# WIND ASSISTED PROPULSION SYSTEM FOR FUEL SAVING

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**Dedicated to my family, and my friends**

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# ABSTRACT

Increasing fuel prices and strong environmental concerns have changed the landscape for the shipping industries. The changing, competitive environment has rekindled an interest in improving ship efficiency and performance sustainability. As MISC Berhad has a vision to become a world class player in the shipping industry, alternative ways have to be discovered for ensuring a competitive edge in the shipping business. Wind assisted ships are to be considered as an alternative way to reduce fuel consumption and damage to the environment. The aim of this study is to develop a wind assisted propulsion system and to assess its techno economic feasibility on a specific vessel and a selected route. Chemical carrier tankers from the MT Bunga Melati series were chosen and the routes selected were between the Middle East, Singapore and the Far East. For this study, actual data collected was for a period of more than two years. This data was taken from the daily noon reports of the ship master which are reports to his company on a daily basis during a ship's voyage. The data consists of the main ship operational parameters as well as the wind speed and directions. A kite was designed and the propulsive forces developed in the voyages throughout the year were estimated. Finally, the economic assessment was carried out using payback period and Net Present Value criteria. The calculations showed a payback period of 10 years while Net Present Value was strongly positive indicating a profitable investment. The effect of using the kite on CO2 emission was determined using Energy Efficiency Design Index (EEDI) and Energy Efficiency Operational Indicator (EEOI) developed by the International Maritime Organisation. Both indicators showed a positive reduction, indicating that the use of the kite is not only profitable economically but also improves the ship CO2 reduction performance.

# ABSTRAK

Peningkatan harga minyak dan kesedaran terhadap masalah pencemaran alam sekitar disebabkan penggunanaan bahan bakar telah menukarkan lanskap industri perkapalan. Perkembangan pesat industri perkapalan telah menarik minat bagi meningkatkan kecekapan prestasi perkapalan untuk terus berdaya saing. Seperti visi MISC Berhad untuk menjadi peneraju utama dunia di dalam industri perkapalan, alternatif lain perlu dicari untuk memastikan MISC Berhad sentiasa berdaya saing dalam perniagaan perkapalan. Kuasa pergerakan dengan bantuan angin perlu diberi perhatian sebagai alternatif dalam mengurangkan kebergantungan terhadap penggunaan minyak dan dapat mengurangkan pencemaran terhadap alam sekitar. Fokus kajian ini adalah untuk membangunkan sistem propulsi bantuan kuasa angin dan untuk menganggarkan kesesuaian dari segi tekno ekonomi pada kapal dan laluan tertentu. Laluan siri MT Bunga Melati, iaitu kapal pengangkut bahan kimia adalah diantara Timur Tengah, Singapura dan Timur Jauh telah dipilih untuk kajian ini. Data harian sebenar untuk tempoh lebih dua tahun yang dilaporkan oleh kapten kapal semasa kapal belayar kepada syarikat akan digunakan untuk kajian ini. Data tersebut mengandungi parameter utama operasi kapal seperti kelajuan dan arah angin. Layar layang-layang dicipta dan daya propulsi semasa pelayaran sepanjang tahun telah dianggarkan. Akhir sekali, penilaian ekonomi dengan menggunakan kaedah “Payback” dan “Net Present Value”. Berdasarkan pengiraan menunjukkan tempoh “Payback” ialah selama 10 tahun, manakala kaedah “Net Present Value” menunjukkan nilai positif pada keuntungan pelaburan. Kesan pengunaan layar layang-layang terhadap $CO_2$ akan ditentukan mengunakan “ Energy Efficiency Design Index (EEDI)” dan “Energy Efficiency Operational Index (EEOI) yang disarankan oleh “International Maritime Organisation”. Kedua-dua indek menunjukkan pengurangan yang positif, ini menunjukkan pengunaan layar layang-layang bukan sahaja baik dari segi ekonomi tetapi juga dalam mengurangkan penghasilan $CO_2$.

# CONTENTS

# LIST OF FIGURES

# LIST OF TABLE

# LIST OF APPENDICES

## SYMBOLS AND ABBREVIATION

| | |
|---|---|
| $A$ | area of kite |
| AR | Area ratio |
| $C_D$ | drag coefficient |
| $C_L$ | lift coefficient |
| $d$ | diameter |
| $F$ | Force |
| $D$ | Drag Force |
| $L$ | Lift Force |
| $V_T$ | True wind speed |
| $V_A$ | Apparent wind speed |
| $V_s$ | Ship Speed |
| $l$ | Length |
| $P$ | Pressure |
| $LOA$ | Length of overall |
| $LBP$ | Length between perpendiculars |
| $W$ | Weight |
| $t$ | Time |
| $V$ | Velocity |
| $R_e$ | Reynolds Number |

| | |
|---|---|
| $\rho$ | Specific density (of air) |
| $V_A$ | Apparent wind speed |
| $V_T$ | True wind speed |
| $V_S$ | Vessel speed |
| $\beta$ | Apparent wind angle |
| $\theta$ | True wind angle |
| $W(z)$ | Wind speed at altitude z above (sea) surface |
| $u_{ref}$ | Wind speed at reference level |
| $z_{ref}$ | Reference level (10m) |
| $z_0$ | Surface roughness (depending on wave height) |
| $R_T$ | Total resistance |
| $P_E$ | Effective power |
| $P_D$ | Delivered power |
| $P_B$ | Brake power |
| $\eta_P$ | Propeller efficiency |
| $\eta_O$ | Open water test propeller efficiency |
| $\eta_s$ | Shaft efficiency |
| $F_P$ | Propulsive force |
| $q$ | Dynamic pressure |
| $n$ | Number of years |
| $R_n$ | Net cash flow |

