DESIGN OF UNDERWATER INSPECTION ROBOT MECHANICAL TRACK SYSTEM

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

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project report entitled "Design Of Underwater Inspection Robot Mechanical Track System" is the result of my own work except as cited in the references.

Signature : ....

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Date : ....

APPROVAL

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

Signature :. ....

Name of Supervisor : Ir. Dr. Tan Chee Fai

Date : ....

ABSTRACT

The main purpose of this project is to design a track system for an underwater inspection robot. This track system needs to be more efficient than the conventional track system. Efficient in this case is measured in speed. The speed of the track system were increased based on the design of the track. The track conventional track system mainly have two sets of tracks on the side of the underwater inspection robot. However, the newly designed track system separate the two part track system into four parts. This allow the underwater inspection robot to move more quickly. The mechanism of army tanks has been switched to a mechanism of a conventional car that consist of four sets of tyres. Furthermore, by applying this design on the underwater inspection robot, it also helps reduce the overall weight of the underwater inspection robot. With a less weight, this the underwater inspection robot to move faster. However, the weight of the underwater inspection robot cannot be too light as it will result in making the underwater inspection robot to have difficulties gripping on to the ground. This is due to the buoyancy force that will make the underwater inspection robot afloat.

ABSTRAK

Tujuan utama projek ini dijalankan adalah untuk mereka cipta sebuah sistem trek untuk robot pemeriksaan bawah paras air. Sistem trek ini perlulah berfungsi dengan lebih baik berbanding sistem trek yang sedia ada di pasaran. Sistem trek baharu ini perlulah lebih mempunyai kadar kelajuan yang lebih tinggi. Kadar kelajuan telah pun ditingkatkan berdasar rekaan yang baharu. Sistem trek yang sedia ada dipasaran kebiasaannya mempunyai dua bahagian trek iaitu dibahagian kiri dan kanan robot. Walaubagaimanapun, rekaan terbaru sistem trek ini telah memecahkan bahagian daripada dua kepada empat. Rekaan sebegini dapat membantu robot untuk bergerak dengan lebih cepat. Mekanisma yang sebelumnya menggunakan kaedah kereta kebal askar telah ditukarkan kepada mekanisma kereta komersial yang menggunakan empat bahagian tayar untuk bergerak. Tambahan pula, rekaan empat bahagian tayar ini membantu mengurangkan berat keseluruhan robot. Robot yang lebih ringan tentunya dapat bergerak dengan lebih pantas. Walaubagaimanapun, robot pemeriksaan bawah paras air ini tidak boleh terlalu ringan kerana ia memerlukan berat yang ideal untuk memastikan ia dapat mencengkam lantai dengan baik. Hal ini dapat menjejaskan cengkaman itu sekiranya robot terlalu ringan kerana terdapat daya apungan terhadap robot yang membuatkan robot untuk terapung.

ACKNOWLEDGEMENT

Greatest praise to Allah Almighty. Grateful to Him with His will I had successfully finished in preparing this ‘Projek Sarjana Muda’ thesis.

Several people played an important role in the accomplishing of this ‘Project Sarjana Muda’ thesis and I would like to acknowledge them here.

I owe my most sincere gratitude to Ir. Dr. Tan Chee Fai. I would like to thank him for his guidance, support, advices and time during the course of my project. I would like to thank Dr Mohd Asri Bin Yusuff in taking an effort in reading this thesis and provide good suggestion in perfected this thesis.

Special thanks to FKM technicians whom are patient in giving me a lot of advice and useful tips in performing the research.

Last but not least, I owe my loving thanks to both of my parents, Mr. Mohd Azman Bin Ahmad Tajuddin and Mdm Zawiyah Binti Jamaluddin. Without their encouragement and understanding, it would have been impossible for me to finish this PSM. My special gratitude goes to my friends Khairul Aqil Bin Mohd Yusof, Syahirah Binti Mohd Fadzil and Amirah Diyana Binti Ahmad Azan whom help me in giving an idea and support to finish this thesis.

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LIST OF ABBEREVATIONS

OTR	Off The Road
CAD	Computer Aided Design
BoM	Bill of Material
HoQ	House of Quality
TS	Track System
-ve	Negative
3D	3 Dimension

LIST OF SYMBOL

π	Pi
$^{\circ}$	Degree

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Underwater inspection are widely required worldwide. The practice usually demands human to went into the water and inspect whatever that need to be check. However, in globalisation era, there are robots that were built to do this kind of task. It is because the robot that were built can withstand the amount of pressure that human cannot bare. Furthermore, human requires oxygen to breath and this make it difficult as they need to bring along their oxygen supply, in order to stay longer in the water. It is easy for the robot as it doesn't requires any oxygen to operate, however, it needs to be waterproof to make sure the electronic devices that operates it doesn't get wet hence the fuse will damaged. Working underwater is both dangerous and difficult for humans.

Currently, there are many types of underwater inspection robots that in the market. There are the biomimetic lobster that mimic the biology or physical of a lobster. There are also underwater robots that only uses propeller to move around. The track wheeled underwater robots are also widely used in the current industry. All of this design are different however, it shares the same objective that is to do underwater inspection. These designs are proposed to overcome many types of environment. The world's oceans are home to the most strange and amazing creatures. So all of the creatures don't usually have the same habitat so there are few that are isolated deep down into the ocean where the ground is not level. So that's where the robot that uses only propeller get in handy. These underwater robots can record data that would be difficult for humans to gather.

However, not all underwater robot are designed to go into the sea. There many other places that needs underwater inspection for example a lake, a reservoir, a tank for storing waters and etc.

There are many types of system for the underwater inspection robot to move around. There are robots that uses wheel, propeller, claws and continuous track system. All of the system that were used has its own advantages and disadvantages. For example, the wheel system can be very fast and it has a longer life span. This is due to the surface area that were exposed to the frictional point is less compared to the continuous track system. However, the wheel actually have a problem when facing an uneven surface because the wheel and its shape will somehow stuck or damage while passing through an uneven surface. This is scenario is totally opposite from the continuous track system. The continuous track system can easily go through any uneven surface because of the design of assembling a series of wheel and combining them using a tread. However, the continuous track system maybe lack of speed and has a less option of maneuverability. This is because the series of wheel that were aligned can be too long for it to make a more flexible movement.

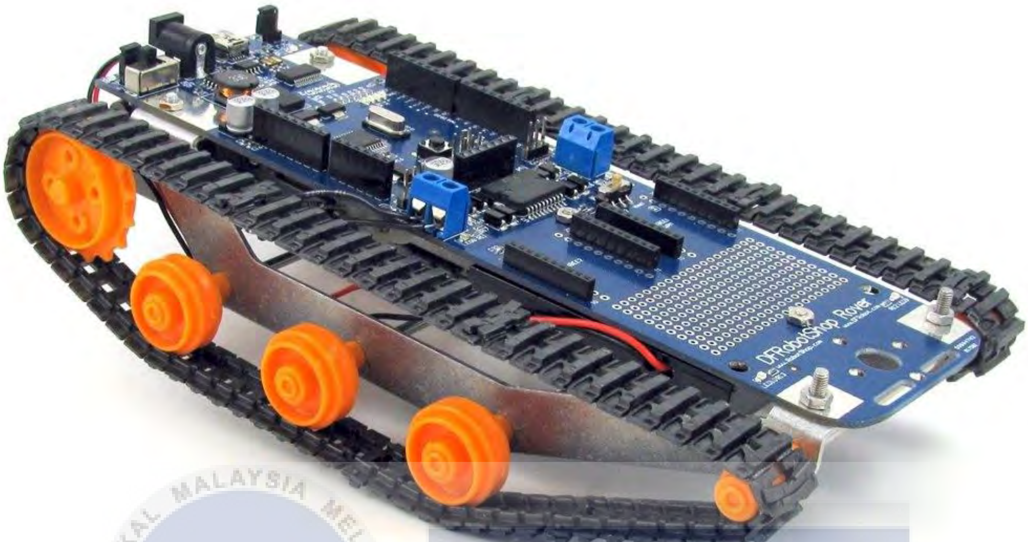


Figure 1.1 Track system robot.

(Source: Robotshop, 2016)

1.2 PROBLEM ST ATEMENT

The current underwater robot that were in the market are mostly using continuous track system. This type of system have a great power to move around however the speed of the robot are a bit slow. This affects the security of the robot if a situation that needs the robot to move away from danger immediately. It also have a shorter life span of its rubber tread as the surface area exposed to the surface are greater compared to normal wheel. The maneuverability of the robot also are quite restricted. This will make it difficult for it to explore even further into a problem that need solving.

1.3 OBJECTIVE

1. To increase the speed of the continuous track system

1.4 SCOPE

The scopes of this project are:

1. To focus on the continuous track system
2. To concentrate on the design of the track

1.5 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review Journals, articles, or any materials regarding the project will be reviewed.

2. The suitable design for the whole continuous track system will be proposed.

3. If the design process of the track system has passed, the calculation process will take place to determine whether the design has fulfil the requirement needed in the objective.

4. The simulation of the track will be done using CATIA software. The maximum pressure of the track system will be tested in the software.

5. The result that was tested will be recorded and be placed to make comparison to further improve the system.

6. Report writing will be done at the end of the project.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses about the overview of the continuous track system. There are many types of continuous tracks that have been invented, therefore the track system is not a new thing to the market. Besides that, the material used to making a track is also plenty. There are tracks that only uses metal. There are also rubber tracks and there are tracks that combines both metal and rubber. The design of the tread is also crucial to consider the contact force between the surface of the ground and the tracks. There are V-shaped, U-shaped and also I-shaped treads in the current market. Finally, this chapter discusses about the dimension of the tracks. Should it be wide or skinny tracks? It will be discuss in this chapter.

2.2 CONTINUOUS TRACK

According to omicsgroup.org (2006), continuous track is a system that is driven by two or more wheels of the vehicle propulsion in which a continuous band of treads that is attached to it. The materials that were used are modular steel plates in the case of military vehicles, or rubber reinforced with steel wires in the case of lighter agricultural or construction vehicles. The vehicle have a large surface area of the tracks that have a purpose of distributing the weight of the vehicle better. This enables a continuous tracked vehicle to drive over soft ground with less possibilities of being stuck due to sinking.

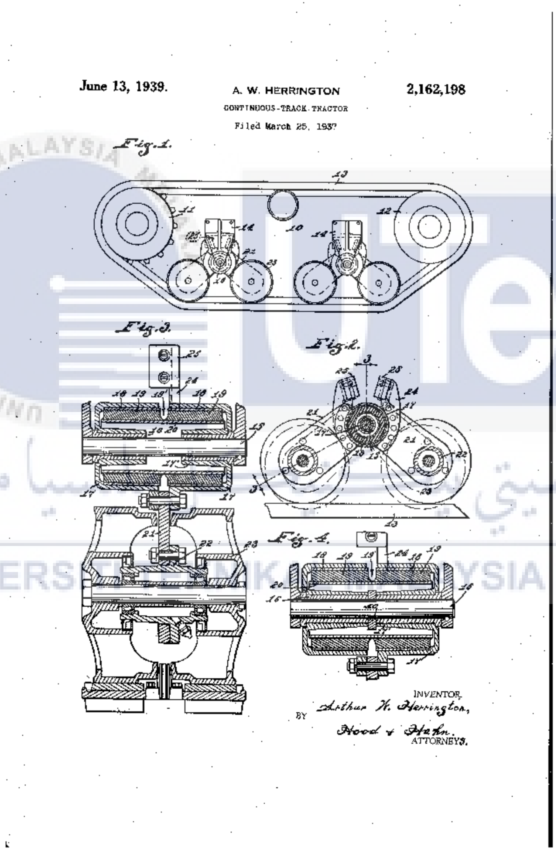


Figure 2.1 Dimension of existing continuous track system

(Source: Arthur, 1939)

The advantages of using metal plates as the tread are both hard-wearing and damage resistant. However, there are some disadvantages of using metal plates. One of it is that it will damage the paved surfaces. This sort of problem can be overcome by replacing metal plates with rubber pads that can be installed for use on paved surfaces to prevent the damage.

A continuous track system consists of two independently rotating rings, with a centre of rotation in the axis of the body. To each of those rings, an arm is attached on a rotary joint. These arms are similarly mounted to both sides of each track. This configuration allows various orientations of track with respect to the body. Each track unit is adjusted by two or more drives. Two drives allow rotation of rings in the robot body axis and the third drive positions one arm with respect to the track.

2.2.1 Hybrid Wheel And Track Vehicle Drive System

A hybrid wheel is similar to an ordinary car tyre system. It have four driving wheel but each wheel are mounted by their own band tread. Each part of the four tyre are the same. It only assembled in a suitable manners. Based on the Patern filed by Giovanetti (2004) a vehicle drive system includes a hybrid wheel and track system, having a drive wheel operably coupled to a motive source, the motive source for imparting rotational motion to the drive wheel, the drive wheel having an axis of rotation, an idler wheel displaced from the drive wheel and rotationally coupled to the drive wheel by a continuous track; and a cantilever beam supporting the idler wheel and being rotatable as desired about the drive wheel axis of rotation.

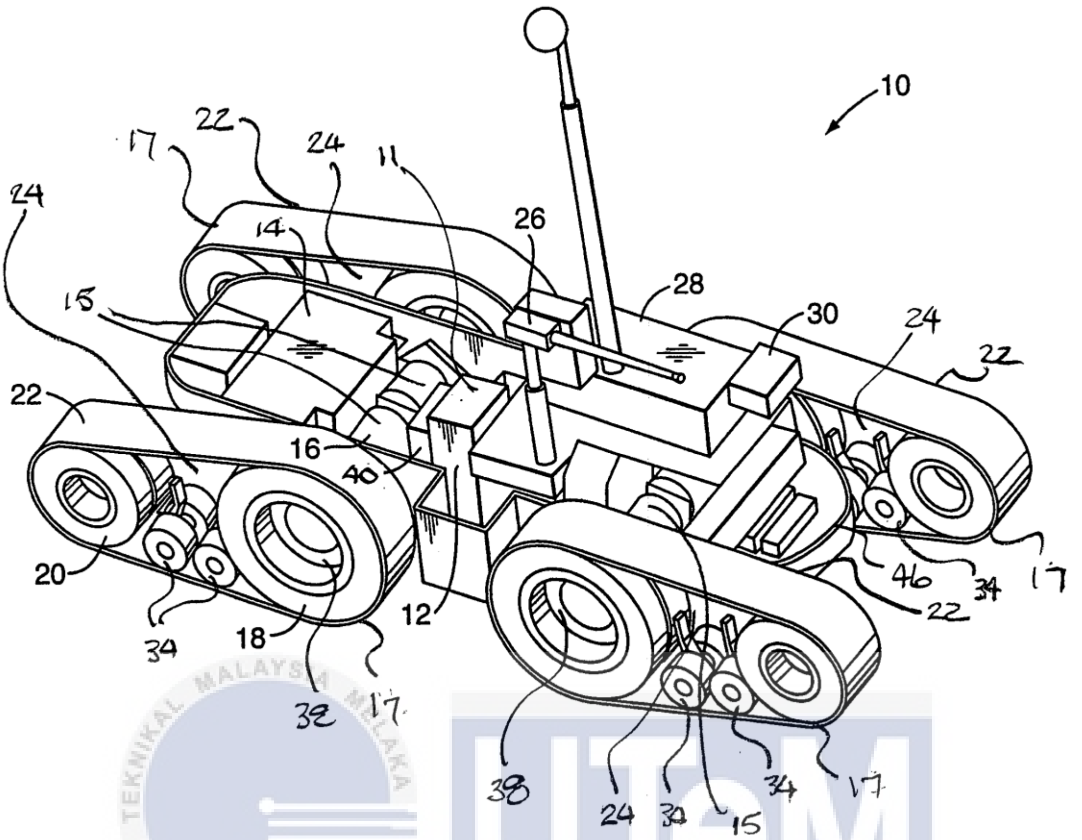


Figure 2.2 hybrid wheel and track vehicle drive system

(Source: Giovanetti ,2004)

2.2.2 Conventional Continuous Track System

As stated by Belotserkovskii (2014), the movement of heavy continuous track vehicles produces massive vibrations of the ground, generating surface waves that propagate over a long distance, causing damage to buildings. If these type of vehicles passing through is prohibited, seismographs are set up at the place of prohibition that record any infringement of the ban. As a result, the waves generated by continuous track vehicles have been extensively studied in recent years. A more simplified model of a drive was used in the study but the dynamic properties of a continuous track that has a periodic structure were not taken into consideration.

