DESIGN IMPROVEMENT AND FUNCTIONAL ANALYSIS OF PORTABLE OIL SPILL SKIMMER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering

By:

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2021

DECLARATION

I declare that this report entitled "Design Improvement and Functional Analysis of Portable Oil Spill Skimmer" is the result of my own research except as cited in the references.

Signature: ……………………………………………………

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Date : 14 JULY 2021

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

………………………………………………………………………

(DR. KHAIRUL FADZLI BIN SAMAT)

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ABSTRACT

The portable oil spill skimmer is a device that used to make a cleanup spillage of oil on the surface of water. Different type of device in the reaction plan of oil spillage is currently used in compliance with the requirements of the waste and the procedures used, such as booms, skimmers, barriers, storage barges, tanks and even vessels. However, the existed oil spill skimmer have a weakness on its performance. It not suitable for wavy surface of water, the linear motion is not stable and need a long period to finish the cleanup. This report proposes and explain the information about redesign the new hull part, reduce the time taken for oil collection and improve the linear motion stability. One of the possibilities to improve the hull part is to embed the catamaran hull design due to high stability performance on the portable spill skimmer. For the oil collecting, the skimmer is most suitable and the material is polypropylene. The dimension of the polypropylene roller need to be increase to able the roller to collect more oil and reduce the time taken. The number of propeller motor can be use either single or more than one. The method used in this project is starting from brainstorming to identify the solution for the problem. Then, need to find out the requirement needs to improve the exsited product and continue to generate the design concept which have five different design of hull. The selection of design and propeller motor must go through the Analytic Hierarchy Process (AHP) method. In conclusion, the portable oil spill skimmer is proposed to be improved by redesign the hull, enlarge the size of skimmer and increase the linear motion stability. With the improvement that have been made, the portable oil spill skimmer could performed well on the wavy water surface and can reduced the period to complete the cleaning job.

ABSTRAK

Skimmer tumpahan minyak mudah alih merupakan alat yang digunakan untuk membuat pembersihan tumpahan minyak di atas permukaan air. Pelbagai jenis alat dalam rancangan tindak balas tumpahan minyak saat ini digunakan sesuai bergantung kepada keadaan tumpahan dan prosedur yang digunakan, seperti *booms*, *skimmer*, penghalang, dayung, tangki dan bahkan kapal. Namun, *skimmer* tumpahan minyak yang sedia ada mempunyai kelemahan pada prestasinya. Ia tidak sesuai untuk permukaan air yang bergelombang, gerakan linier tidak stabil dan memerlukan masa yang lama untuk menyelesaikan pembersihan. Laporan ini mencadangkan dan menjelaskan maklumat mengenai reka bentuk semula bahagian lambung baru, mengurangkan masa yang diambil untuk pengumpulan minyak dan meningkatkan kestabilan gerakan linier. Salah satu kemungkinan untuk memperbaiki bahagian lambung adalah menyisipkan reka bentuk lambung catamaran kerana prestasi kestabilan yang tinggi pada skimmer tumpahan minyak mudah alih. Untuk pengumpulan minyak, *skimmer* paling sesuai dan bahannya adalah *polypropylene*. Dimensi penggelek *polypropylene* perlu ditingkatkan agar penggelek dapat mengumpulkan lebih banyak minyak dan mengurangkan masa yang diambil. Bilangan motor *propeller* boleh digunakan sama ada tunggal atau lebih dari satu. Kaedah yang digunakan dalam projek ini adalah bermula dari percambahan idea untuk mengenal pasti penyelesaian untuk masalah tersebut. Kemudian, perlu mengetahui keperluan-keperluan untuk meningkatkan produk yang sudah sedia ada dan terus menghasilkan konsep reka bentuk yang mempunyai lima reka bentuk lambung yang berbeza. Pemilihan reka bentuk dan motor *propeller* mesti melalui kaedah *Analytic Hierarchy Process (AHP)*. Kesimpulannya, *skimmer* tumpahan minyak mudah alih dicadangkan untk diperbaiki dengan merancang semula bahagian lambung, memperbesar ukuran *skimmer* dan meningkatkan kestabilan gerakan linier. Dengan penambahbaikan yang telah dilakukan, alat ini dapat bekerja dengan baik di atas permukaan air bergelombang dan dapat mengurangkan waktu untuk menyelesaikan kerja-kerja pembersihan

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DEDICATION

I wholeheartedly dedicate this study

to my beloved father, Azhar Bin Ahmad; to my mother, Azizah Binti Yusof;

to my family;

to my helpful classmates and friends;

to my honorable and resourceful supervisor, Dr. Khairul Fadzli Bin Samat

for assisting me by means of giving me moral supports, knowledge, time, cooperation, encouragement and understandings.

Thank You So Much

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Firstly, I would like to thank Allah swt, because of His grace has allowed me and give me chance to complete this PSM 1 report. I would like to express my gratitude to my precious supervisor, Dr. Khairul Fadzli Bin Samat for his guidance and support towards completing this report.

My completion of this project could not have been accomplished without the support from my family that always support me to finish this report. Same goes to my friends who help and give me some guide during completing this report.

Lastly I would like to thanks any person which contributes to my project directly or indirectly. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this report.

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LIST OF ABBREVIATION

CAD	-	Computer-aided design
PVC	-	Polyvinyl chloride
PE	-	Polyethylene
PP	-	Polypropylene
DC	-	Direct current
AHP	-	Analytic Hierarchy Process

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LIST OF SYMBOL

%	-	Percentage
Mm	-	Millimetre
N/mm^2	-	Newton per millimetre square
kg/mm^3	-	Kilogram per millimetre cube
N/A	-	Not available
Hr	-	Hours
ml/min	-	Millilitre per minute
Rpm	-	Revolution per minute
NaCl	-	Sodium chloride
V	-	Volt
Nm	-	Newton metre
F	-	Force
P	-	Density
M	-	Mass
M_{max}	-	Maximum mass of oil can be occupied
g	-	Acceleration due to gravity ($9.81\ m \cdot s^{-2}$).
S	-	Speed
d	-	Distance
t	-	Time
Π	-	Pi
Vs	-	Volume of submerge
ρ	-	Density
F_b	-	Buoyant force
L	-	Litre
kg/L	-	Kilogram per litre
r	-	Radius
h	-	Height
m^2	-	Metre square
m^3	-	Metre cubic
N	-	Newton

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CHAPTER 1

INTRODUCTION

1.1 Background Study

One of the natural resources that contain in earth is oils. Over the years, however, demand for oil and transport has risen (Cakir et al., 2021). The disadvantages of oil is it non-renewable energy which is oil will finish from earth in future. Oils may be characterised as any acidic, nonpolar chemical material, which is hydrophobic as well as lipophilic in the shape of viscous liquid in the ambient temperature. The oil that obtained from the seabed is called as crude oil/raw oil. The oil need to be process to produces petroleum, petrol, kerosene, butane gas and etc.

The waste generators must use the appropriate containers to ensure proper handling of the waste. Then, the guidelines have been developed for oil and chemical handling. Before the oil is shipped, reinjected or stored somewhere, it is treated on the ground, the oil is reused or stored anywhere, the oil is handled on the field or oil is handled at the processing facility before it is transported, reinjected or stored anywhere, the oil is reused in the field, or is handled at the construction site until oil is transported, reinjected or stored somewhere (Muizis, 2013).

Oil spill were one of the world's greatest issues for a long time and be the main cause of water pollution (Singh et al., 2020). Oil spill may cause the underwater ecosystem damage (Huang et al., 2019). These are disasters for industry and the community. Ocean water has been tainted with liquid petroleum hydrocarbons as a result of a collision involving vessels and oil plants, causing disruption to the atmosphere for decades. Although only big injuries leading to pollution are the main subject of concern, there are frequent events of certain minor and repeated cases. It also takes months of oil washing to restore the areas surrounding the event to normal.

An oil skimmer is an oil removing instrument from a sheet of grease. The usage of robot can help in cleaning the spillage of oil on surface of water (Shukla & Karki, 2016). The water saturation scent can be reduced by eliminating the top layer of the oils and the unexpected surface scum. Depending on the nature, skimmers are also needed before further treatments with respect of the environmental discharge to extract oils, grates and fats in industrial applications. In order to increase wastewater discharge quality, an oil skimmer placed before the oily water treatment system can achieve greater overall oil separation performance.

1.2 Problem Statement

An oil spill skimmer are used to separate the floating oil on the surface of water from a body of water. Nowadays, there are a few system used to clean up the spillage such as drum skimmer, wire skimmer, brush skimmer and disc skimmer. Every system have their advantages and disadvantages. The system were selected by considering the limitation of the usage such as the variable space and radius of spillages.

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The design of hull are not suitable for wavy surface of water such as ocean. The existing oil skimmer were design with flat hull and it will limit the movement of the oil skimmer (Manivel & Sivakumar, 2020). Beside that, the time taken to clean up the spillage are to long because of the rate of oil collection are too small. The existing oil spill skimmer consists a complex maneuver system which is made by 2-propeller system. There are some difficulty was discovered on the maneuverability due to uneven power distribution due to installation of 2-propeller system and caused the oil spill skimmer sailing in improper desired direction.

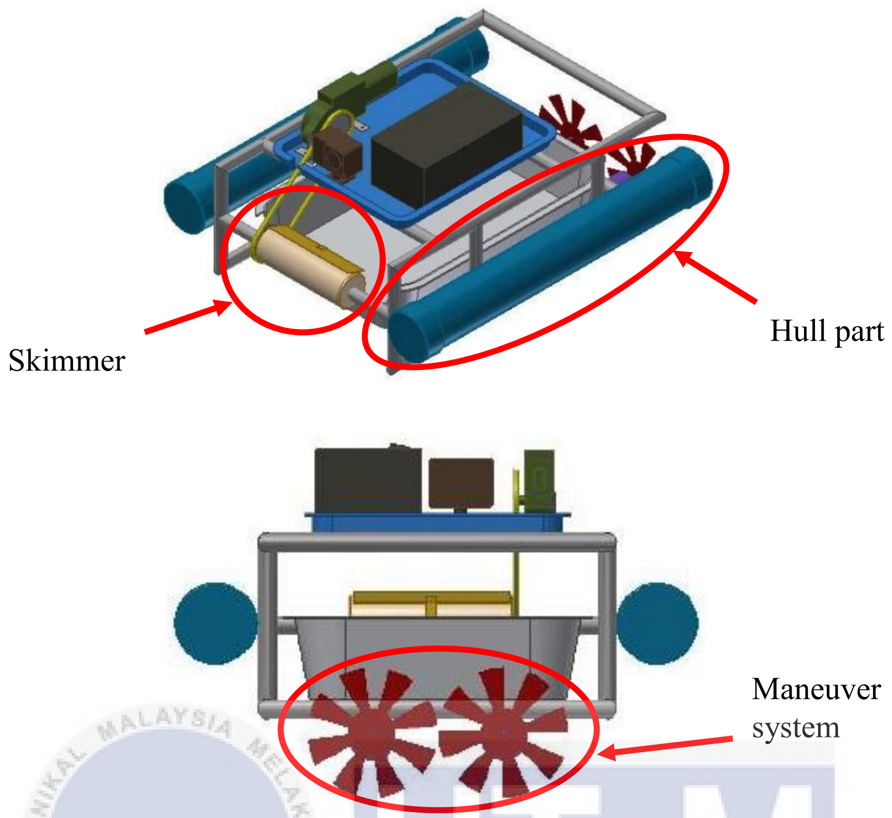

Figure 1.1: Reference model of existing Portable Oil Spill Skimmer (Santuso, 2018)

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1.3 Objectives

Objectives of this task are;

- To design a new hull part of the portable oil spill skimmer that following the catamaran hull design.
- To evaluate the selection process of the propeller motor by using Analytic Hierarchy Process (AHP) method.
- To analyse the buoyant force of the hull and the oil collection rate.

