UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ENHANCEMENT OF MECHANICAL PERFORMANCE OF PORTABLE OIL SPILL SKIMMER FOR OIL SPILLS RESPONSE AND RECOVERY (OSRR) ACTIVITIES

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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Date : 28 AUGUST 2021

APPROVAL

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

…………………………………………………………

(IR. DR. LOKMAN BIN ABDULLAH)

ABSTRAK

Insiden tumpahan minyak boleh membawa kesan buruk kepada kehidupan manusia dan akuatik serta alam sekitar sekiranya tiada tindakan cekap yang diambil untuk menyelesaikan masalah itu. Antara cara konvensional bagi mengawal tumpahan minyak adalah menggunakan halangan dan bahan penyerap untuk mengambil minyak tumpah secara mekanikal. Sebuah prototaip iaitu "Portable Oil Spill Skimmer" telah dicipta untuk melengkapkan kaedah pengambilan semula tumpahan minyak yang sedia ada tetapi telah menghadapi beberapa masalah pada komponen mekanikal dalam operasi. Projek ini menekankan penambahbaikan "Portable Oil Spill Skimmer" dari segi prestasi mekanikalnya untuk menahan keadaan buruk di laut dengan lebih baik dan kebolehlaksanaan dalam kawasan air terbuka semasa tindak balas tumpahan minyak dan aktiviti pengambilan. Penambahbaikan ini melibatkan pemilihan bahan yang sesuai untuk aplikasi di kawasan yang berbeza seperti laut, sungai dan kawasan yang tertakluk kepada tumpahan minyak. Analisis "Stress-Strain" dan "Computational Fluid Dynamics (CFD)" telah digunakan untuk mengkaji reka bentuk prototaip yang sedia ada dan membuat perubahan untuk mengoptimumkan kawasan bawah model seperti bingkai, badan dan "thruster". Model 3D bingkai, badan dan "thruster" telah dihasilkan dengan menggunakan perisian pemodelan iaitu SOLIDWORKS. Selepas simulasi "Stress-Strain", keputusan menunjukkan bahawa bingkai aluminium yang direka mampu menampung beban komponen-komponen "Portable Oil Spill Skimmer". Selain itu, simulasi CFD telah digunakan untuk mendapatkan kuasa seretan dan tujahan pada badan dan "thruster" untuk membuat keputusan dan justifikasi pada bahagian yang dicadangkan. Kesimpulannya, penambahbaikan yang dicadangkan pada "Portable Oil Spill Skimmer" untuk meningkatkan keteguhan dan kemampuan bergerak dapat membantu dalam ketahanan dan kecekapan sistem semasa operasi pengambilan minyak.

ABSTRACT

Oil spill incidents can bring adverse effects to both human and aquatic life as well as the environment if there is not any efficient action taken to resolve the problem. Conventional ways of controlling the oil spillages which are using barriers and absorbent materials to recover the spilled oil mechanically. An earlier prototype of Portable Oil Spill Skimmer has been developed to compliment the recovery of oil spills of the existing methods but encounters limitations on the mechanical components during operation. This project emphasizes on the enhancement of the Portable Oil Spill Skimmer in terms of its mechanical performance for better seakeeping ability and maneuverability in the open water during oil spill response and recovery activities. The enhancement includes the selection of material suitable for the application in different areas such as sea, river and area subjected to oil spill. Stress-Strain and Computational Fluid Dynamics (CFD) analyses are employed to review the design of the existing prototype and make changes to optimize the underperformed area of the model like the frame, hull and thruster. 3D models of frame, hull and thruster are produced by using solid modelling software like SOLIDWORKS. After performing the stress-strain simulation, the results show that the designed aluminium frame is able to sustain the heavy loading of the various components of Portable Oil Spill Skimmer. Also, the CFD simulations are used to determine the drag and thrust force of the hull and thruster so that the results can be used to make decisions and justifications on the proposed parts. In conclusion, the enhancements proposed onto the Portable Oil Spill Skimmer to improve the robustness and maneuverability could help in the durability and efficiency of the system during oil recovery operations.

DEDICATION

I would like to dedicate this work to my

Beloved parents and siblings

Appreciated friends

Honourable supervisor and lecturers

For giving me moral support, knowledge, time, cooperation and encouragements.

Thank you so much.

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First and foremost, I am very grateful with the help and guide given directly or indirectly from respected parties throughout the completion of my final year project. I would like to express my utmost appreciation to Ir. Dr. Lokman bin Abdullah, my respected supervisor, for his great mentoring, valuable guidance, keen interest and encouragement throughout this project.

In addition, I would like to express my thanks to my friends and family who give unconditional help and support through the period of completing my final year project. Their comments and advice have meant so much and without these motivations, I would have faced many problems during this time of pandemic.

