DESIGN OF TRANSPORT TRAILER FOR FIRE FIGHTING ROBOT

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DESIGN OF TRANSPORT TRAILER FOR FIRE FIGHTING ROBOT

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SUPERVISOR’S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :..

Name of Supervisor :...................................

Date :..

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor Of Mechanical Engineering (Design & Innovation).

Signature :……………. ....

Supervisor Name :……………………… ....

Date :…………………….. ....

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DEDICATION

To my beloved parents (Mr. Sayoti bin Sanuri & Mrs Jamiah bt Mustam)

Supervisor (Ir. Dr. Tan Chee Fai)

Friends and housemate

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ABSTRACT

Fire fighters always exposed to danger during their duty in order to save peoples live. Invention of fire fighting robot was a big helps to them as they could avoid danger during the duty. Several countries had participated in the invention of fire fighting robot during the last decade. Each country has developed their own robot with various specifications and their own specialty. Major problem encountered by the fire fighters regarding the robot is their lack of speed. With average speed of 10 km/h, it became a big problem during emergency cases. Thus, a transport trailer were needed to bring the robot to the fire scene. This research present about developing a transport trailer for the fire fighting robot. The content of this research is about choosing suitable design, size and material. Basically, the design was developed suitable with size of fire fighting robot in Malaysia. As for the material of the design, two type of material which is aluminium alloy and structural steel is compared to find the most suitable type of material for the trailer. Then, the design of the trailer is developed and 3D modelling is done by using SOLIDWORK software. Next, analysis of the design is done by using ANSYS software.

ABSTRAK

Ahli bomba sentiasa terdedah kepada bahaya semasa tugas mereka untuk menyelamatkan orang-orang hidup. Ciptaan memadamkan api robot adalah besar membantu untuk mereka kerana mereka boleh mengelakkan bahaya semasa duti. Beberapa negara telah mengambil bahagian dalam penciptaan memadamkan api robot sepanjang dekad yang lalu. Setiap negara telah membangunkan robot mereka sendiri dengan pelbagai spesifikasi dan khusus mereka sendiri. masalah utama yang dihadapi oleh anggota bomba mengenai robot adalah kekurangan mereka kelajuan. Dengan kelajuan purata 10 km / h, ia menjadi satu masalah besar semasa kes-kes kecemasan. Oleh itu, sebuah treler pengangkutan diperlukan untuk membawa robot ke tempat kejadian api. Kajian ini ini kira-kira membangunkan treler pengangkutan untuk robot memadam kebakaran. Kandungan kajian ini adalah tentang memilih reka bentuk yang sesuai, saiz dan material. Pada asasnya, reka bentuk telah dibangunkan sesuai dengan saiz memadamkan api robot di Malaysia. Bagi bahan reka bentuk, dua jenis bahan yang adalah aloi aluminium dan keluli struktur berbanding untuk mencari jenis yang paling sesuai bahan untuk treler. Kemudian, reka bentuk treler dibangunkan dan pemodelan 3D dilakukan dengan menggunakan perisian SOLIDWORK. Seterusnya, analisis reka bentuk dilakukan dengan menggunakan perisian ANSYS.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. First I would like to express my sincere acknowledgement to my supervisor Ir. Dr. Tan Chee Fai from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) whose contribution in stimulating suggestions and encouragement, helped me to coordinate my project and especially guide me towards the completion of this thesis.

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Nobody has been more important to me in the pursuit of this project other than the members of my family whose loveand support are always with me. Last but not least A special thanks goes to my friends and class mate, who help me to fulfill and gave suggestion about the project.

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LIST OF ABBEREVATIONS

JPJ	Jabatan Pengangkutan Jalan
CATIA	Computer Aided Three-dimensional Interactive Application
IAFF	International Association of Fire Fighters
USA	United States of America
PDS	Product Design Specification
ASF	Audi Space Frame

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Fire fighting is a risky works which is involving act of extinguishing fire in order to save life and prevent destruction of property. This works are done by fire fighters that were trained technically to perform the job. Fire fighters are exposed to danger during performing their job as they need to go near to the fire scene. Example of the hard that they need to face are toxic environment created by combustible materials, falls and structural collapse. Many accidents involving fire fighter during performing their job has been reported throughout the years.

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In order to prevent accidents and injuries, a fire fighting mobile robot has been designed. This robot was able to reduce the direct contact of the fire fighters to the fire scene as it was remotely controlled. It is widely used nowadays as it is very effective in extinguishing fire and can be handled easily. There were various type of the robot has been developed in many difference countries.

Example of fire fighting robot is MVF-5 and LUF 60 as shown in figure 1.1 and figure 1.2. Fire fighting robot comes with difference specifications that make them able to perform fire fighting job. For example, LUF 60 is diesel powered and equipped with air blower and rubber track system. The rubber track system enables the robot to climb the stair. The monitor nozzle has a flow rate up to 800 GPM and it can blow the water beam as far as 80m. As for MVF-5, it is equipped with high-pressure cannon on a hydraulic arm that pumps water up to 55 m away. The MVF-5 has a high-temperature-resistant fire protection shield. The protection shield is able to withstand 700 C for 15 minutes or 400 C for 30 minutes. The MVF-5 can spray 2000 liters of water per minute.

Figure 1.1 : MVF-5 Autonomous Fire Fighting Machine

Figure 1.2 : LUF60

Example of other robot specifications is shown below:

Table 1.1 : Fire Fighting Robot Specifications

Model	Weight(kg)	Length(m)	Width(m)	Height(m)	Speed(km/h)
Firemote 4800	450	1.40	0.70	1.14	4.5
FFR-1	940	1.14	1.62	1.38	3 - 4
Service Robot FIREROB	250	1.30	0.69	0.39	3
JMX LT50	1500	2.40	1.44	1.56	12

There are different specifications of different model fire fighting robot. All the specifications and features for the robot make the job to extinguish fire easier and safer. However, this robot has one crucial problem which is mobilizing. Although it is equipped with tracks and wheels, this robot speed is only between 3km/h to 10km/h which make it very slow.

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That speed would be sufficient for the robot to mobilize at the fire scene but not for the robot to move from the fire station to the scene.

Thus, this research was done in order to give a solution to this problem. The main purpose of this research is to design and develop a transport trailer for the fire fighting robot to help it to reach the fire scene as soon as possible. However, the design of the transport trailer must be following Department of Road Transportation Malaysia. Details such as safety sticker and reflector must be included on the trailer to follow the road safety. Besides that, the design parameter such as shape, weight, size and type of material must suitable with the robot. This is to ensure the smoothness of the work to be done and as safety precautions.

1.2 PROBLEM STATEMENT

Fire fighting is a risky work as fire fighters are exposed to many dangerous situation and fire hazard in order to save life and property. There were many accidents that had happened to fire fighters whether or not involving their life. Although they are equipped with safety suit, helmet and tools, they are still exposed to danger as they need to go near to the fire scene.

Recently, an automatic fire fighting robot was developed in order to reduce loss of lives and risk of danger to fire fighter during fire incident. Fire fighting robot is a mobilize remote controlled machine that can that replace fire fighter to extinguish fire. This robot was able to reduce the direct contact of the fire fighters to the fire scene as it was remotely controlled. This fire fighting robot is widely used nowadays. Although the robot can be mobilize, but the speed is very slow which is from 3km/h to 10km/h as it is mainly using steel track or rubber track.

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Thus, it becomes the main problem for the robot as it needs to travel from the fire station to the scene as fast as possible.

The solutions that can be suggested is by design and build a transport trailer for the fire fighting robot to travel from the fire station to the scene. The design of the transport trailer must following specifications that had been drafted by Department of Road Transportation in Malaysia (JPJ). Besides that, type of material that will be use also important for the trailers. The material must have characteristic that suitable to transport the heavy robot. Characteristic that need to be consider is strength and ductility. This properties is very important for the trailer to avoid accident and mishap during the travelling of the robot. Other than that, the design of the trailers must be suitable with the specifications of the robot. The trailer must be wide and long enough for the robot to be place.

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1.3 OBJECTIVE

The objective of this research is :

1. To design a transport trailer for mobilizing a fire fighting from fire station to fire scene.
2. To choose a suitable material that will be used for the transport trailer.
3. To design a transport trailer for fire fighting robot based on suitable specifications and pass Jabatan Pengankutan Jalan's(JPJ) law.
4. To develop prototype of the transport trailer for the fire fighting robot from the research that had been done.

1.4 SCOPE OF PROJECT

1. To do a research about fire fighting robot specifications in order to design a transport trailer for the robot.
2. To do a research about JPJ's law involving transport trailer specifications.
3. To design the trailer from the research that has been done by using drawing software such as SOLIDWORK.
4. To analyze the design's structure stress analysis by using Finite Element Analysis in ANSYS software.

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CHAPTER 2

LITERATURE REVIEW

2.1 Fire Fighting Mobile Robot

In order to reduce the risk of injuries to the fire fighters, mobile fire fighting robot was used to replace the fire fighter at the fire scene. IAFF (2000), state that: “There are 1.9 firefighters are killed per year in the USA, per 100,000 structure fires”. Thus, the research and developing fire fighting robot project has been done by a few country such as U.S.A and China over the past few years. There are various types of fire fighting robot that produced by different countries. Each robot has different specs. We can see the specs of the different type of robot at **table 2.1**:

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Table 2.1 : The comparison of current fire fighting robot from the source (Fire Fighting Mobile Robot: State of the Art and Recent Development, Tan, C.F., and H.F. Kong, 2013)

Specification	LUF60	FFR-1	FIREMOTE -4800	MVF5	JMXLT50	SACI	ArchiBot	Thermite	FFM3000
Size (L x W x H)	2.3 x 1.35 x 2 m	1.62 x 1.14 x 1.38 m	1.4 x 0.7 x 1.14 m	3.8 x 2.18 x 2.1 m	2.44 x 1.44 x 1.56 m	1.8 x 1.5 x 1.6 m	1.4 x 0.8 x 0.65 m	1.88 x 0.89 x 1.4 m	1.5 x 1.0 x 1.3 m
Speed (km/h)	6	4	4.5	12	12	12	20	20	2.36
Power source	Diesele ngine	Battery	Battery	Diesel engine	Diesel engine	Battery	NA	Diesel engine	Battery
Control	Radi o contr ol	Wireless control	WiFi	Remote control	Radio control	Radioco ntrol	NA	Radio control	Radio control
Weight (kg)	2000	940	450	9274	1500	NA	450	744	910
Price (USD)	200,0 00	NA	NA	NA	49,000	NA	NA	98,000	40,000
Origin	Austria	US	UK	Croatia	China	Brazil	Korea	US	Malaysia

Fire fighting robot uses different material to extinguish fire. The extinguisher need to be used based on the type of fire sources. The type of fire sources is (Teh, Patrick, Abu Bakar, 2012). :

- A-Solids (Paper, Wood, Plastic).
- B-Liquids (Paraffin, Petrol, Oil).
- C-Gases (Propane, Butane, Methane).
- D-Metals (Sodium, Lithium, Manganese, Aluminium, Magnesium, Titanium in the form of swarf).
- E-Electrical Apparatus.
- F-Cooking oil & fat

Suitable type of extinguisher needed to be used to extinguish fire efficiently. However, fire fighting robot was mainly use two type of extinguisher which is water and foam. Water can extinguish all class of fire sources except for class B. While foam was suitable for all class of fire and is the best extinguisher for class B fire source. (Teh, Patrick, Abu Bakar, 2012).

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In order to avoid the direct contact of fire fighters with fire, the robot was remotely controlled. The fire fighting robot will be operated in a dangerous area and is controlled by a remote operator which are using a digital packet communication system to mobilize and an analog image communication system for video observation by the fire fighters (Hyung Park and June Kim, 2008).

Most of the robot are using wireless data communication system to mobilize, A reliable digital packet communication is necessary to control the fire fighting robot body. Environmental information around the robot is transmitted from the robot body to the remote operator. By checking this information, the operator can know the status of the robot and transmit appropriate control data corresponding to the status of the robot (Wook Jin and Joo Park, 2008). Example of the controller is shown in **figure 2.1.**

Figure 2.1 : Fire fighting robot remote controller (Wook Jin and Joo Park, 2008).

Besides wireless data, there are a fully automated robot which can detect the fire and extinguishing it by itself. This type of robot are using sensor and developed algorithms to blow the foam to the fire. Automatic Fire extinguisher Robot that needed assembles of various components to make it able to detect and extinguish a fire by itself. Components such as thermostat Sensor or optical sensor will help to sense the fire usually in a narrow range (V. Kale and D. Rengge, 2015) .

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Many implementation can be made to the robot can be made for upgrading the system of the robot. Some of the robot is using flame sensor and infrared sensor to detect fire. The main purpose of the sensor implementation is to increase the fire detection capabilities and its accuracy, preferably at the minimum level of error as possible (Teh, Patrick, Abu Bakar, 2012). Obstacle avoidance by using ultrasonic sensor can be extra features can be applied to the robot system so it not collide or hit any obstacle during navigate (Teh, Patrick, Abu Bakar, 2012).

Fire fighting robot has a major problem which is it moving very slow. The average speed of the robot was below 20 km per hour. Thus, a transport trailer for the robot need to be developed in order to mobilize the robot to the fire scene as fast as possible.

2.2 Material for Trailer

There were two common material used for semi-trailer which are aluminium and steel. Both materials has their own pros and cons in building semi-trailer. However aluminium behavior makes it has bigger advantages in semi-trailer industries over steel. A few advantages of aluminium are its resist rust and corrosion ability. Besides that, aluminium also has less weight and it makes it easier to be tow. Aluminum trailers has 10 – 15% less weight than steel trailers. This means that an aluminum trailer able to haul more load than steel trailers with same total load (load plus axle load and trailers load). This helps gain better gas mileage when hauling an aluminum trailer rather than steel trailer when it empty. As we know, steel has a reputation of being one of the toughest common alloys, while aluminum is more commonly known as soft material. However, the aluminum used in all-aluminum trailers is a type of alloy. It has about the same yield strength as steel. It has at least 95 % aluminum, and composed of copper, titanium, chromium and zinc (aluminium vs steel trailers, 2014).

Both trailers requires constant maintenance to ensure it is in good working conditions. Aluminum trailers maintenance routine was simply lubricating the hinges and cam latches. Besides that, an aluminum trailer should be given an acid bath yearly to make sure it is clean and for cosmetic purposes. Unlike aluminium trailers, steel trailers frequent maintenance in order to prevent rust. Any scratches in the paint need to be repaired before it start to rust. However, galvanized or galvannealed steel trailer did not need to be inspected as frequently as normal steel. On the other hand, welded and riveted areas must have been properly finished after every repair. The galvanic layer must be removed to weld. This constant maintenance of the paint coat and the galvanic coat make steel trailer repairs tend to be more expensive. Steel trailer repairs are usually more expensive than similar repairs to an aluminum trailer because trailer dealers have to repaint it to prevent rust (Aluminium trailers vs steel trailers, 2015).

2.2.1 Aluminium Alloys Advantages in Automotive Industries

When discussing about material selection for transportation purposes, the main expectation to it is its performance and the capability of designing materials characteristics to meet specific requirements. Fan and Njuguna (2016) found that the use of lightweight material brings many benefits to many aspects in automotive industry. First, the use of lightweight material for vehicles is the availability and cost-effectiveness in market which possibly reducing the capital for manufacturing. Second benefits is the lightweight material obey conservation of regulations and policies designated by some nation such as the European Commission with the End of Life Vehicles (ELV) European Union have enacted that the construction of vehicles have to be constructed of 95% recyclable materials with 85% recoverable through reuse or mechanical recycling and 10% through energy recovery or thermal recycling. The regulation and policies enacted in Europe also helps environment from being polluted and help to extend the life of roadway.

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Figure 2.2 : Roadway damage by overweight vehicle

(Google pothole detection, 2015)

Forth, Fan and Njuguna (2016) stated that the reduction in weight reduces the fuel consumption. For example, compact car like Volkswagen Golf has 1160kg of total vehicle mass with body in white (BIW) mass is 296kg. This model has 30% mass reduction on its BIW. For a lifetime rod performance of 150,000 km, fuel consumption reduction in this lifetime is approximately 0.3L/ 100 km fuel savings for each car.

The fifth benefits listed in Fan and Njuguna (2016) research is that the lightweight vehicle especially in the aspect of engine mass reduction is a main factor contributes in the improvement of fuel efficiency. All of the benefits found in Fan and Njuguna (2016) research can lead to one hypothesis which is the lighter the mass, the better the performance of vehicles in many aspects. Aluminium is widely used in many constructions and in vehicle industry nowadays to replace traditional steel due to its attractive properties. What makes it an attractive material to be used in vehicle industry is its low in density of 2.69 g/cm^3 (Benedyk, 2010).. There are several benefits of selecting aluminium as materials for vehicle components. First, Benedyk (2010) stating that aluminium is amenable to a variety of production such as casting, extrusion, stamping, forging, impacts and machine components. Besides, the strength of the material can be tempered by means of cold and/hot treatment according to desired designed. The composition and temper, the solidification rate (metallurgical structure control), shape, and degree of soundness, specifications of mechanical properties may affect the mechanical properties of aluminium alloy castings.

The study found that cast aluminium alloy component is rated on the basis of functional and performance criteria as well as weight reduction relative to the component made of assembled steel stampings or made of cast iron. Second benefit that research by Benedyk (2010) and Fan and Njuguna (2016) found is that the number of components in vehicle part can be reduce thus producing the lighter weight of vehicles which results in the conservation of fuel and energy consumption. Moreover, in terms of acceleration, handling and braking distance, the performance and safety of the vehicle is enhanced. Research by Benedyk (2010) also found that 18 tonnes of carbon dioxide emissions over the average lifetime of a mid-size sedan can be saved on each tonne of aluminium used which it reduced 10% of vehicle weight translates, on average, to a 5-6% fuel saving.

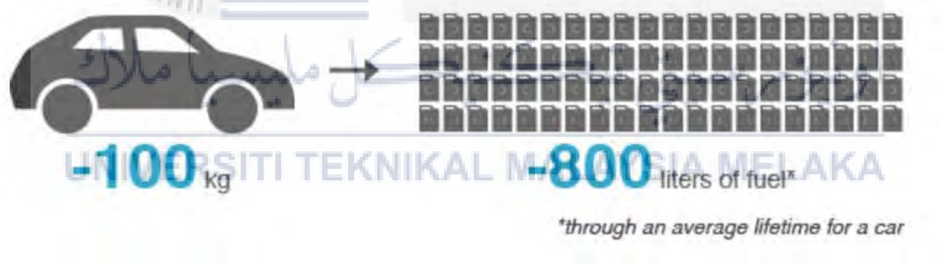

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Figure 2.3 : As the weight of vehicles reduces, the energy or fuel consumption also reduced.