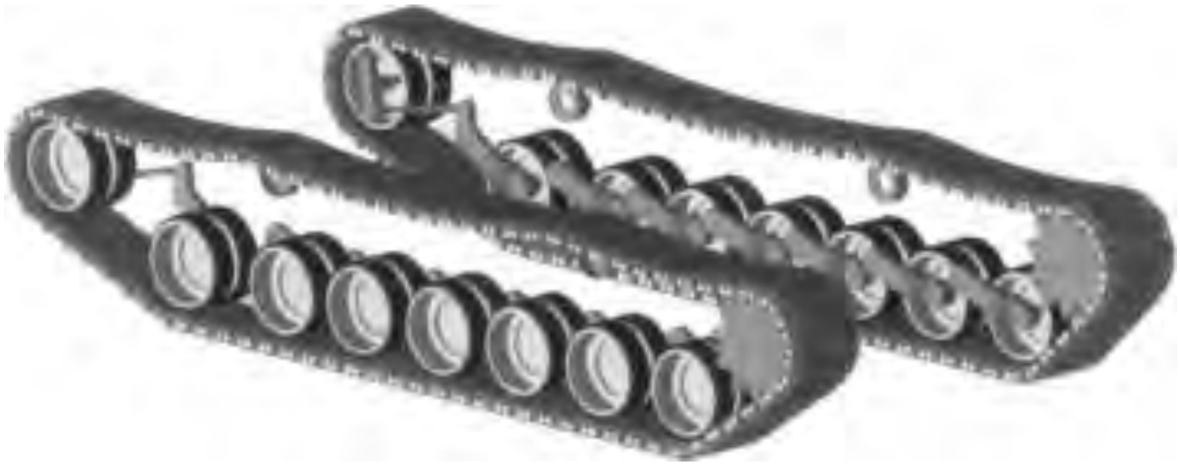


Figure 2.3 Conventional continuous track design

(Source: Belotserkovskii ,2014)

2.3 MATERIALS USED

2.3.1 Rubber

By referring to Anne & Evans (2006), all passenger car, lorry and off-the-road ("OTR") tyres are products of complex engineering. Many different rubber compounds, numerous different types of carbon black, fillers like clay and silica, and chemicals & minerals added to allow or accelerate vulcanisation in making a set of brand new tyres. For reinforcement of the tyre, they uses various types of fabric and a few kinds and size of steel. It uses twisting or braiding method to form a strong cables. Tyres are made for their use on vehicles therefore it is not suitable for recycling.

Table 2.1 Composition of a tyre

(Source: Anne & Evans, 2006)

Ingredient	Passenger Car Tyre	Lorry Tyre	OTR Tyre
Rubber/Elastomers[1]	∀47%	∀45%	∀47%
Carbon Black[2]	∀21.5%	∀22%	∀22%
Metal	∀16.5%	∀25%	∀12%
Textile	∀5.5%	--	∀10%
Zinc Oxide	∀1%	∀2%	∀2%
Sulphur	∀1%	∀1%	∀1%
Additives[3]	∀7.5%	∀5%	∀6%
Carbon-based materials, total[4]	∀74%	∀67%	∀76%

- Lorry & OTR tyres contain higher proportions of natural rubber than passenger car tyres.
- Silica replaces part of the carbon black in certain types of tyres
- Some of the additives include clays, which may be replaced in part in some tyres with recycled rubber crumb from waste tyres

- These approximate totals would be slightly higher if clays were replaced by recycled crumb rubber from waste tyres

Common size tyre vehicle made by Goodyear company are mainly made up of 8 different natural rubber, 30 different synthetic rubber, steel cord for belts, polyester and nylon fibre, 8 types of carbon black, steel bead wire, 40 different waxes, chemicals, oils, silicas, pigments & clays based on the book that is written by Anne & Evans (2006).

Tyres are made up of so many different compounds and ingredients so that it can handle the tortures of heat and cold, high speed, abrasive conditions, and often not enough air pressure. They are expected to perform for tens of thousands of miles and retain their essential properties despite horrendous driving habits and sometimes poorly maintained or built roads.

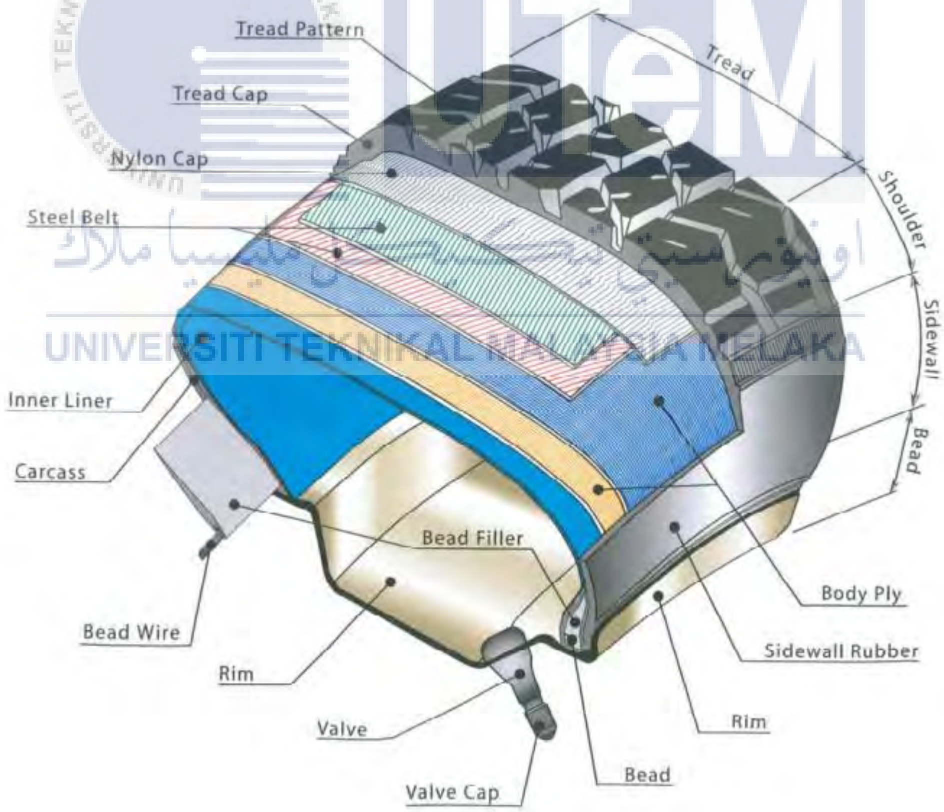


Figure 2.4 Cross-sectional image of a tyre

(Source: Anne & Evans, 2006)

2.3.1.1 Belt

Based on an article written by Kris (2013), injection molded kits are the original type of tracks that was used in 1960s as shown in Figure 2.5 was widely available for that time because it is the only technology that can produce such tracks. Those tracks have low quality and durability.

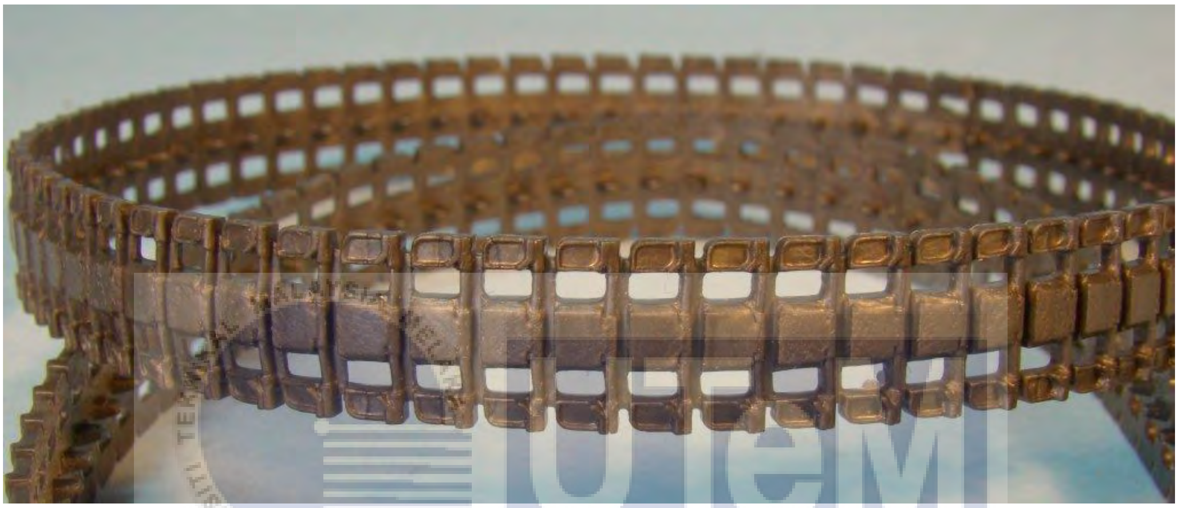


Figure 2.5 Original Rubber Continuous Tread

(Source: Kris, 2013)

This early types of tracks have a lot of disadvantages. It is not as strong as the current continuous track that is in the market. The old track system have a belt that will have marks after passing through a rough surface. As we know now, the belt will form back to its original shape after had gone through rough surfaces. This is totally different from the old version of tracks. The marks will be permanently embedded on the rubber belt. Sometimes the belt only come with one side showing details and the other side being flat.

2.3.1.2 Manufacturing Process

According to Kovac (1978), the manufacturing process of a rubber tyre are as follows:-

The rubber compound was done by mixing is the first step in the tyre manufacturing process. Large quantities of natural and synthetic rubber, sulphur, carbon black, and other oils and chemical were delivered by railcars that are usually kept aside until it is time to use.all sort chemicals that needs to be mixed with rubber are all automatically controlled by a computer system. The computer that kept all the recipes will precisely mix the compounds together.

Then, before softening the batch to continue mixing the compounds, it must first undergo re-milling process by applying some heat to it. After it have been soften, it undergoes another mixing process to get the final mix by adding some more chemicals.to ensure the mixture is soft and the chemicals were diluted evenly, heat and vibration were applied to the mixer. The vibration is to generate friction between the mixing compounds. Each part of the tyre have a different type of chemical composition used. There are three examples of parts that have different rubber recipes that is the beads, tread and body.

The rubber mixed were turned into thick sheets of rubber that have been rolled by a highly pressured rolling mills. Only then the body of the tyres can be formed from the sheet of rubber that have been flatten. The sheet is then converted to become a ply by stripping the rubber sheet to form the tyre's body. Usually, the number of plies for a commercial car are only four.

An extruder is then became a mold for the batch mixer to flow in and becomes the sidewalls and tyre tread for the tyre. In the extruder, a new layer of rubber were formed from the process of beating and mixing. The new layer is then were poured out through an orifice-shaped like die. Protection for the sidewall were then applied using plastic sheet by rolling. Then, the rubber tread is stored into a large metal case after being strip down into slices.

Then, a skilled assembler that is located at the tyre building machine will be a place to gather all the large metal case that contains tread rubber, rolls of sidewall and the rack of beads together. A rotating drum that act as a holder of the tyre is placed at the centre. The process of wrapping the rubber-covered fabric plies starts at the tyre assembler to build the tyre around the drum of the machine. A glue is then applied to the end of the plies to join them together followed by adding the beads with the additional tyre plies after the beads have been added and locked into place. A specific tool were used to generate the needed shape of the tyre plies. Finally, the removal process and gluing process took place for the rubber layers of the sidewalls and the tread respectively. Then, the shaped tyre or green tyre is removed from machine of tyre-building.

Curing process took place in a large mold where the green tyre is placed for curing process. A bladder is then revealed which looks like a giant balloon. The bladder is opened by a tyre mold that looks like a metal clam. Then, the bladder is placed inside the green tyre which then been pumped with air to let the bladder inflate like a floaters. The inflated bladder will then fill the open spaces between the bladder and the inside wall of the green tyre. This will force the green tyre to stay compacted.

Finally, the cooling process took place to cool down the tyre after curing process that have heated the tyre up to 280 degrees. The tyre will then be submerged fully into a pool of water to detect if there is any holes. It can be detected by observing for bubbles. After the inspection for holes of the tyre have complete, it is time to test the tyre on a rotating machine. The tyre will be inflated and it will be spun for a few minutes. This is to check the balance of the rubber distributed around the tyre. It is also to check the alignment of the tyre. Usually, it is very rare to have a rejected tyre for the modern day tyre production. After all the inspection process have done, the tyre is ready to be distributed to the market.

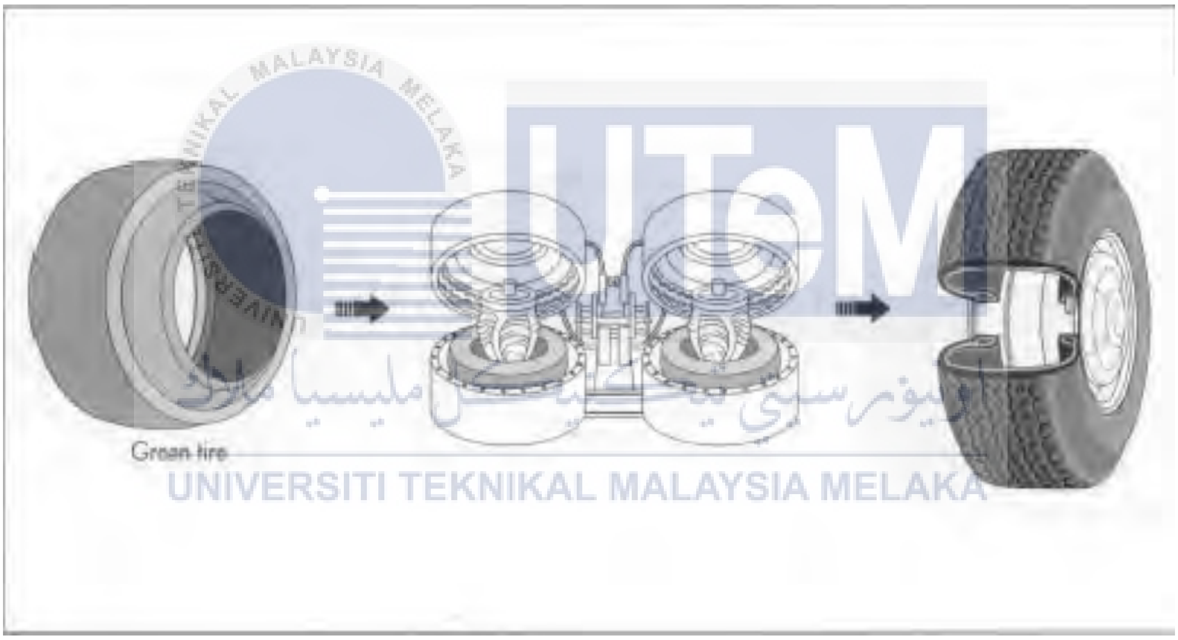


Figure 2.6 Conversion from green tyre to final shape of a tyre

(Source: Kovac, 1978)

2.4 DESIGN OF BELT

There are several types of design in the current market for the belting of this continuous track system. Each design of the tread is different according to the usage. Every design of tread have its own specialty and disadvantages. For example, there are V-shaped, U –shaped and I-shaped tread. If in the car industries, V-shaped tread are better tyres for rainy condition. This is because the V-shaped tread allow water to flow out of the contact surface between the tyres and the ground. However, this types of tread produces a louder noise that other types. For the I-shaped tread, it produces less noise compared to V-shaped but have a disadvantage when passing through water in a high velocity. For the case of underwater inspection robot, that mainly having a lot of water involve, it is more suitable to have a V-shaped tread.

Figure 2.7 V-shaped tread

(Source: Superdroidrobots.com, 2016)

Figure 2.8 Doubled-U tread

(Source: Superdroidrobots.com, 2016)

Figure 2.9 U-shaped tread

(Source: Superdroidrobots.com, 2016)

Figure 2.10 I-shaped tread

(Source: Superdroidrobots.com, 2016)

2.5 DIMENSION OF THE TRACKS

Based on an article by Marsh (2015), for a motorcycle, there are three benefits of wider tyres:

1. They're faster at the same pressure than skinny tyres.
2. More grip.
3. They feel better and ride better.

However, Marsh (2015) also stated the advantages for using skinny tyres. It is because theoretically, smaller tyres can move faster due to less of weight. Even though rider can pump skinny tyres up to higher pressure than wider tyres.