1.4 Scope

This study will focus on designing new improvement for the oil spill skimmer. The scope for this study are:

1. The dimension of hull is subjected to the existing design of skimmer and its suitability. Catamaran is a combination of two hull on port side and starboard side. The skimmer need to be located at between of the hulls.
2. Without changing the type of skimmer, the suggestion to increase the rate of oil collection is by enlarge the dimension of polypropylene roller such as the diameter and the length of skimmer.
3. Simplify and ease the maneuverability system which relate to analysis on the propeller system. The idea to reduce the number of propeller could be considered in this project.

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1.5 Significance of Study

The aims of the project is to make the reaction and recovery teams of oil spills easy to manage, and clean the spilled oil on water surface by making the improvement of the existing portable oil spill skimmer. The time to complete the skimming process is expected to be reduced with the implementation of new improved design of portable oil spill skimmer.

1.6 Project Schedule

Table 1.1: Gantt chart PSM 1

No.	Activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
1	Title approval																
2	Chapter 1 (Introduction)																
3	1.1 Background study																
4	1.2 Problem statement																
5	1.3 Objective																
6	1.4 Scope																
7	1.5 Significant of study																
8	Chapter 2 (Literature review)																
9	Chapter 3 (Methodology)																
10	3.1 Introduction																
11	3.2 Flowchart																
12	3.3 Product planning																
13	3.4 Identify the requirement																
14	3.5 Generate design concept																
15	3.6 Concept selection																
16	3.7 Analytic Hierarchy Process																
17	3.8 Designing the hull																
18	3.9 Final conceptual design																
19	3.10 Analysis																
20	Thesis writing																
21	PSM 1 presentation																
22	PSM 1 report submission																

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Table 1.2: Gantt chart PSM 2

No.	Activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
1	PSM 1 correction																
2	Chapter 4 (Result and discussion)																
3	4.1 Introduction																
4	4.2 Selection of hull design																
5	4.3 Selection of propeller motor																
6	Solidwork drawing																
7	4.4 Buoyant force																
8	4.5 Maximum oil collected																
9	4.6 Rate of oil collection																
10	Chapter 5 (Conclusion)																
11	5.1 Conclusion																
12	5.2 Recommendation																
13	Thesis writing																
14	PSM 2 presentation																
15	PSM 2 report submission																

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1.7 Thesis Organisation

This thesis consist of five (5) chapters that reports all the related theories, finding and analysis in respects of the stated objectives in this study. Below shows the organisation of this thesis.

Introduction

- Explain the aim of this study, problem statement, objectives, and scope.

Literature Review

- Review the theories that related to this project from the previous research and journals.

Methodology

- Describe the details explanation of methods and process flow that is used to complete this project well and successful.

Result and Discussion

- Discuss about the result and analysis obtained from this project.

Conclusion

- Summarizing the contributions and significant findings related to the objective in this project.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The response and recovery system for oil spills are a system for purifying and preventing oil spills from spreading further and wider in the ecosystem. Few kinds of recovery system are in operation. One of them is skimmers. Depending on the form of oil and environmental conditions, mechanical methods may be successful. The best choice for the atmosphere may be seen, as waste from the sea is directly removed. Therefore, considering heavy investment in resources and complicated operations, mechanical approaches are deemed to be the most common anti-oil spill measures (Y. Wang et al., 2018). The methods and processes used to clean up oil spills are different based on the types of systems used (Cho, 2013). There are a few mechanism and components need to be improve from the existing oil spill skimmer.

Oil skimmers of boat type will include hull, rollers sections and scrapper, cover, transmission, gear box, tank set, tank stage indicator for bearing, belt and pulley. The scooter is covered the roller is perpendicular to the scrapper with a Teflon board, Adjustable for adjusting the location and method of withdrawal. The rotary roller part attached to a bearing and connected to a belt and pulley to the engine. The scrapper is put in the slope tank and roller close. The engine is located on the boat stuff of any component is added to the boat's back (Manivel & Sivakumar, 2020).

2.2 Float Mechanism

Hull is a part of any floating vehicle such as boat that help to float on the water. The floating force of the hull is depend on the material used to fabricate it and the total weight of the object that acting on it. The movement of the boat also depends on the design of the hull.

2.2.1 Design of Hull

Design of hull play an important role in the making of an oil spill skimmer. The design made also must fulfil the requirement of the oil skimmer such as can support the heavy load and high stability. Catamaran hull has been selected because its stability is fine. The building on this boat must be strong to carry all of the pressure on the boat. Catamarans are so famed and prosperous because of their large dock area as well as the comfort and security of their stability, as a mode of transport (Dabit et al., 2020).

Mesh type	Solid Mesh
Mesher used	Standard Mesh
Jacobian points	4 point
Element size	36.3852 mm
Tolerance	1.81926 mm
Mesh quality	High
Total nodes	18909
Total elements	9840
Maximum Aspect Ratio	79.103
Percentage of elements with Aspect Ratio < 3	0.0711
Percentage of elements with Aspect Ratio > 10	80.4
% of distorted elements (Jacobian)	0

Figure 2.1: Meshing data for catamaran hull (Dabit et al., 2020)

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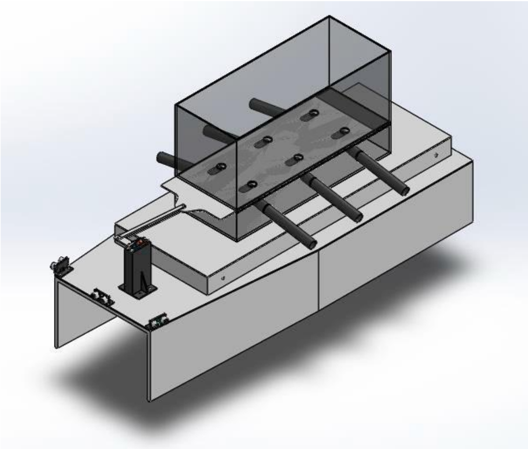

Figure 2.2: Design of Catamaran hull (Dabit et al., 2020)

Catamaran is a watercraft with several hulls of the same size with two parallel hulls. The geometry is stabilised by its stability, based not on a ballasted keel like a monohull sail, on its long beam and on its stability. Usually, catamaran volumes are smaller than equivalent length monohulls, with smaller displacement and a shallower draught. The combined two hulls are also less resistant to hydrodynamic than similar monohulls and need less propulsive power either from sails or motors. In contrast to a monohull which can provide decreased wakes, the wider location of the catamaran on the water can minimise heeling and wave-induced movement. Furthermore, the catamaran design was selected because the skimmer will located between the port hull and starboard hull.

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Figure 2.3: Device that using Catamaran hull (del Águila Ferrandis et al., 2018)

2.2.2 Dimension of Hull

The dimension of the hull is depend on the total load that exert on it. The bigger the load, the larger the dimension of hull. According by (Dabit et al., 2020), the hull of a catamaran hull is used for autonomous unmanned Surface Vehicle Feeder Ships. The hull size is 1 000 mm long, 400 mm wide and 200 mm thick. We use a patrol boat with 19M Catamaran Patrol Vessel (1C16108) in a 1:10 compare to the height of the hull to get the hull's dimension. The boat's total height is both a hull high and a feed tank with an eight kilos feed configuration.

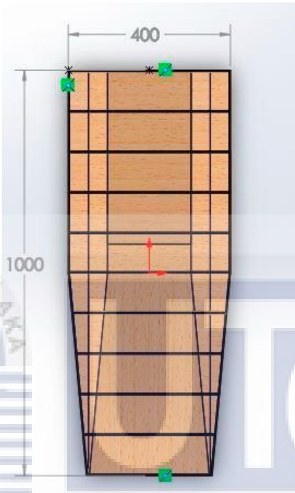

Figure 2.4: Length and width of the catamaran hull (Dabit et al., 2020)

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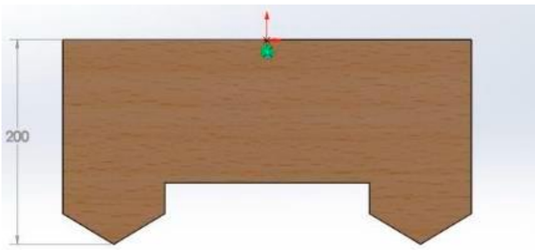

Figure 2.5: Height of the catamaran hull (Dabit et al., 2020)

2.2.3 Material of Hull

Composite components with a wide variety of economical and economical benefits are used in the boat construction industry (Caramatescu & Mocanu, 2019). Material selection is the important part that to make sure the oil skimmer is float on the water successfully. The material on the entire body of the boat uses reinforced resin splintering. In the simulation, however, it is defined as a material of the balsa wood with nearly the same features as splinter (Dabit et al., 2020).

Property	Value	Units
Elastic Modulus	2999.9	N/mm^2
Poisson's Ratio	0.29	N/A
Shear Modulus	2999.9	N/mm^2
Mass Density	159.9	kg/m^3
Yield Strength	19.9	N/mm^2

Figure 2.6: Characteristic of balsa wood (Dabit et al., 2020)

Some of the researcher use composite material as the hull. The composite material used is hand laid fibreglass with a single skin in polyester resin matrix (Caramatescu & Mocanu, 2019) and (Hoge & Leach, 2016). This is because the properties of composite material has high buoyancy and high strength to be the hull. The hull of boat also can be made from polyethylene (Cho, 2013). In this journal, the researcher shows the detail design of hull that can be made from this kind of material and the result of analysis. According to ("Fishing Boat Features Insulated Hull," 2003) and (Vigneshwaran & Yuvaraj, 2020), composite such as polyvinyl chloride (PVC) also can be used to be the hull. The material is famous with their high buoyancy and low in price. After PE and PP, PVC also widely used in manufacturing and it is flexible in making any kind of product.

2.3 The Skimmer

According to (Guidi et al., 2016), mechanical instruments for extracting floating oil from the surface of water are skimmers. They can be used on the shore or by ships. In fairly rough or choppy seas, skimmers prefer to recover more water than oil. Quality depends on the environmental conditions. Skimmer is the important part in oil spill simmer which usually used with the boom. However, the booms in calm seas are most powerful, with a decrease in output at elevated wave height (Skinner et al., 2018). Without making any changes in their physical or chemical properties, the skimmers extract oil from the water surface and pass this to storage tanks on board the ships. There are many type of skimmer such as suction skimmer, weir skimmer, drum skimmer, disc skimmer and etc. Each skimmer have their advantage and disadvantages. It selected based on the suitability and the usage.

2.3.1 Type of Skimmer

Oelophilic skimmers have a surface on which oils may be attached to remove oil from the surface, sometimes referred to as the sorbic surface skimmers. The surface may be a brush, drum, disc or string flowing across the surface of the water. The oil has been taken off by a Wi-Fi blade or push roller and then stored in a tub on board or directly drained into a barge or shoreline storage facility. Steel, brass, cloth and plastics, such as polyvinyl chlorides and polypropylene, are the oleophilic surface itself.