This reduces of fuel consumption leads to a better significance in environmental health as the carbon dioxides released in the air can be reduced with the lightweight vehicles. Besides, 95% of aluminium in end-of-life vehicles offers a significant reduction in life cycle greenhouse gas emissions. Third, Benedyk (2010) research also stated that aluminium can improve crashworthiness in automotive vehicles if their size is maintained. This is also due to its high strength and lightweight. As an example mentioned by Benedyk (2016) Audi A8 was the first automobile that Audi built with their patented all-aluminium space frame design (Audi Space frame or ASF); the A8 had a five star safety rating and was considered one of the safest vehicles on the road in the 1990s, as it is today.

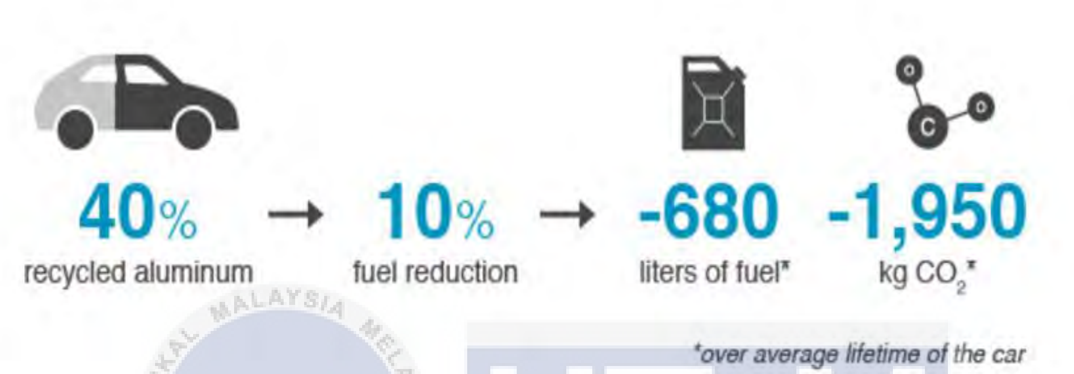

Figure 2.4 : Relationship of weight reduction with fuel consumption

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Figure 2.5 below shows the application and the product form of aluminium alloy in automotive industry.

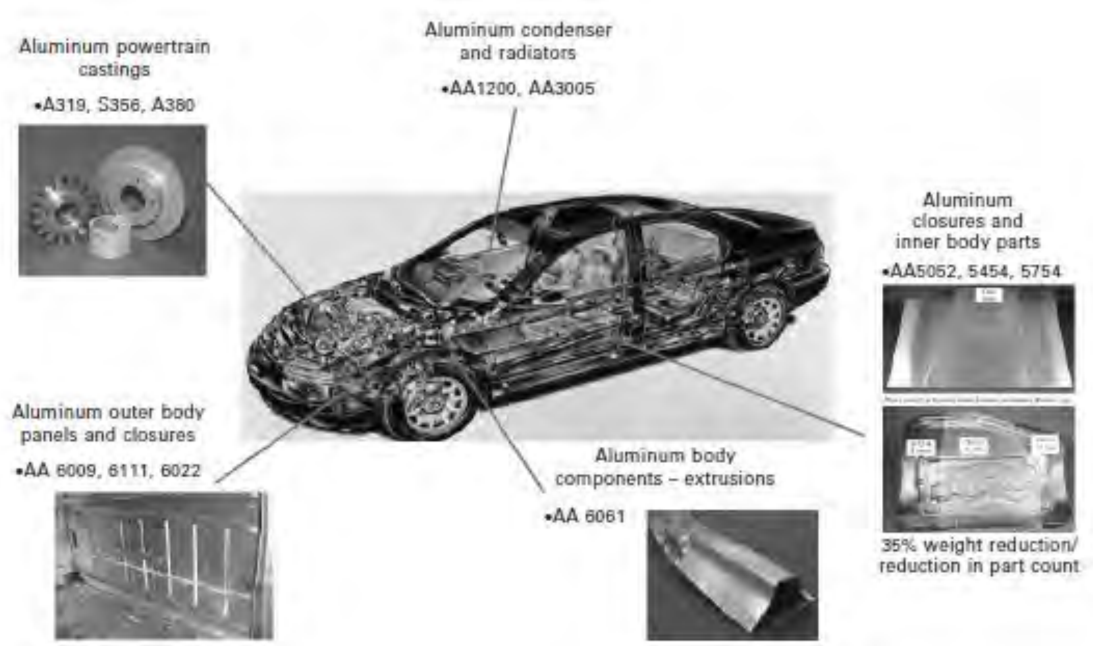

Figure 2.5 : Some typical automotive aluminum alloy applications and product forms

(J. C. Benedyk, n.d)

The lower weight of an aluminum trailer additionally converts into a lower payload limit, which means more things can be stack into an aluminum bearer before achieving the most extreme measure of weight the vehicle will tow. At long last, better fuel consumption by towing an aluminum trailer rather than steel trailer because aluminum trailers weight on average 10 – 15% less than steel trailers. Energy consumption of numerous articulated heavy goods vehicles is evaluated through an idealised drive cycle analysis mirroring a long haul travel over a roadway. The analysis has demonstrated that diminishing the unfilled weight of trailers by 30% can cause decreases of up to 18% and 11% in mass energy performance index for trailers and semi-trailers (Galos, Sutcliffe, Cebon, pieyck & Greening, 2015). There were three categories that can be main contributors to energy consumption of vehicle (Odhams et al., 2010):

1. Vehicle design factors; such as vehicle measurements, mass, volume, engine efficiency, moving resistance, aerodynamic profile and material selection.
2. Logistical factors; such as vehicle usage, vehicle speed and vehicle direction.
3. External factors; such as the drive cycle, the traffic conditions, drive style and weather conditions.

In the previous case studies, energy consumption estimation can be estimated by applying an idealised drive cycle analysis. Figure below shows the estimation for few types of trailer.

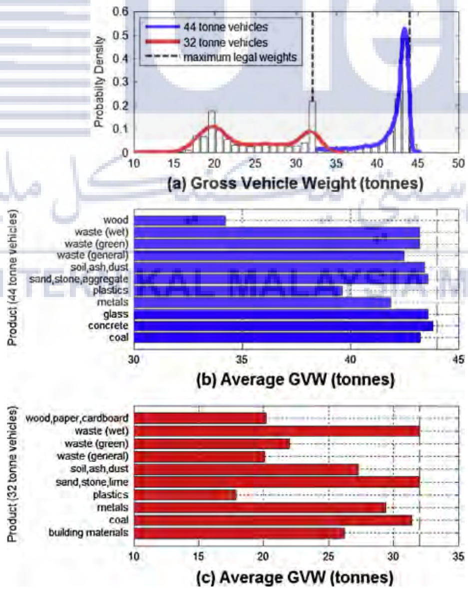

Figure 2.6 : Energy consumption estimation through an idealised drive cycle analysis

(J. Galos et al., 2015)

As vehicles get to be distinctly lighter it is judicious from an operations point of view to utilize the additional weight spared to build the payload weight of the vehicle. Energy consumption can be quantified through an energy performance index. Energy performance index (EI_m) was defined with units of kJ/weight km. It can be calculated by using (Odhams et al., 2010):

$$EI_m = \frac{\text{Total energy used}}{\text{Mass payload x Distance travelled}} \tag{2.1}$$

We can expect a reduction of up to 18% in mass energy performance index by reduce the weight of the trailers by 30% and increasing their payload until the vehicle reaches its maximum legal gross vehicle weight. This weight reduction could be achieved through applying lightweight composite materials to the trailer chassis and/or main subcomponents such as: sidewalls, decking and wheels (Galos, Sutcliffe, Cebon, pieyck & Greening, 2015).

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2.3 Transport trailer stability

Trailer stability is important as it needs to carry loads of the fire fighting robot. The trailer design must be stable to avoid it from overturn at . This is because load from the robot gives a huge effect to the stability of the trailer. The vertical load at the hitch point has an effect on the friction forces at the hitch. The variation of the hitch point load modifies the friction torque that dissipates the energy of the oscillations. The hitch point load has an effect on the load of the car rear axle too which influences the sizes of the contact patches and the corresponding lateral stiffness of the tires (S. Beregi and G. Stepan, 2016). Figure below show the mechanical model of the trailer combination. The mechanical model was following assumption that the vehicle can move in the (X,Y) plane, and its motion is described in the ground-fixed Lagrangian coordinate system (S. Beregi and G. Stepan, 2016).

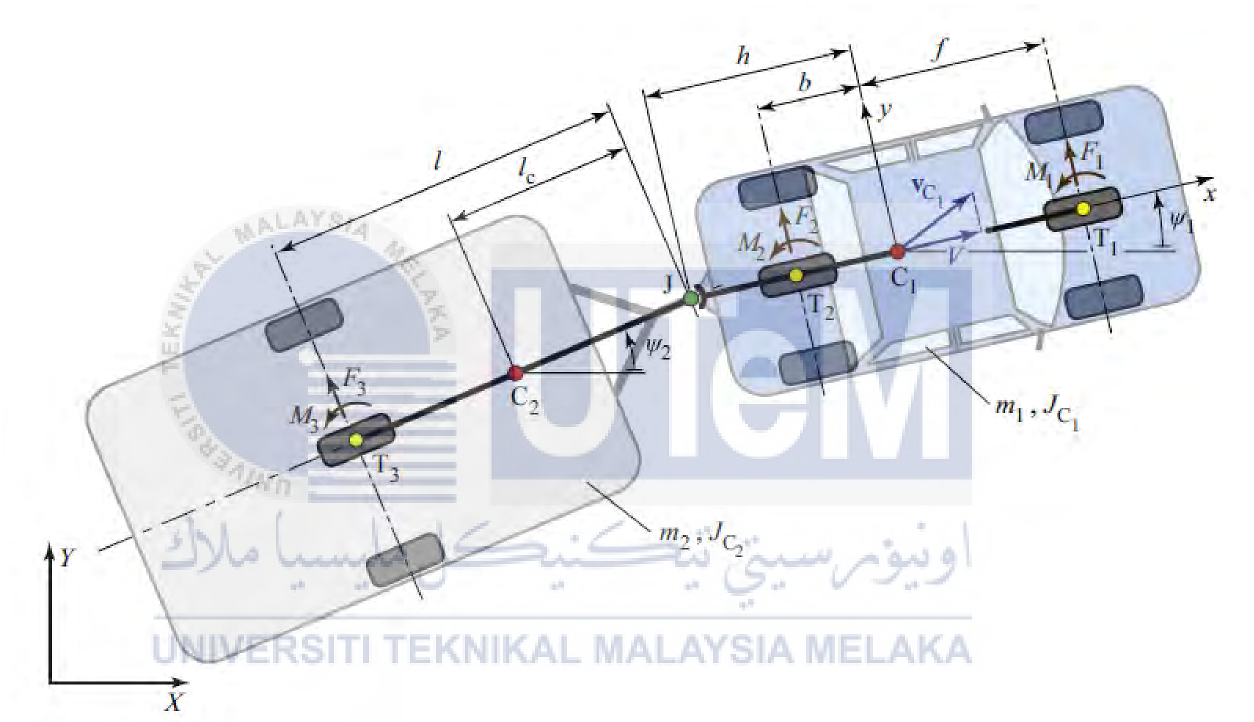

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Figure 2.7 : Single track model of car-trailer combination (S. Beregi and G. Stepan, 2016).

Transport trailer for the robot have same characteristic as normal semi-trailer.

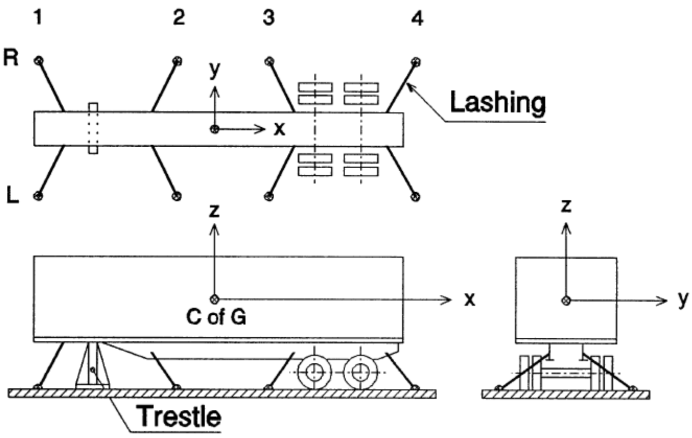

Figure 2.8 : Centre of mass location of trailer (S. Beregi and G. Stepan, 2016).

From the figure, it shows that the trailer high centre of mass and the low level at which the lashings are attached to the trailer. The flexibility of the trailer coming from the bending of the chassis members. Besides, the trailer also have torsionally flexible flat- bed characteristic. From the mechanical model assumptions that can be made is that the trailer has the six degrees of freedom associated with a rigid body, plus a chassis that is flexible at both in bending and torsion(Turnbull and Dawson, 1995) . There were two parts which can be assumed as rigid. The first part is chassis under the suspension mass is assumed rigid due to the stiffening effects of the suspension member and the second part is spars which protrude from the spine and which carry the lashings. The masses move with the vertical and horizontal deflections but they are not affecting the local slope of the spine (S. Beregi and G. Stepan, 2016). This is because of the load is a distributed one and that it does not contribute to the bending or torsional stiffness of the trailer. The chassis stiffness has

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only a secondary effect on the loads and thus it can be assumed that the chassis is not only torsionally flexible (Turnbull and Dawson, 1995) .

2.4 Aerodynamics drags

As we know, most heavy commercial vehicles have un-streamlined body shapes. This characteristics makes them aerodynamically inefficient compared to other ground vehicles. A large commercial vehicle consumes about approximately 52% of the total fuel to provide power to overcome the aerodynamic drag travelling at 100 km/h (Firoz and Watkins,2013). Even using custom body parts such as skirting and spoilers gives low impact on drag force reduction. An experiment had been carried out to study the drag force on semi-trailer vehicles. The experiment was carried out in RMIT Wind Tunnel. The purpose of using this tunnel was to measure the aerodynamic drag on the experimental model. The tunnel has maximum speed of 145 km/h. The experiment use a 10% scale model of a semi-trailer truck which connected through a mounting strut that has JR3 multi axis sensor. This sensor was capable to measure all three forces which are drag, lift and side forces(Firoz and Watkins,2013).

Formula of drag force was given by :

$$D = C_D \frac{1}{2} \rho V^2 A \qquad (2.2)$$

Where :

- D aerodynamic drag force (N)
- A projected frontal area (m^2)

- C_D drag coefficient (dimensionless)
- V vehicle speed (ms^{-1})
- ρ air density

Aerodynamic drag with a semi-trailer truck typically accounts for about 75-80% of the total resistance to motion at 100 km/h. Several gaps can be found in a semi-trailer truck. For example, gaps between the semi-trailer and the tractor unit. Additionally, several open spaces can be found near the lower section of the semi-trailer unit. Wheels are also kept uncovered. This experiment was conducted by applying a few modifications by installing front fairing and cover differents parts and gap of the semi-trailer (Abd. Kadir and Moria,2013).

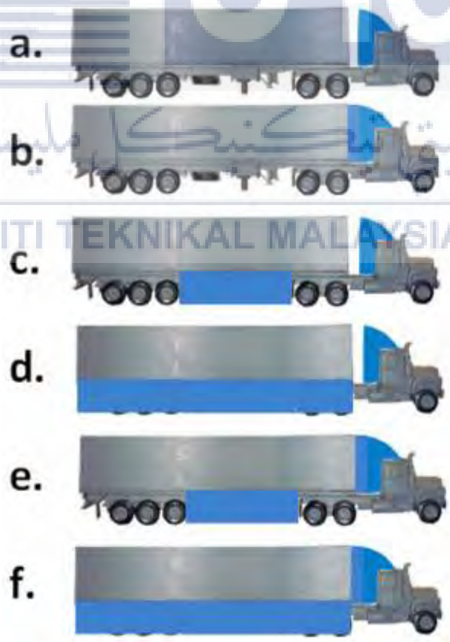

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Figure 2.9 : Different combinations of fairing on the baseline semi-trailer truck model. (Chowdury and Moria,2013)

Table 2.2 : Percentage reduction of drag (D) on yaw angle

(A study on aerodynamic drag of a semi-trailer truck, Chowdury and Moria,2013)

Configuration	Average drag reduction
a	17.6%
b	25.5%
c	18.3%
d	20.6%
e	24.4%

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The result of the experiment shows that baseline model has the highest C_D value whereas the model with any fairing attached has lower C_D values. Experimental data also indicate a decrease of C_D values with the increase of speed for the baseline model with any fairing attachment. The baseline model with the front and side fairing, and gap filled has the minimum C_D value among all other configurations tested. The experimental data indicated that not only by using the front fairing but also by covering different parts of the gaps in different portion has effect on aerodynamic drag reduction (Firoz and Watkins,2013).

The results of the experiment indicated that partial covering of the gaps can increase the performance for drag reduction. Furthermore, full covering indicated the maximum drag reduction. Thus, it is possible to reduce drag by using external attachments by covering the gaps and open area within thevehicle and the semi-trailer unit.

2.5 Approval of vehicles

"Jabatan Pengangkutan jalan Malaysia (JPJ)" had provided a guideline for road user to make an application for a modified vehicle to be allowed to use on the road. This application is involving all type of mobilze vehicle including trailer vehicles. Trailer vehicle were divide into three types which is semi-trailer, full trailer and centre axle trailer. A semi-trailer was classified in class O. GUIDELINES FOR APPROVAL OF VEHICLES, 2015 states that semi-trailer "a towed vehicle in which the axle are positioned behind the centre of gravity of the vehicle (when uniformly loaded), and which is equipped with a connecting device permitting horizontal and vertical forces to be transmitted to the towing vehicle. One or more of the axle may be driven by the towing vehicle" is classified under class O vehicles. Class o is divided into four more classes which is O1, O2, O3 and O4. It was divided by maximum load that can be carried by the trailers. The definition of the classes was given in the **figure 2.6** below.