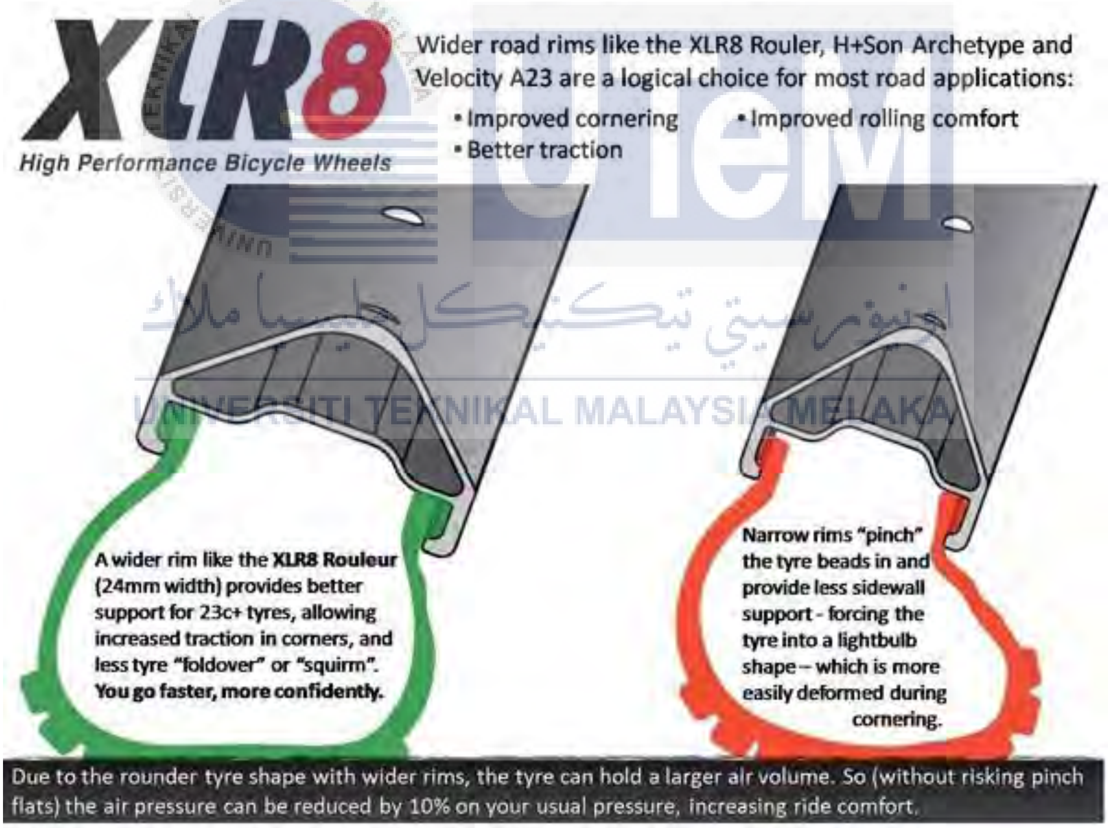


Figure 2.11 Wide tyre versus skinny tyre

(Source: Marsh, 2015)

From figure 2.11, it shows that a wider tyre can handle cornering better. This is because a wider tyre provides a better sidewall support compared to skinny tyre, the tyres will deform easily due to a light bulb-shaped effect of the tyres.

Figure 2.12 Wind resistance through tyres

(Source: Marsh, 2015)

Figure 2.12 explains the airflow through both wider and skinny tyres. A wider tyre have a smoother airflow around it while the skinny tyre causes turbulence airflow at the rim. This airflow will affect the wind resistance. And the lesser wind resistance the tyre have, the faster it can spin.

CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

This chapter explains about the continuous track and it's method of development. A flowchart was made to help make the process of development more systematic and in order to ensure all the steps needed to complete this project is followed. This is to overcome some missing part of the project. The flowchart showed the whole idea about this project, the current work and the further work. This flowchart would help ease the mind of forgetting any steps of the process.

Figure 3.1 show the flowchart that manner the process on develops this continuous track system to achieve the objectives of this project. The methods used in product design development for continuous track system are identify customer requirements, product design specifications, morphology chart, concept selection, detail design and design analysis, Bill of Material BoM.

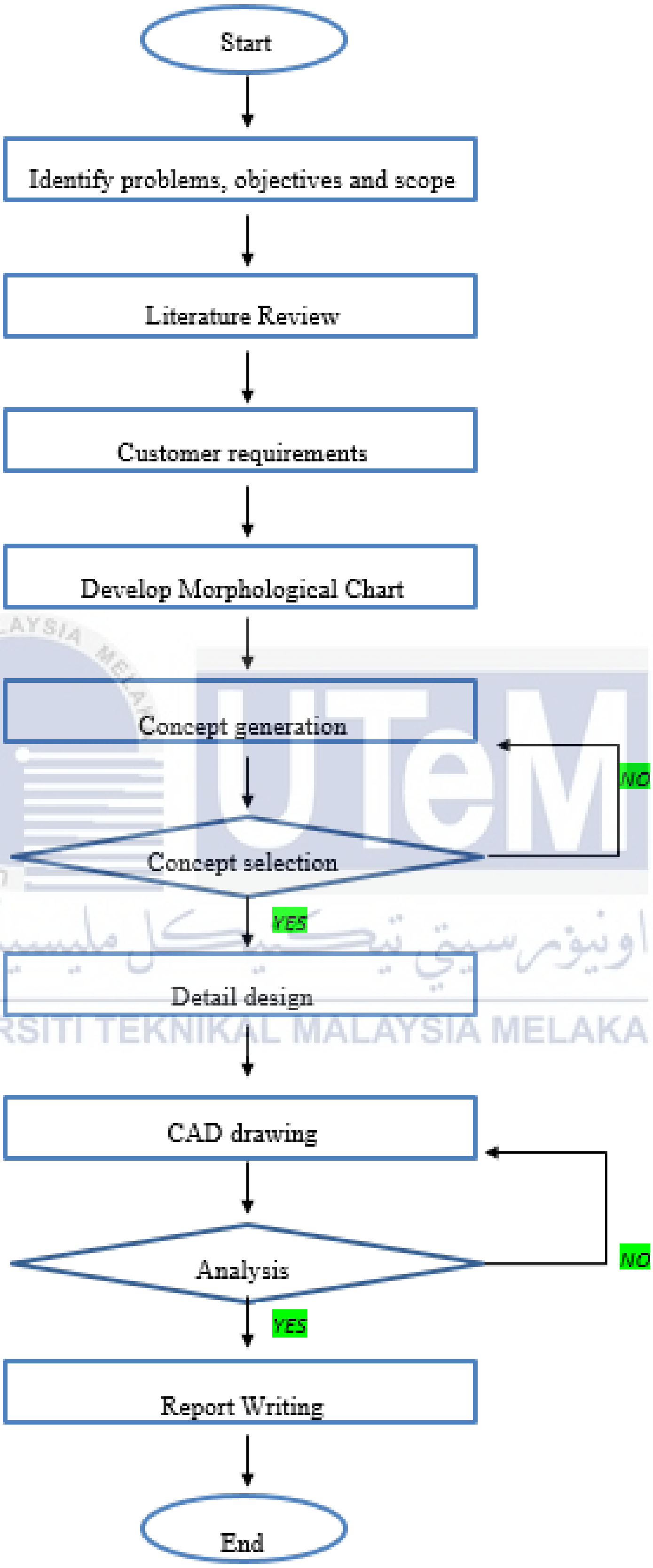


Figure 3.1 Flowchart of project

3.2 IDENTIFY CUSTOMER REQUIREMENTS

The main information collected from customers are their requirements to carry out research about the product on the market. Therefore, identify customer requirements is an important method contribute to creating a ranked list of customer needs. The aim of this method is to identify needs of customer, make sure the product is focused on customer needs, provide information to justify the specifications of the product, overcome critical customer need is neglected and develop a common understanding of customer needs.

The purpose of this method is to create a high quality information channel that create directly link between customers in the target market and the inventors of the product (George & Linda, 2009). Design development are difficult to be done properly without this method, innovative solutions to customer needs may not possible exposed and the product development may not develop a deep commitment to assembly customer needs. Figure 3.2 shows six step to identifying customer needs.

Figure 3.2 Steps to identify customer's need

(Source: Corporateedge, 2006)

3.3 PRODUCT DESIGN SPECIFICATION

A specification usually consists of a metric and a value. Note that the value may take on several forms, including a particular number, a range or an inequality. Values are always labelled with the appropriate units. Together, the metric and value form a specification. The product specifications are simply the set of the individual specifications (McGrath & Michael E, 1995).

The customer needs should be identified first before target specifications were established but before product concept have been generated. The process of establishing the target specifications contains four steps that is:

1. Prepare the list of metrics.
2. Collect competitive benchmarking information.
3. Set ideal and marginally acceptable target values.
4. Reflect on the results and the process.

3.4 MORPHOLOGICAL CHART

Morphological charts, also known as concept combination tables or function means tables, are a design tool for generating a listing of integrated conceptual design solutions for a design problem (Bryant, 2007). Morphological charts is a table that created by decomposing the design problem by listing all the critical functions in a column. Combining one means for each function will produce a possible combined conceptual design solution. Repeating this process with every possible combination contained in the morphological chart will generate a complete list of conceptual design solutions. By this way, morphological charts provide a logic sense of the product's design. The morphological chart is usually applied in the beginning of idea generation.

The word morphology means the study of shape and form. Morphological analysis is a way of creating new forms. The general morphological approach to design is summarized in the following three steps:

1. Divide the overall design problem into simpler sub problems.
2. Generate solution concepts for each sub problem
3. Systematically combine sub problem solutions into different complete solutions and evaluate all combinations.

The morphological approach to mechanical design begins with the functional decomposition of the design problem into a detailed function structure.

3.5 CONCEPT SELECTION

Based on BusinessDictionary.com (2016), the definition of concept selection is a used of matrix to show how well different alternatives meet the requirement that a customer wants. A concept selection matrix is organized by the requirements. It also includes numerical values for target specifications as well as observed specifications for the best outcome and solution. The flow of processes in doing concept selection is as shown in figure 3.3 below.

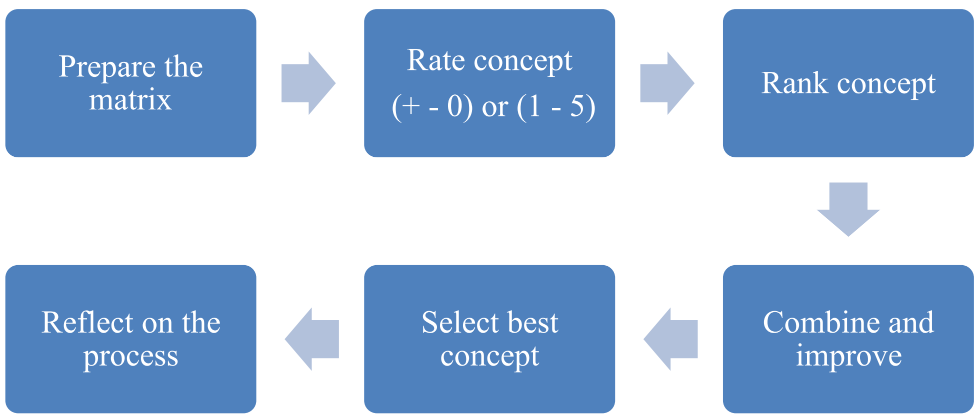


Figure 3.3 Flow of concept selection

Based on an article by Dahan and Hauser (2000) he stated that a Pugh chart is a simple design tool for comparing design ideas against your design criteria early in the design process.

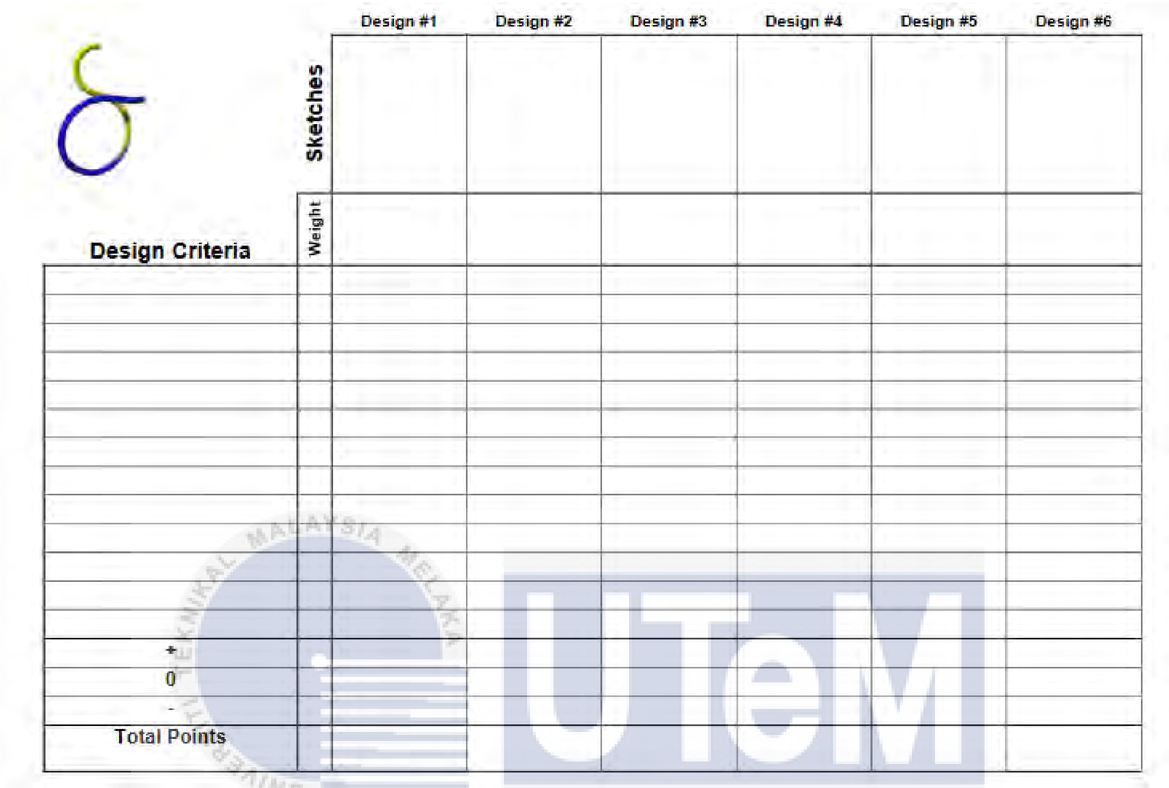


Figure 3.4 example of a Pugh chart

(Source Dahan and Hauser, 2000)

The function of this pugh chart is to compare and mix other criteria with another design. This method help to improve the existing products and probably create a new product that is better in all aspects. The goal of using pugh chart is to minimize the unwanted item and maximize the function of the product.

3.6 DESIGN TOOLS

3.6.1 CATIA Software

According to Narayan (2008), computer aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Electronic files for print, machining, or other manufacturing operations are often the output form of the CAD. The uses of CAD software is to:

1. Increase the designer's productivity.
2. Improve the design's quality.
3. Improve communications through documentation.
4. To create a manufacturing's database.

The CAD software have a lot of function that is to design as well as to do analysis. The design of a product can be straight away tested according to its strength and curves. The Von Misses analysis test can show how much the product can bear a weight or pressure acted on it. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD systems can shorten the design time of a product.

Furthermore, CAD can design a 3D or 2D curves. This is very useful for manufacturing process. Complete assemblies can be modelled and a full analysis of a virtual model can be performed.

3.7 BILL OF MATERIAL

Transweb (2014) state the bill of materials (BoM) is a list that provides a list of materials and their quantities required to produce the end item. It is also called as product structure file or indented bill of material. It contains the list of finished products, material needed for each finished product in units, assembly structure, sub-assemblies, parts, and material. BoM file also provides relationship of each end product with sub-assemblies and raw material.

Figure 3.6 shown an example of BoM structure for product A has three sub-assemblies 1, 2 and 3. These three sub-assemblies are constituted from three components X, Y and Z. The BOM structure show on Figure 3.6 indicates that each product A needs two components X, three components Y and two components Z.

