2250-1991 volume:2, Issue:12, Dec 2018

Hafiz,A. A. M., Hussein,H. M. A.,Gemeal A. M. B., Naranje,V. (2019) 'Topology Optimization of Sheet Metal Combination Die',2019 *International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, Dubai, United Arab Emirates, pp. 191-196

OpgenoordM. M. J.,Willcox, K. E (2019) 'Design for additive manufacturing: cellular structures in early-stage aerospace design', *Structural and Multidisciplinary Optimization*, 60 (2) pp. 411–428.

Diwakar, Surendra.A, Bhaskar.N&Mallikarjuna. P *"Static structural Analysis and Weight optimization of engine mounting bracket using Topology*" Vol-3, (June 6, 2017)

Wu, P., Ma, Q. H., Luo, Y. P. and Tao, C. (2016) *Topology Optimization Design of Automotive Engine Bracket*. Energy and Power Engineering, 8, 230-235.

Vinchurkar, S. C., & Khanwalkar, P. M. (2016). *FEA and Topology Optimization of an Engine Mounting Bracket*. published in 'International Journal of Current Engineering and Technology E-ISSN, 2277-4106.

Monali Deshmukh, Prof. K.R.Sontakke, "*Analysis and Optimization of Engine Mounting Bracket,*"IJSER: Volume 3 Issue 5, May 2015

Diwakar K, Surendra. A, Bhaskar. NandMallikarjuna. P, "*Static Structural Analysis and Weight Optimization of EngineMounting Bracket Using Topology*" Vol-3, Issue-6, 2017

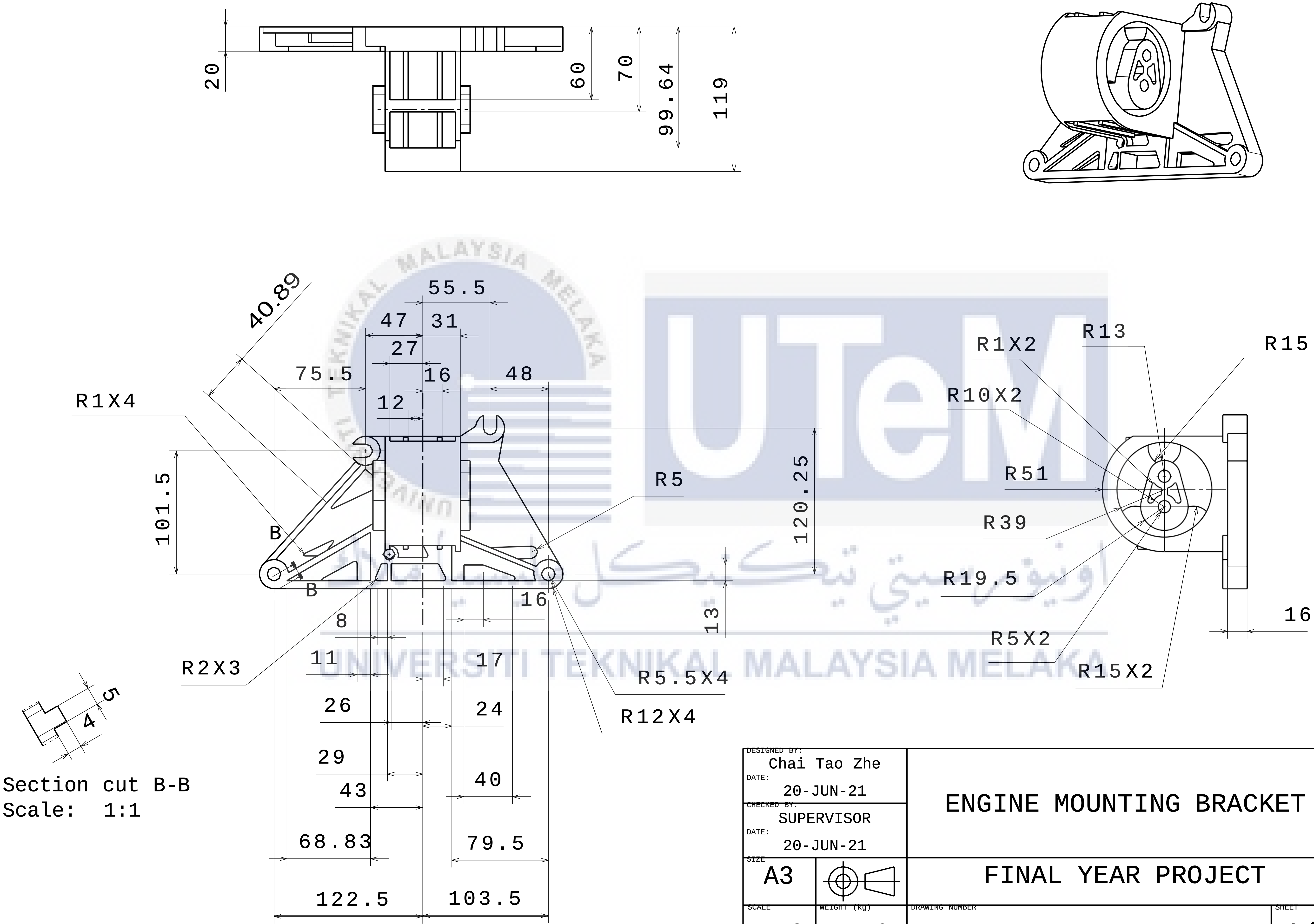
Vijay Kalantre, K. H. Munde and Ashish Pawar, "*Topology Optimization of Front Leaf Spring Mounting Bracket,*" IJSDR:Volume 3, Issue 7 July 2018.