Table 2.1: Recovery rate based on oil type (Muizis, 2013)

Skimmer type	Recovery Rate (M3/hr) for given oil type				Percentage of oil
	Diesel	Light crude	Heavy crude	Bunker C	
Oleophilic skimmer					
Small disc	0.4 to 1	0.2 to 2			80 to 95
Large disc		10 to 20	10 to 50		80 to 95
Brush	0.2 to 0.8	0.5 to 20	0.5 to 2	0.5 to 2	80 to 95
Large drum		10 to 30			80 to 95
Small drum	0.5 to 5	0.5 to 5			80 to 95
Large belt	1 to 5	1 to 20	3 to 20	3 to 10	80 to 95
Inverted belt		10 to 30			75 to 95
Rope		2 to 20	2 to 10		85 to 95
Weir skimmer					
Small weir	0.2 to 10	0.5 to 5	2 to 20		20 to 80
Large weir		30 to 100	5 to 10	3 to 5	50 to 90
Advancing weir	1 to 10	5 to 30	5 to 25		30 to 70
Elevating skimmer					
Paddle conveyor		1 to 10	1 to 20	1 to 5	10 to 40
Submersion skimmer					
Large	0.5 to 1	1 to 80	1 to 20		70 to 95
Suction skimmer					

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Small	0.3 to 1	0.3 to 2			3 to 10
Large trawl unit		2 to 40			20 to 90
Large vacuum unit		3 to 20	3 to 10		10 to 80
Vortex centrifugal skimmer					
Centrifugal unit	0.2 to 0.8	0.2 to 10			2 to 20

In addition to the amount of oil extracted, oil-filled skimmers catch very little water, offering a high recovery from oil to water. Therefore, they work with relatively thin slicks of oil successfully. They are less vulnerable than conventional skimmers to ice. The skimmers are produced in several sizes and operate best in unrefined petroleum but are suited to various kinds of oil with design and shape.

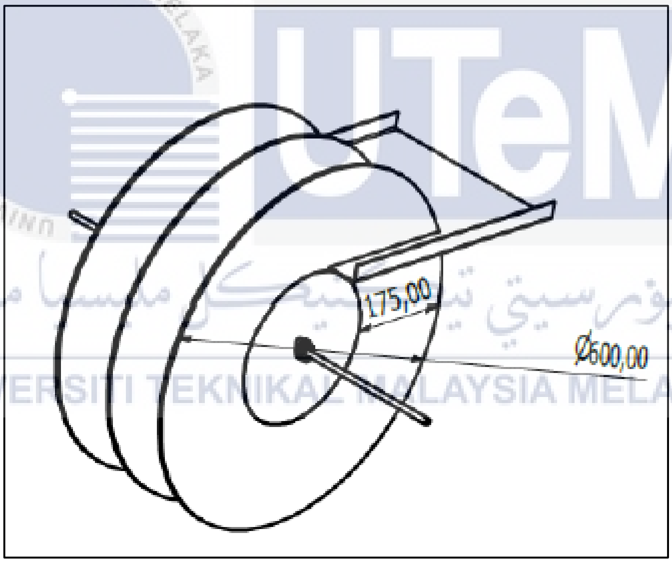

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Figure 2.7: Rotary disc type skimmer (Supriyono & Nurrohman, 2020)

The disc skimmer is an oleophilic surface device widely used. The device of oil skimmer consists of a revolving disc for oil on the water's surface and two propellers for pushing the olive oil skimmer. DC motor powers the spinning disc and propeller, which are attached to the engine driver and to the controller Arduino Super. An oil stick is also fitted with a joystick, which controls the movement of the oil sticker by changing the rotary disc rotating speed. The oil skimmer will take and separate oil at a speed of 18 rpm on the water surface at a separation speed of 620.28 ml/min, as a result of the tests (Supriyono & Nurrohman, 2020).

Figure 2.8: Drum type skimmer (Rd, 2017)

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Another form of oleophilic surface skimmer is the drum skimmer. Either a polymer or steel was made of the drums. The drum skimmer operates with raw fuel and light, yet it is inefficient with hard oils. A coat is produced by the oil skimmer to mitigate emissions due to the oil pollution in the ocean. Oil skimmer substance under corrosion often impacts a live aquatic organism, meaning that we create a coating with two different approaches for making water contamination environmentally friendly (Manivel & Sivakumar, 2020).

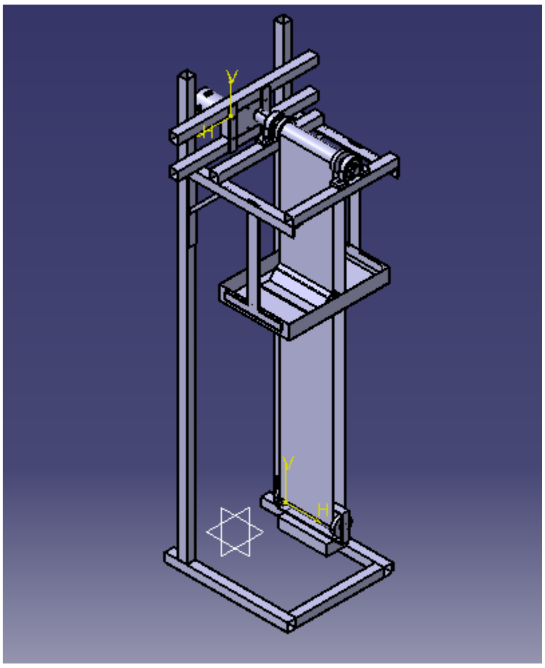

Figure 2.9: CAD diagram for belt type skimmer (Pathare et al., 2015)

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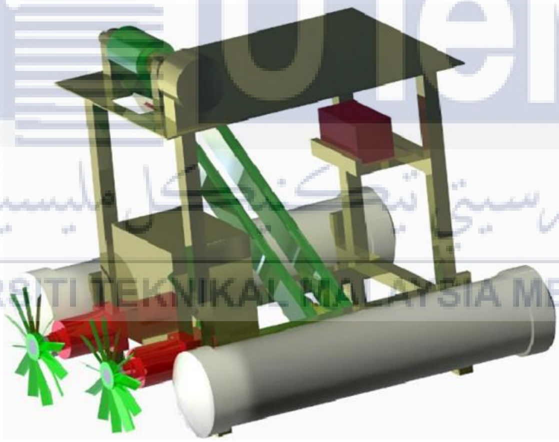

Figure 2.10: Portable oil spill skimmer belt type (Vigneshwaran & Yuvaraj, 2020)

The factories are being used in different types of oil skimmers to distinguish mixed oil from water. The purpose of this project is therefore to plan and perform performance studies with the use of many materials of belt-type oil skimmer. The belts draw the oil out of the water and collect it in a vessel by arranging piping. For certain uses, the oil obtained may be reused (Pathare et al., 2015). The DC Wiper motor magnetic transport belt is continually allowed to roll over the top of the water by using a rectangular magnet shape stitched between the nylon belts. The robot is driven on the surface of the water through the

DC Wiper engine propellers. The oil is then transferred and extracted by a metal plate scrubber on the rear of the robot in the tank. Once the oil is topped up at a given stage in the tank, the float switch is used to sensor and energise the relay, and the DC wiper for the conveyor is switched off. The robot's steady input is given by the sensor (Vigneshwaran & Yuvaraj, 2020).

Figure 2.11: Weir type skimmer (Muizis, 2013)

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The basic weir forms the original feature in a wide variety of oil spill recovery systems and, as such, monitors the oil content of the blend which must be stored or moved to a secondary processing point. A broad variety of test details has been gathered over the years, documenting different facets of the performance of commercially available oil skimmers. It is understood from these, that both the smooth thickness of the oil and the wear flow rate influence the resultant oil concentration considerably (Topham, 2002). Weather skimmers are installed offshore, typically converting the top surface of water and oil into a calm environment. This will boost the potential of the weir skimmer to very high seas. Weir skimmers don't operate well in ices and debris or in raw waters and for heavy oil or tar balls they are not reliable.

Figure 2.12: Floated brush type skimmer (Muizis, 2013)

A brush skimmer is constructed of rigid oleophilic fibre banks that are connected to a revolving conveyor. These brushstrokes run through a pebble to extract fastened oil again, so it can be pumped (Wadsworth, 2015). Usually, wedge-formed scrapers strip the oil from the brosses. Brush skimmers are especially suitable for heavier oil recovery, but they are inefficient for light crudes and fuels. Some skimmers include a light fuels drum and a heavier oils brush. They may also be used for small concentrations of debris or salt.

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2.3.2 Material of the Skimmer

Material selection to produce the skimmer must be oil absorbents, so it can separate the oil from the water without any interrupt. High oil absorption absorbent potential is usually related to substrate porosity, which is why highly porous materials are regularly used in oil absorption (Acevedo et al., 2017). The material for each type of skimmer is different and depends on the suitability on the skimmer.

Usually, the material used to absorb the oil is polymer. At present, the most common polypropylene oil-absorption felt in this field is due to the relatively low volume costs, but its selective capacity to absorb oil is very limited (Song et al., 2015). The most widely absorbent for oil spill is the polymeric absorbents including polyurethane, polypropylene, polyethylene and linked polymers. These polymers are commonly used for the absorption of organic compounds due to their high porosity, absorption potential and hydrophobicity. Innovations have now been imperative in this region (Acevedo et al., 2017). This material usually used at drum type skimmer because the drum will rotate and collect the oil into the tank. However, the usage of polypropylene on the ice surface are ineffective due to the chemical properties of polypropylene cannot absorb the temperature of oil is too low (Øksenvåg et al., 2019).

For drum type skimmer, Teflon plates are used for sticking an oil and sticking water to fill the drum. The oil is easy to extract from the tank and the oil is easy and fast to remove. The Teflon coating is super hydrophobic and translucent, spraying nanoparticles with alcohol suspensions to make the water repel and oil adhere gradually deposited onto parchment. Super hydrophobicity depends on the aggregation state of the oh group mixed nanoparticles, which are determined by charcoal form suspended on the ethanol and NaCl. This sheet is low in cost and can perform better in absorbing the oil (Manivel & Sivakumar, 2020).

Figure 2.13: Activated carbon mixed with water (Manivel & Sivakumar, 2020)

Carbon products, including activated carbon, catalysis and others, are commonly used in many applications and activated carbon is a popular material for industrial applications, which involves easily oil absorption, purging and catalytic phase, among others. For many decades, activated carbon has been expanding its use in air and water treatment systems as renewable adsorbents to agricultural waste and traffic emissions. This material is prepared according to the source and state of the preparation (Manivel & Sivakumar, 2020).

Table 2.2: Thickness of oil film on skimmer (Manivel & Sivakumar, 2020)

Recovery rate (ml/min)	Drum speed (RPM)	Thickness (mm)
450 (Activated charcoal)	60	1
400 (Teflon)	60	1

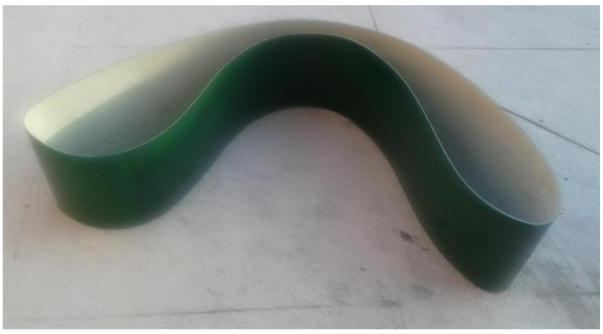

Figure 2.14: Polymer belt skimmer (Pathare et al., 2015)

For the belt type skimmer, it consists of a polymer. It's a never-ending 154 mm wide kind. The substance is thus chosen to stick oil to the curtains. It is mounted on a pulley of aluminium. The open strip is 1800 mm long. The liquid is up to 100 mm immersed. The material on the belt has good oil removal rates and up to 180 F is resistant so that we have chosen a belt of polyurethane. Lower pulley with a dead weight provides friction to the belt (Pathare et al., 2015).