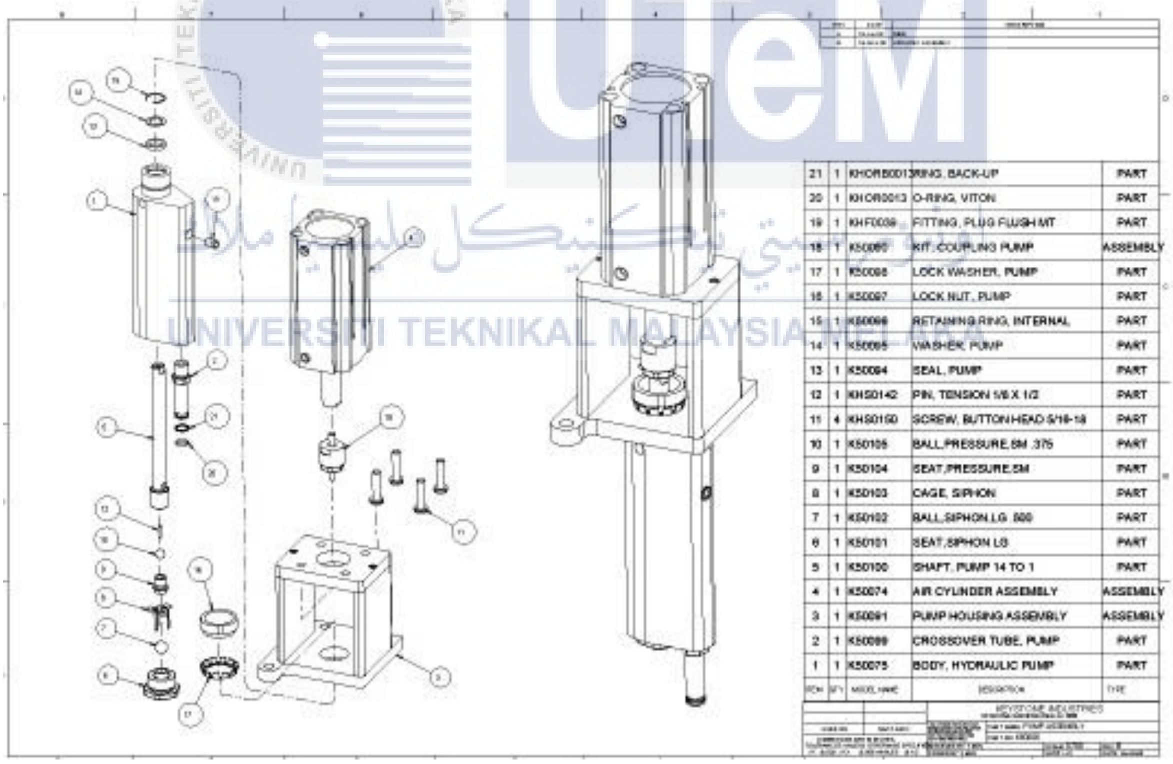


Figure 3.5 Example of Bill of Material BoM

CHAPTER VI

RESULT AND ANALYSIS

4.1 HOUSE OF QUALITY (HoQ)

House of Quality (HoQ) is method of identifying the customer requirements and the importance of it. In Figure 1 shows a HoQ for the track system of the underwater inspection robot. This HoQ will help as a reference and guideline for this project. The main criteria in developing the track system that the customer need is the speed, all terrain track, design, light weight and handling ability.

Table 4.1: House of Quality for the track system

		Engineering Characteristic				
Improvement Direction		↑	↑	↑	↑	↓
Unit		n/a	n/a	Kg	Km/h	n/a
Customer Requirements	Importance Weight Factor	Size of track system	Maneuvaribility of robot	Weight of robot	Acceleration rate	Mechanical operation
Speed	5	◎		◎	□	◎
All Terrain Robot	4	△	□			
Design	3	□	□	△		
Light Weight	3	□		□	◎	
Handling Ability	4	△	□			□
Raw Score		77	99	45	54	51
Relative Weight (%)		23.6	30.4	13.8	16.6	15.6
Rand Order		2	1	5	3	4

Priority = Customer assigned value from 1 to 5 used to weight relationship value

Correlation shown the degree of independence among engineering characteristic

□	Strong	9
◎	Medium	3
△	Weak	1

Based on the Figure 1 shown, the maneuvaribility of robot is the most important factor in the ranking of engineering characteristic. Engineering characteristics are variable for the design and can put unlimited variable. Maneuvaribility of robot is the most important factor because the robot needs to move in various terrain that is challenging. In order to overcome all the challenging obstacles, the maneuvaribility of the robot needs to be well in all conditions.

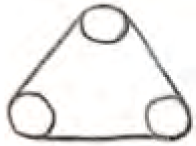
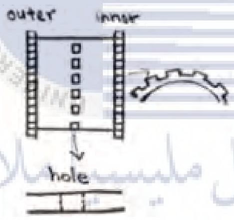
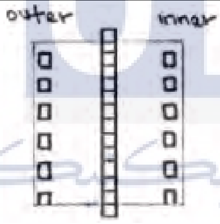
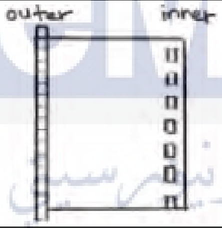
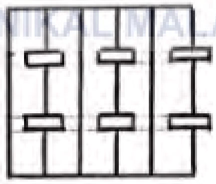
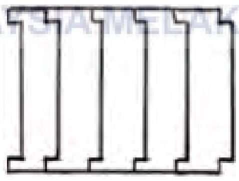
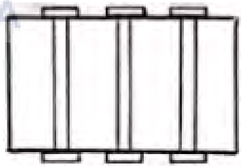
The second most important factor in designing track system is the size of the track. This factor is important to ensure the speed and maneuveribility rate is high. By decreasing the size of the track, the contact surface of the track can be reduce and this will eventually increase the speed by reducing the frictional force on the ground. Other than that, the customer requirement is to increase the speed of the robot, mechanical operation and the weight of the robot.

4.2 MORPHOLOGICAL CHART

Figure 2 shows the morphological chart that act as a method to generate ideas in an analytical and systematic manner on designing this track system of the underwater robot. This morphological chart method gives the systematic exploration of much possible design solution on designing the new product. There are three summarized steps of the general morphological approach to design the product (Book, 2013):

1. Divide the overall design problem into simple sub-design.
2. Generate solution concept for each sub-design.
3. Systematically combine the sub-design solution to different complete solution and evaluate all the combinations.

Table 4.2: Morphological Chart for track system

Specifications	Design			
	1	2	3	4
Design of body				
Design of gear				
Design of wheel				
Design of tracks				

Based on the Morphological Chart shown in Figure 2, it was divided into four or three options to design the track system of the underwater inspection robot. The specifications for the track system are the design of the body, gear, wheel and the tracks itself. There are four types of design for the body of the track system that is the U-Shaped, triangle, round and inverted triangle. For the gear, there are also four types that is the spiky with fillet, the edged gear, edged with fillet gear and the spiky gear. Moreover, the wheel have only three design as shown. For the tracks, there are four design.

4.3 CONCEPTUAL DESIGN

Conceptual design is a method of combining the option of design with various specifications. This enable designers to choose which are the most well balance in the designing a product to fulfil the customer's need. By combining each design to different specification, designers are able to identify which have most weakness and which are the best criteria to put in a design to generate the final product. There will be more than one design that will be produce in this method in order to choose which are the best combined in the end.

4.3.1 Conceptual Design 1

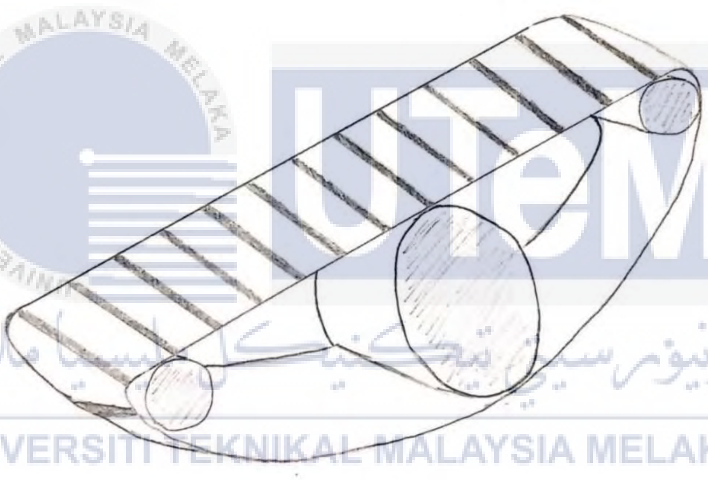


Figure 4.1: Conceptual design 1

Figure 3 shows Conceptual design 1 that uses the design body number 1. This body design has the conventional type of continuous track design. It is similar to the army tank's track system. For the design of gear, it uses design number 4 that has a spiky shaped. The wheel design number 3 is chosen that has the extruded gear in the middle and the hole both on the sides. The design of tracks uses design number 2 that has 2 connectors in the middle.

4.3.2 Conceptual Design 2

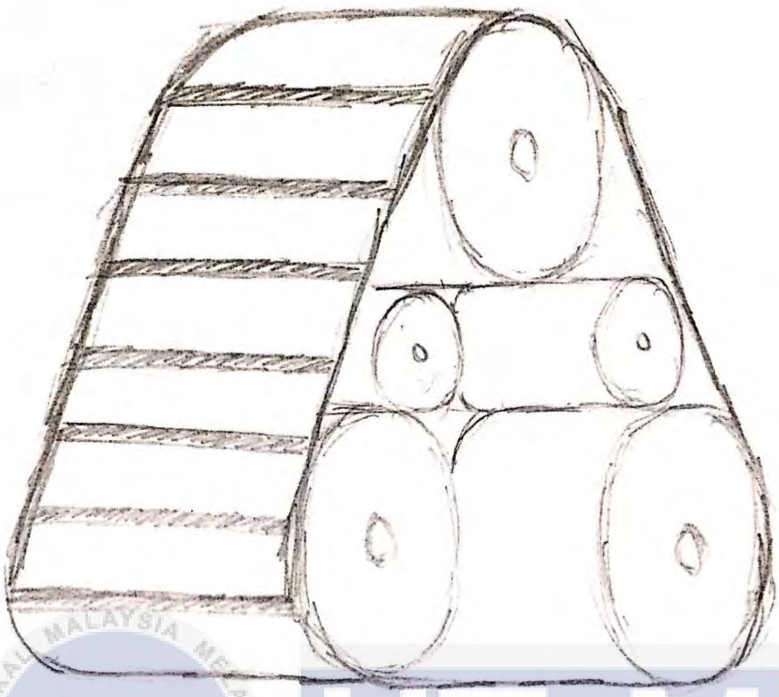


Figure 4.2: Conceptual design 2

Figure 4 shows Conceptual design 2 that uses the design body number 2. This body design has the shape of a triangle and uses 5 wheel for the inner part. It is similar to the hybrid track system. For the design of gear, it uses design number 2 that has a more blunt shape. The wheel design number 1 is chosen that has the extruded gear at both sides and the hole in the middle. The design of tracks uses design number 4 that has 2 connectors at both sides.

4.3.3 Conceptual Design 3

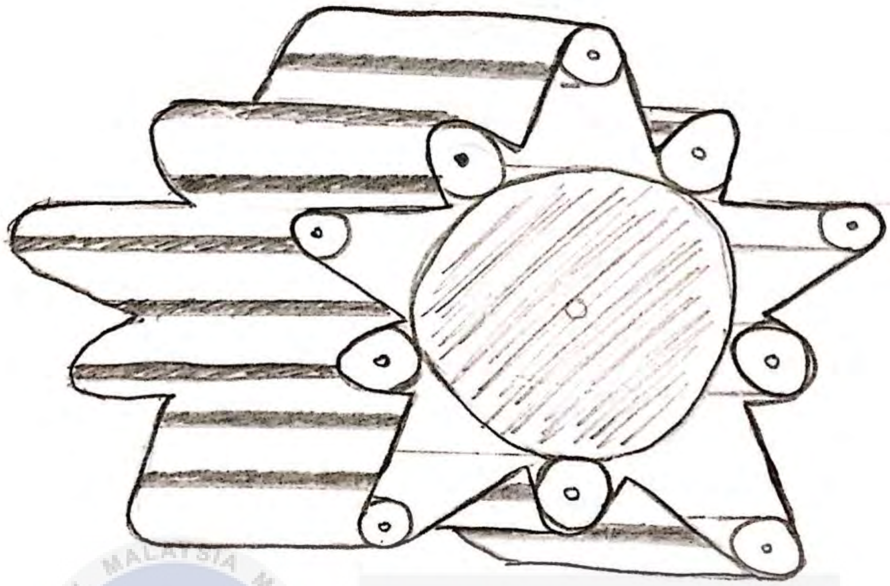


Figure 4.3: Conceptual design 3

Figure 5 shows Conceptual design 3 that uses the design body number 4. This body design has the shape of a star and uses 11 wheel for the inner part. The design is like a star that has rounder shape at each edges. This design enables the wheel to move in various kind of terrain. For the design of gear, it uses design number 2 that has a more blunt shape. The wheel design number 1 is chosen that has the extruded gear at both sides and the hole in the middle. The design of tracks uses design number 4 that has 2 connectors at both sides.

4.4 CONCEPT SELECTION

All concept designs were evaluated using selection matrix method. A concept designs with highest net score will be the final design.

Table 4.3: Concept selection list table

	Concept Design		
Selection Criteria	1	2	3
Diving Ability	+	+	+
Easy Handling	0	+	-
Design	+	+	-
Movement Of Robot	+	+	+
Power Supply	-	+	0
Speed	-	+	0
Sum +'s	3	6	2
Sum 0's	1	0	2
Sum -'s	2	0	2
Net Score	1	6	0
Rank	2	1	3
Recommended Concept	×	√	×

The selection criteria are set by referring the product design specification. In this evaluation, the concepts is rated against the reference concept using a simple code (+ for "better than", 0 for "same as", - for "worse than") in order to identify best concept for further consideration.

4.5 BEST CONCEPT

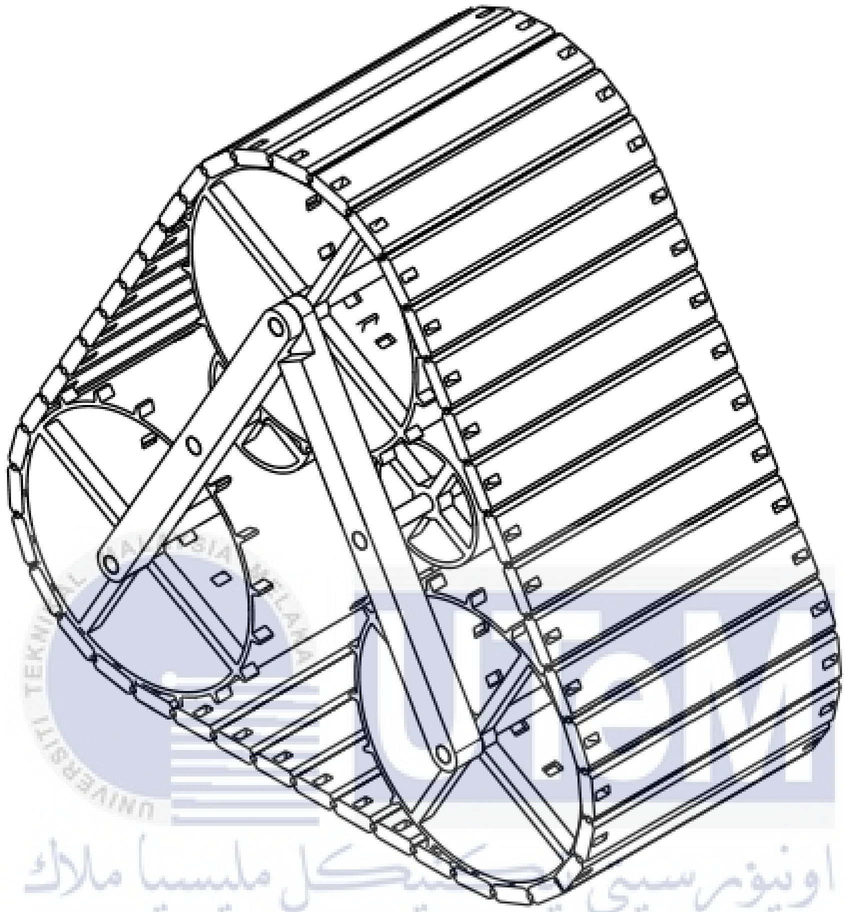


Figure 4.4: Conceptual design 2 is chosen as the best concept.

4.6 STRUCTURE MODELING

The design of underwater inspection robot's track system is inspired by different type of vehicle and shapes to produce more interesting design. The body is design frame is design based on a triangle shape that has wheel in the body. The number of wheel in the track system consist of five wheels that has three big size wheel and two small size wheel. The upper big wheel is the driver wheel while the rest act as a driven wheel. If the upper wheel turns clockwise, the two smaller wheel will turn in opposite direction and then it will turn the two bigger wheel in the same direction as the driver wheel. Only the big wheel will be in contact with the track system.

All of the wheel will be connected by a connector that is placed on both sides of the track system. The thread of the track system consist of holes in both ends to allow the gear on the wheel to penetrate into the wheel. This will automatically makes the thread of the tracks system rigid to the wheel and eliminates slip effect.