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Category	Definition	Term
O1	*A non-powered vehicle used to transport persons or goods and is intended to be towed by a motor vehicle, with a maximum mass not exceeding 0.75 t.*	*Trailer*
O2	*A non-powered vehicle used to transport persons or goods and is intended to be towed by a motor vehicle, with a maximum mass exceeding 0.75 t, but not exceeding 3.5 t. Types of the trailers are as in Table 2 - page 34.*	*Trailer*
O3	*A non-powered vehicle used to transport persons or goods and is intended to be towed by a motor vehicle, with a maximum mass exceeding 3.5 t, but not exceeding 10 t. Types of the trailers are as in Table 2 - page 34.*	*Trailer*
O4	*A non-powered vehicle used to transport persons or goods and is intended to be towed by a motor vehicle, with a maximum mass exceeding 10 t. Types of the trailers are as in Table 2 - page 34.*	*Trailer*

Figure 2.10 : Definition of vehicles class O (Guidelines of vehicle approval, 2015)

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The design of the fire fighting robot transport trailer was under class 1. This is because the robot was weight below 0.75 ton or 750 kg. There are a few safety measures that need to be followed to design the O class vehicle. This parameter was following a few different regulations of United Nations (UN). The parameters needed for O class vehicles are as follow:

1. Reflex reflector
2. Direction indicators
3. Stop lamps and end- outline marker
4. Braking
5. Rear marking plates for Slow Moving Vehicle

6. Rear marking plates for Heavy and Long Vehicle
7. Light Emitting Diode (LED) light sources (If fitted)
8. Side-marker lamps (If fitted)
9. Reversing lamps
10. Vehicle for the Carriage of Dangerous Goods
11. Special Warning Lamps (If fitted)
12. Tyres with regard to rolling sound emission

Figure 2.11 : Reflex reflector (Guidelines of vehicle approval, 2015)

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Figure 2.12 : Rear marking plates for Heavy and Long Vehicle

(Guidelines of vehicle approval, 2015)

Figure 2.13 : Rear marking plates for Slow Moving Vehicle

(Guidelines of vehicle approval, 2015)

All the parameters have been drafted as safety precautions for all road users. In order to make the vehicle legal on the road, it has to be registered and approved by JPJ. Besides following the guidelines parameters that had been given, a few registration procedures must be done in order to register the vehicle.

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CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology used during development of transport trailer for fire fighting robot. The flow chart of the project is shown in Figure 3.1. The projects start by doing research about the fire fighting robot. All the specifications, types, advantages and flaws of the robot were taken. Specification such as weight and size was very important in developing the trailer for the robot. The trailer must able to support the robot and the size of the trailer must suitable with the robot as it needs to transport it. Next, Product Design Specifications(PDS) methods used to identify the criteria needed in developing the transport trailer. After that, conceptual design method was used. This method involving morphological chart, different design concepts and pugh concept selection method. Morphological chart method is used to generate different designs according to the several criteria listed from PDS. The alternatives are drawn and sketched. Then, pugh method was used to compare the design concept. Then, design selected was drawn by using SOLIDWORK software. After finishing the drawing, the trailer design will be analysed in ANSYS software.

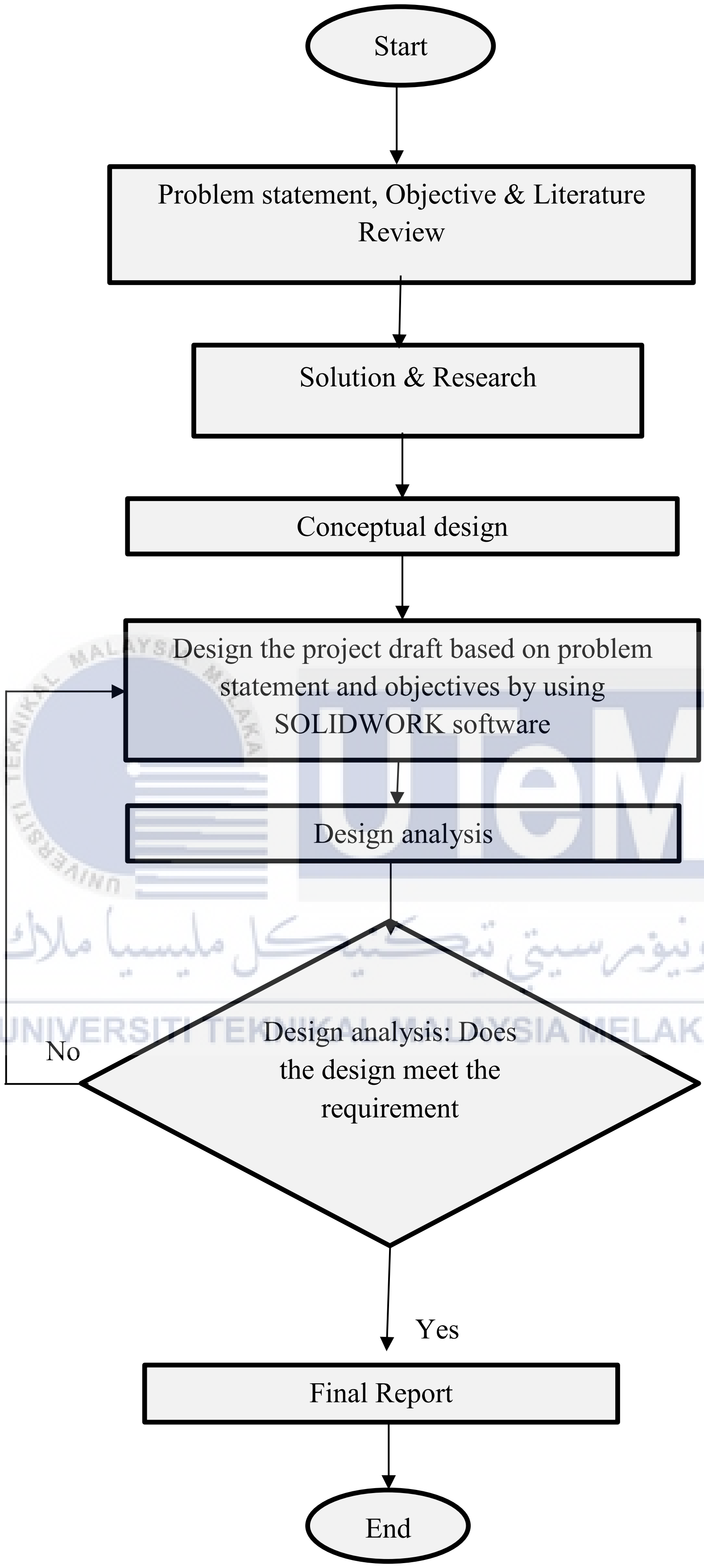

Figure 3.1 : General Methodology

3.2 RESEARCH METHODOLOGY

Information from journal, thesis, books, internets and lecturers had been gathered to carry out this project. Journal and articles involving the process of development of this project were studied in order to finish this project. The development and process of the project was shown in **Figure 3.2**.

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Activities \ Week	PSM 1													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Problem Statement & Objectives														
Literature review														
Conceptual Design														
Methodology (Morphological chart & pugh concept)														
Methodology (Sketching and design selection)														
Design development														
Draft of report writing														
Report writing submission														
PSM 1 presentation														

Figure 3.2 : Gantt chart

3.3 METHODS

3.3.1 Product Design Specification (PDS)

Before developing design, A few criteria need to be considered for the trailer. The criteria needed or called product design specification (PDS) are listed in Table 1

Table 3.1 : PDS table

No.	Criterion	Specification
1	Performance	• Can support maximum body weight of 5000 kg of the robot • Rigid frame
2	Safety	• Safety belt or harness for the robot to lock the robot in place. • Strong welding joint to get strong body frame • Suitable material for the body frame. • Safety bar • Reflection light
3	Manufacturability	• Easy to manufacture and fabricate
4	Weight	• Trailer need to have low weight for fuel consumption • Material can stand high weight object

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5	Material	• Light • Highly durable • Low cost • Strong • Ductile
6	Dimension	• 4 – 5 m x 3 m
7	Cost	• Low cost
8	Maintenance	• Low cost of maintenance • Frequency of maintenance

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3.3.2 Morphological Chart

This method is used by generating different designs according to the several criteria listed. By applying this method, a few design concepts of transport trailer can be develop.

Morphological Chart

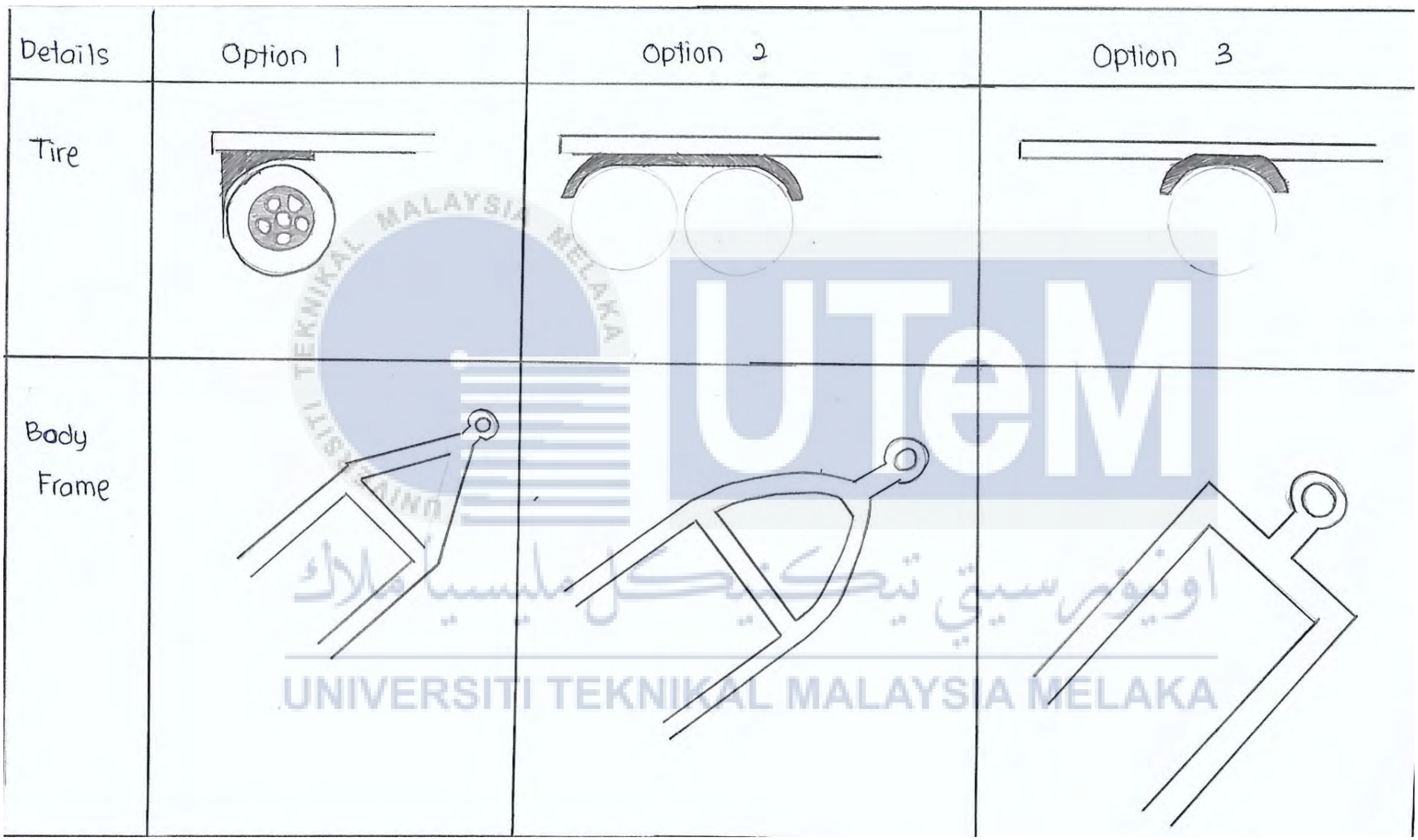

Figure 3.3 : morphological chart I

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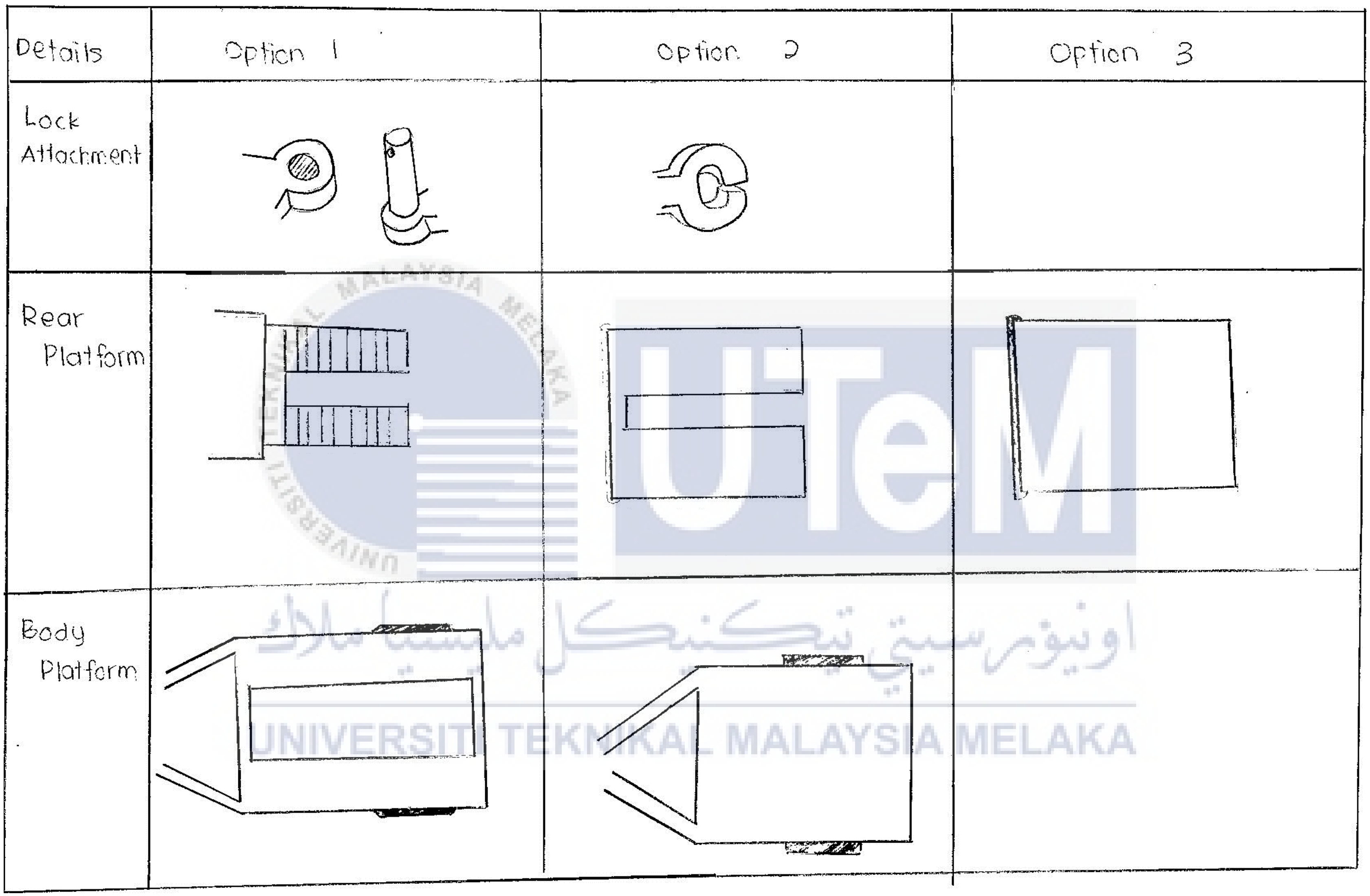

Figure 3.4 : morphological chart II

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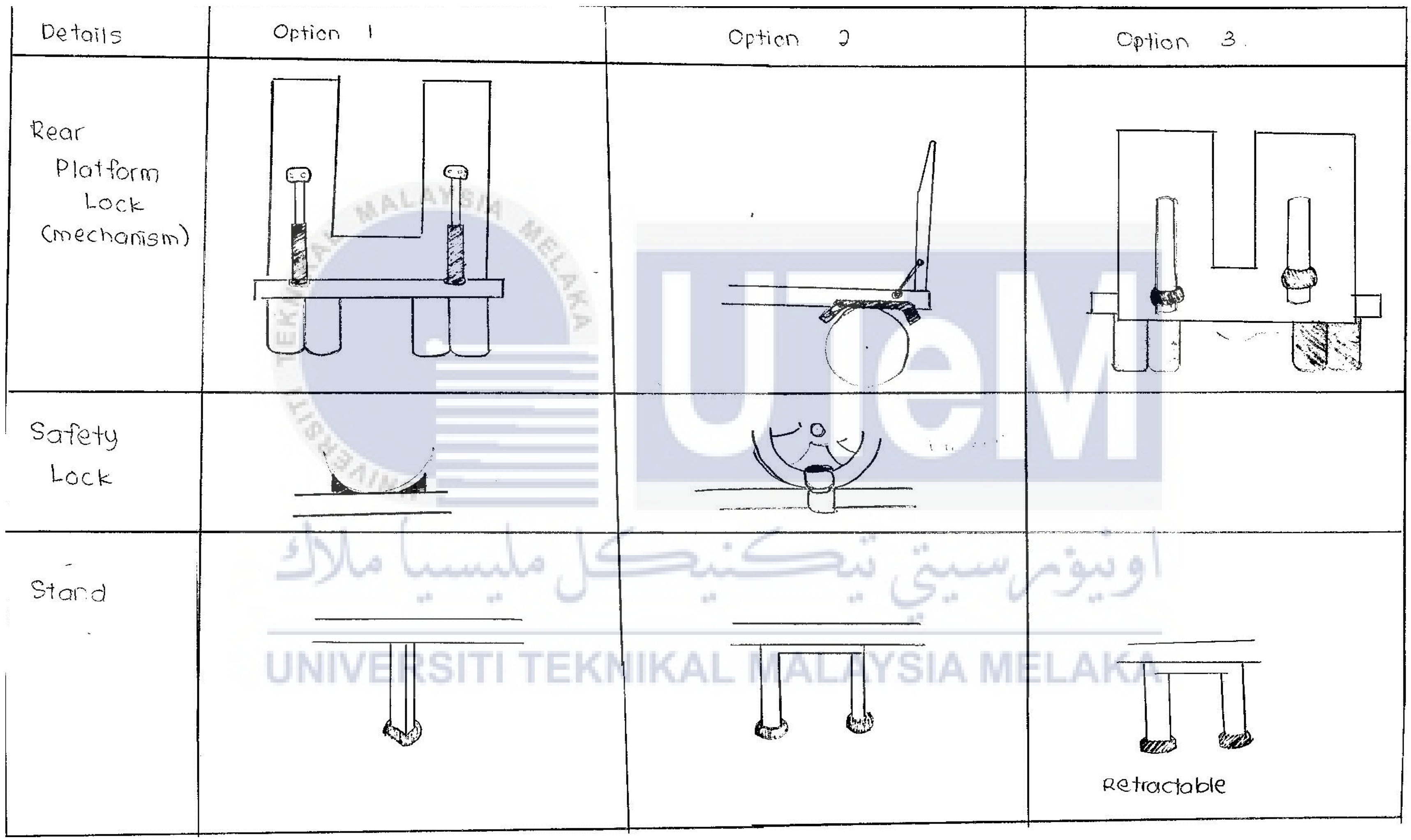

Figure 3.5 : Morphological chart III

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3.3.3 Conceptual design concept

In the conceptual design stage, alternative design concepts are generated using Morphological Chart. Three design sketches are produced before drawn by using CATIA software. Then, Pugh Concept Selection method is used to determine the best conceptual design among the three design concepts. The alternatives design was drawn by sketching on A4 paper. The sketches drawn are listed in figure below.