Lastly, I would like to express appreciation to everyone who directly or indirectly contributes to this project and extend my apology to those for not being able to mention each and every one of you.

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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
ASV	-	Autonomous surface vehicle
AUV	-	Autonomous Underwater Vehicle
CAD	-	Computer Aided Design
CFD	-	Computational Fluid Dynamics
CFRP	-	Carbon Fibre Reinforced Polymer
CNC	-	Computer Numerical Control
DC	-	Direct Current
EMF	-	Electromotive Force
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
GFRP	-	Glass Fibre Reinforced Polymer
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
IOT	-	Internet of Things
LENS	-	Laser Engineered Net Shaping
LMD	-	Laser Metal Deposition
OSRR	-	Oil Spill Response and Recovery
PC	-	Polycarbonate
PP	-	Polypropylene
PVC	-	Polyvinylchloride
RANS	-	Reynolds-Averaged Navier-Stokes
RAO	-	Response Amplitude Operator
RBF	-	Radial Basis Function
ROV	-	Remotely Operated Vehicle
SWATH	-	Small Waterplane Area Twin Hull
TIG	-	Tungsten Inert Gas
USV	-	Unmanned Surface Vehicle
3D	-	3-Dimensional

LIST OF SYMBOLS

kg	-	Kilogram
kgf	-	Kilogram-force
%	-	Percent
N	-	Newton
Fr	-	Froude Number
RAO	-	Response Amplitude Operator
°C	-	Degree Celsius
kg/m^3	-	Kilogram per Cubic Meter
kg/mm^3	-	Kilogram per cubic Millimetre
MPa	-	Mega Pascal
Pa	-	Pascal
m	-	Metres
mm	-	Millimetre
rpm	-	Revolution per Minute
m/s	-	Meter per second
s	-	Seconds
W/m°C	-	Watts per Meter Degree Celsius
I_o	-	No-load Current
R_m	-	Winding Resistance
K_v	-	Speed Constant
A	-	Ampere
V	-	Voltage
W	-	Watt

CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to Doerffer (1992), oil refers to all form of petroleum which includes crude oil, sludge, fuel oil, oil refuse and refined products. Appropriate guidelines are vital to make sure that the waste oil is securely kept inside containers and sent over to collection center for disposal (Abdullah et al., 2019). Without proper handling, the oil oftentimes ends up being released into the water sources like rivers and oceans. When the issues of oil spillage are resolved immediately, it will affect the environment and ecosystem around the oil spillages area in a negative way. An action plan for oil spill response is highly critical for maintaining the environment around the field of oil spills. During an emergency situation, the action taken must be sensitive and successful in order to prevent widespread spillage and cause more harm to the creatures around the area of incident. Dave & Ghaly (2011) claimed that the traditional methods of removing oil such as booms, skimmers, in-situ burning, chemical dispersion, etc. have common disadvantages of labour intensive, expensive, and high complexity as well as additional treatment to separate the water from the recovered oil.

As a result of these limitations, Abdullah et al. (2019) has developed a prototype of portable oil spill skimmer to serve as an alternative solution to current method of oil recovery from the water surface. The prototype has a vast area of operation that covers the ocean, seashore, water treatment plants, rivers and reservoirs. The prototype uses a roller-type of skimmer which is oleophilic and hydrophobic to capture oil from the water surface. Based on the results and observations obtained from the study, there are shortcomings in the prototype such as the low robustness of the frame structure when it reaches area of rough water condition, the usage of chain and sprocket which is inefficient in oil skimming system, design of propellers that is not optimized for low and high speed maneuvering and the selection of electric motor and power source. Moreover, it shows that if the machine broke down, capsized or power depleted in the middle of operation, there is not a way to recover it but to abandon which will result in a financially loss and failure of oil recovery operation.

This study is about developing and optimizing the drawbacks on the current portable oil spill skimmer to further enhance in terms of its mechanical functionality. This includes the optimal design of propellers, selection of appropriate electric motors and materials for each application in the enhanced version of portable oil spill skimmer. According to Windyandari et.al (2018), the geometry of the hull shape and the dimension of watercraft have to be taken into consideration when determine the suitable design of propeller in order to maximize the efficiency of the propulsion. Odetti et al. (2019) claimed that a catamaran design for the hull has an advantage of draft reduction while keeping the similar high payload of an autonomous surface vehicle (ASV). Besides, Carlson et al. (2019) also stated that design of catamaran is light in weight and robust and at the same time, increasing the stability to reduce the chance of the ASV to roll over on the water surface. With the ideal combination of the hull, frame structure, electric motor, skimming system and propeller, overall efficiency can be improved, so that the energy is conserved and at the same time, improving endurance over the operation of oil spill response and recovery.