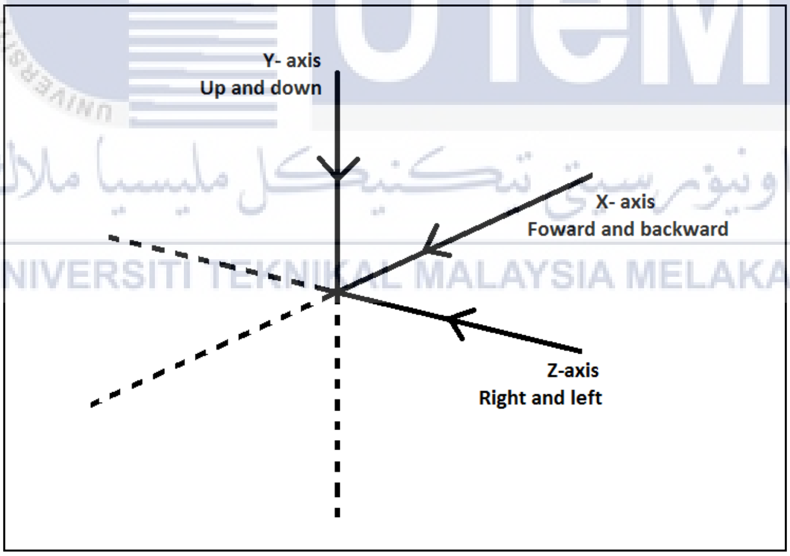


Figure 4.5: Direction and axes of Track System movement.

Figure 4.6: 3D rough modelling

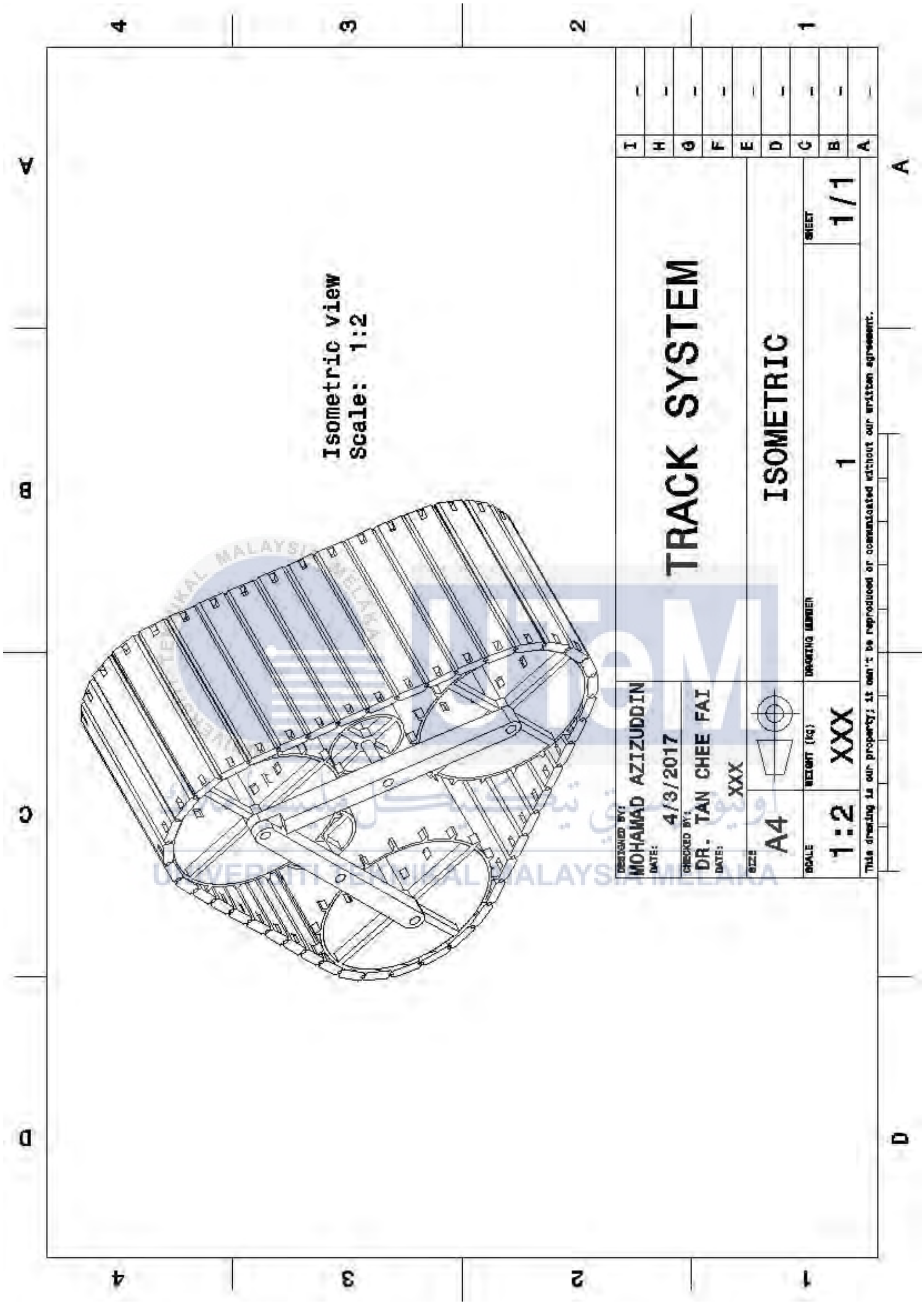


Figure 4.7: 3D Rough Modelling Isometric View

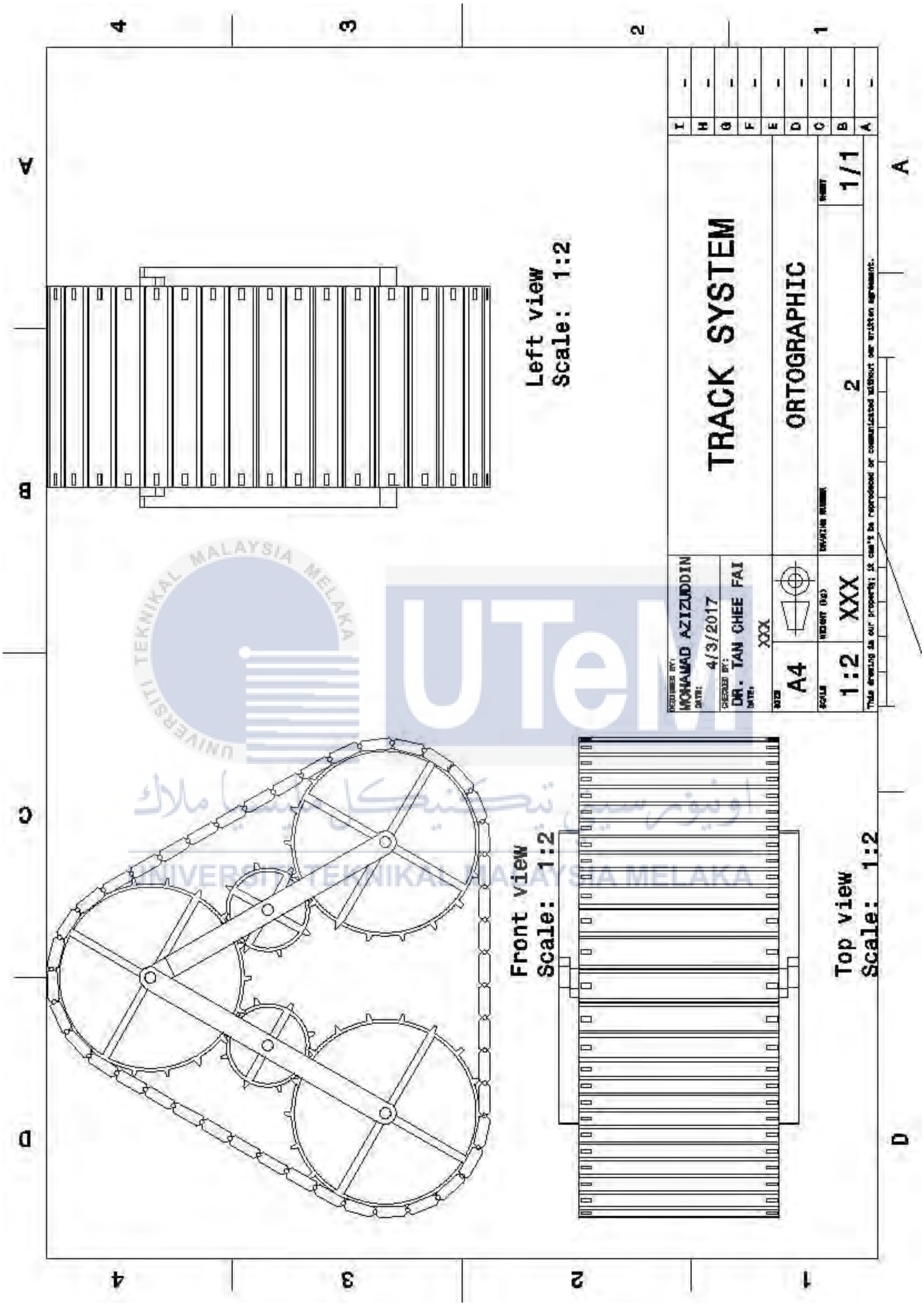


Figure 4.8: Track System Orthographic View

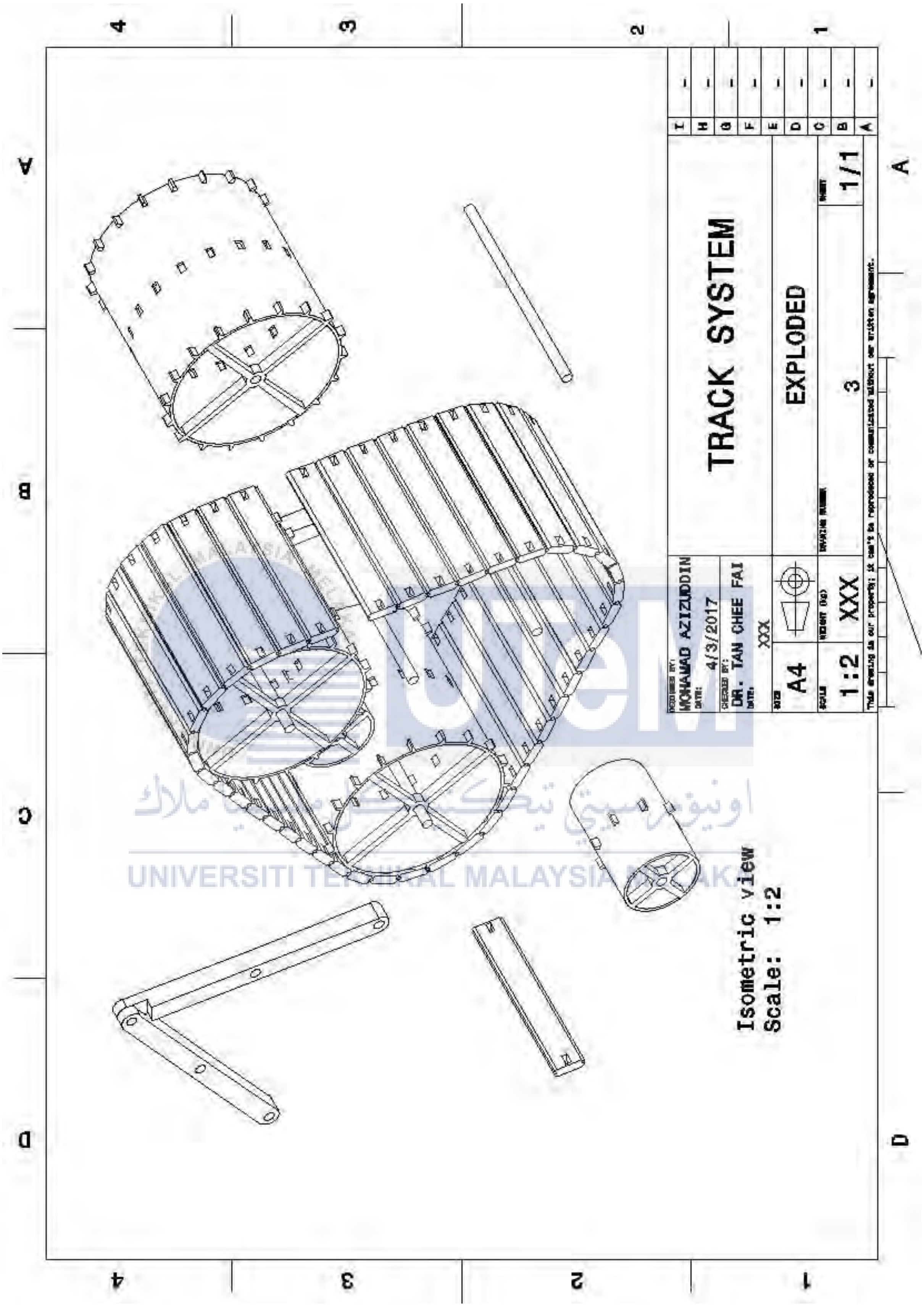


Figure 4.9: Track System Exploded View

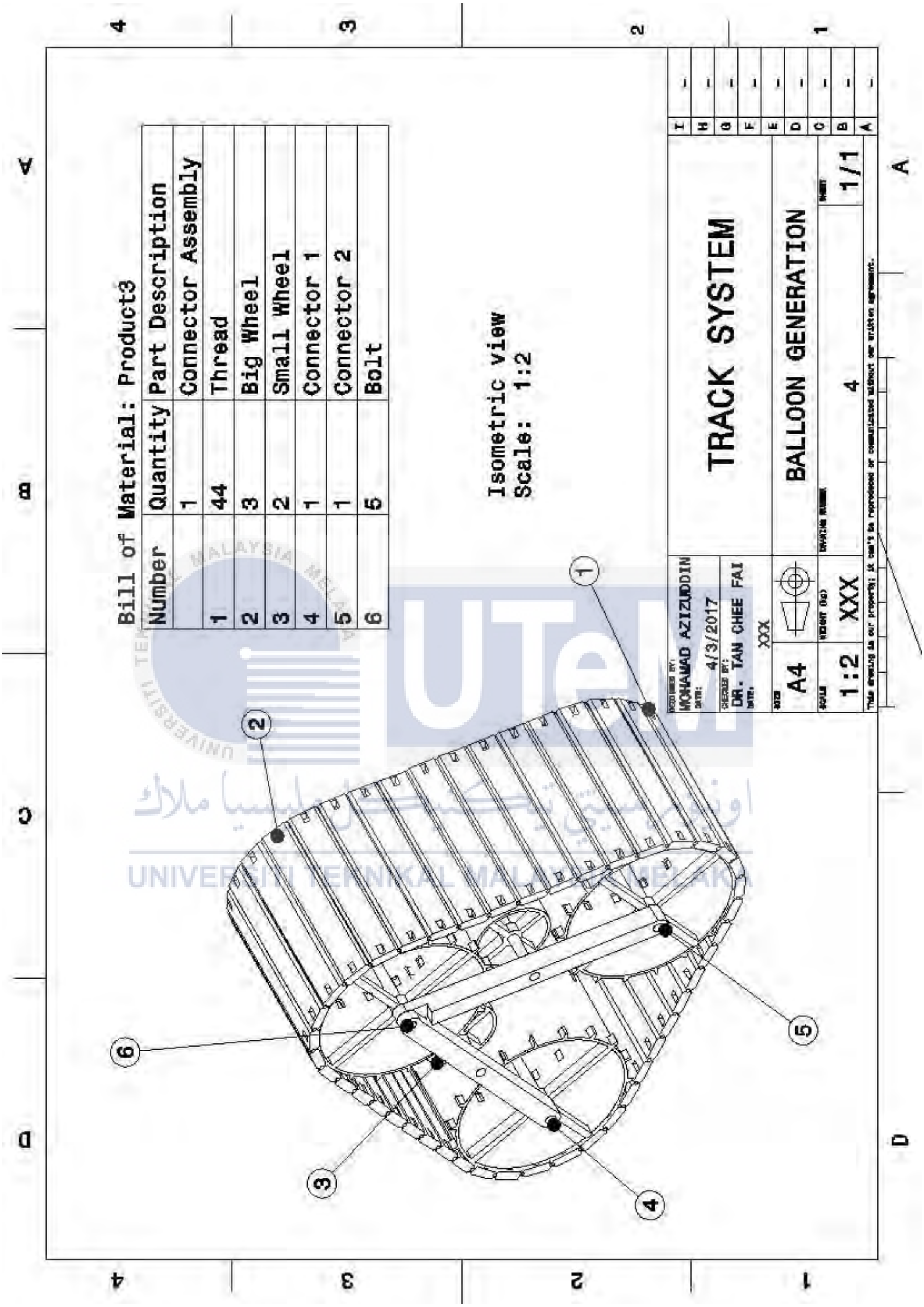


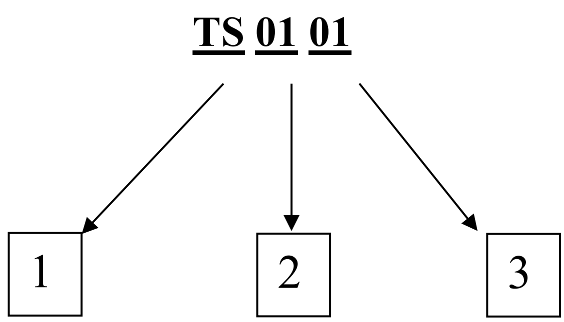
Figure 4.10: Track System Balloon View

4.7 NUMBERING PART

A part number is an identifier of a part used in a particular industry. Its purpose is to simplify referencing to that part. A part number unambiguously defines a part within a single manufacturer. In this section, we will determine the part number of each part the track system. Table below shows the way to numbering the part.