Sandeep Maski, Yadavalli Basavaraj, "*Finite Element Analysis of Engine Mounting Bracket by Considering Pretension Effect and Service Load*" IJRET: International Journal of Research in Engineering and Technology, e-ISSN: 2319-1163, p-ISSN: 2321-7308, Volume: 04 Issue: 08, August-2015

P.Lakshmi Kala and V.Ratna Kiran, "*Modeling and Analysis of V6 Engine MountBracket*"(2015), International Journal of Innovative Research in Science,Engineering and Technology, Vol. 4, pp 5907-5914.

A.S.Adkine, V.S.Kathavate, G.P.Overikar, S.N.Doijode — *Static Behaviour of Engine Mounting Bracket*, International Advanced Research Journal in Science, Engineering and Technology, Vol. 2, Issue 4, April 2015.

**APPENDICIES**




| | | |
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| DESIGNED BY: Chai Tao Zhe<br>DATE: 20-JUN-21<br>CHECKED BY: SUPERVISOR<br>DATE: 20-JUN-21 | ENGINE MOUNTING BRACKET | |
| SIZE A3 | FINAL YEAR PROJECT | |
| SCALE 1:2 / WEIGHT (kg) 1.19 | DRAWING NUMBER 1 | SHEET 1/1 |

| | |
|---|---|
| I | _ |