1.2 Problem Statement

Oil spill is a form of water pollution whether it is released from the marine accidents, operations or from the irresponsible dumping into nearby water sources. When the oil is dumped into open or confined body of waters such as seas and rivers, the ecological damage on the ecosystem could be huge and irreversible. Currently, a prototype of mechanical oil skimmer called Portable Oil Spill Skimmer (Abdullah et al., 2019) as shown in Figure 1.1 has been developed specifically for the oil spill response and recovery activities. However, there are a few limitations regarding this prototype that have been observed during the testing. In real world situation, oil recovery activities might take hours to complete, and this will have a great impact on the durability of the frame, electronics and propulsion systems such as the electric motors and power sources. Other than that, the maneuverability and robustness as well as the stability of the oil skimmer are significantly reduced in rough water conditions due to the flaws in the frame, hulls and thrusters. Although the frame and hulls made of PVC pipe material is lightweight, but it is not strong and durable to withstand the force of the water waves and loading of the components as well as the recovered oil. Also, the poorly designed propellers and unsuitable electric motors are not producing sufficient thrust for agile movement. As a result, these flaws lead to water seepage and inefficient propulsion system in the Portable Oil Spill Skimmer and ultimately causing permanent damage or failure of machine.

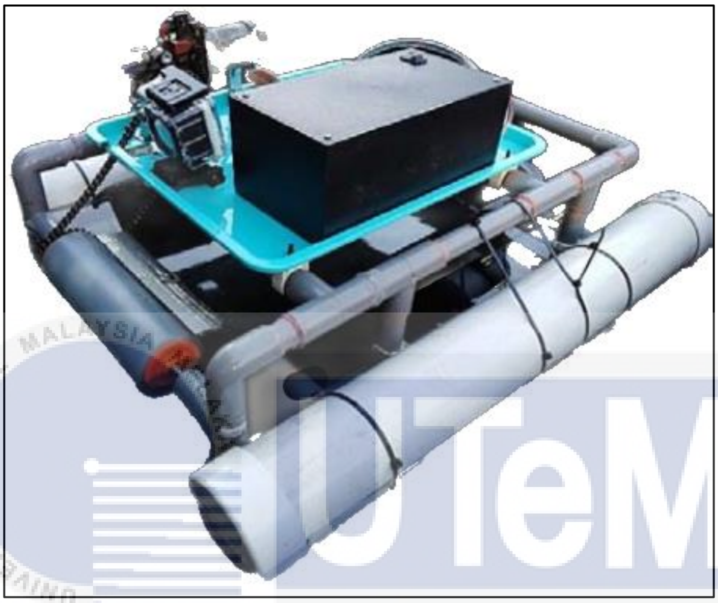

Figure 1.1: Reference model of existing Portable Oil Spill Skimmer (Abdullah et al., 2019)

1.3 Objectives

The objectives of this project are as follows:

a) To conduct finite element analysis (Stress-Strain Analysis, deformation, factor of safety) for the designed Portable Oil Spill Skimmer frame by using ANSYS Mechanical Simulation.

b) To simulate and analyze the Portable Oil Spill Skimmer hull resistance by using ANSYS Fluent CFD analysis.

c) To determine the thrust force produced by thruster by using ANSYS Fluent CFD analysis.

1.4 Scope of Study

The project was carried out to review the current portable oil spill skimmer and make amends primarily focusing on the mechanical performances of the semi-autonomous machine. Improvements and new features will be analyzed through extensive research on the related field.

A number of scopes and guidelines are listed to ensure that the project is conducted within its intended boundary and heading in the right direction to achieve its objectives.

a) Study on the mechanical performance of structural parts of Portable Oil Spill Skimmer. Mechanical analysis will be performed on the frame to select the most appropriate materials and parts for the Portable Oil Spill Skimmer for enhanced capability in oil spill response and recovery activities.

b) Review current hull design of Portable Oil Spill Skimmer through journals and articles related to oil spill response activities. 3D-modelling will be performed on the appropriate hull design using computer aided design (CAD) software and simulated with computational fluid dynamics (CFD) analysis.

c) Study and select on the propeller design and the choice of electric motor to maximize propulsion and energy efficiency over the operation of oil spill response. Appropriate propeller design will be designed through computer aided design software for optimization and simulated by using computational fluid dynamics (CFD) analysis.

1.5 Significance of Study

Following the completion of this study, the current version of Portable Oil Spill Skimmer will be enhanced in terms of the robustness of the entire system and structure. Improving the design and selection of suitable material for the frame to house the electrical and mechanical parts could help it to perform well without fail under rough conditions like wavy sea. Furthermore, appropriate hull design coupled with optimized propeller design and electric motor will aid the propulsion efficiency with higher speed and maneuverability at the same time help saving energy for better endurance.