Table 4.4: Numbering Part

Section	Item	Description
1	Part Model	This section represents the name of product by using two to three alphabets. Track System is the product in this project. Therefore, the suitable alphabets use in the section is TS.
2	Sub-assembly (cluster) number	The numbers used in this section represent the order to assembly test tube washer. There are six sub-assembly of the test tube washer. The sub-assembly with number 01 is the first sub-assembly done before the other sub-assembly or part start to assembly.
3	Assembly step of sub-assembly	In this section, 01 is representing the main part position of the sub-assembly which followed by the further number which represent the order to assembly cluster part.



4.7.1 Product Structure Tree

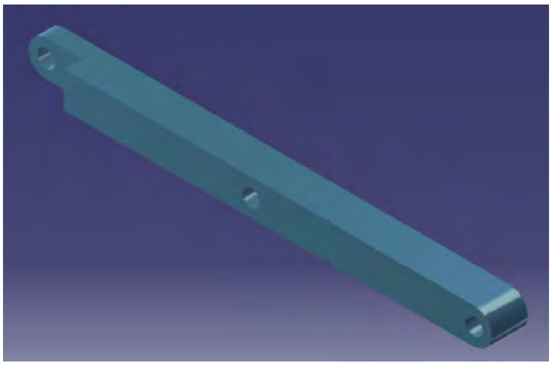
In products structure tree, part compilation would be vital especially in that products cluster assembly process. As such products structure tree is one of the solutions to look how part form one sub assembly (cluster) before sub assembly (cluster) this form one product. The part compilation for the track system is done according to the region.

Part name: Connector 1

Part no.: TS 01 01

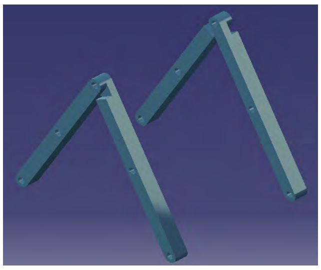
Part name: Connectors

Part no.: TS 01



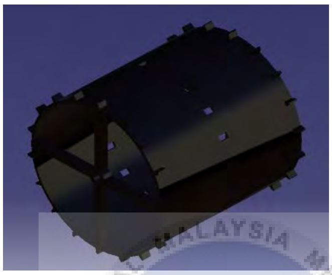
Part name: Connector 2

Part no.: TS 01 02



Part name: Connectors

Part no.: TS 01

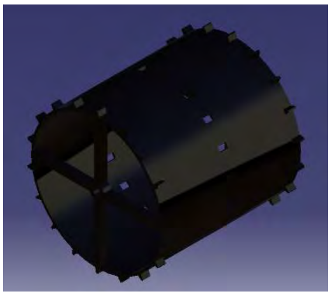


Part name: Big Wheel 1

Part no.: TS 02 01

Part name: Big Wheel 2

Part no.: TS 02 02

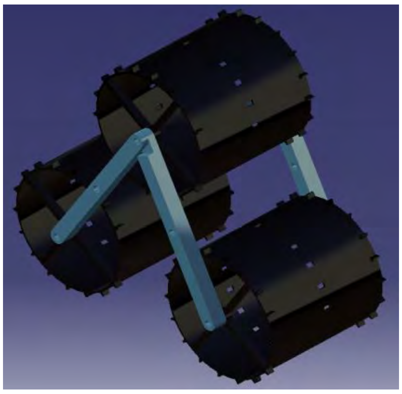


Part name: Big Wheel 3

Part no.: TS 02 03

Part name: Assembled Big Wheel

Part no.: TS 03

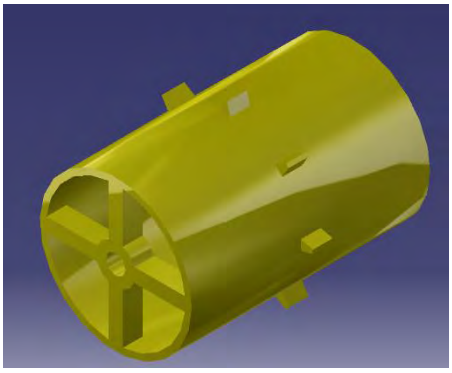


Part name: Assembled Big Wheel

Part no.: TS 02

Part name: Small Wheel 1

Part no.: TS 03 01

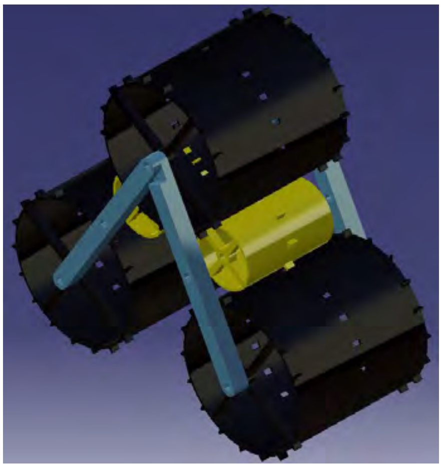


Part name: Small Wheel 2

Part no.: TS 03 02

Part name: Assembled Small Wheel

Part no.: TS 03



Part name: Assembled Small Wheel

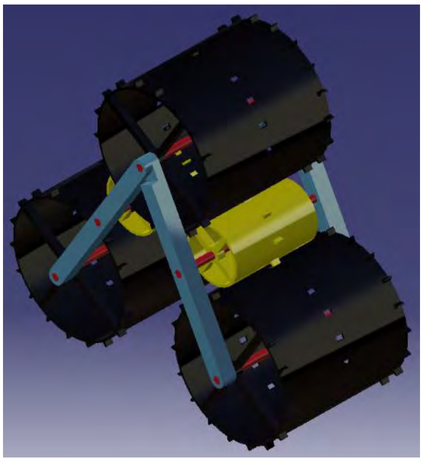
Part no.: TS 03

Part name: Assembled Bolt

Part no.: TS 04

Part name: Bolt

Part no.: TS 04 01 – TS 04 05



Part name: Assembled Bolt

Part no.: TS 04

Part name: Assembled Thread

Part no.: TS 05

Part name: Thread

Part no.: TS 05 01 – TS 05 44

4.8 DESIGN ANALYSIS

4.8.1 Basic Analysis (Length of Belt)

Diameter of Big Wheel, $D_1 = 0.09\ m$

Diameter of Small Wheel, $D_2 = 0.04\ m$

Number of teeth of Big Wheel, $t_1 = 18\ teeth$

Gear Ratio between Big and Small Wheel, n_{12}

$$n_{12} = -\frac{w_2}{w_1} = -\frac{d_1}{d_2} = -\frac{9}{4} \ (-ve\ opposite\ direction)$$

Number of teeth of Small Wheel, t_2

$$\frac{d_1}{d_2} = \frac{t_1}{t_2}$$

$$\frac{0.09}{0.04} = \frac{18}{t_2}$$

$$t_2 = 18(\frac{0.04}{0.09})$$

$$t_2 = 8\ teeth$$

Length of thread, l_t

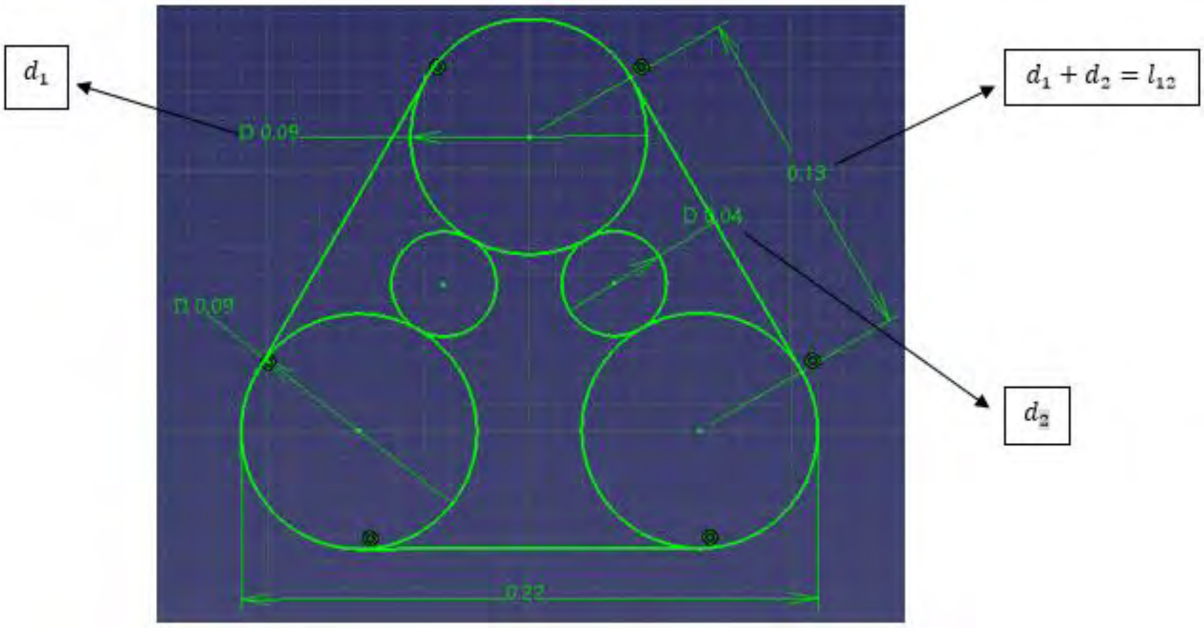


Figure 4.11: Dimension of thread

Circumference, $C = \pi d_1$

$$C = \pi \; X \; 0.09 = 0.2827 \; m$$

$$l_{12} = d_1 + d_2$$

$$l_{12} = 0.045 + 0.040 + 0.045$$

$$l_{12} = 0.13 \; m$$

Length of thread, $l_t = 3(l_{12}) + 3(\frac{C}{3})$

$$l_t = 3(0.13) + 3(\frac{0.2827}{3})$$

$$l_t = 0.39 + 0.2827$$

$$l_t = 0.6727 \; m$$

4.8.2 Basic Analysis (Hydrostatic Pressure)

Depth of water, $D_w = 8.0000\ m$

Length of overall belt, $L_b = 0.6727\ m$

Width of belt, $W_b = 0.0920\ m$

Length of track system, $l_1 = 0.2200\ m$

Height of track system, $h_1 = (\tan 60\ X\ 0.0650) + 0.045 + 0.045$

$= 0.2030\ m$

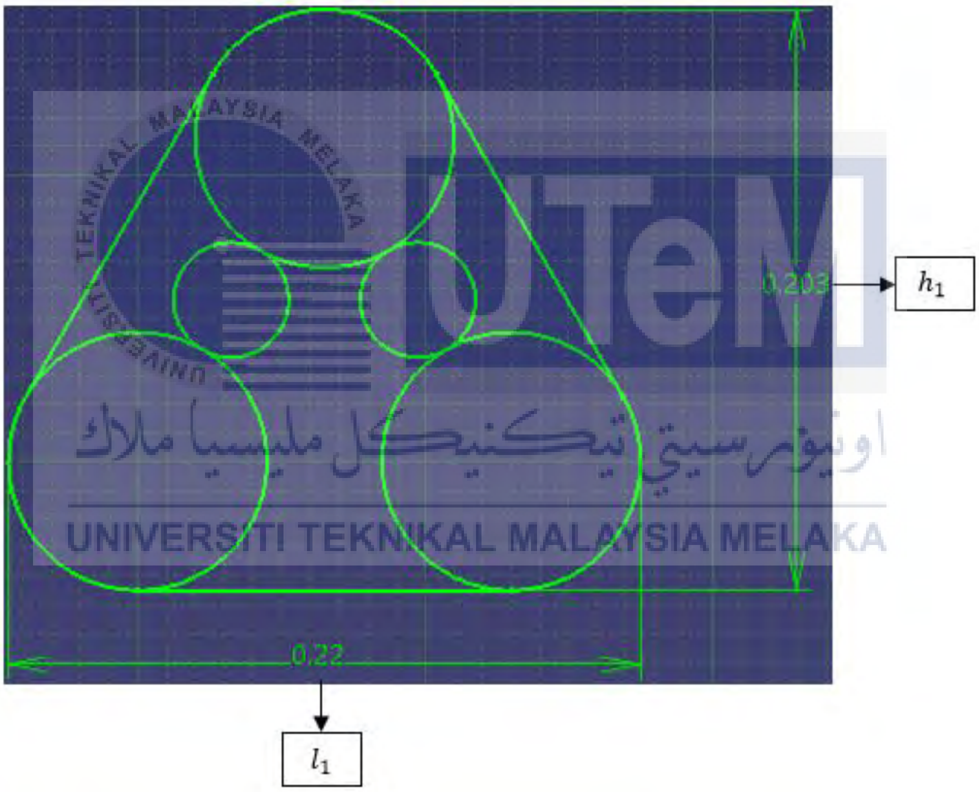


Figure 4.12: Length and height of thread

Density of water, $\rho_{water} = 1000 \frac{kg}{m^3}$

Pressure value at the centroid point of the wheel,

$$P_{avg} = P_c = \rho g h_c = \rho g \left[D_w + \left(\frac{h_1}{2}\right)\right]$$

$$= \left(1000\,\frac{kg}{m^3}\right)\left(9.81\,\frac{m}{s^2}\right)\left[8.000\ m + \left(\frac{0.1905\ m}{2}\right)\right]\left(\frac{1kN}{1000\ kg\ .\frac{m}{s^2}}\right)$$

$$= 79.41\ kN/m^2$$

Resultant Hydrostatic Force,

$$F_R = P_{avg}A = \left(79.41\,\frac{kN}{m^2}\right)(0.6727\ m\ X\ 0.0920\ m)$$

$$= 4.9146\ kN$$

Therefore, the maximum resultant force that the track system can withstand under water with depth of 8 m is 4.9146 kN.

4.8.3 Apply 'Ansys Fluent' Analysis On 3D Rough Modelling

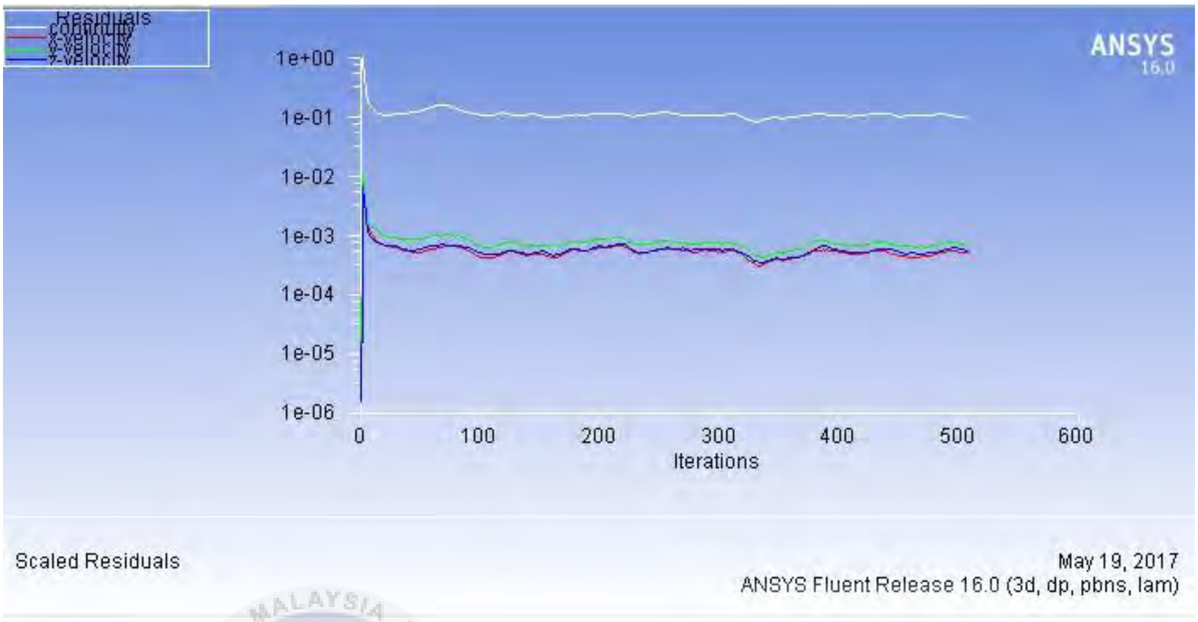


Figure 4.13: The iterations on the 3D modelling

One of the first indicators that your simulation calculation is progressing on the right path is through monitoring the convergence of the iteration. The different colour plots shows the convergence rate of each solved equation. All these tools help the user to quickly identify. Convergence of simulation is achieved after a number of time steps. Iteration means the act of repeating a process with the aim of approaching a desired goal, target or result, so that leads us to asking what is the desired goal? It is specified by the researcher on how many zeros he wants to see after a dot meaning 0.00000 that would require a reasonable amount of allocated software depending on the wanted accuracy. In this project the number alteration is set to be 500 times. Therefore the accuracy of this project had been calculated 500 times to ensure that the data and analysis are more accurate. In this analysis, the speed of the water travelling is assumed to be 10.0 m/s.