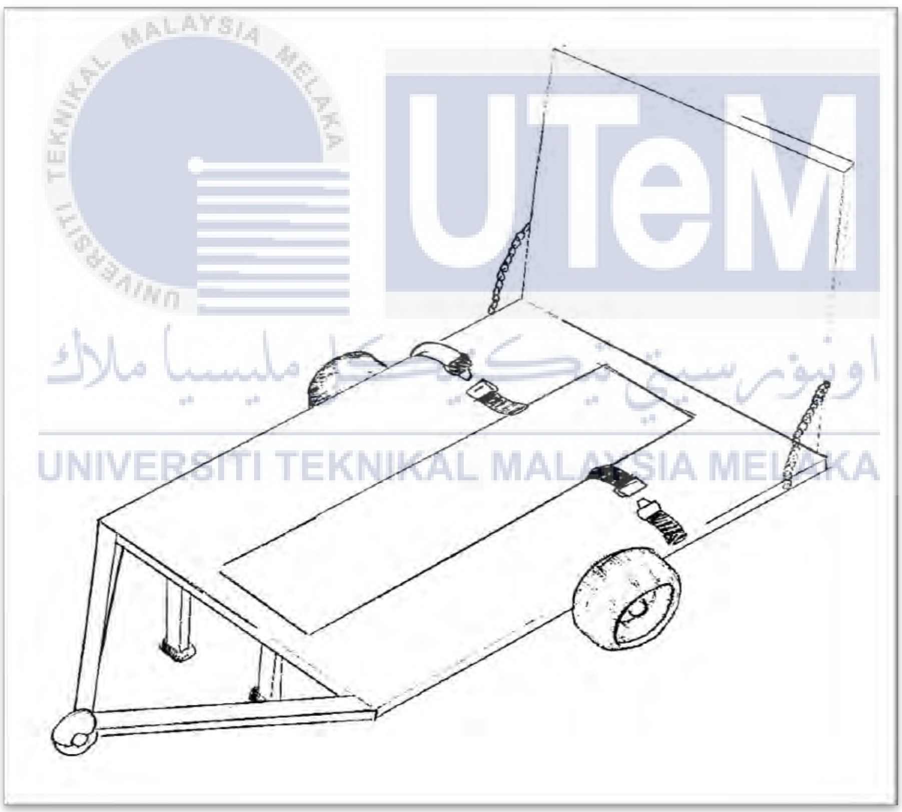

Figure 3.6 : Design 1

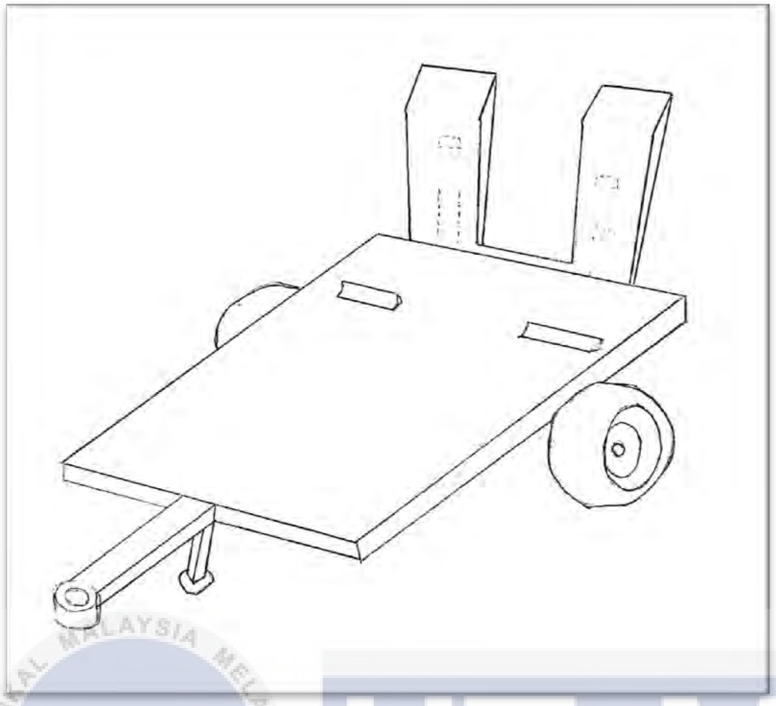

Figure 3.7 : Design 2 (Datum)

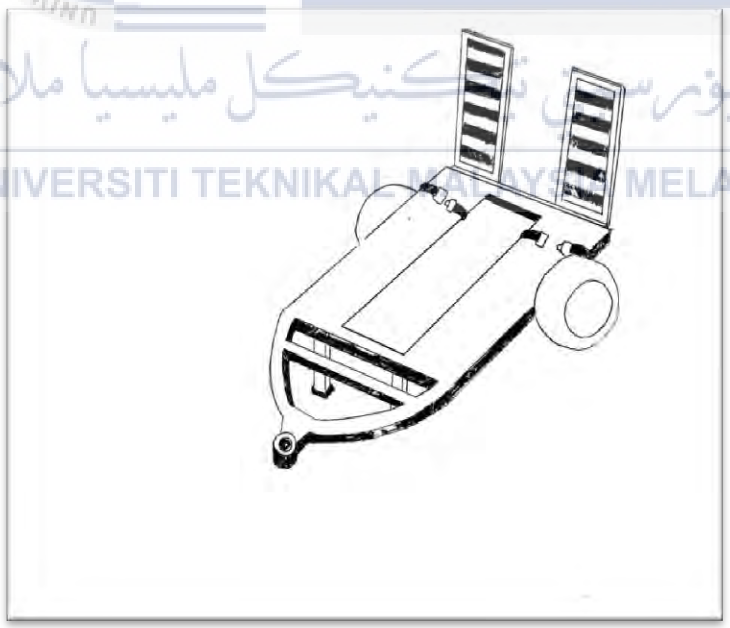

Figure 3.8 : Design 3

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3.3.4 Pugh Concept Selection Method

This method is used to compare the alternative design and choosing the best design. This method requires the comparison between the three design concepts against the criteria of evaluation (PDS). In each comparison, the product is evaluated with each other as being better (+), same (0) or worse (-). The best conceptual design with the highest "+" sign is further described in design selection.

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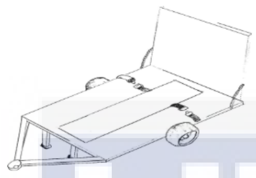
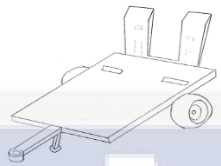
Table 3.2 : Pugh Concept Selection Method

CRITERIA	WEIGHT	DESIGN 1 	DESIGN 2 (DATUM) 	DESIGN 3 
Performance	5	-	0	+
Safety	5	+	0	+
Weight	4	-	0	+
Manufacturability	3	+	0	-
Cost	4	+	0	-
Ease of maintenance	5	-	0	+
Size (dimension)	3	0	0	0
Material	4	0	0	+
Plusses		3	0	5
Minuses		3	0	2
Total Score		0	0	3

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3.3.5 Final design selection

Based on the pugh concept selection method, the best design for the project is design 3. From the details, design 1 and 2 is using steel as their structure components while design 3 is using aluminium alloys. Aluminium vs steel trailers, 2014 states that aluminium alloys has about the same yield strength as steel. Thus, aluminium alloys is on the same par as steel in term of material strength. Design 1 and 3 is using safety belt or harness to lock the robot in place. Design 2 has less safety as it use backstop lock to hold the robot in position. Next, design 3 is less weight than design 2 and 1. This is because design 3 using aluminium alloys. Aluminium trailers vs steel trailers, 2015 states that aluminum trailers has 10 – 15% less weight than steel trailers. This criteria gives huge advantages to aluminium trailers performance. Besides, less weight trailer contribute in reducing fuel consumption cost. In market, aluminium alloys price was higher than steel. However, aluminium trailers has lower rate of maintenance frequency. Other than lubricating its hinges, yearly acid bath were enough for optimum performances and makes it look clean. This is because aluminium alloys can resist corrosion and rust. Unlike aluminium alloys, steel trailer needs frequent maintenance in order to prevent rust. The constant maintenance makes steel trailers repair more expensive. In term of manufacturability, aluminium is at disadvantages as welder is more familiar with steel welding. Besides that, soft aluminium makes it harder for the welding process. However, nowadays aluminium welding technique is commonly known. It did not become a problem in manufacturing aluminium trailers. All trailers design have same dimension which is 3m total length and 1.5m wide. This dimension was based on size of robot available in Malaysia which is 1.5m length and 1.0 m wide(Tan, C.F., and H.F. Kong, 2013). Thus, we can conclude that the best design between the three options is design 3.

3.4 SOLIDWORK DRAWING AND ANALYSIS

3.4.1 SOLIDWORK

Detailed drawing for every part of the transport trailer is drawn with SOLIDWORK software. Each part such as body frame and tires of the trailer will be drawn by using the software. All the parts will be drawn using actual dimension of normal size trailer. Basically, to draw a part in SOLIDWORK software, a plane need to be chosen. We can choose from 3 different plane which is front plane, top plane or right plane. Then, choose sketch tool to start sketching. After that, finished sketch will be extruded to generate a 3d model drawing.

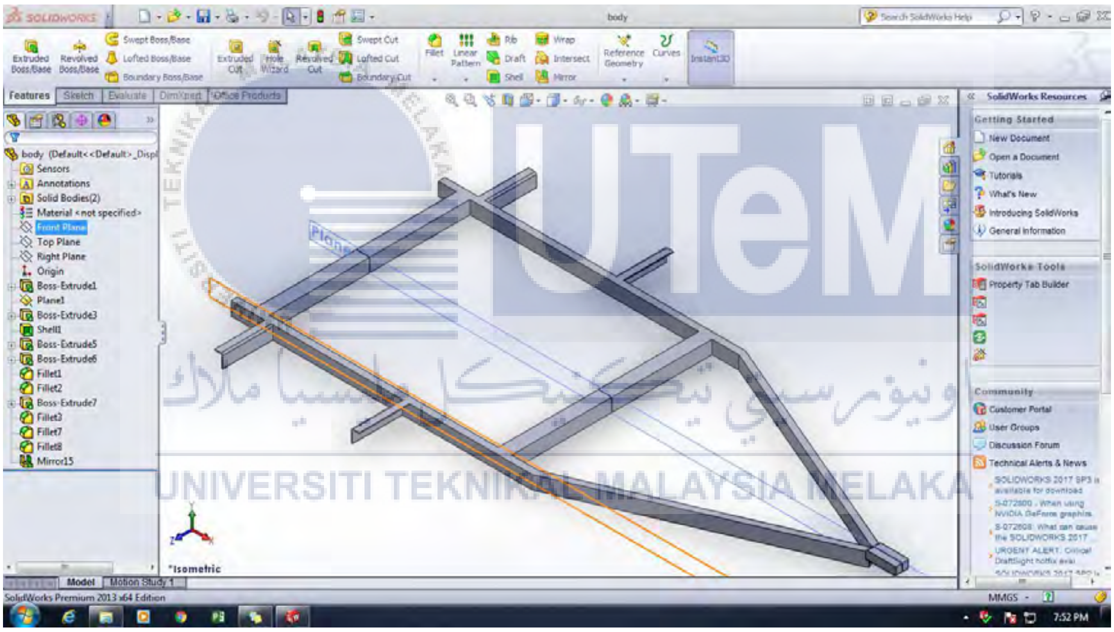

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Figure 3.9 : Example of 3D model drawing

Then, all the parts included will be assembled by using SOLIDWORK software. The assemble process start with inserting a main part and placed it as fix part. A fix part will stay at its place and cannot be moved. Then, next part will be insert by inserting component tool. After the part was inserted, it will be mate with other part by using suitable mate condition. There are several mate options such as coincidence, parallel, perpendicular or horizontal that allows the part to be mated to its suitable place.

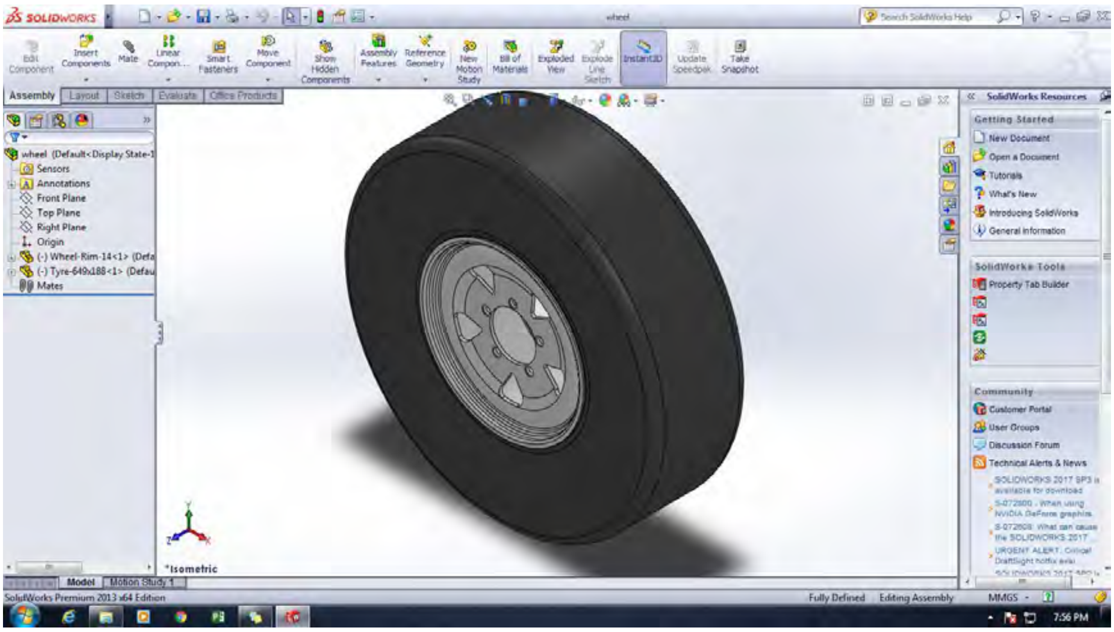

Figure 3.10 : Example of wheel assembly

Besides part drawing and assembling, SOLIDWORK software also allows user to create isometric drawing of the part. From isometric drawing, dimension of the part can be seen more clear.

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3.4.2 ANSYS STRUCTURAL ANALYSIS

After finish with the assembling process, stress analysis was analyzed to the design drawing. ANSYS software allows user to do stress analysis by applying material selected by users. From the analysis, high stress area and low stress area can be seen. High stress area will be in red color while low stress area will become blue. Besides stress, value of von misses also can be seen from the software. From the analysis, failure of the design can be identified. If the product failed, new product design need to be develop. The next step of the project can be done if the design was valid. Thus, this analysis was a very important step to determine the progress of this project.

ANSYS analysis is started with choosing structural analysis option at the toolbar.

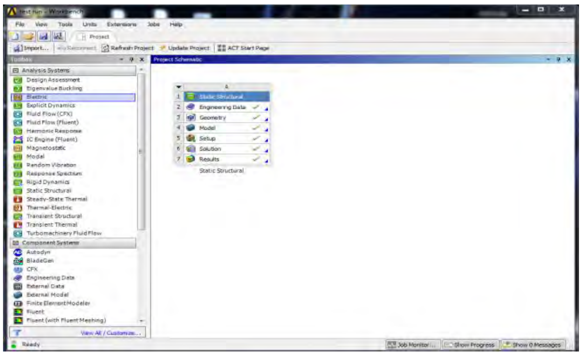

Figure 3.11 : Structural analysis options

Then, choose aluminium alloy material in engineering data bar. There are many type of material that can be choosen from there.

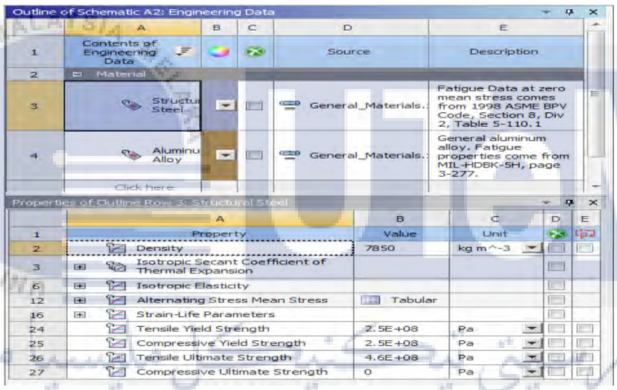

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Figure 3.12 : Choosing material

Next step is inserting geometry that had been saved in igs file previously at SOLIDWORK software.