1.6 Organization of Report

In this project, there are five chapters consisting of introduction, literature review, methodology, results and discussion as well as the conclusion and recommendations. Each and every chapter of this project have its own purpose of describing the content.

The background of the study is discussed in the Chapter 1 of Introduction. The problems related to the field of study are identified through observation and analysis. This comes after the objectives to be achieved during the study and scope which narrows down the area of the study. Impact of this study will have shown how is the optimization of parts benefitted the performance of machine.

Thesis and research regarding to this project is discussed in Chapter 2 which covers literature review of the report. It focuses on the development of autonomous surface vehicle and the design and performance analysis of propeller as well as the manufacturing technique of material suitable for the application of this project. This usually covers the study subject hypotheses and prior papers, books, journals, articles and internet reviews.

The process to be performed on the Portable Oil Spill Skimmer is addressed throughout Chapter 3, Methodology. The flow of this project is illustrated and discussed with a flowchart. This chapter comprises the process flow which covers the selection of material, steps of conducting stress-strain analysis on the frame design and computational fluid dynamics analysis on the hull and thruster for Portable Oil Spill Skimmer.

The results obtained from the analyses is discussed in Chapter 4. The stress-strain analysis performed on the frame using ANSYS which includes the total deformation, equivalent stress and strain value. In addition, the values of hull resistance and thruster thrust force are obtained using the ANSYS FLUENT computational fluid dynamics are discussed in this chapter.

Project summarizing and conclusion are discussed in Chapter 5, which covers the important findings of the project, and recommendation of future works that can be carried out to enhance the system and fabrication of Portable Oil Spill Skimmer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review of study and work that are related to the enhancement of Portable Oil Spill Skimmer. This will also cover the areas of research regarding of autonomous surface vessels which is the foundation of the project. This chapter describes the finite element analysis and computational fluid dynamics which are covered in computer aided engineering for analyzing and optimization. Explanations regarding the materials used in marine application and the oil skimming system using roller are also discussed in this chapter. In addition, a literature review on the marine propeller and DC motor are covered as well.

2.2 Autonomous Surface Vessel (ASV)

Autonomous surface vessel is a type of watercraft that does not need the operators to be onboard in order to control the operation of the vessel. Over the years of developing ASV and with the integration of Internet of Things (IOT) technology, a compact-sized partially autonomous surface vessel is a revolutionary way for monitoring and carry out marine activities. As for the application of oil spill response and recovery activities, a specifically developed compact semi-autonomous vessel can serve as a replacement to the traditional method of oil spill recovery. In fact, this innovative way of exploring the waters is proven to lower the risk as there is no direct intervention from human at the site. Thus, the flexibility of the activity will be higher due to the low number of human involvements. With the usage of small-sized ASV, operational cost can be cut marginally as a result of less labour involved, high portability as well as low power consumption of machine (Romano & Duranti, 2012).

ASVs are often relied on electric power source, i.e., solar energy or battery to operate. When they run for an extended period of time during a mission, their source of energy can be depleted over time and leaving the ASV stranded at the site. Wang et al. (2009) highlighted that the speed and the endurance of the ASV can be improved through the ideal matching of the electric motors, propellers and hull resistance despite the small capacity of battery. Majid and Arshad (2016) pointed out that the capability to run continuously of an ASV can be achieved with a rechargeable battery and onboard power charging component. Moreover, the type of hull the ASV is based on often play a crucial role as they will affect the dynamics and resistance as well as the seaworthiness on rough environment.

2.2.1 Type of Hull

There are two different design of hull configurations to be reviewed in this project namely catamaran and small waterplane area twin hull (SWATH)

2.2.1.1 Catamaran Hull

Catamaran hull design is made up of two parallel hulls of the same size placed at the sides of the vessel as shown in Figure 2.1. A large usable area on the deck can be provided following the design of catamaran. Catamaran is so stable due to the wide beam at the sides and thus, eliminating the need of ballasting to counter the heeling moment due to the centrifugal force developed in turning. Therefore, twin-hull vessel can move more effective weight in water as compared to mono-hull vessel. Catamaran has a higher transverse stability than mono-hull due to the large moment of inertia given the separation between hulls. Furthermore, wave resistance of catamaran is reduced at displacement speed as the interference between the waves and the hull is lower than single hull vessel. However, there is limitation to the payload on a catamaran vessel if the bottom surface comes to contact with the wave, it will induce a large resistance to the vessel at low speed. Therefore, the payload is limited to 10% of the total displacement of the hull (Misra, 2016).