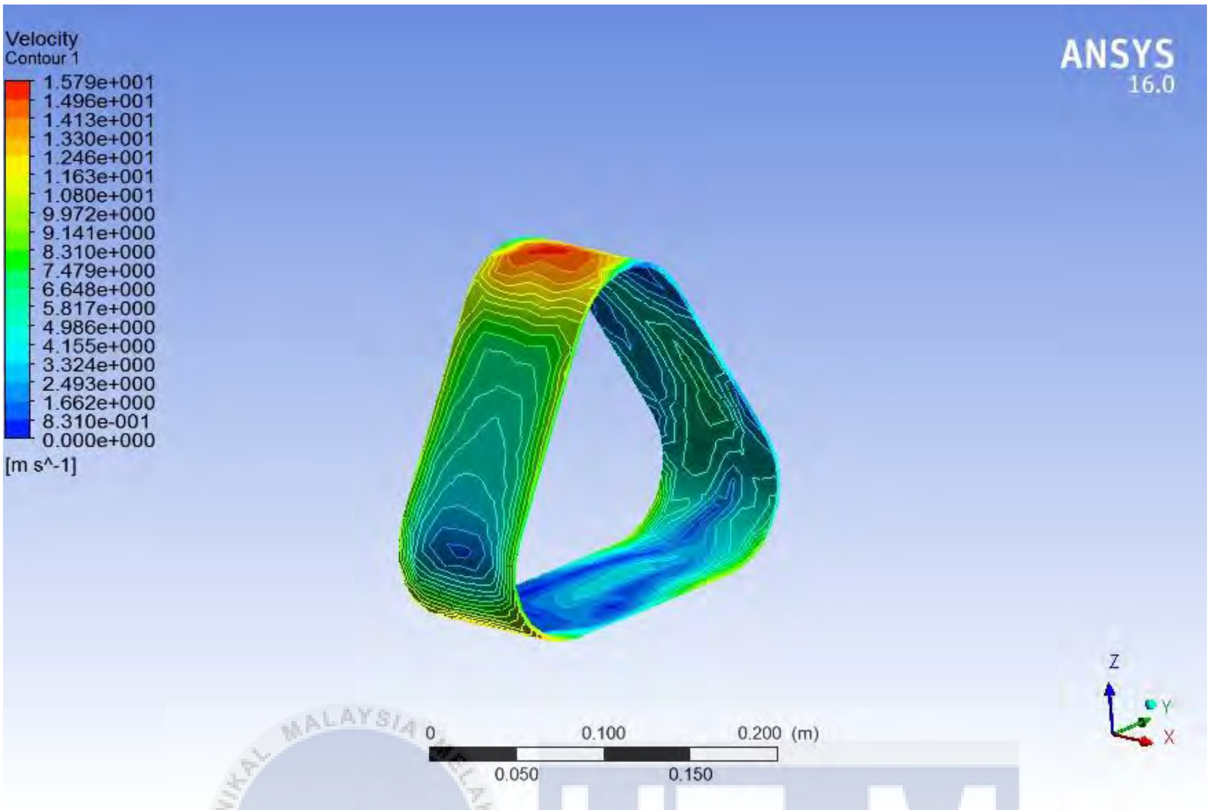


Figure 4.14: Velocity contour on the 3D modelling

The velocity contour from Figure 4.14 shows that the velocity distribution that acts on the surface of the track system. There were slightly red region found on the upper part of the track system. The other surface didn't have the same amount of velocity distribution as the bottom base robot surface. The maximum value collected was 15.79 m/s and the lowest were 0 m/s.

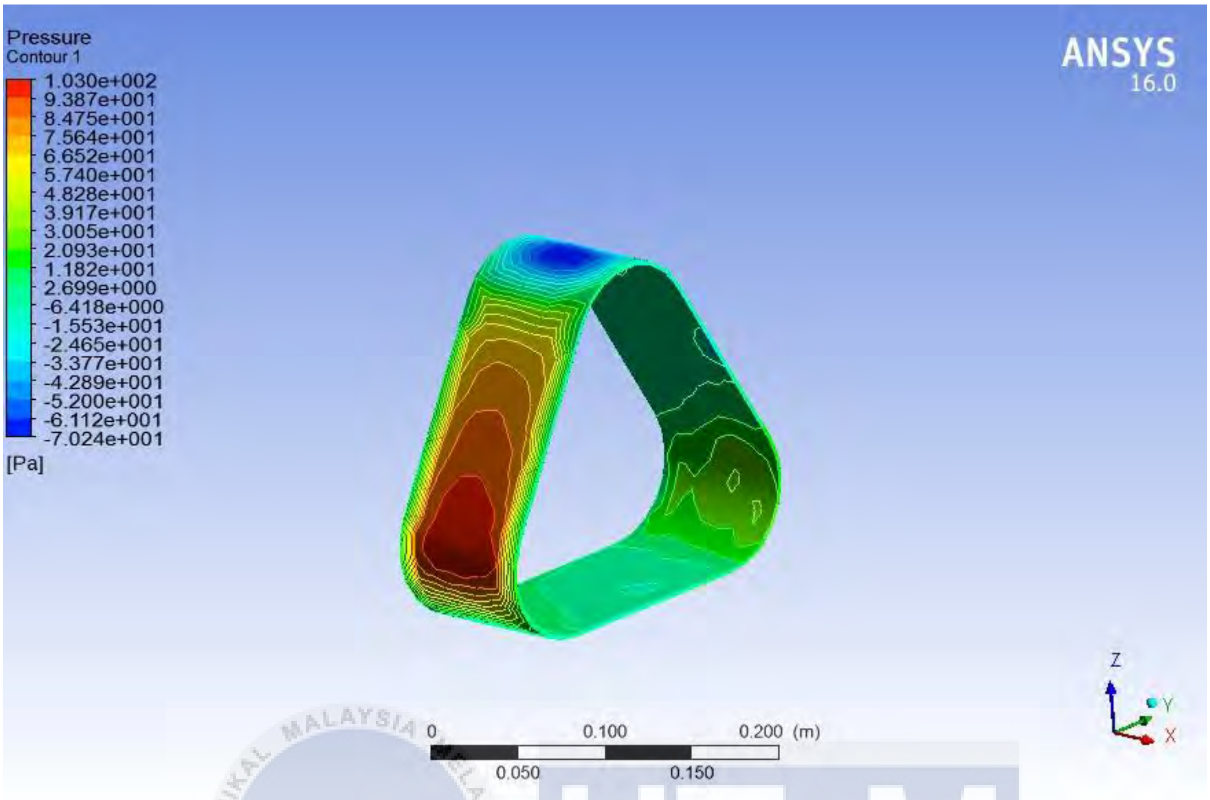


Figure 4.15: Pressure contour on the 3D modelling

Figure 4.15 shows the pressure distributed along the track system body when the system moves underwater. The maximum value that has been obtained from the analysis is 103.00 pa. From the data collected, the highest pressure distributed was red in colour. From the figure, the reddest region was on the front part of the contact surface of the track system. This is because the red regions on the front surface were the surface that makes a direct contact with the water flow.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objectives of this project are concern with the problem statement that has been discussed. Firstly, the design of track system for the underwater inspection robot reduces the weight of the current track system. This is because the conventional track system uses two large track system while the newly designed uses four smaller track system. Secondly, the design of the track system can generate more speed compared to the conventional track system. This is due to the turning point of a smaller track. The objective was achieved with the scope of designing a track system for an underwater inspection robot. As a conclusion, the objective of this project was achieved.

The newly designed track system consist of one driver wheel that is on the top part of the track. It is then attached to two smaller driven wheels that is placed 30° left and right from the lower part of the driver wheel. After that, two more wheels that is the same size as the driver wheel is attached to both smaller driven wheels. Then, two connectors were used to hold all of the wheels together to form a triangle shape. The connectors connects all the wheels from both sides. Finally, 44 sets of thread are chained together and covers the wheels. However, only the big wheels will have contact point with the thread. The thread act as the track of the system.

The analysis for determining the number of teeth and the size of the wheels were done using the gear drive equation. This is to ensure the ratio for the driver and the driven gear are calculated correctly. If the ratio is wrong, the whole gear system cannot works properly. In this case, the big wheels have a diameter of 9.0 m with 18 teeth while the smaller wheels have a diameter of 4.0 m with only eight teeth. Then, another analysis was carried out to determine the behaviour of water passing through the track system. This is called the Ansys Fluent Analysis. This analysis showed that the design produces very small turbulent flow. This is good to ensure the speed of the track moving in the water is smooth.

This project covered the structure 3D modelling, applying CAD operation on generate 3D detail modelling, and product structure tree. The drawing process is using engineering software, CATIA V5R19.

5.2 RECOMMENDATION

There are some recommendations for future research to the design of underwater inspection robot track system. First recommendation is identify the mechanism of the track system that is used in the conventional underwater inspection robot. Furthermore, creativity to come up with different type of design that can solve even more problems not only the speed of the track system. Besides that, taking into account on the materials. This is very important as the usage of which material used can determine the overall performance of the track system. Moreover, design a system which can automatically balance the track system to make sure it moves in a precise manner. This type of balancing are usually found in the commercial car suspension.

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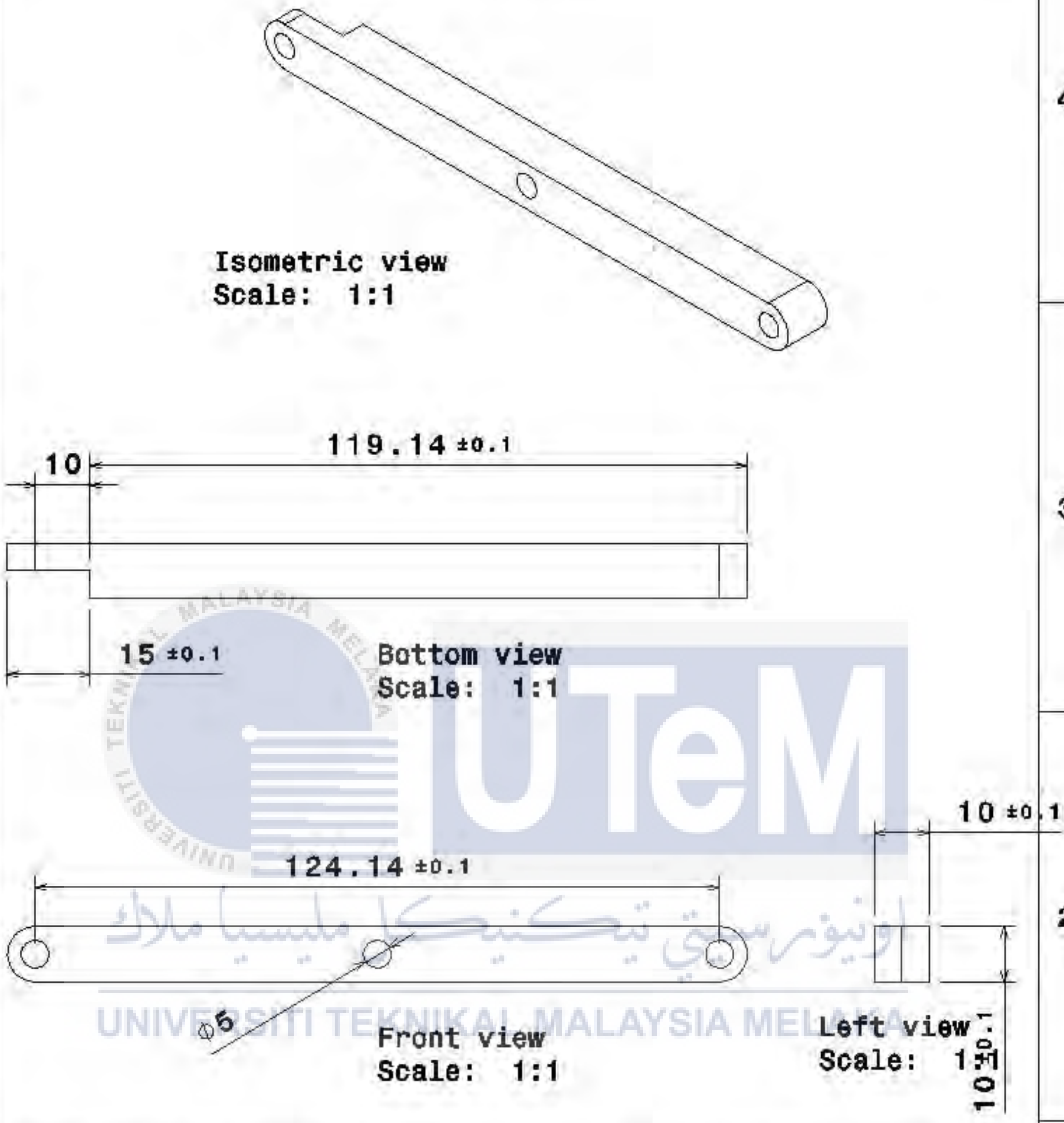
APPENDICES

Table A1 Gantt chart for PSM 1

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	PSM 1													
Problem Statement & Objectives	■													
Literature review		■	■											
Conceptual Design				■	■	■	■	■						
Design development					■	■	■	■	■					
Design analysis								■	■	■	■			
Data collection										■	■	■	■	
Draft of report writing	■	■	■	■	■	■	■	■	■	■	■	■	■	
Report writing submission														■
Seminar 1 presentation														■

Table A2 Gantt chart for PSM 2

Week / Activities	PSM 2													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Concept Selection	■	■												
Detail design		■	■	■										
CAD drawing				■	■	■	■	■						
CAD analysis									■	■	■			
Data collection									■	■	■			
Report writing	■	■	■	■	■	■	■	■	■	■	■	■	■	
Report submission														■
Presentation														■