2.4 Maneuverability System

Many automated vehicles, such as search and rescue, spill collection, control of, net positioning, development of bathymetric maps, transport, exploratory activities, environmental surveillance, underwater surveys etc. are being established and used today to perform ocean surveys (P. Wang et al., 2020). Maneuverability system is a system which the control the movement of an object. In portable oil spill skimmer, the maneuverability must be perfect to control the movement of the skimmer. Usually, the water transportation use propeller that attached to the motor to make a movement for the oil skimmer (Eskandarian & Liu, 2019). An electrical motor and propeller has a limited optimum operating point. This means that the motor cannot operate optimally for multiple forces and therefore varying torques and revolutions (Gorter, 2015).

2.4.1 Number of Motor Used

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The number of motor and propeller is depend on the suitability of the oil skimmer. According to (Manivel & Sivakumar, 2020), (Supriyono & Nurrohman, 2020) and (Vigneshwaran & Yuvaraj, 2020), this articles stated that the motor used is more than two motor. Referring from theses article, the reason of using two motor is to support the total weight and able to move the whole oil skimmer. With two motors, the total torque from the motor will move the whole oil skimmer forward and backward easily. The goal is to increase the energy efficiency of electric vehicles with two new dual motor input powertrains (Wu et al., 2018)

According to (Munde & Wagh, 2018), there were three motor that attached on the oil spill skimmer. But only one motor that used to control the movement of the oil spill skimmer machine forward and backward. The function of other motors are to move the conveyor belt to collect the oil into the collector tank. So that, the skimmer still can move by using only one motor to control the movement of the oil spill skimmer.

2.4.2 Power Supply

Most of the portable oil skimmer are using 12V battery to supply the power said (Manivel & Sivakumar, 2020), (Supriyono & Nurrohman, 2020) and (Vigneshwaran & Yuvaraj, 2020). This is the simplest method to supply the power for portable oil spill skimmer. One time, the battery will lack of energy and power. So the operator need to change the new battery at the main vessel. However, according to (Munde & Wagh, 2018), they stated that the battery can be charge by install the solar system. So that the battery can be fully charge without going back to the main vessel. But the solar system is complex because need to attach with DC generator to convert the light energy to electrical energy.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the details explanation of methodology that is used to complete this project well and successful. Figure 3.1 shows the flowchart of process planning. The flowchart and related inspection lists have been created to enhance the documentation, as well as to explain acceptable practises, and standardise study reporting (Brand et al., 2020). The selection of design, manufacturing process and analysis that be carried out based on the complete hull fabrication. The method is used to achieve the objective of the project. For design selection, the method used is screening and scoring about the sketching of design. Same goes with selection of motor. There are a few element need to be consider in making the selection.

The reference from the journal also is one of the method in selecting the best design and motor. From the journal, related information can be gathered and the data can be analysed. To generate the new ideas, need to identify the problem that faced on the existed model to improve the functions. Brainstorming method is an effective tool to generate a new ideas, solve the problem that already happen and others.

3.2 Flowchart

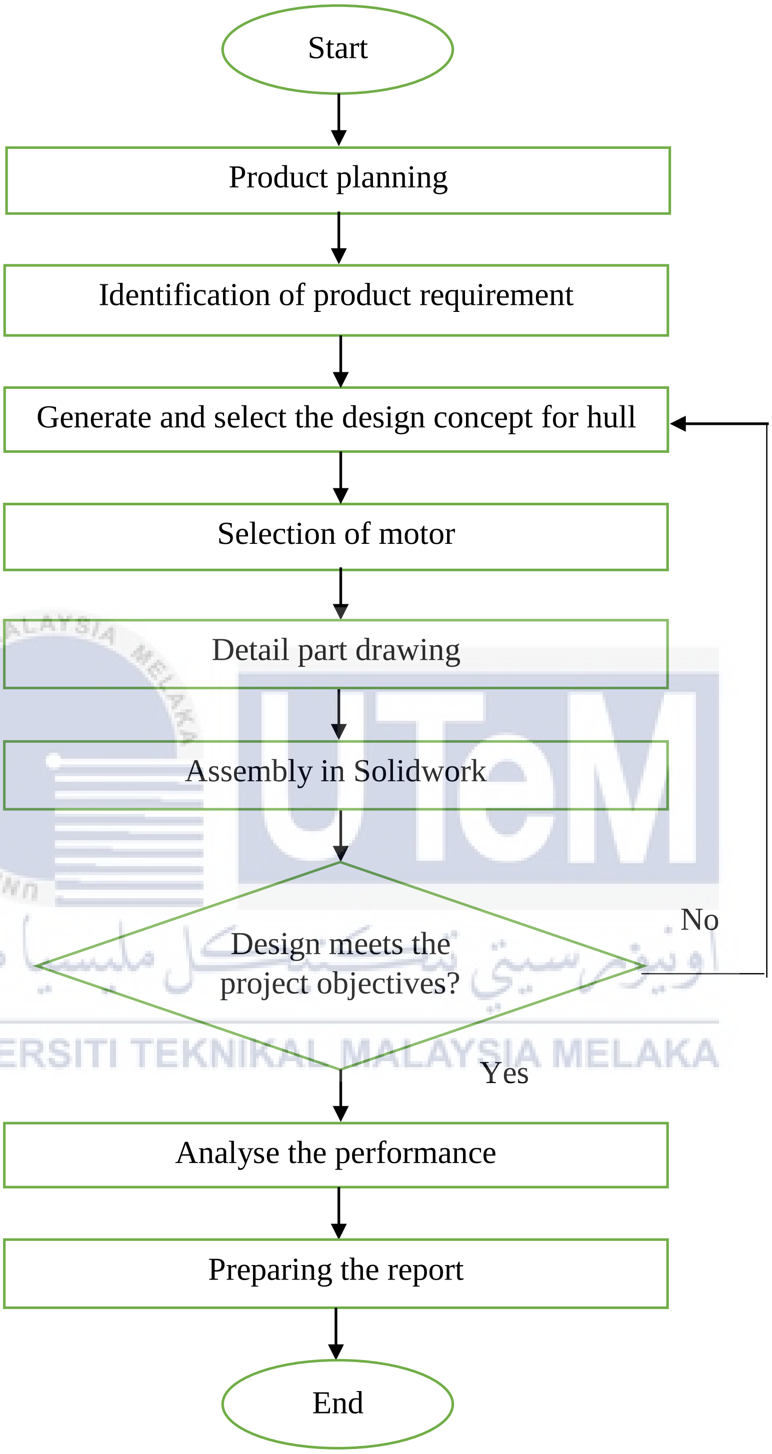

Figure 3.1: Flowchart of process planning

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3.3 Product Planning

The result that obtained from this step is to make a new design for hull part which it can move on the wavy surface of water easily. After that, to reduce the time taken of oil collecting, need to enlarge the size of the skimmer because the dimension of existed skimmer is not big enough to collect the oil in a short period. Lastly, the idea to solve the problem on its linear motion is maintain the number of motor, but by using high specification of motor. The motor will located at the frame part. So that the linear motion of this oil skimmer will move in straight line.

3.4 Identification of the Requirement

The requirement needed is very important in making the improvement of the product. It aims to ensure the new product have an improvement and better than the reference. The requirement needs to consider the objective of this project. Tables below shows the requirement needed for redesign the hull part and selection of motor.

Table 3.1: Requirement need for hull part

Element	Explanation
Stability on water	To ensure the whole product is stable
Buoyancy	Can exert high load
Complexity	To ease the fabrication work
Speed	Can move with high speed even on wavy water

Table 3.2: Requirement need for motor

Elements	Explanation
Torque	High torque to able the motor move the whole weight
Speed	High speed to move the product faster
Power	Optimum voltage to give enough power to the system
Weight	Need a lightweight motor to avoid overload

3.5 Generate the Design Concept

Catamaran hull contain 2 part of hull. The figures below shows the sketching of the one side of hull part. Figure 3.2 is the cylindrical shape of hull, figure 3.3 is the round-bottom hull, figure 3.4 is V-shaped hull, figure 3.5 is the U-shaped hull and figure 3.6 is the flat-bottom hull.

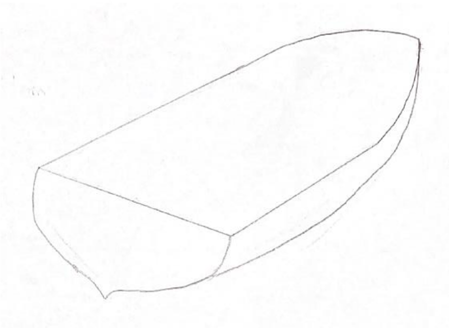

Figure 3.2: Design concept 1

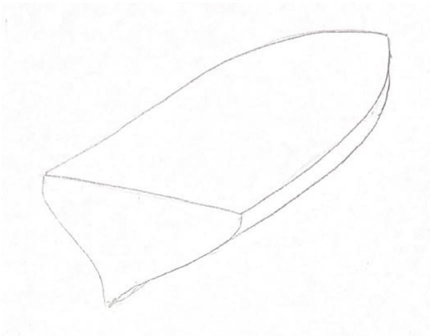

Figure 3.3: Design concept 2

Figure 3.4: Design concept 3

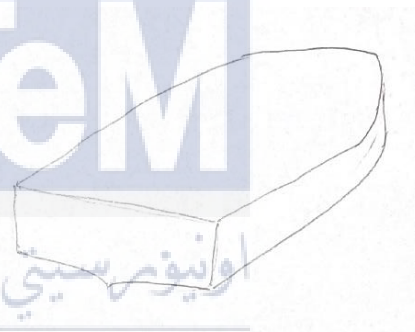

Figure 3.5: Design concept 4

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3.6 Concept Selection

The Analytic Hierarchy Process (AHP) method is a Pugh method which is numerically weighted and analyses the relatively few concepts more extensively so as to decide the only concept which leads to product success.

3.6.1 Selection of Hull Design

Design of hull have been explained at chapter 2. From the research, the design of hull selected is catamaran. Catamaran is a combination of two hull. The design of each hull must fulfil the requirement needed. The objective of this project is to redesign the hull that can move on the calm and wavy surface of water smoothly. The cylindrical shape of hull have been used as the reference. The element need to be consider are stability on water, buoyancy, complexity and speed.