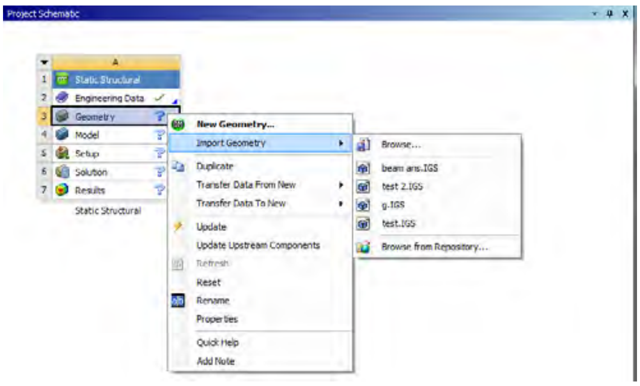

Figure 3.13 : Importing geometry

After that, the geometry will be inserted to the workbench. Editing the geometry can be done here. Next, material need to be apllied by click geometry > part and the material tab will appear and choose aluminium alloys as the material for the geometry.

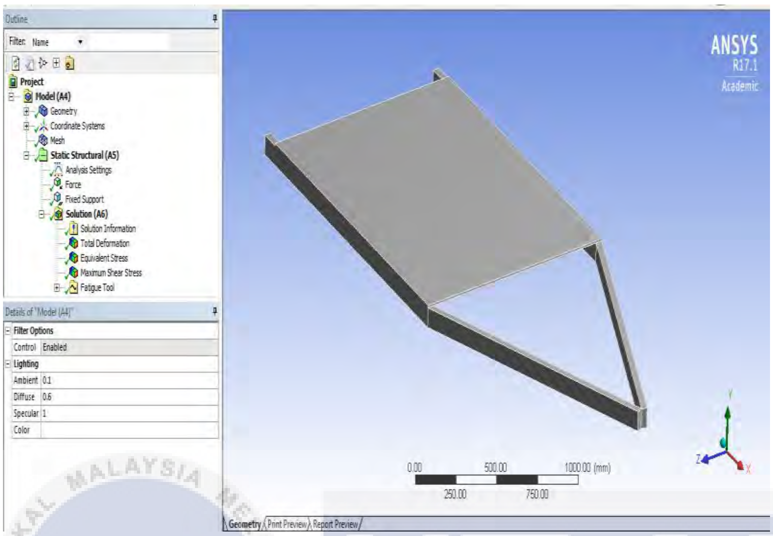

Figure 3.14 : Applying material to geometry

The next step is choosing fix support and apply load. The load was applied on the floor face and the fix support is the lower body face. Load of -4000kg is inserted at Y component as it is facing downward.

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Details of "Force"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. N (ramped)
Y Component	-4000. N (ramped)
Z Component	0. N (ramped)
Suppressed	No

Figure 3.15 : Apply load value

After that, the geometry will be meshed with default meshing area. Mesh will auto generated.

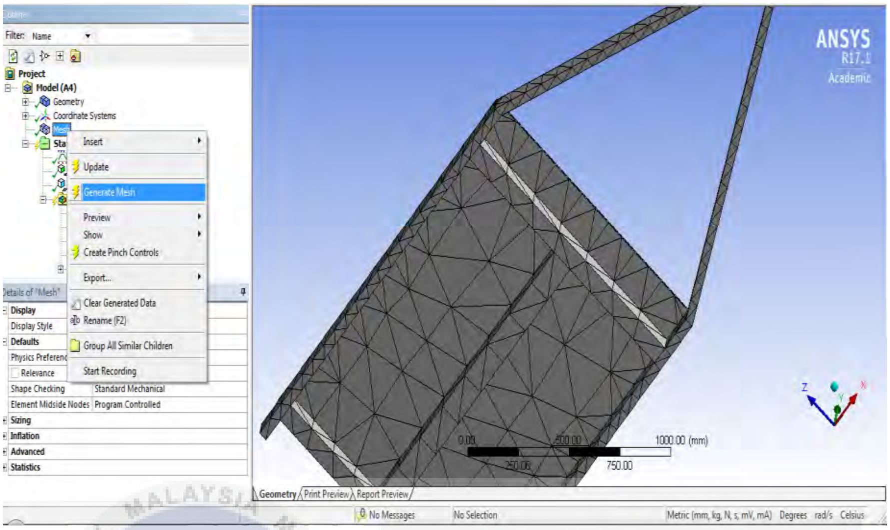

Figure 3.16 : Mesh geometry

Next, desired data was chosen by selecting solution option, insert, then choose between stress, strain or deformation. Data such as safety factor, total deformation and maximum shear stress is chosen. Then choose solve to get the data.

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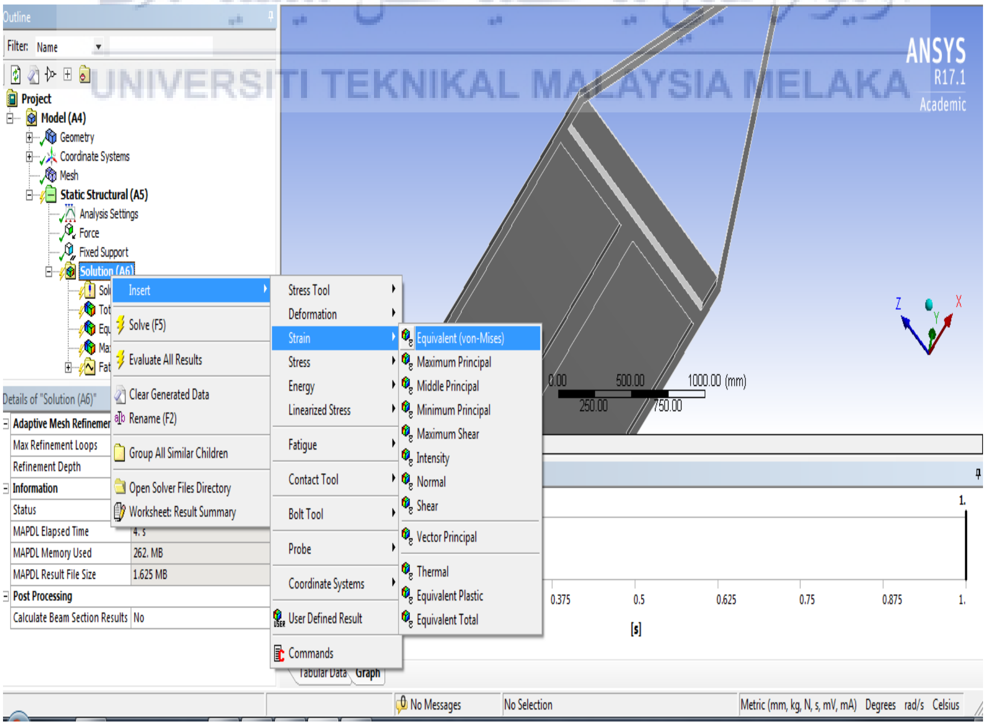

Figure 3.17 : Selecting desired data analysis

CHAPTER 4

RESULT AND DISCUSSION

4.1 TRANSPORT TTRAILER FINAL DESIGN

In this chapter, the process was started with draw 3d model by using SOLIDWORK software. Each parts of the trailer were drawn with suitable dimension before being assembled. The transport trailer consist of more than 20 parts. Figure 4.1 below shows the final design of the trailer.

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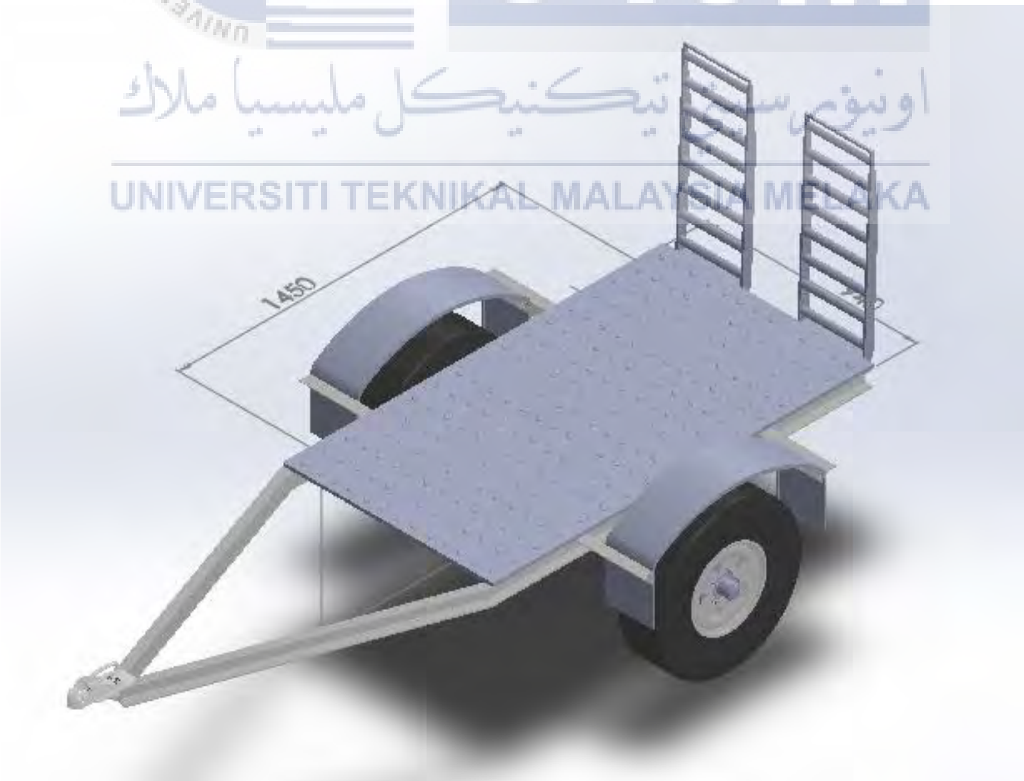

Figure 4.1 : Transport trailer final design

4.2 STRUCTURE ANALYSIS USING ANSYS SOFTWARE

The trailer body was analysed by using ANSYS software. This analysis is to evaluate the stress and shear force that happened to the trailer body when load was applied. Besides that, this analysis can give the safety factor value of the design. The part that being analysed was only the top part of the trailer which load was applied to it. Other part such as mudguard and tire was not included in the analysis.

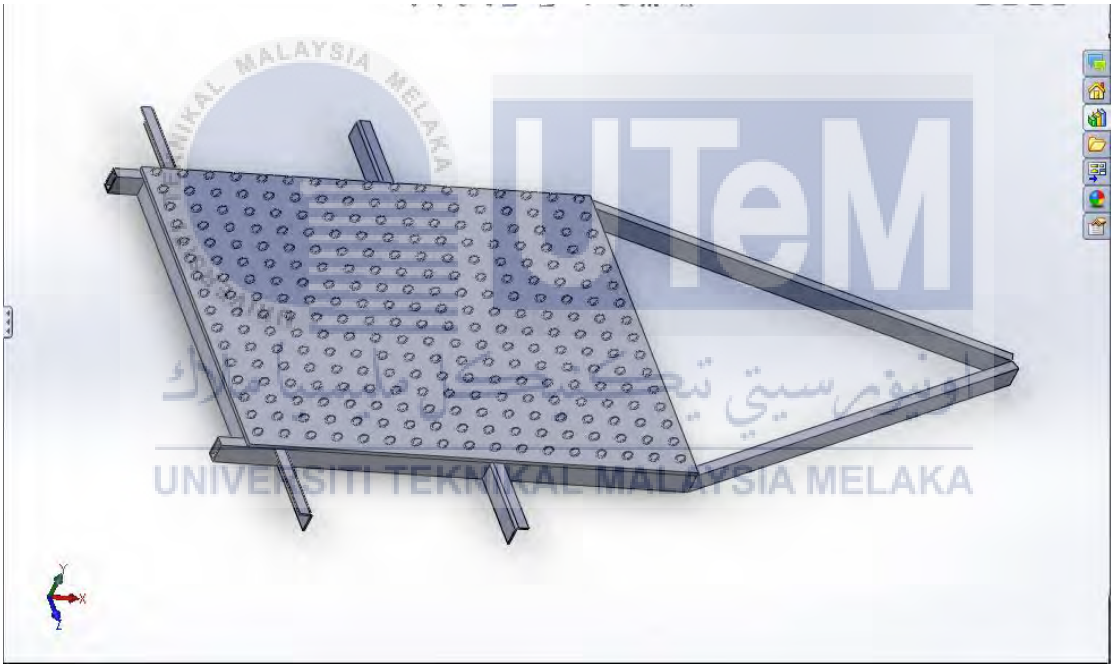

Figure 4.2 : Part of trailer use in analysis

A few details such as von misses, maximum stress and safety factor of the design were taken in this analysis. The raw material selected for the semi-trailer chassis structure is Aluminium alloy 6xxx series. The alloying elements that used in this series of aluminium alloy are magnesium and silicon.

Alloys of this series are moderate in strength (200 – 350 MPa) which is enough to support the body semi-trailer.

The strength of this alloy is achieved through the heat treatment processing or forming. The property of the aluminium alloy is presented in Table below.

Table 4.1 : Properties of aluminium alloy 6xxx series

Density	2770 kg/m^3
Ultimate Tensile strength	310 MPa
Tensile Yield strength	276 MPa
Modulus Of Elasticity	68.9 GPa
Fatigue strength	96.5 MPa
Shear strength	207 MPa

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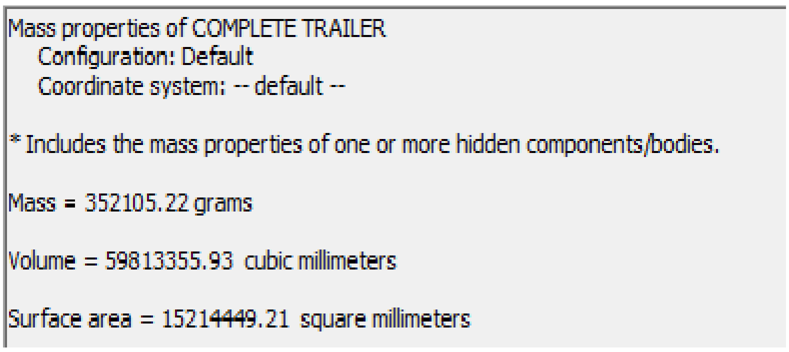
The load applied in the analysis is 4000kg. This load was chosen as fire fighting robot weight that has been invented has highest weight of 3000kg (Tan, C.F., and H.F. Kong, 2013). The fix surface applied at the design is at the below side of the trailer body. From the material applied, mass properties of the model can be calculated.


Mass properties of COMPLETE TRAILER
Configuration: Default
Coordinate system: -- default --

* Includes the mass properties of one or more hidden components/bodies.

Mass = 352105.22 grams

Volume = 59813355.93 cubic millimeters

Surface area = 15214449.21 square millimeters

Figure 4.3 : Mass properties of the design

From figure 4.7, the total mass calculated is 452.105 kg. Total surface area of the model is 15.21 m^2. Lastly, the total volume of the design is 59813355.93 m^3.

4.2.1 TOTAL DEFORMATION

Figure 4.3 below shows the total deformation of the transport trailer design.

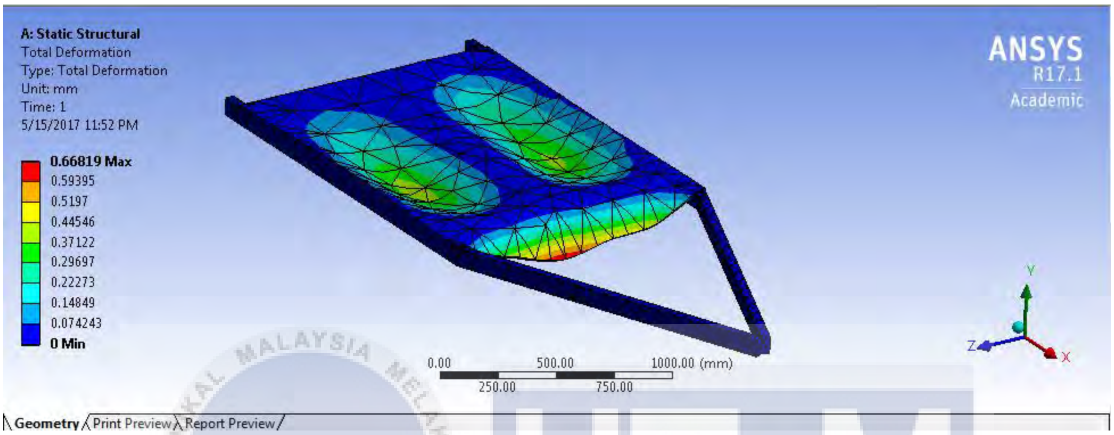


Figure 4.4 : Total deformation of design

From the figure above, we can see that the design has maximum deformation of 0.66819mm which occurs at the front side of the trailer floor. The figure indicated that when 4000kg of load was applied to the body, the front area (red area) will deflect 0.66819mm which is very low. This deformation cause by the thin floor with 15 mm thickness do not have any support beam. The value shows that the design did not affected much by the force applied. However, the fire fighting robot will not be placed on that area. As the robot is only 1.5m length and the floor is 1.730 length, the robot will be placed a bit behind that area which has support beam below. The robot will be placed on the blue area which has minimum deflection. This minimum deflection is cause by the support beam that is attached below the floor. ANSYS software shows that the red area was on the front area because the force applied to the floor was distributed throughout all area of the floor. As the robot will not be placed on that

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area, it will not be a problem to the design. In the center area, the highest deflection occurs was 0.445646mm (yellow area).