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| G | _ |
| F | _ |
| E | _ |
| D | _ |
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| B | _ |
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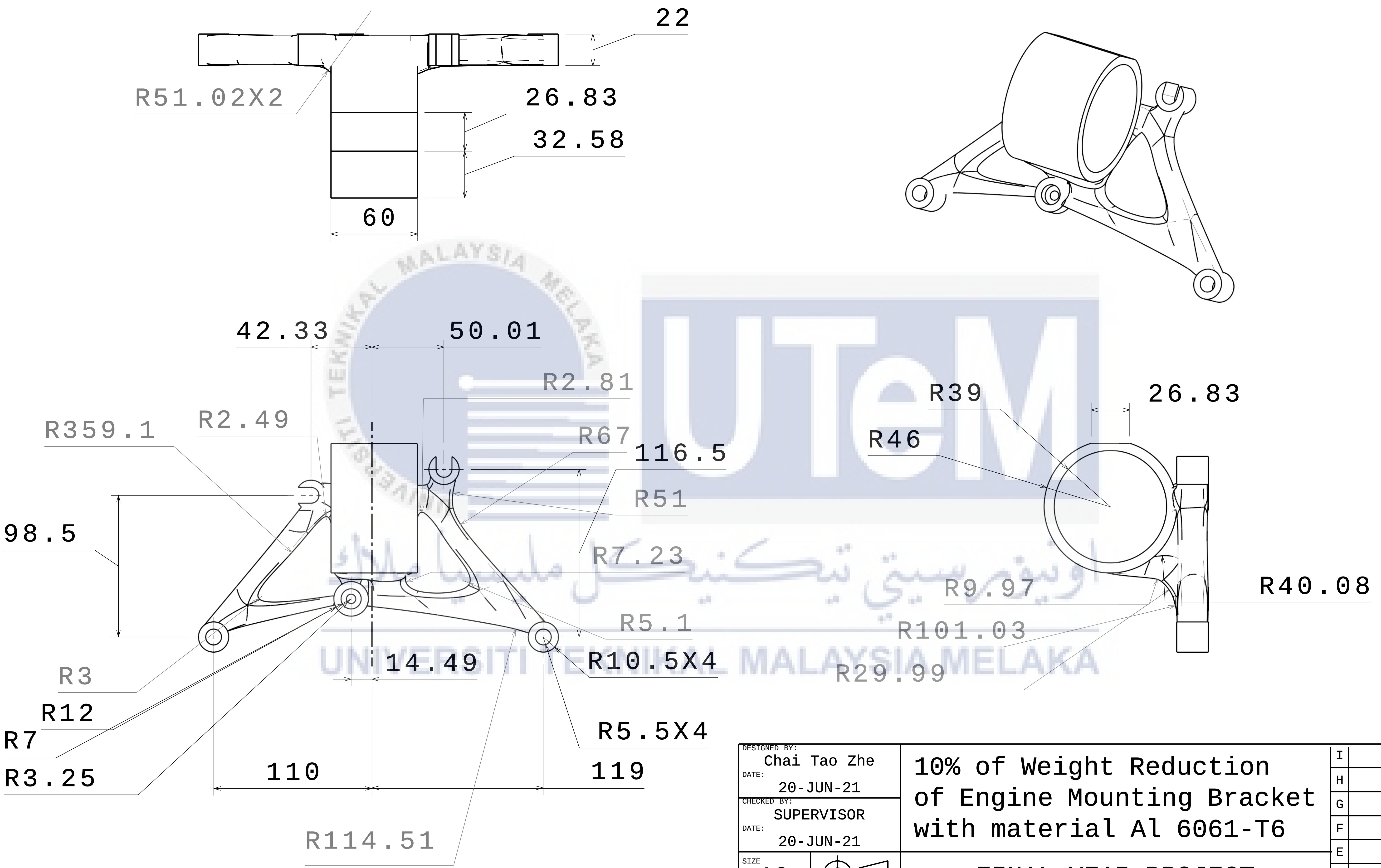




| | | |
|---|---|---|
| DESIGNED BY: Chai Tao Zhe<br>DATE: 20-JUN-21 | 10% of Weight Reduction of Engine Mounting Bracket with material Al 6061-T6 | |
| CHECKED BY: SUPERVISOR<br>DATE: 20-JUN-21 | | |
| SIZE A3 | FINAL YEAR PROJECT | |
| SCALE 1:2<br>WEIGHT (kg) 0.992 | DRAWING NUMBER Part 1 | SHEET 1/1 |

| | |
|---|---|
| I | _ |
| H | _ |
| G | _ |
| F | _ |
| E | _ |
| D | _ |
| C | _ |
| B | _ |
| A | _ |

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TAJUK: **Topology Optimization of Engine Mounting Bracket using Altair Inspire**

SESI PENGAJIAN: **2021/22 Semester 1**

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**Tajuk Tesis: Topology Optimization of Engine Mounting Bracket using Altair Inspire**

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