Figure 3.6: Reference of hull design (Santuso, 2018)

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3.6.2 Selection of Motor

The second objective of this project is to improve and simplify the linear motion stability of oil spill skimmer. Hence, the number of motor and propeller used is reduced to one motor and one propeller. The servo motor will attached at the propeller to make the oil spill skimmer turns left and right. The linear motion of this model will better when using only 1 motor because there are no different efficiency of each motor. Figure and table below shows the specification of motor as reference

Figure 3.7 : Reference motor (Santuso, 2018)

Table 3.3: Specification of reference propeller motor

Torque	0.54 Nm
Speed	75 rpm
Voltage	12 V
Diameter	37 mm

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3.6.2.1 List of Propeller Motor

Table 3.4: List of propeller motor

Motor	Figure
Motor 1	 Figure 3.8: Motor 1 (*T200 Thruster for ROVs, AUVs, and marine robotics* 2021)
Motor 2	 Figure 3.9: Motor 2 (Hgardena.com, 2021)
Motor 3	 Figure 3.10: Motor 3 (*400HFS-L Hi-Flow Thruster. Product Guide and Warranty* 2021)
Motor 4	 Figure 3.11: Motor 4 (Mapongram, 2021)

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3.7 Analytic Hierarchy Process (AHP)

Determine the best design concept in conceptual design stage is an important decision (Ariff et al., 2012). AHP is a method which used select the best conceptual design by considering all the criteria needed and the weightage of each criteria. In this project, AHP is used for selection method for hull design and propeller motor. Below shows the step of generating the AHP method.

Step 1 – Identify the problem

- List all the conceptual design and all criteria needed

Step 2 – Generate the hierarchy framework

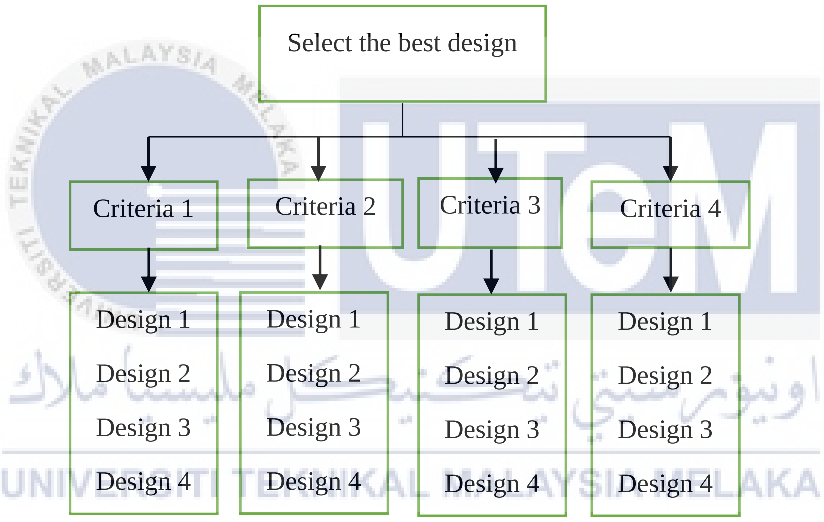

Figure 3.12: Hierarchy framework

Step 3 – Construct pairwise matrix

Table 3.5: Pairwise comparison matrix

Criteria 1	Design 1	Design 2	Design 3	Design 4
Design 1	a_1	a_2	a_3	a_4
Design 2	b_1	b_2	b_3	b_4
Design 3	c_1	c_2	c_3	c_4
Design 4	d_1	d_2	d_3	d_4
Total	$a_1+b_1+c_1+d_1=e_1$	$a_2+b_2+c_2+d_2=e_2$	$a_3+b_3+c_3+d_3=e_3$	$a_4+b_4+c_4+d_4=e_4$

Step 4 – Divide element by the column total

Table 3.6: Synthesizing judgements

Criteria 1	Design 1	Design 2	Design 3	Design 4
Design 1	a_1/e_1	a_2/e_2	a_3/e_3	a_4/e_4
Design 2	b_1/e_1	b_2/e_2	b_3/e_3	b_4/e_4
Design 3	c_1/e_1	c_2/e_2	c_3/e_3	c_4/e_4
Design 4	d_1/e_1	d_2/e_2	d_3/e_3	d_4/e_4
Total	1	1	1	1

Step 5 – Average of the row

- Calculate the average of the row

Step 6 – Repeat step 3-5 for other criteria

- By using step 3-5, calculate for the other criteria. Also use to calculate the weightage of each criteria

Step 7 – Overall design priority

- Calculate the overall design priority. The ranking of the design is identified by the total mark given for each design.

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3.8 Designing the Hull Part

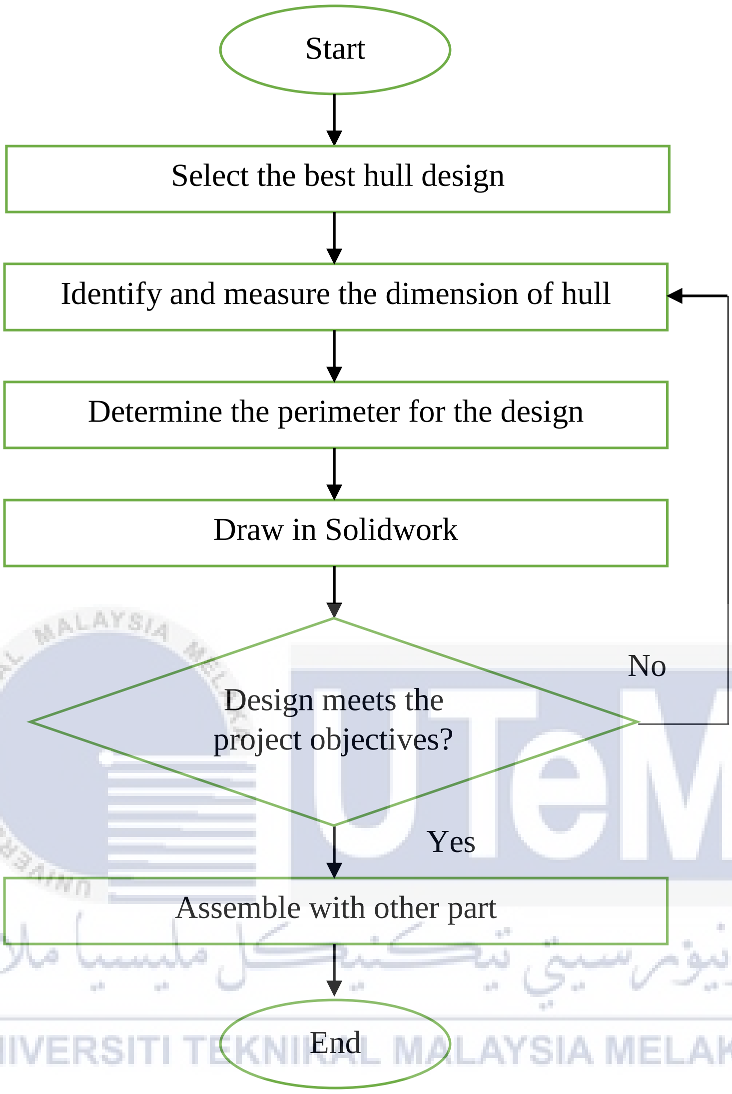

Figure 3.13: Flowchart of designing the hull

3.9 Final Conceptual Design

The figure below show the final conceptual design after finish the concept selection. The design of hull used is catamaran with round-bottom hull and using 2 propeller motor Hi Flow Thruster 400HFS-L.

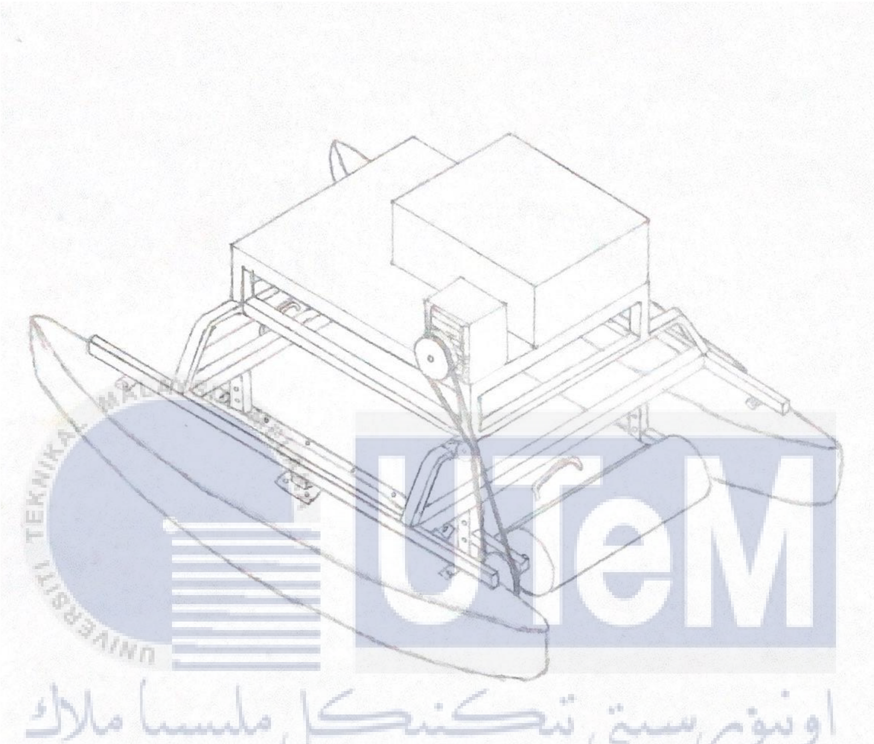

Figure 3.14: Final conceptual design

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3.10 Analysis

3.10.1 Buoyant Force Analysis

Buoyancy is the ability to raise or float a fluid. Buoyant force, F is the upward force on fluid-immersed objects.

The formula of buoyant force:

$$F = \rho V g = mg$$

Where;

ρ = density

V = volume

m = mass of the displaced fluid

g = acceleration due to gravity ($9.81\ m \cdot s^{-2}$).

3.10.2 Rate of Oil Collection Analysis

Rate of oil collection is how much volume of the oil collected by the oil skimmer in a certain time.

Rate of oil collection formula:

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$$V = T \times D \times A \times d \times N$$

V = volume rate

T = thickness of oil film in mm

A = circumferential area of skimmer

W = width of the roller

D = diameter of roller drum

N = speed of rotation shaft (rpm)

3.10.3 Maximum Oil Occupied Analysis

Maximum oil occupied is defined as how much the maximum volume of the oil can be occupied into the tank without sink. The safety factor is consider during generating this analysis to ensure it still float on the water.

The formula to calculate the maximum oil occupied in the tank is:

$$s.f = \frac{M}{M_{max}}$$

s.f = safety factor

M = mass allowed for oil

M_{max} = maximum mass of oil can be occupied

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CHAPTER 4

RESULT AND DISCUSSION

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4.1 Introduction

This chapter will discuss about the result obtained from this project. The results are essentially the outcome of the field test for the critical functions of the project. The results of the test are analysed for the impact on these initiatives and the outcomes are discussed.

4.2 Selection of Hull Design

The list of hull design are shown in subchapter 3.5. Figure 3.2 is the round-bottom hull, Figure 3.3 is V-shaped hull, Figure 3.4 is the U-shaped hull and Figure 3.5 is the flat-bottom hull.