4.2.2 MAXIMUM SHEAR STRESS AND NORMAL STRESS

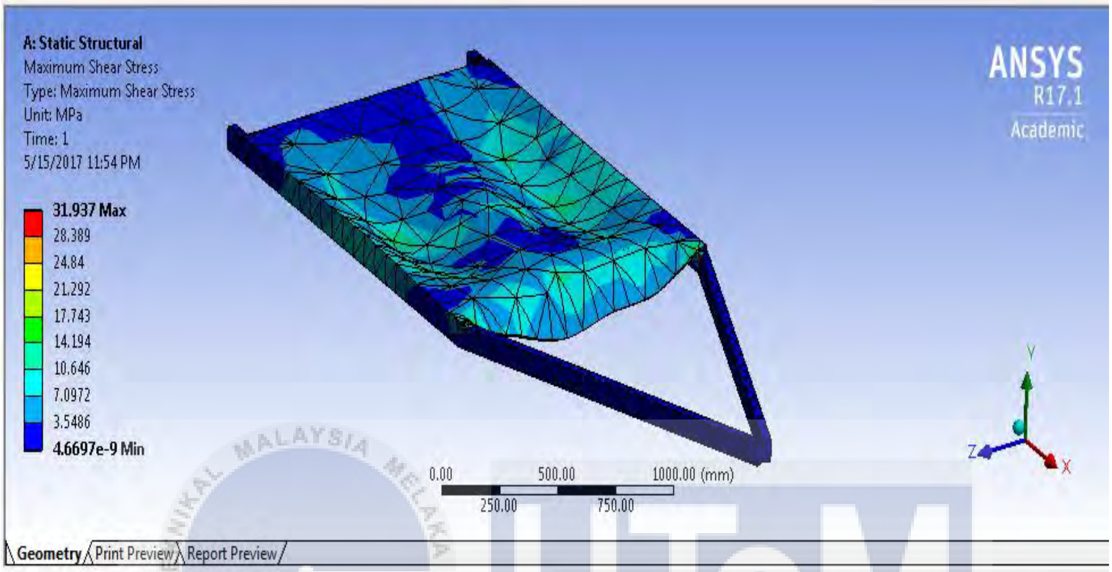

Figure 4.5 : Maximum shear stress of design

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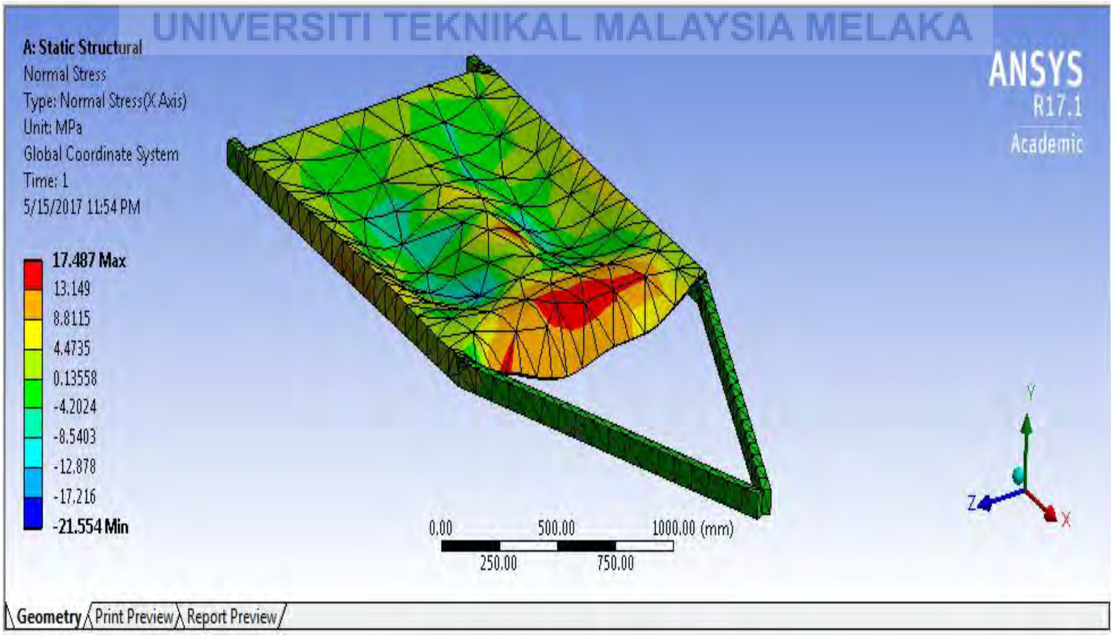

Figure 4.6 Maximum normal stress of design

From figure 4.4, the design has maximum value of shear stress of 31.937 MPa. This value can be considered as low for aluminium alloy material as it has shear strength of 207MPa. While in figure 4.5, the maximum normal stress is 17.487 MPa which occur at the front side of the design. It shows that when 4000kg of load was applied perpendicular to the floor area, the red area will have the highest normal stress rather than other area.

4.2.3 VON MISSES

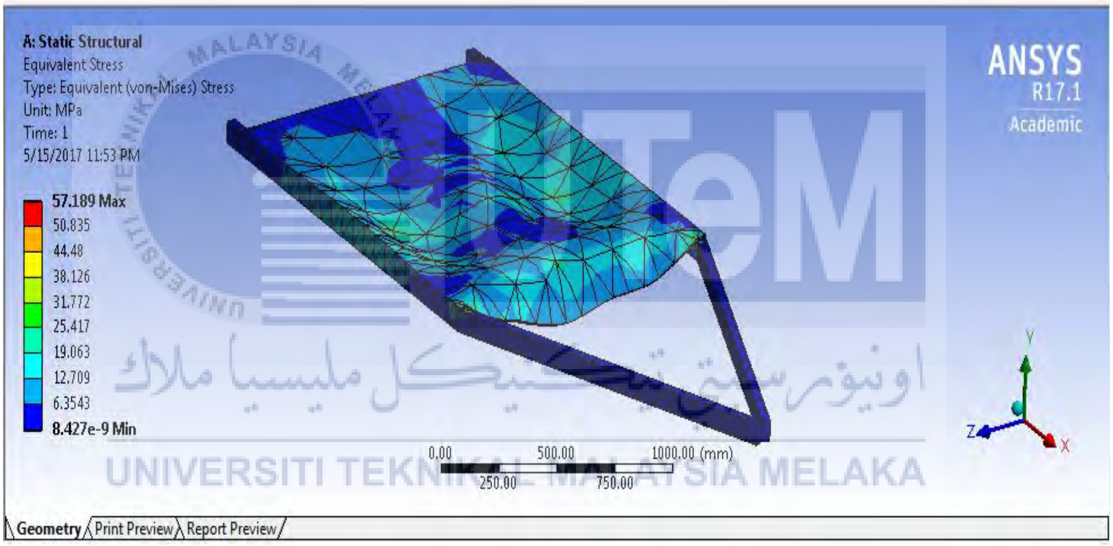

Figure 4.7 : Von misses value of the design

Maximum von misses value of the design is 57.189Mpa which occur at the edge joint of floor and trailer body. However, most area of the design have minimum or average value of von misses which is from 6MPa to 19MPa. It can be stated that the material did not yielding as the von misses value is still far from the yield strength of aluminium alloy which is 276 MPa.

4.2.4 FACTOR OF SAFETY

During factor of safety analysis was conducted, there was a problem which makes the value of safety factor was invalid. The safety factor value at 4000kg load was 15 which is the maximum value available in ANSYS software.

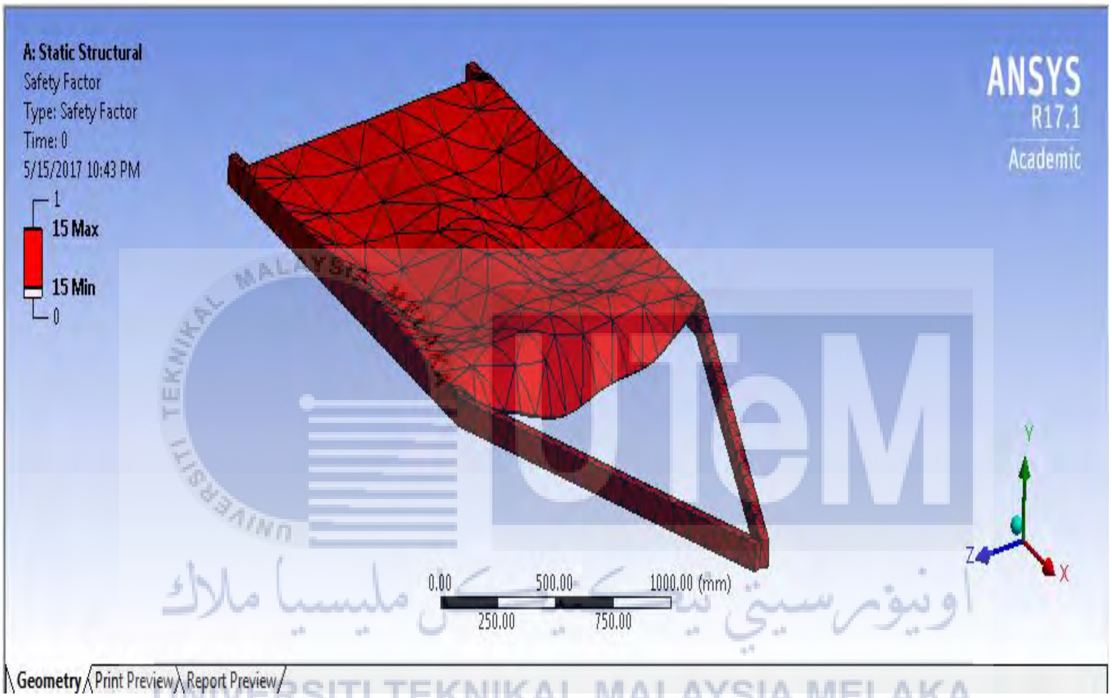

Figure 4.8 : Safety of factor at 4000kg

This problem happen because of the small value of load. In order to overcome this problem, the analysis was done by increase the value of load to 8000kg.

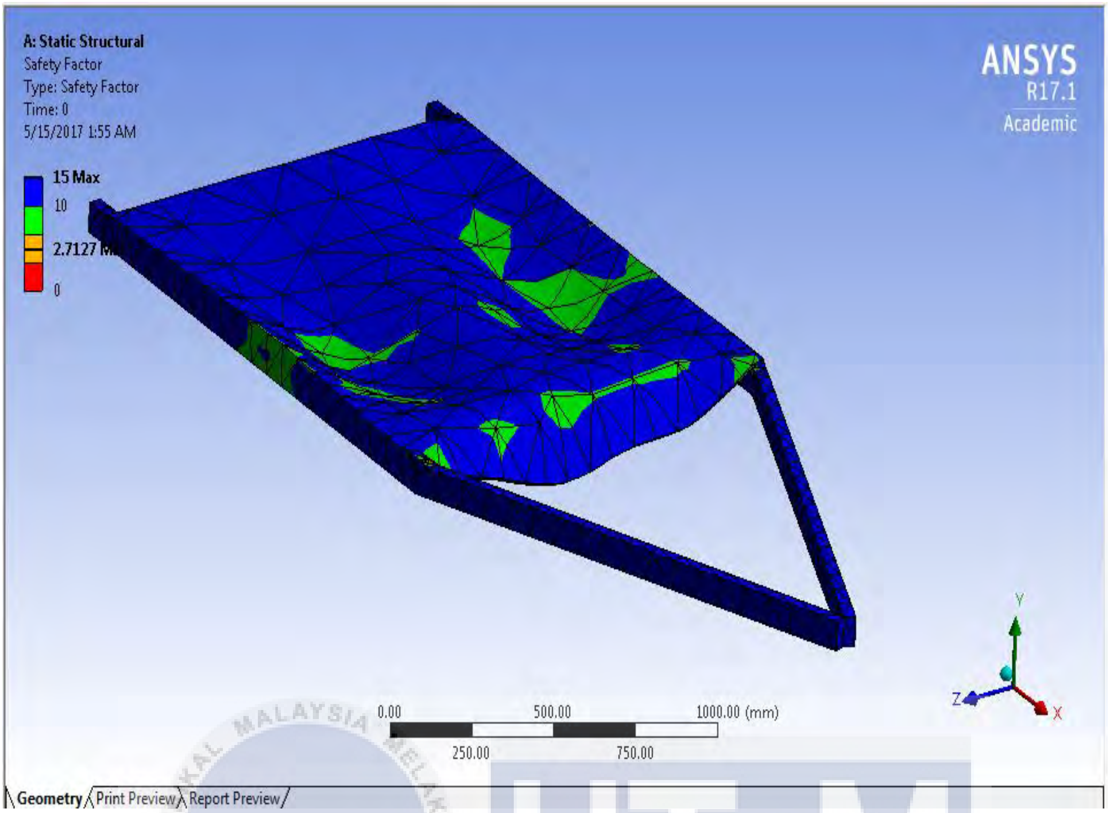

Figure 4.9 : Safety factor at 8000kg

At 8000kg load, there were a critical area shows at the edge joint of the floor to the base body (red area). This shows that when 8000kg load applied to the design, this area will be the first area to be fractured or fail. The factor of safety calculated at 8000kg is 2.7127. As the weight of the robot in Malaysia was only 950kg which is far lighter than 8000kg, the design can be stated as safe.

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4.3 COMPARISON BETWEEN MATERIAL

Table 4.2 : Comparison between aluminium alloy and structural steel properties

Structural steel A36 series		Aluminium alloy 6xxx series
7850kg/m^3	Density	2770 kg/m^3
460MPa	Ultimate Tensile strength	310 MPa
250MPa	Tensile Yield strength	276 MPa
75 GPa	Modulus Of Elasticity	68.9 GPa

The material for structural steel is A36 series which commonly used as transport trailer material, while aluminium alloy type is 6xxx series. Table 4.2 stated that there are not much different between the two chosen metal properties. However, steel has higher density which is 7850 kg/m^3. As discussed in chapter 2, higher weight of steel can cause higher consume of petrol and make the trailer difficult to handle by people. Besides that, steel can rust which make it have higher cost of maintenance rather than aluminium which did not rust. Thus, both material were analysed to see the different in mechanical properties. The analysis procedure was same as the procedure for aluminium analysis by using ANSYS software. The load of the analysis used for steel was also same which is 4000kg. As for the safety factor analysis, the load was changed to 8000kg to match the load of aluminium analysis.

Table 4.3 : Comparison between aluminium alloy and structural steel data

Structural steel A36 series		Aluminium alloy 6xxx series
0.3334.mm	Total deformation	0.66819mm
39.377 MPa	Maximum shear	31.937 MPa
58.826 MPa	Von misses	57.189 MPa
1.4653	Factor of Safety	2.7127

From the table 4.2, comparison between both material can be made. Details picture of analysis can be refer at appendix C. Structural steel have lower value than aluminium alloy which is only 0.3334. This maximum deformation occur at the same area for both material which is at the front side of the trailer floor. However, aluminium alloy has lower value of maximum shear stress and von misses. Aluminium alloy has 31.937 MPa while steel has 39.377 MPa. As for von misses, steel has 58.826 MPa while aluminium alloy is 57.189 Mpa. Although steel has higher maximum value of von misses and shear stress, it is still can be considered as safe as it has higher value of tensile yield strength than aluminium alloy. Aluminium alloy has higher value of safety factor which 2.7127. Steel material only has 1.4563 safety factor.

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4.4 I BEAM DEFELECTION

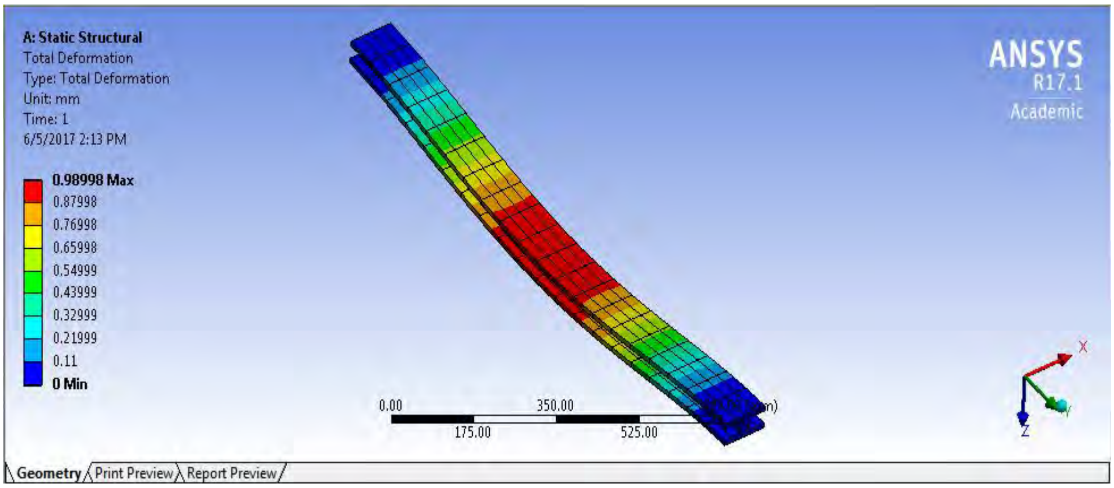

Figure 4.10: I Beam total deformation

From the figure 4.11, we can see that the maximum total deformation occur at the middle of the beam which is in red area. The maximum total deformation is 0.90998mm.

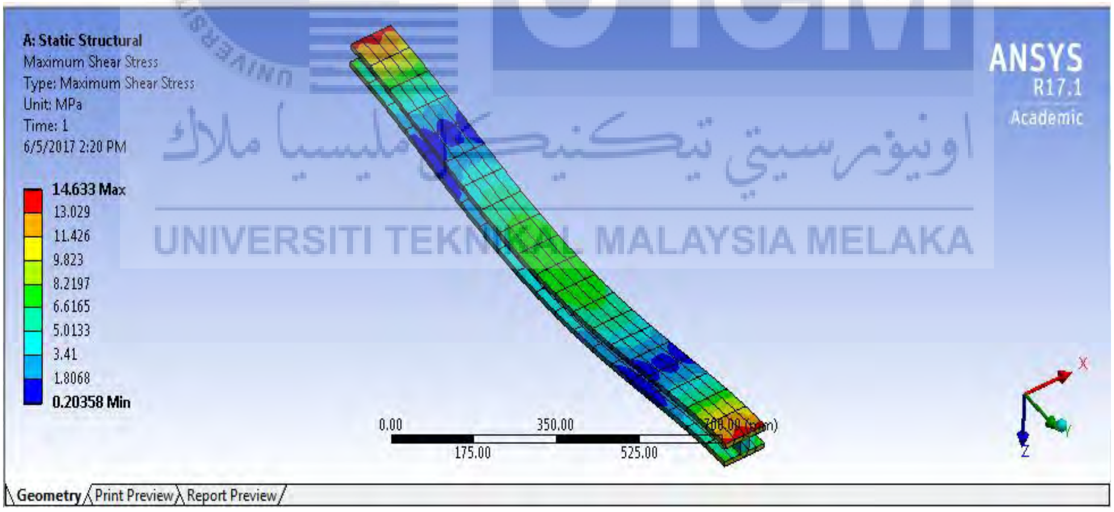

Figure 4.11: I Beam Maximum shear

Figure above shows that the maximum shear of the I beam is 14.663 MPa which occur at the both end of the beam.