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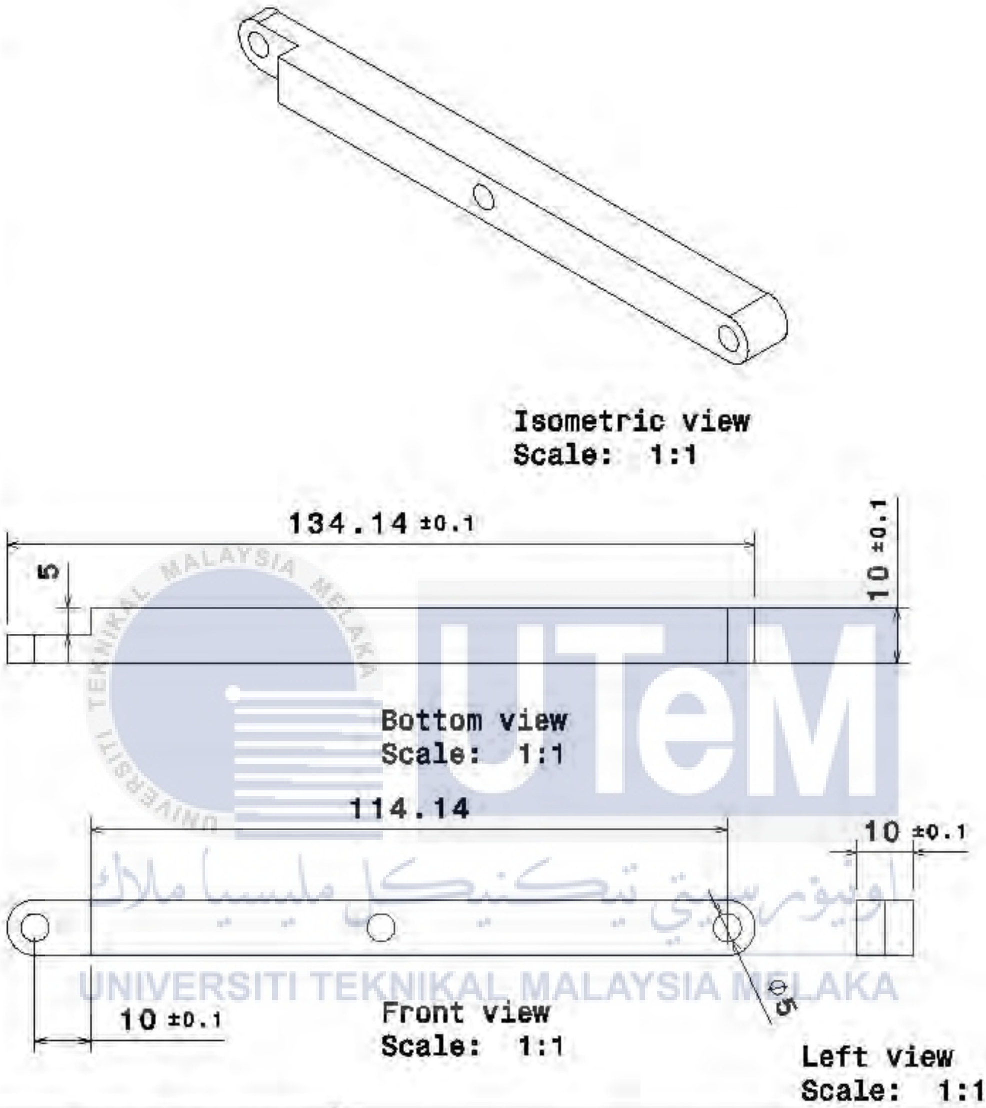
DRAWN BY AZIZUDDIN	DATE 4/3/2017					
CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 01 01			UNIT mm
DESIGNED BY AZIZUDDIN	DATE 4/3/2017	SCALE 1:1	WEIGHT(kg) XXX			SHEET 1/1



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CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 01 02			UNIT mm
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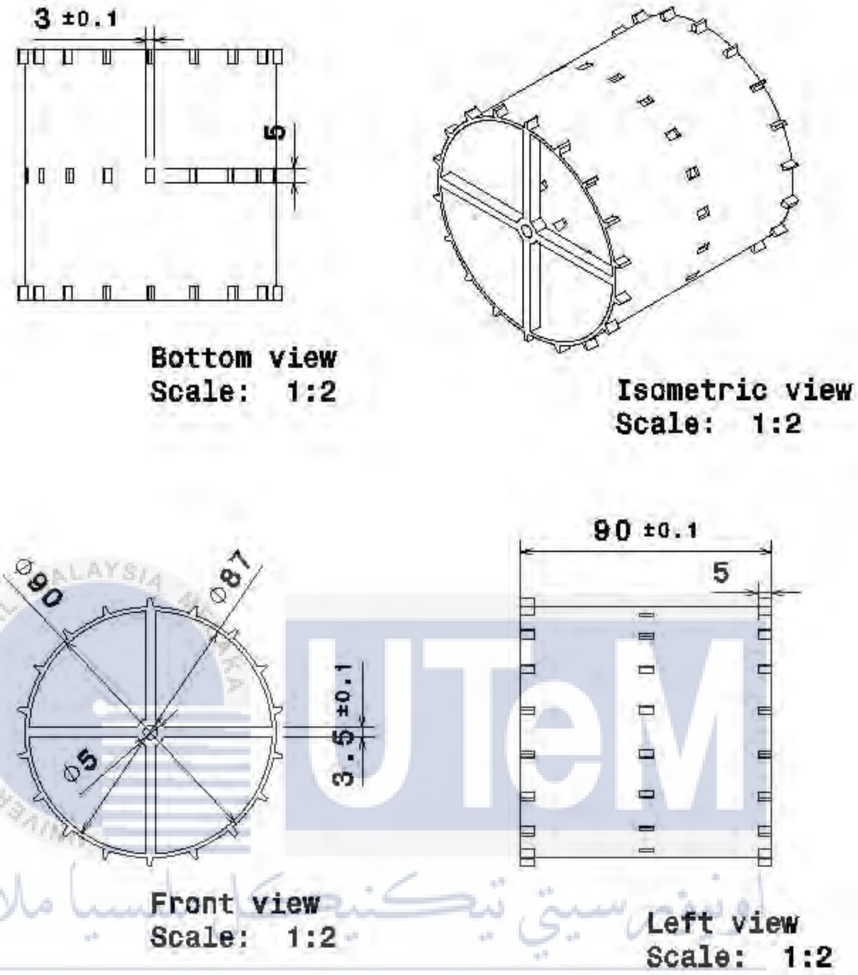

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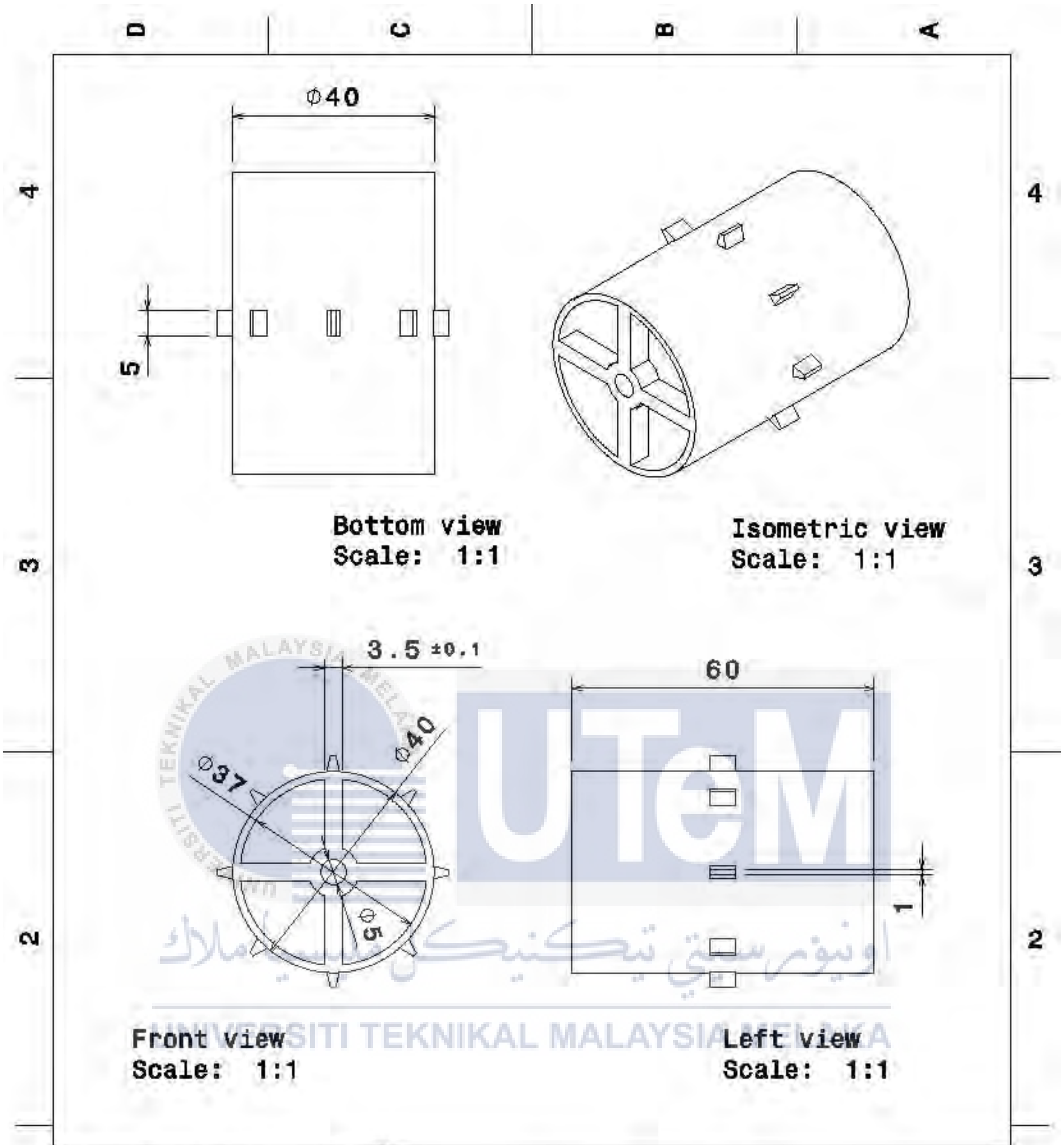
DRAWN BY AZIZUDDIN	DATE 4/3/2017	DRAWING TITLE BIG WHEEL			
CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 02 01		UNIT mm
DESIGNED BY AZIZUDDIN	DATE 4/3/2017	SCALE 1:2	WEIGHT(kg) XXX		SHEET 1/1



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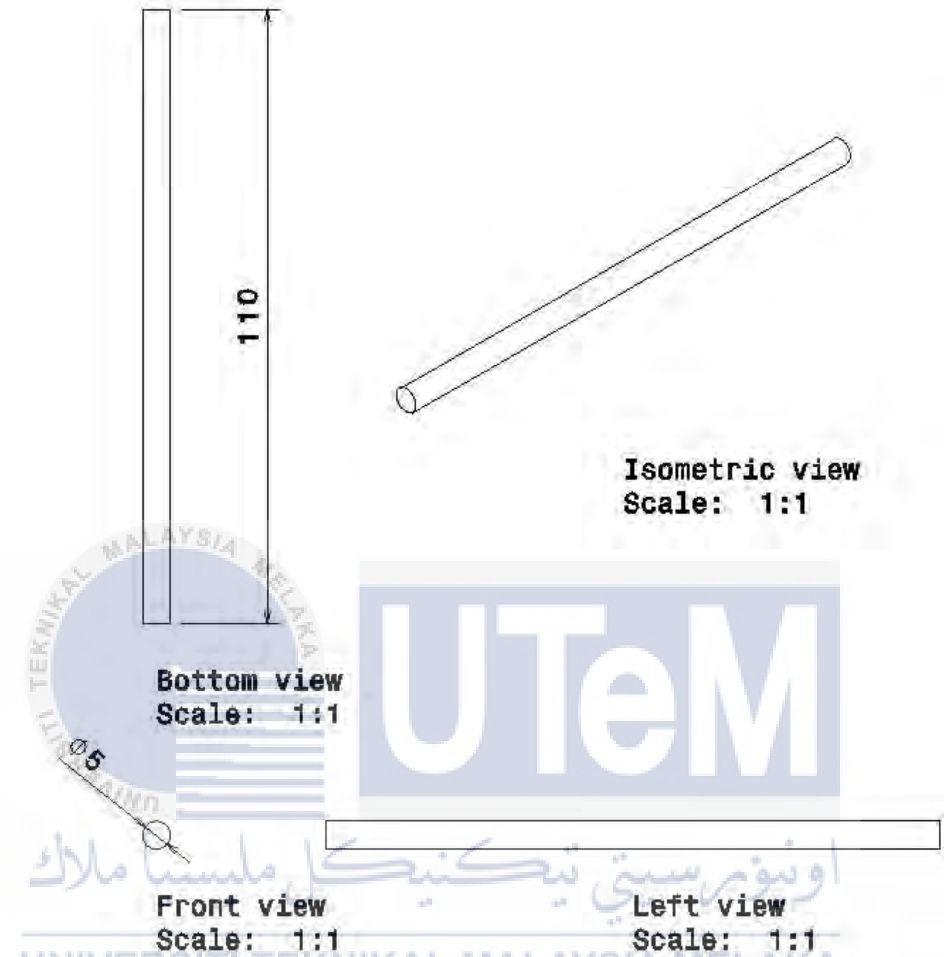
DRAWN BY AZIZUDDIN	DATE 4/3/2017	DRAWING TITLE SMALL WHEEL			
CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 03 01		UNIT mm
DESIGNED BY AZIZUDDIN	DATE 4/3/2017	SCALE 1:1	WEIGHT(kg) XXX		SHEET 1/1

D A



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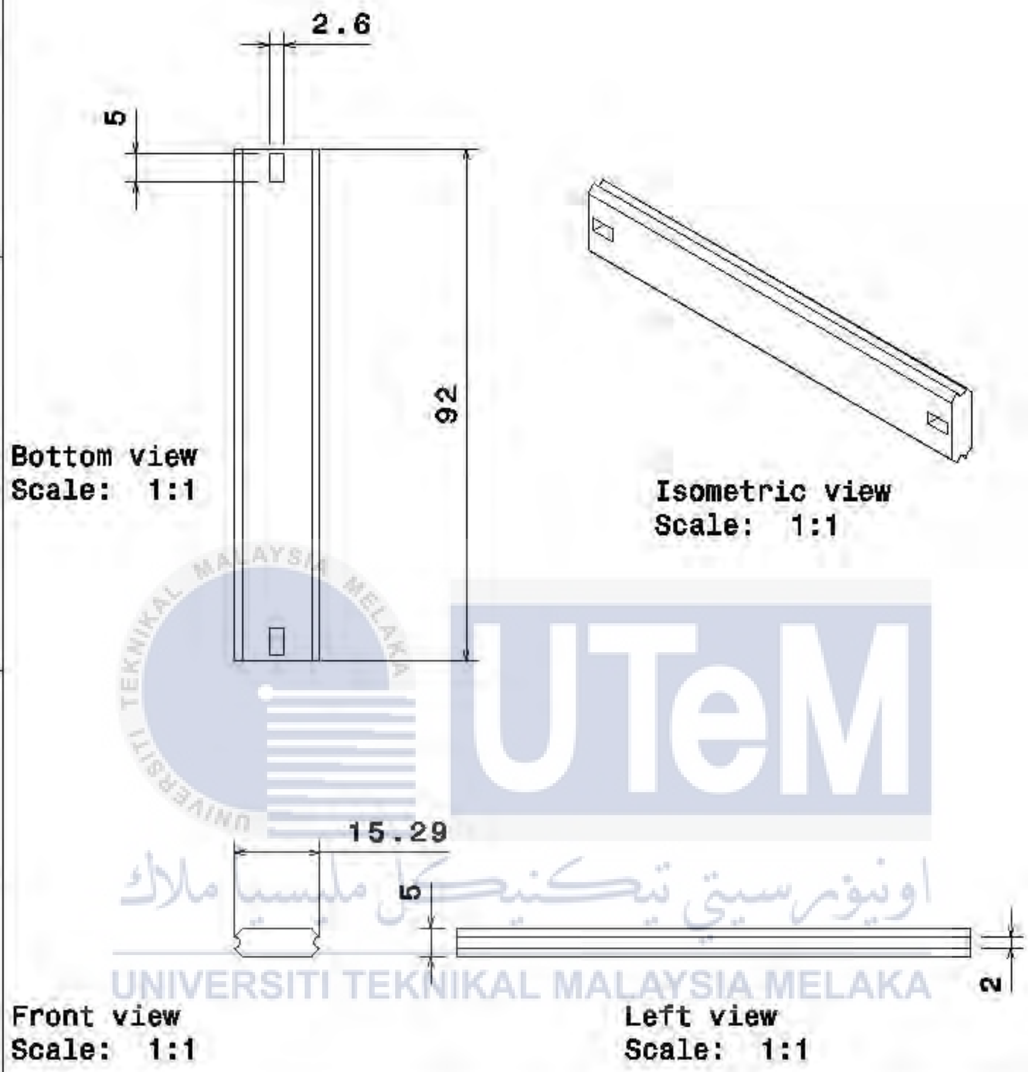
		DRAWING TITLE	BOLT		
DRAWN BY AZIZUDDIN	DATE 4/3/2017				
CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 04 01		UNIT mm
DESIGNED BY AZIZUDDIN	DATE 4/3/2017	SCALE 1:1	WEIGHT(kg) XXX		SHEET 1/1



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DRAWN BY AZIZUDDIN	DATE 4/3/2017	DRAWING TITLE THREAD		
CHECKED BY DR. TAN	DATE XXX	SIZE A4	DRAWING NUMBER TS 05 01	UNIT mm
DESIGNED BY AZIZUDDIN	DATE 4/3/2017	SCALE 1:1	WEIGHT(kg) XXX	SHEET 1/1