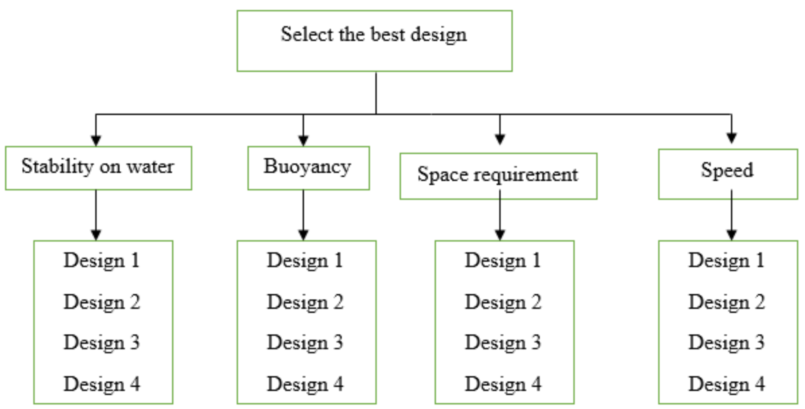

Figure 4.1: Hierarchy of decision for hull design

Table 4.1: Pairwise matrix (Stability on water)

Stability on water	Design 1	Design 2	Design 3	Design 4
Design 1	1	4	8	1/2
Design 2	1/4	1	3	2
Design 3	1/8	1/3	1	1/4
Design 4	2	1/2	4	1
Total	3.375	5.833	16	3.75

Table 4.2: Synthesizing judgements (Stability on water)

Stability on water	Design 1	Design 2	Design 3	Design 4
Design 1	0.2963	0.6858	0.5	0.1333
Design 2	0.0741	0.1714	0.1875	0.5333
Design 3	0.0370	0.0571	0.0625	0.0667
Design 4	0.5926	0.0857	0.25	0.2667
Total	1	1	1	1

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Priority vector:

- Design 1 : 0.4039
- Design 2 : 0.2416
- Design 3 : 0.0558
- Design 4 : 0.2988

Table 4.3: Pairwise matrix (Buoyancy)

Buoyancy	Design 1	Design 2	Design 3	Design 4
Design 1	1	8	1/4	1/2
Design 2	1/8	1	1/3	1/2
Design 3	4	3	1	2
Design 4	2	4	1/2	1
Total	7.125	16	2.083	3.75

Table 4.4: Synthesizing judgements (Buoyancy)

Buoyancy	Design 1	Design 2	Design 3	Design 4
Design 1	0.1404	0.5	0.12	0.1333
Design 2	0.0175	0.0625	0.16	0.0667
Design 3	0.5614	0.1875	0.48	0.5333
Design 4	0.2807	0.25	0.24	0.2667
Total	1	1	1	1

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Priority vector:

- Design 1 : 0.2234
- Design 2 : 0.0767
- Design 3 : 0.4406
- Design 4 : 0.2594

Table 4.5: Pairwise matrix (Complexity)

Space requirement	Design 1	Design 2	Design 3	Design 4
Design 1	1	7	8	5
Design 2	1/7	1	6	3
Design 3	1/8	1/6	1	1/2
Design 4	1/5	1/3	2	1
Total	1.468	8.5	17	9.5

Table 4.6: Synthesizing judgements (Complexity)

Space requirement	Design 1	Design 2	Design 3	Design 4
Design 1	0.6811	0.8235	0.4705	0.5263
Design 2	0.0973	0.1176	0.3529	0.3158
Design 3	0.0851	0.0196	0.0588	0.0526
Design 4	0.1362	0.0392	0.1176	0.1053
Total	1	1	1	1

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Priority vector:

- Design 1 : 0.6253
- Design 2 : 0.2209
- Design 3 : 0.0540
- Design 4 : 0.0996

Table 4.7: Pairwise matrix (Speed)

Speed	Design 1	Design 2	Design 3	Design 4
Design 1	1	4	1/2	5
Design 2	1/4	1	1/3	3
Design 3	2	3	1	4
Design 4	1/5	1/3	1/4	1
Total	3.45	8.333	2.0833	13

Table 4.8: Synthesizing judgements (Speed)

Speed	Design 1	Design 2	Design 3	Design 4
Design 1	0.2899	0.48	0.24	0.3846
Design 2	0.0725	0.12	0.16	0.2308
Design 3	0.5797	0.36	0.48	0.3077
Design 4	0.0579	0.04	0.12	0.0769
Total	1	1	1	1

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Priority vector:

- Design 1 : 0.3486
- Design 2 : 0.1458
- Design 3 : 0.4319
- Design 4 : 0.0737

Table 4.9: Pairwise matrix (Criteria)

Criteria	Stability on water	Buoyancy	Space requirement	Speed
Stability on water	1	5	8	7
Buoyancy	1/5	1	7	4
Space requirement	1/8	1/7	1	2
Speed	1/7	1/4	1/2	1
Total	1.4679	6.3929	16.5	14

Table 4.10: Synthesizing judgements (Criteria)

Criteria	Stability on water	Buoyancy	Space requirement	Speed
Stability on water	0.6812	0.7821	0.4848	0.5
Buoyancy	0.1362	0.1564	0.4242	0.2857
Space requirement	0.0852	0.0223	0.0606	0.1429
Speed	0.0973	0.0391	0.0303	0.0714
Total	1	1	1	1

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Priority vector for each criteria of hull:

- Stability on water : 0.612
- Buoyancy : 0.2506
- Space requirement : 0.0778
- Speed : 0.0595

Table 4.11: Developing an overall priority ranking (Hull design)

Criteria	Stability on water	Buoyancy	Complexity	Speed
Design 1	0.4039	0.2234	0.6253	0.3486
Design 2	0.2416	0.0767	0.2209	0.1458
Design 3	0.0558	0.4406	0.054	0.4319
Design 4	0.2988	0.2594	0.0996	0.0737

Table 4.12: Final AHP ranking of alternative (Hull design)

Design	Score	Ranking
Design 1	0.3726	1
Design 2	0.1929	3
Design 3	0.1745	4
Design 4	0.26	2
Total	1	

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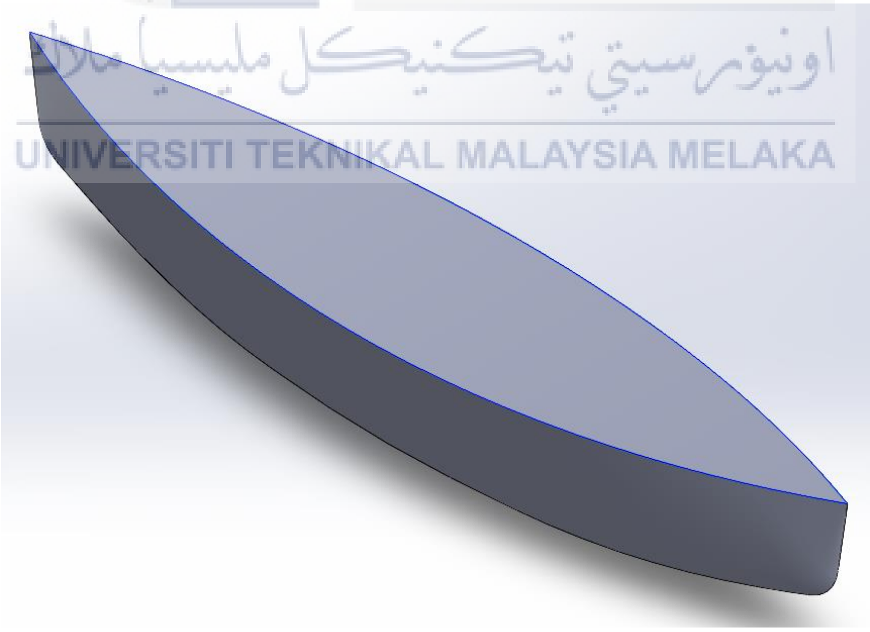

Figure 4.2: Improved drawing of selected design

From the data above, the best design for hull is Design 1. Figure 4.2 shows the hull design that have been improved from the sketching. During selecting the design, all criteria were considered. The most critical criteria must be consider is stability on water. The stability is very important for an object that floating on water. It is because to ensure the oil spill skimmer will not upside down when operate.

4.3 Selection of Propeller Motor

By referring in subchapter 3.6.2.1, table 3.4 represent the list of propeller motor that randomly choosen to be select through AHP method. Motor 1 is T200 Thruster, Motor 2 is TFL B54253-A Water Jet Thruster, Motor 3 is 400HFS-L Hi Flow Thruster and Motor 4 is MSQ 100mm Water Jet Thruster. Motor 1 and Motor 3 work with the propeller inside the motor, while Motor 2 and Motor 4 are using water jet thruster.

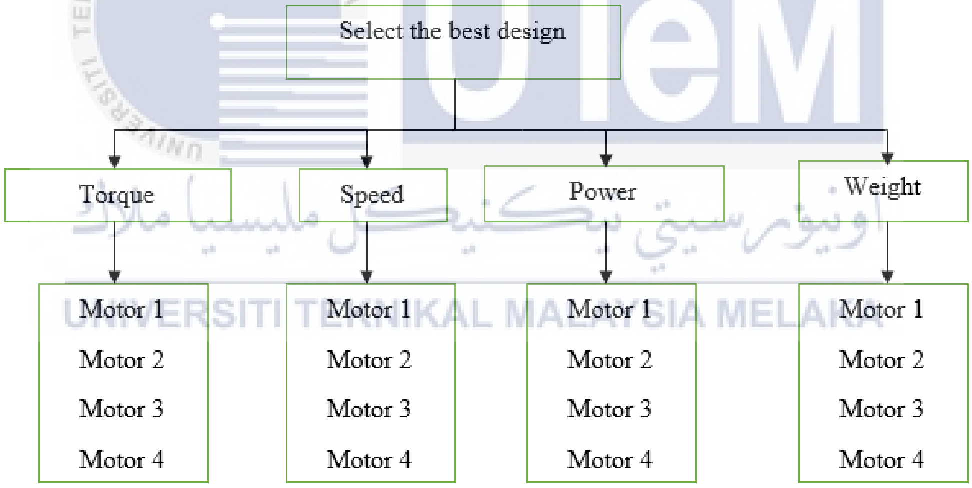

Figure 4.3: Hierarchy of decision for propeller motor

Table 4.13: Pairwise matrix (Torque)

Torque	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	1	3	5	1/3
Motor 2	1/3	1	3	1/3
Motor 3	1/5	1/3	1	1/5
Motor 4	3	3	5	1
Total	4.5333	7.3333	14	1.8667

Table 4.14: Synthesizing judgements (Torque)

Torque	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	0.2206	0.4091	0.3571	0.1786
Motor 2	0.0735	0.1364	0.2143	0.1786
Motor 3	0.0441	0.0455	0.0714	0.1071
Motor 4	0.6618	0.4091	0.3571	0.5357
Total	1	1	1	1

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Priority vector:

- Motor 1 : 0.2914
- Motor 2 : 0.1507
- Motor 3 : 0.0670
- Motor 4 : 0.4909

Table 4.15: Pairwise matrix (Speed)

Speed	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	1	5	1/3	3
Motor 2	1/5	1	1/5	3
Motor 3	3	5	1	5
Motor 4	1/5	1/3	1/5	1
Total	4.5333	11.3333	1.7333	12

Table 4.16: Synthesizing judgements (Speed)

Speed	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	0.2206	0.4412	0.1923	0.25
Motor 2	0.0441	0.0882	0.1154	0.25
Motor 3	0.6618	0.4412	0.5769	0.4167
Motor 4	0.0735	0.0294	0.1154	0.0833
Total	1	1	1	1

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Priority vector:

- Motor 1 : 0.2760
- Motor 2 : 0.1244
- Motor 3 : 0.5242
- Motor 4 : 0.0754

Table 4.17: Pairwise matrix (Power)

Power	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	1	1/5	3	3
Motor 2	5	1	3	5
Motor 3	1/3	1/3	1	1/5
Motor 4	1/3	1/5	5	1
Total	6.6667	1.7333	12	9.2

Table 4.18: Synthesizing judgements (Power)