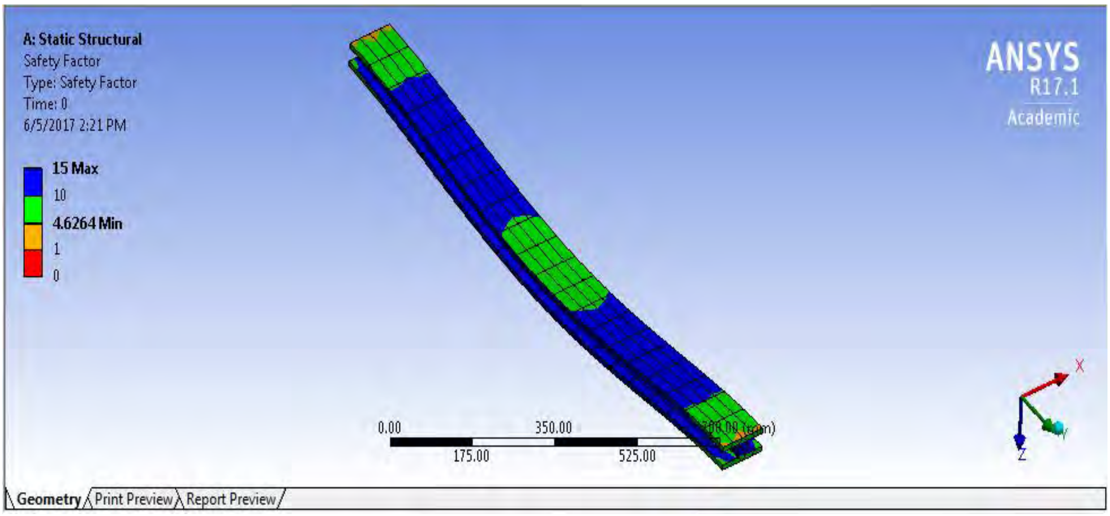

Figure 4.12 : I Beam safety factor

Figure 4.13 shows that the safety factor of the beam is 4.624.

4.4.1 I BEAM CALCULATION

The raw material selected for the semi-trailer chassis structure is Aluminium alloy 6xxx series. The alloying elements that used in this series of aluminium alloy are magnesium and silicon. Alloys of this series are moderate in strength (200 – 350 MPa) which is enough to support the body semi-trailer. The strength of this alloy is achieved through the heat treatment processing or forming.

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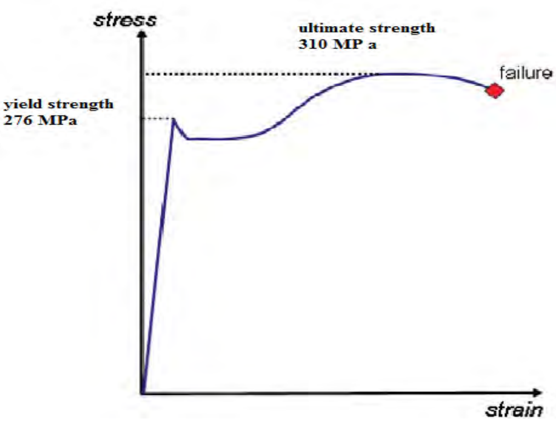

Figure 4.13 : stress and strain curve for aluminium alloy 6xxx series

I Beam

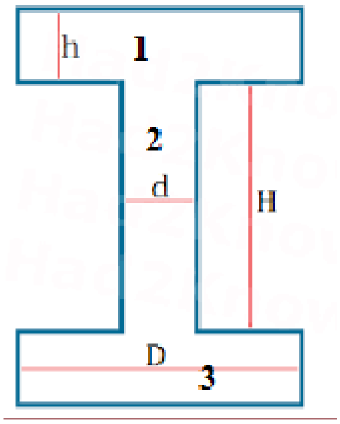

Figure 4.14 : I beam details

Properties :

h = 11 mm

d = 22 mm

H = 30 mm

D = 102 mm

Length, l (m)	**2.2**
Surface Area (m^2)	**0.002904**
Uniform Load, w (N/m)	**17830.273**
Moment of Inertia, I ($10^{-4}m^4$)	**$0.118x10^{-6}$**
Perpendicular distance to neutral axis, y (m)	**0.026**

Calculate **w**

Load that be used in this calculation is 4 ton = 4000kg. This is because the malaysia's robot is weight 1500kg and the highest weight of the fire fighting robot that had been produced is 3000kg. Thus, 4 000kg load is chosen.

$$4000\text{kg} = 39240\text{N}$$

$$\text{w} = \frac{F}{l}$$

$$\text{w} = \frac{39240}{1.37}$$

$$\text{w} = 28642.34 \text{ N/m}$$

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calculate I_{beam}

$$I = \frac{1}{12}bh^3 \ , \ A = b \times h \ , \ |\, y - \acute{y} \,|$$

surface	1	2	3
moment of inertia, I	11313.5	49500	11313.5
Area, A	1122	660	1122
distance from centroid, d	20.5	0	20.5

$$I_{total} = (I_1 + A_1 \times d_1) + (I_2 + A_2 \times d_2) + (I_3 + A_3 \times d_3)$$

$$= 18129 \text{ mm}^4 \ , \ = 0.118\text{x}10^{-6} \text{ m}^4$$

For analytical calculation, the structure is considered as uniform distribution of load at simple beam. The maximum stress is given by

$$\sigma_{\text{max (beam)}} = \frac{ywl2}{8I}$$

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$$= 14.806 \text{ MPa}$$

maximum deflection can be calculated by.

$$\delta_{\text{max (beam)}} = \frac{5wl4}{384EI}$$

$$= 0.8644 \text{ mm}$$

$$\text{Factor of safety}_{\text{(beam)}} = \frac{\textit{yield strength}}{\textit{applied load}}$$

$$= 4.93$$

CHAPTER 5

CONCLUSION AND RECCOMMENDATION

5.1 INTRODUCTION

In this chapter, the overall result is concluded based on the data obtained from the research. It can be stated that the conclusion and recommendation are about the design, material used, and the safety factor of the design.

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5.2 CONCLUSION

The studies of this thesis is mainly focus on developing a design of transport trailer that will be used by fire fighting robot in order to mobilize to fire scene. The design must use a suitable material with enough strength to carry the robot. The studies start with finding info and data about the robot. Next is developing a suitable design and choosing material for the trailer. 3D design were drawn by SOLIDWORK software. The material chosen is aluminium alloy as it has much more advantages rather than normal structural steel. Then the design structure was analysed by using ANSYS software. The data obtain shows that aluminium alloy gives light weight of trailer which is only 352.105kg. Next, the structural analysis has proven that a trailer build using aluminium alloys material is suitable for the trailer. The data shows that the total deformation of the design is very small which is 0.66819 mm that occur at the front side of the trailer floor. This deformation cause by the thin floor with 15 mm thickness do not have any support beam. Area of floor that have support beam gives min value of deflection which is zero. Shear stress in figure 4.4, indicates that the design has maximum value of shear stress of 31.937 MPa which is lower than the aluminium alloys shear strength which is 207MPa. Next, the maximum normal stress of the design is 17.487 MPa. For the von misses value stated at figure 4.7 which is at 57.189MPa. It shows that the material did not yielding when load applied. Lastly, the studies in the analysis shows that the design is very strong as it has safety factor of 2.7127 for 8000kg of load. Safety factor of analysis with 4000kg of load can not be obtained in ANSYS as the value is higher than 15. From the comparison, it can be stated that aluminium alloy 6xxx series is comparable to steel A36 series. Both material gives slight different value of von misses, deformation and shear stress. It can be concluded that steel is stronger material than aluminium alloy. However, in term of long term maintenance cost, aluminium alloy is better choice. This is because steel trailer rust and need yearly appearance maintenance such as new paint or coating work. Cost for the job was high. For aluminium trailer, yearly acid bath is enough to make the trailer look as good as new.

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5.2 RECCOMMENDATION

In this studies, a few improvement can be recommended for further consideration. Firstly, make a comparison of analysis with several type of material. Material such as stainless steel or carbon steel can be considered to be use for the trailer. By comparing several type of material, the best option between the material can be choose.

Next, specify the robot that will be mobilized by the trailer will helps to make the studies more accurate with the design. As Malaysia have their own robot, the next studies should be focusing on Malaysia's fire fighting robot. So, the design will be develop was specify for the robot.

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LIST OF APPENDICES

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APPENDIX A

اونيۆرسيتي تيکنيکل مليسيا ملاك
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Week Activities	PSM 1													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Problem Statement & Objectives														
Literature review														
Conceptual Design														
Methodology (Morphological chart & pugh concept)														
Methodology (Sketching and design selection)														
Design development														
Draft of report writing														
Report writing submission														
Seminar 1 presentation														

Table A1 : Gantt chart for PSM 1

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Activities / Week	PSM 2													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature review														
3D design drawing by using SOLIDWORK														
Analysis of the design by using ANSYS software														
Report writing														
Final report writing submission														
PSM 2 presentation														

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Table A2 : Gantt chart for PSM 2

APPENDIX B

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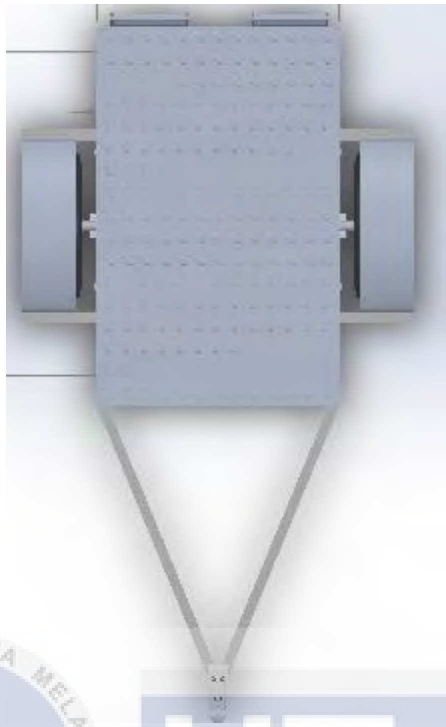

Figure B1 : Top view of the trailer

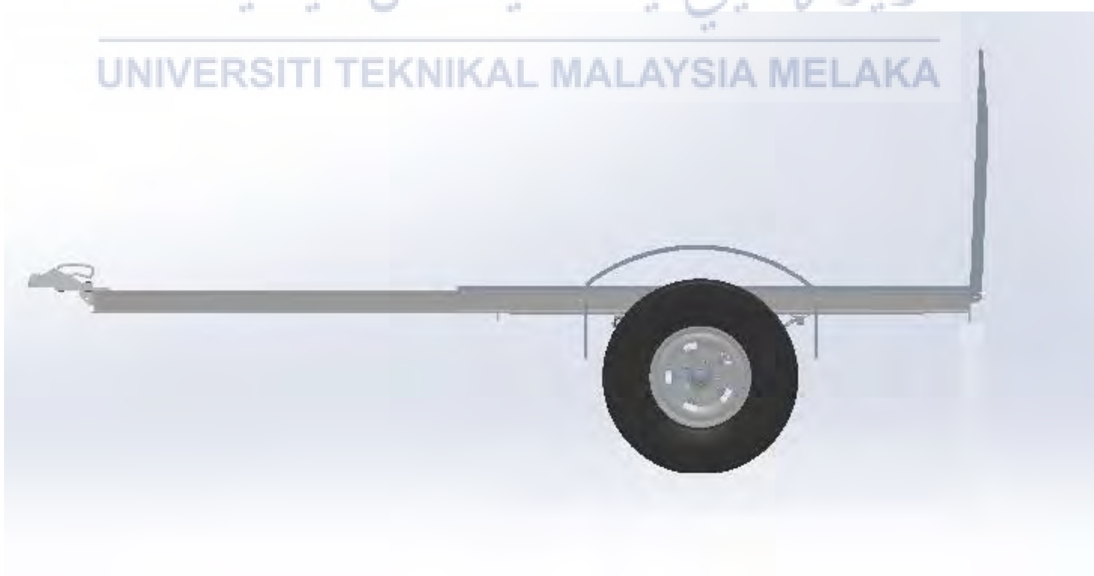

Figure B2 : Side view of the trailer

Figure B3 : Rear view of the trailer

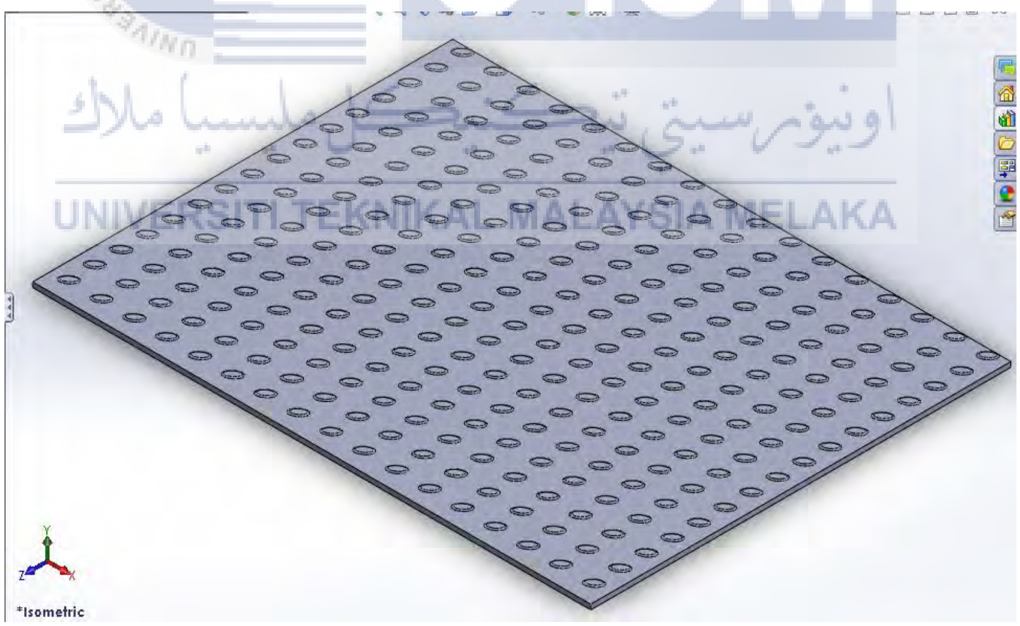

Figure B4 : Trailer floor

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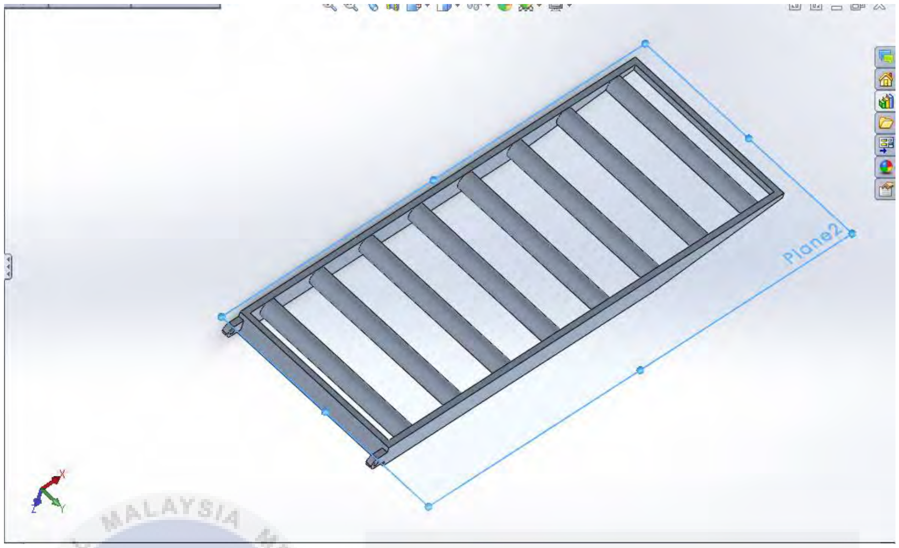

Figure B5 : Trailer rear platform

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Figure B6 : 14''rim

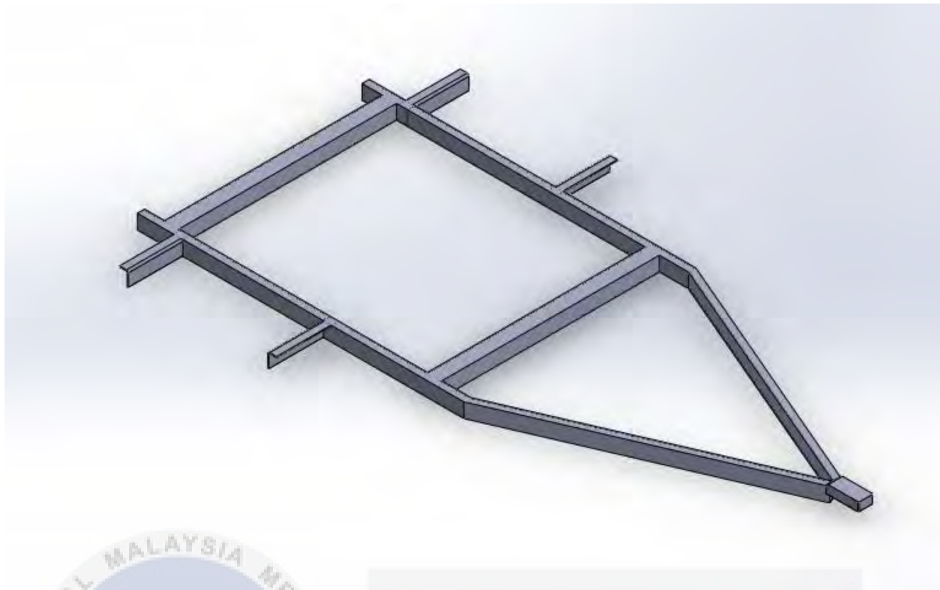

Figure B7 : Trailer base body

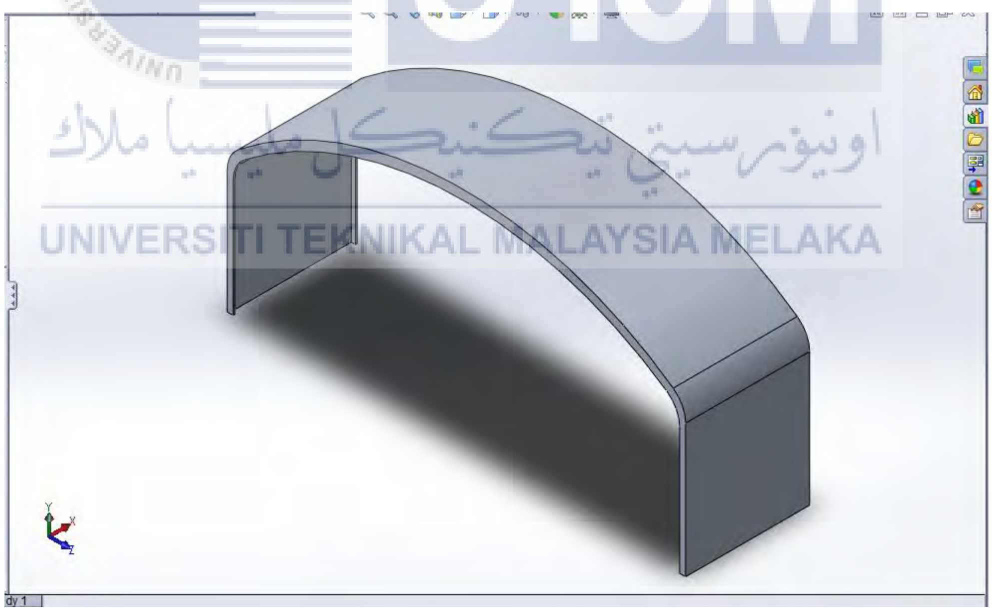

Figure B8 : Mudguard

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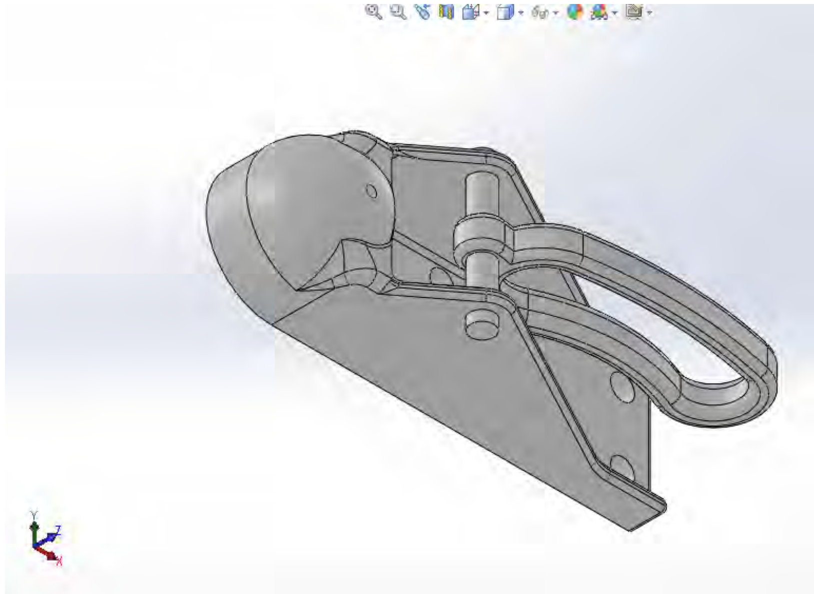