Power	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	0.1499	0.1154	0.25	0.3261
Motor 2	0.7499	0.5769	0.25	0.5435
Motor 3	0.0499	0.1923	0.0833	0.0217
Motor 4	0.0499	0.1154	0.3333	0.1087
Total	1	1	1	1

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Priority vector:

- Motor 1 : 0.2104
- Motor 2 : 0.5301
- Motor 3 : 0.0868
- Motor 4 : 0.1518

Table 4.19: Pairwise matrix (Weight)

Weight	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	1	1/5	3	3
Motor 2	5	1	1/5	1/3
Motor 3	1/3	5	1	3
Motor 4	1/3	3	1/3	1
Total	6.6667	9.2	4.5333	7.3333

Table 4.20: Synthesizing judgements (Weight)

Weight	Motor 1	Motor 2	Motor 3	Motor 4
Motor 1	0.1499	0.0217	0.6618	0.4091
Motor 2	0.7499	0.1086	0.0441	0.0455
Motor 3	0.0499	0.5435	0.2206	0.4091
Motor 4	0.0499	0.3261	0.0735	0.1364
Total	1	1	1	1

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Priority vector:

- Motor 1 : 0.3106
- Motor 2 : 0.2370
- Motor 3 : 0.3058
- Motor 4 : 0.1464

Table 4.21: Pairwise matrix (Criteria)

Criteria	Torque	Speed	Power	Weight
Torque	1	1/7	1/5	1/3
Speed	7	1	5	1/5
Power	5	1/5	1	3
Weight	3	5	1/3	1
Total	16	6.3429	6.5333	4.5333

Table 4.22: Synthesizing judgements (Criteria)

Criteria	Torque	Speed	Power	Weight
Torque	0.0625	0.0225	0.0306	0.0735
Speed	0.4375	0.1577	0.7653	0.0441
Power	0.3125	0.0315	0.1513	0.6618
Weight	0.1875	0.7883	0.0510	0.2206
Total	1	1	1	1

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Priority vector for each criteria of propeller motor:

- Torque : 0.0473
- Speed : 0.3512
- Power : 0.2897
- Weight : 0.3119

Table 4.23: Developing an overall priority ranking (Propeller motor)

Criteria	Torque	Speed	Power	Weight
Motor 1	0.2914	0.2760	0.2104	0.3106
Motor 2	0.1507	0.1244	0.5301	0.2370
Motor 3	0.0670	0.5242	0.0868	0.3058
Motor 4	0.4909	0.0754	0.1518	0.1464

Table 4.24: Final AHP ranking of alternative (Propeller motor)

Motor	Score	Ranking
Motor 1	0.2685	3
Motor 2	0.2783	2
Motor 3	0.3078	1
Motor 4	0.1393	4
Total	0.9939 ≈ 1	

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Figure 4.4: Motor 3 (*400HFS-L Hi-Flow Thruster. Product Guide and Warranty* 2021)

From the data above, the best propeller motor is Motor 3. Figure 4.4 shows the propeller motor that have been selected from AHP ranking. The motor that obtained from the result is 400 HFS-L Thruster motor. The weight of this thruster motor is 185g, the power is 40W to 390W/24V and the torque is $44.43Nm^{-1}$. During selecting the motor, all criteria were considered. The most critical criteria must be consider is speed of motor. The speed of motor is very important to ensure the performance and movement of the oil spill skimmer is at optimum level. If the speed of motor is slow, the oil collecting job will take a long time to finish it.

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4.4 Analysis

4.4.1 Buoyant Force

Buoyant force or also called as buoyancy is the force that applied to an item totally or partially submerged in a fluid. Buoyancy is the consequence of pressure differences on the opposite side of the item that are submerged in static fluid and thus lead to a net increase in force of the object. The force magnitude is related to the difference in pressure. The principle of Archimedes states that buoyancy corresponds to the weight of the fluid, which othermore would occupy the object's volume.

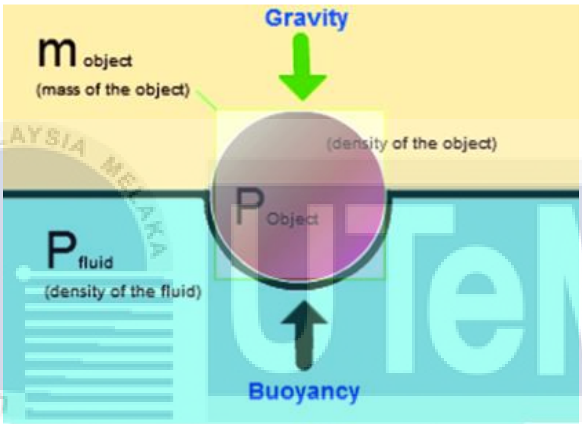

Figure 4.5: Buoyant force (*Buoyant Force* 2020)

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Formula of buoyancy is:

F_b = Vs x ρ x g

Where; V = volume of hull (0.0765m^3)

ρ = density of water (1000 kg/m^3)

g = gravity acceleration (9.81 m/s^{-2})

F_b = buoyant force

Vs = volume of submerge (1/2 of hull)

G = weight of oil spill skimmer

The hull is submerge half of the total height. So,

Vs = 0.03825m^3 submerge (for 1 hull)

Vs for 2 hull = 0.0765m^3

From the information given, the buoyant force can be calculate by using the formula of buoyant force.

F_b = Vs x ρ x g

F_b = 750.465 N

The buoyancy of hull need to compare with the total weight of the portable oil spill skimmer. So that, the total weight need to be identify.

G = mass x g

= 12.28 kg x 9.81 m/s^{-2}

= 120.467 N

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750.465 N > 120.467 N

F_b > G

A hydrostatic principle has been found, which indicates that "a body that is fully or partially dipped in a fluid is pushed upwards equal to the mass of the moving fluid." The volume of the displaced water is the volume of the item immersed in the water when measured. The results of this analysis, the buoyant force is larger than the weight of load. It demonstrate that Portable Oil Spill Skimmer is partially immersed in water so that the necessary activities may be performed.

4.4.2 Maximum Oil Occupied

Maximum oil occupied analysis is identified to know how much the volume can be occupied without cause the portable oil spill skimmer sink in the water. There are a few safety that considered during generate this analysis such as safety factor which it shows just how efficient a system is than for a designed load.

Given:

Buoyant force = 750.465N

Mass of oil spill skimmer = 120.467N

So that, the mass of oil allowed is 629.998N

To ensure the Portable Oil Spill Skimmer did not sink and may support the load, the safety factor of the load was set to 1.5. The formula of safety factor is:

Safety factor, s.f = $\frac{\text{mass}}{\max oil \text{ mass}} = \frac{M}{M_{max}}$

Max oil mass = 419.999 N

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From the formula above, all the data was insert in the formula and the maximum mass of oil is obtained which is 419.999 N. The oil collected by the oil skimmer is diesel which the density of oil is 0.85 kg/L. After converting the mass of oil to the unit of volume, the value obtained is 50.39 Litres.

For the conclusion, the maximum volume of oil occupied in the tank is 50.39 Litres with the safety factor of 1.5. The value of safety factor is enough for the Portable Oil Spill Skimmer to stay floating on the surface of water.

4.4.3 Rate of Oil Collection Analysis

This analysis was conducted to identify the rate of oil collection for Portable Oil Spill Skimmer. Rate of oil collection is the volume of oil tha can be collected by the skimmer in a certain time. In this analysis will shows the rate of oil collected by the skimmer per minute.

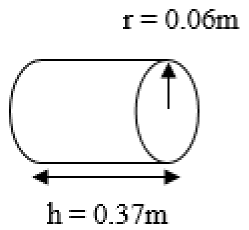

Figure 4.6: Dimension of skimmer

Surface area of skimmer = $2\pi rh$

= $0.1395m^2$

To identify the volume of oil collected per revolution;

Thickness of oil on skimmer = 0.05mm or 0.0005m

Volume of oil per revolution = $0.1395m^2$ x thickness of oil

= $0.00006975m^3$

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By using power window motor with 90 rpm, the rate of oil collection for this skimmer is:

= Volume of oil per revolution x rpm

= $0.006278m^3$ or 6.278 L per minute

From the analysis above, the rate of oil collection is 6.278 L per minute. This is the new data that obtained from the existing oil spill skimmer. So that, the analysis can be used as a guide to user. The rate of oil collection can be improved by increasing the surface area of the skimmer or using higher speed of skimmer motor.

4.5 Final 3D Design of Improved Portable Oil Spill Skimmer

Figure below shows the final 3D design of portable oil spill skimmer. This drawing was assembled by using Solidwork software. All part is attached at the frame and it is strong enough to support all the load. The blue part is hull which act as floating mechanism. The skimmer is attached at the front of frame to collect the oil into the tank. Panel box contain the electrical instrument such as battery and electrical wire. The function of motor cover is to prevent the motor from water splash.

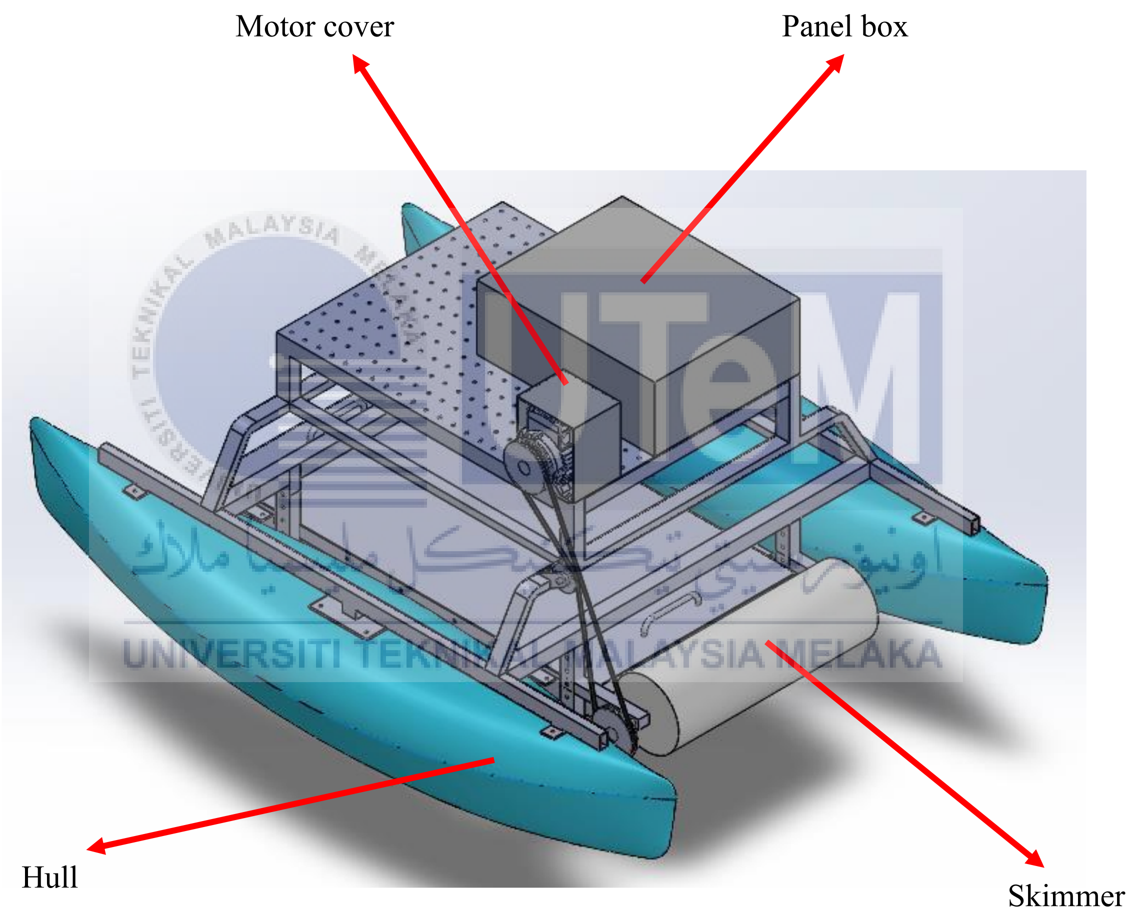

Figure 4.7: Final 3D Design of Improved Portable Oil Spill Skimmer

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter depicts an overall conclusion for the entire project. In addition, some recommendations for further improvement related to this project are presented.

5.1 Conclusion

There are three objectives that had been stated to be achieve at the end of this project. The first objective is to design the new hull part of the portable oil spill skimmer that following the Catamaran hull design. Four conceptual design had been proposed to choose the best design of hull. The selection of hull is using AHP method which selecting by the highest mark given. The round-bottom shaped of catamaran hull is selected because it high of stability on wavy water, high buoyancy, low complexity and can move with high speed.

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To evaluate the selection process of the propeller motor by AHP method, the suitable motor that obtained from the result is 400 HFS-L Thruster motor. The weight of this thruster motor is 185g, the power is 40W to 390W and the torque is 44.43Nm^{-1}. Compared to the other motor, this motor is good at its speed, lightweight, moderate power and moderate torque. This specification are able give the best the performance for the oil spill skimmer.

The changes of the hull design give a huge impact to the buoyancy of oil spill skimmer. From the analysis, the new buoyant force obtained is 750.465N, better than the existing oil spill skimmer which is its buoyant force is 60.822N. The maximum volume of oil can be collected in the tank is 50.39L. This analysis was calculated by considering the safety factor of 1.5 to ensure the portable oil spill skimmer still can float on the water. The new data which is the rate of oil collection also has been obtained from this project. This new portable oil spill skimmer can collect 6.27L per minute. This project has achieve all the objective and requirement based on the result and analysis.

Table 5.1: Result from the objective

OBJECTIVE	**RESULT**
• Design the new hull part	• The hull design selected is catamaran hull • High stability on wavy water, high buoyancy, low complexity
• Selection process of the propeller motor using AHP method	• High speed, lightweight, moderate power and moderate torque
• Analyse the buoyancy force of the hull and rate of oil collection	• Buoyancy for new oil spill skimmer is better than before (750.465N vs 60.822N) • New data for rate of oil collection (6.278L per minute)

5.2 Recommendation

The project has succeeded in meeting the required criteria and goals, however possibilities can be made for further effort. It may be enhanced for the frame material by utilizing lighter materials such as fiberglass. Beside that, the general design and overall size of the Portable Oil Spill Skimmer can also be enlarge for big spilled of oil and occupied more oil at one time. Furthermore, the product that used for cleaning the environment need to be encourage to ensure the environment and surrounding is in clean condition.

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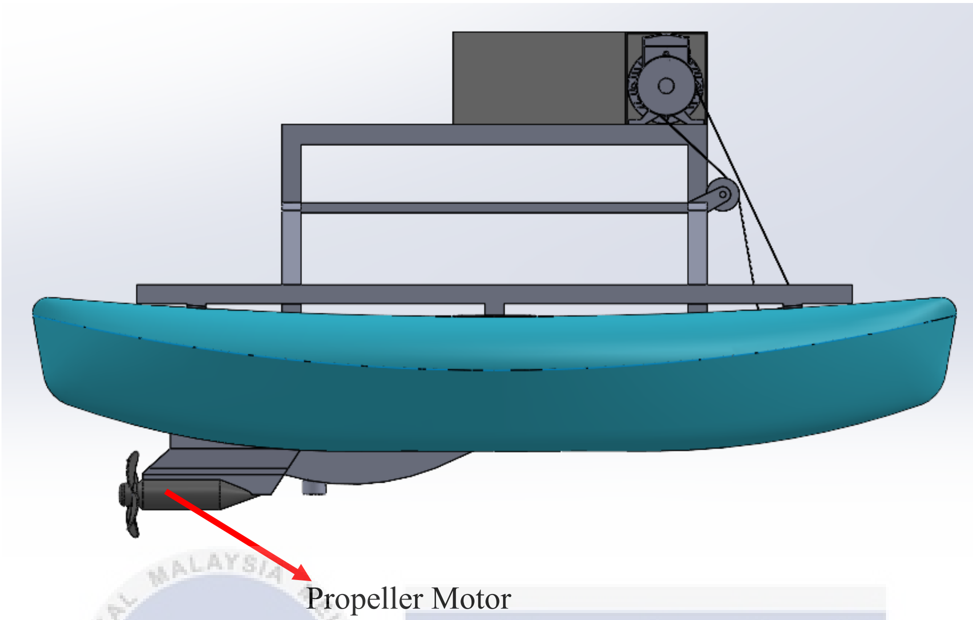
Appendix



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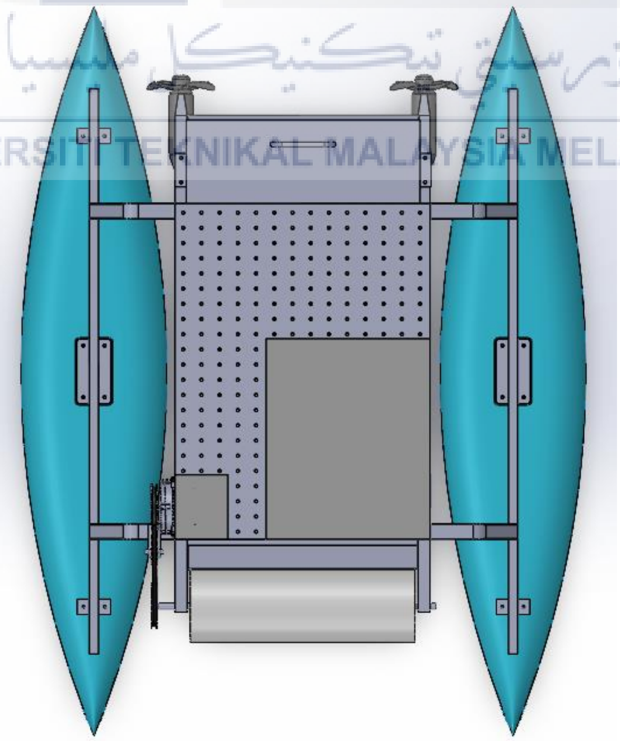

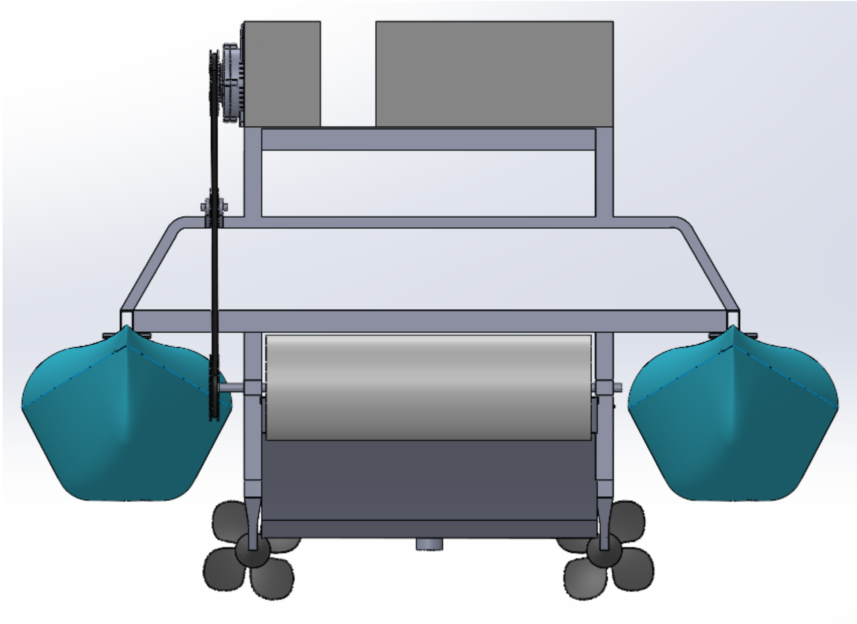

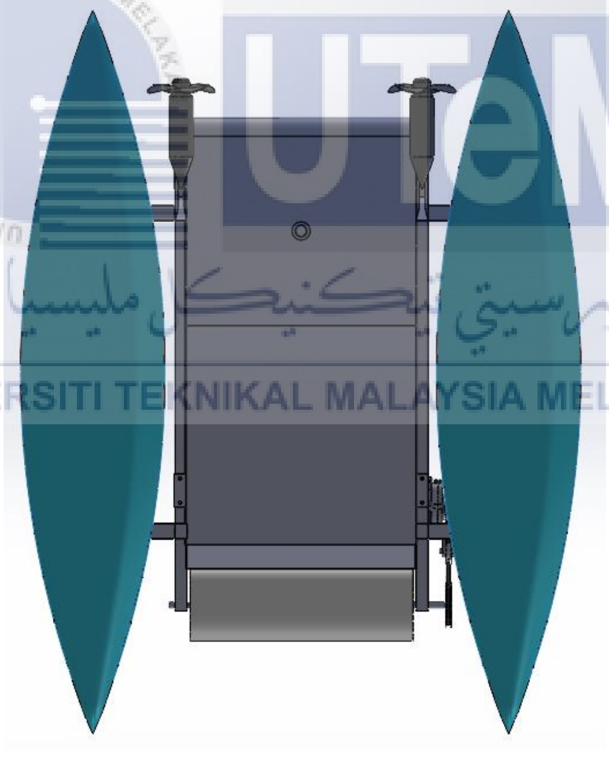

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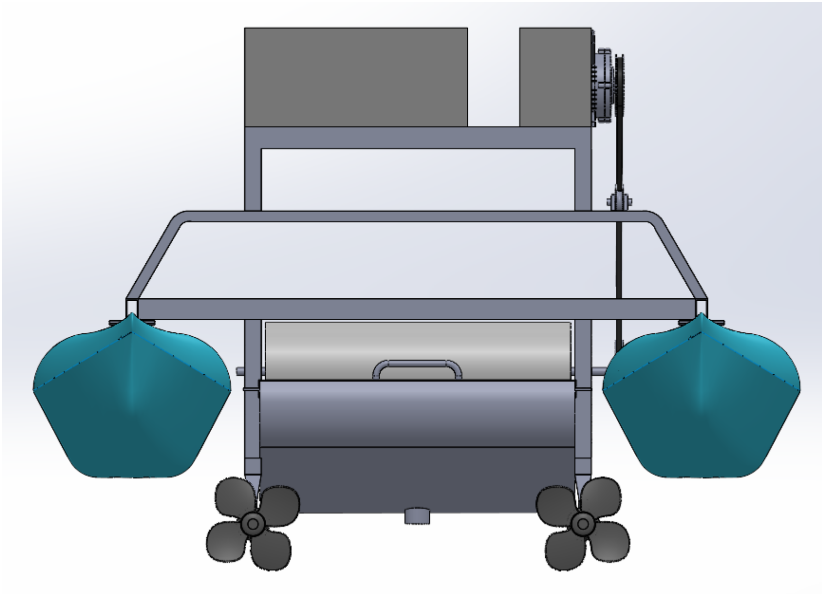

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