Figure B9 : Trailer lock

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Figure B10 : Tire

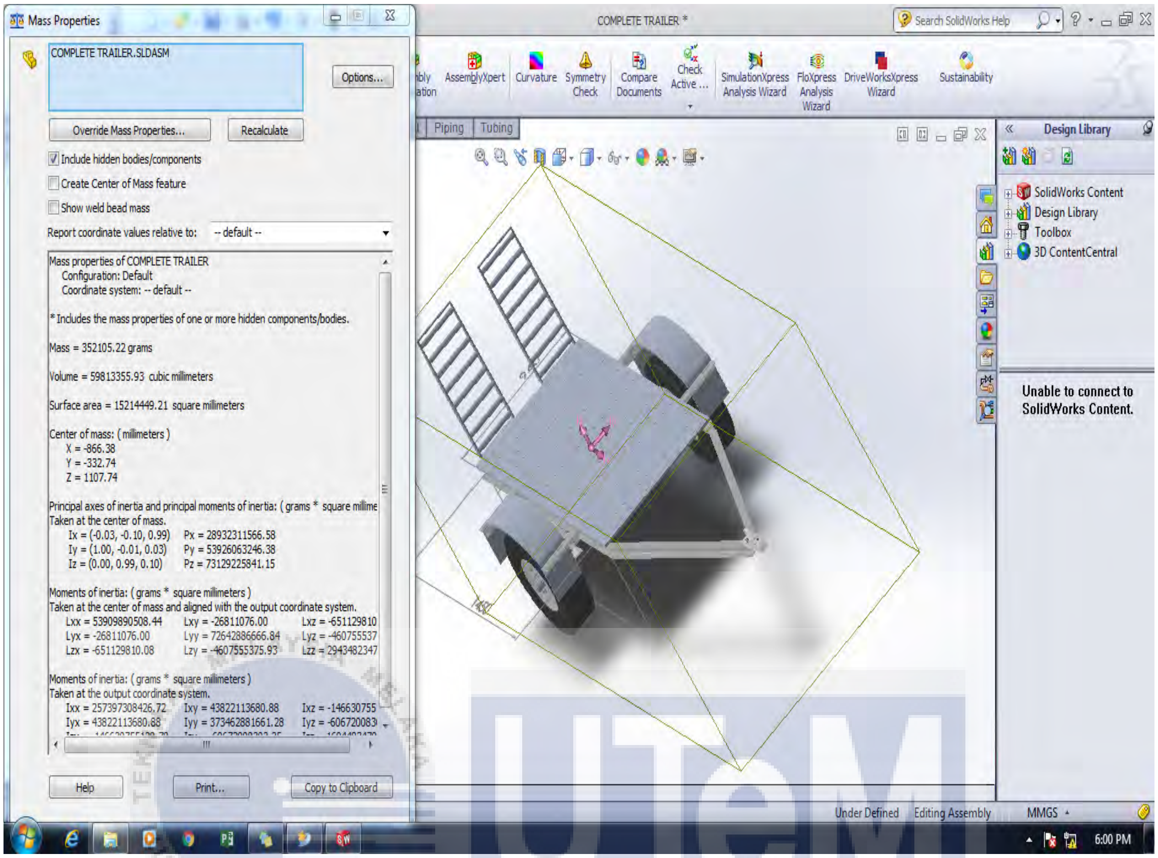

Figure B11 : Mass properties of the trailer

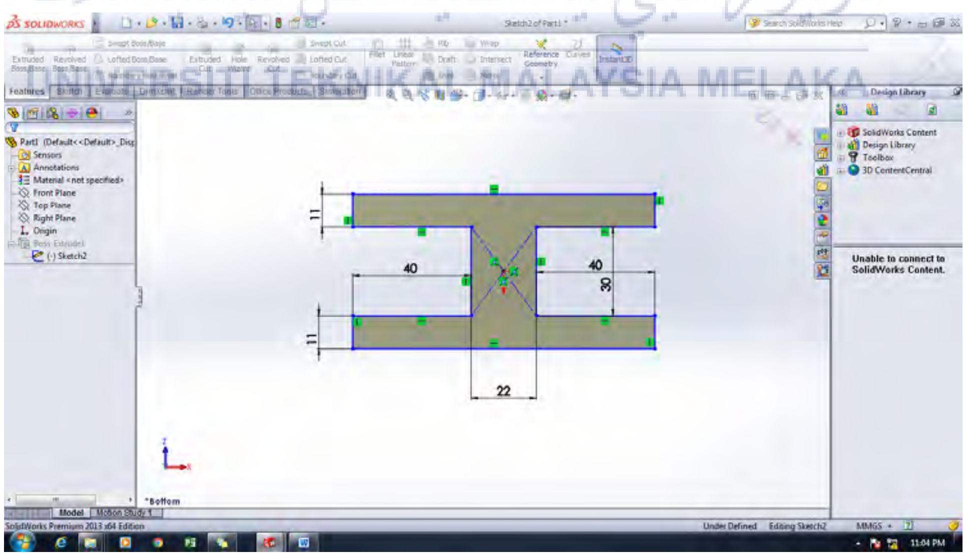

Figure B12 : I beam properties

APPENDIX C

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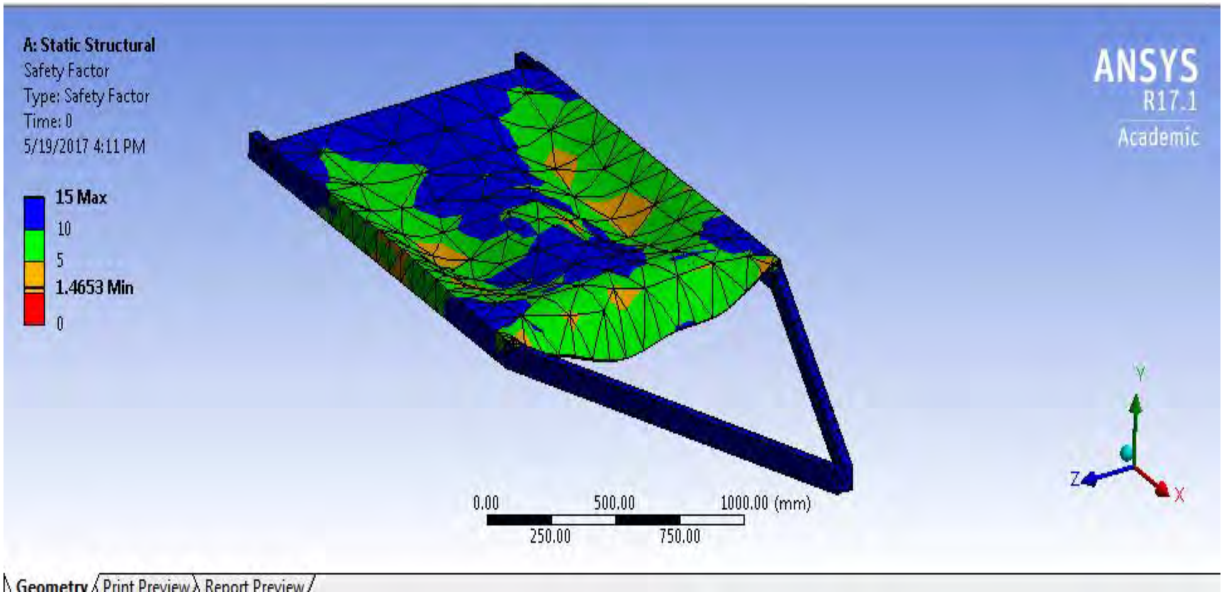

Figure C1 : Safety factor of trailer base body (steel material)

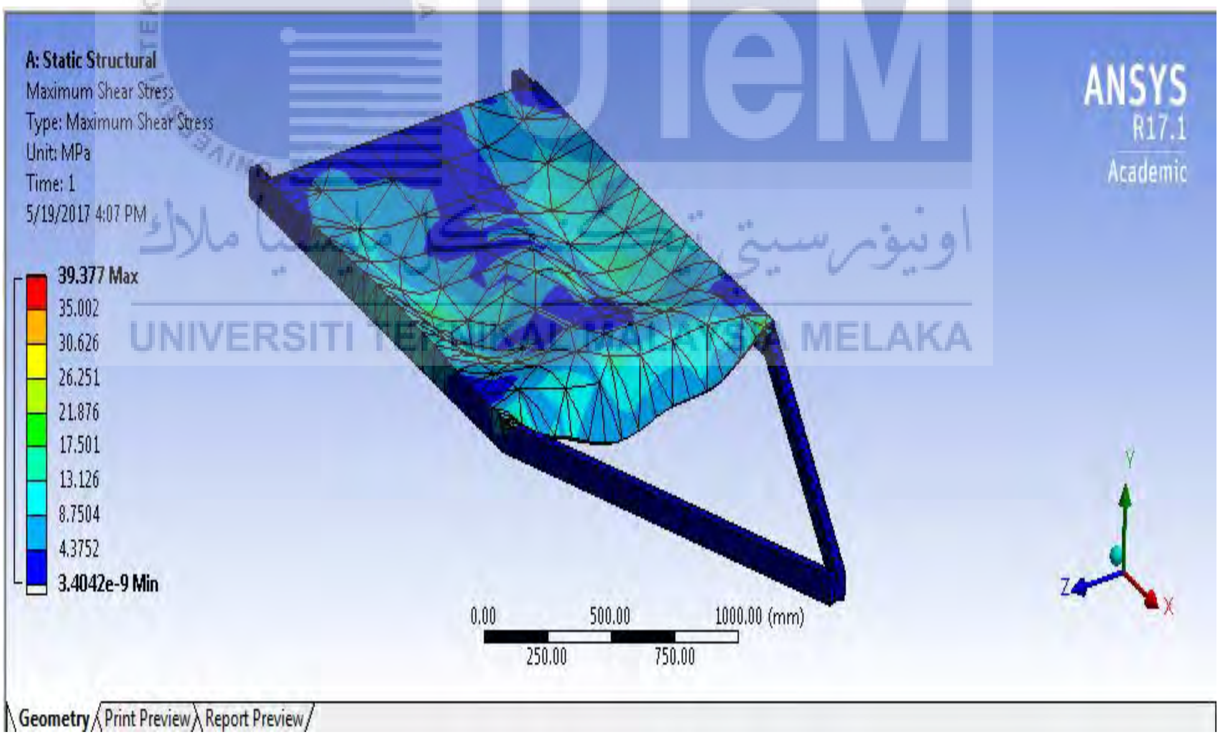

Figure C2 : Maximum shear stress of trailer base body (steel material)

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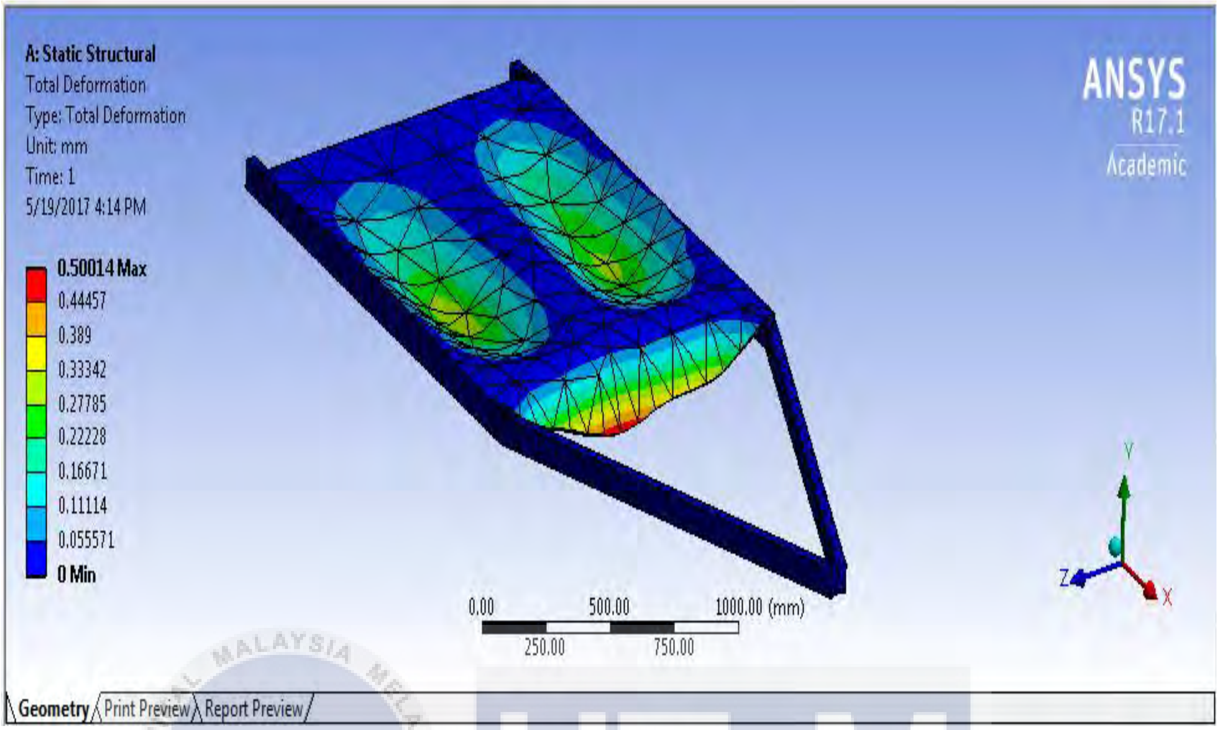

Figure C3 : Total deformation of trailer base body(steel material)

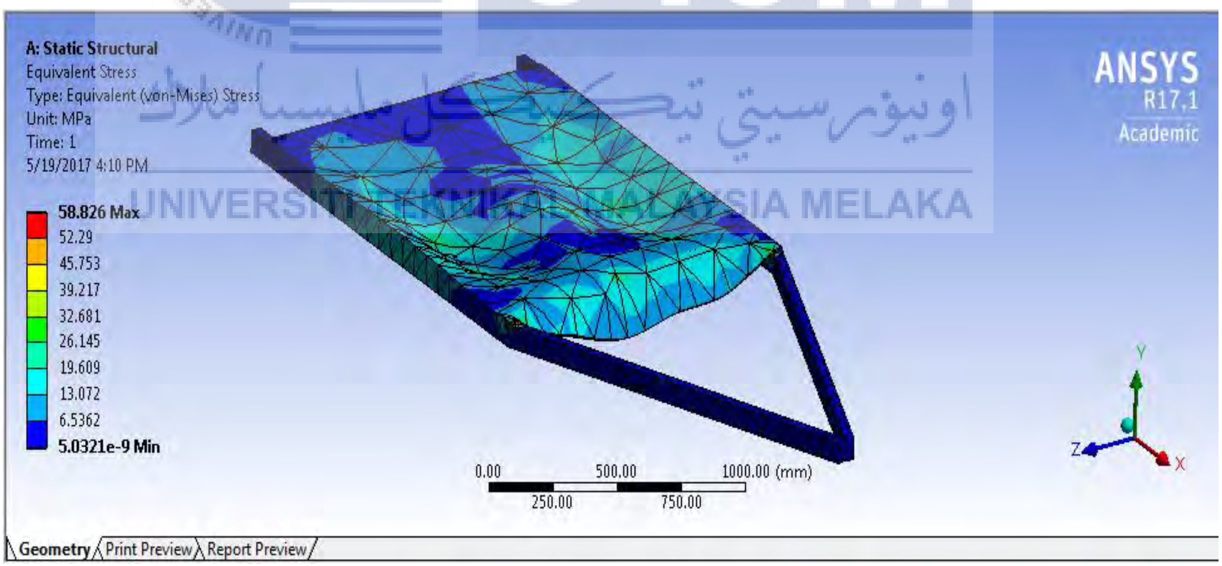

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Figure C3 : Von misses of trailer base body(steel material)