| | |
|---|---|
| $e$ | Yearly cost increment |
| $i$ | Discount rate |
| $CF$ | Non-dimensional conversion factor between fuel consumption measured in g and CO2 emission also measured in g based on carbon content. The subscripts $ME_i$ and $AE_i$ refer to the main and auxiliary engine(s) respectively. |
| $V_{ref}$ | Ship speed, measured in nautical miles per hour (knot), on deep water in the maximum design load condition. |
| *Capacity* | Deadweight for dry cargo carriers, tankers, gas tankers, Containerships, RoRo cargo and general cargo ships, gross tonnage for passenger ships and RoRo passenger ships, and 65% of deadweight for container ships. |
| *Deadweight* | Means the difference in tonnes between the displacement of a ship in water of relative density of 1,025 kg/m3 at the deepest operational draught and the lightweight of the ship. |
| $P$ | *P*ower of the main and auxiliary engines, measured in kW. The subscripts *ME* and *AE* refer to the main and auxiliary engine(s), respectively. |
| $SFC$ | *C*ertified specific fuel consumption, measured in g/kWh, of the engines. |
| $f_j$ | *C*orrection factor to account for ship specific design elements. |
| $F_w$ | Non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed. |

| | |
|---|---|
| $feff_{(i)}$ | Availability factor of each innovative energy efficiency technology. |
| FC | (Fuel consumption) is all fuel consumed for the period in question |
| $C_{carbon}$ | CO2 emission per tonne of fuel calculated from the carbon content of the fuel used (e.g. HFO) |
| $m_{cargo}$ | Mass of transported cargo in metric tonnes |
| D | (distance sailed) is the actual distance sailed in nautical miles |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Increasing fuel prices and strong environmental concerns have changed the competitive landscape of the shipping industry today. This present environment has rekindled an interest in improving efficiency and sustainability in the performance of ships. To meet with the changing commercial markets and the economic environment, there is the requirement for new vessel designs with more flexibility, longer lifespan, and with more energy efficient operating systems which will be highly cost effective.

The need to minimize operating costs is paramount in order to be competitive. The current oil fuel based energy source, at recent high prices, can result in fuel costs as high as 50 percent of the operating costs [1]. Alternative energy sources for power generation such as LNG, fuel cells, nuclear, wind assisted ships are now being considered by many shipping companies. Apart from the hull and propulsion efficiency, optimization of ship running costs and quality of services depend on the performance of the operational systems and processes such as voyage management, loading and maintenance.

As the MISC vision is to become a world class player in the shipping industry, alternative ways have to be discovered for ensuring a competitive edge in the shipping business. Such development procedures are illustrated in Appendix A. These procedures range from fuel oil consumption monitoring, voyage management and propeller polishing for increasing fuel efficiency and to reducing fuel consumption [10]. However there is no alternative study that has been done within the MISC group for reducing dependence on fossil fuel. Wind assisted shipping is to be considered as an alternative way to reduce fuel consumption and prevent further damage to the environment. Earlier studies have shown that with the current wind assisted system technology, annual savings of between 10 to 30 percent of fuel consumption can be expected [31].

This study will focus on the feasibility of a wind assisted system to be applied onboard a MISC ship. The wind assisted systems generate thrust from the wind and thereby reduce dependence on fossil fuel and main engine operation.

## 1.2 Statement of Problem

Maritime Shipping is nearly dependent on fuel oil. In the last 10 years, crude oil prices rose annually by 10 percent on the average and in 2009, a high upward movement has been observed. This development, places tremendous financial pressure on the shipping industry as the fuel oil cost accounts for more than half of a ship's operating cost. The International Energy Agency (IEA) has projected an average oil price of USD 200 per barrel by 2013. According to the IEA report the main reason for this price increase is the continuing decline in oil production rates by about 6-7 percent annually and faces a growing demand of 1 percent per year. Soon, shipping companies will be forced to reduce their sulfur emissions which are already damaging the environment at present. The maritime industry is responsible for almost 4 percent of the worldwide $CO_2$ emission. The only way to reduce the emission is by reducing the burning of fuel. The way out of this crisis is by opening up alternative energy sources for the ships and this makes the use of free wind power more attractive.

## 1.3 Objective

The objective of this study is to develop a wind assisted propulsion system and to assess its techno economic feasibility.

## 1.4 Scope

The scope of this study covers the wind assisted propulsion system, the route and ship selection, the collection and compilation of wind data from noon reports, analyses of wind data of chosen routes, the development of wind assisted propulsion system, the calculation of power generated by wind and expected fuel savings, the assessment of techno economics with the application of the wind assisted propulsion system and finally the recommendations for further research work.

## 1.5 Outline of Thesis

This thesis comprises five chapters. Chapter one will cover the introduction and background of the study, the objective to study the wind assisted propulsion system and lastly the scope of the study. Chapter two covers the literature reviewed. There are three main parts in this chapter. Part one discusses the contribution of the wind assisted propulsion system to fuel saving and the effect of releasing $CO_2$ into the atmosphere by the shipping industry. The second part, discusses the previous study conducted for the wind assisted propulsion system and the application and advantages of the wind assisted propulsion system. In the third part, the kite sail theory and its application on the vessel are discussed. Chapter three covers the methodology and selection of the vessels, the routes of study, method on actual data collection from the vessel, kite dimensions, cost estimation, a case study of a ship and lastly an investment appraisal will be determined. Chapter four contains the main discussion on the route analysis and the wind analysis for the launching of kites. This chapter also discusses the propulsion force derived by applying a kite on the vessel. By generating a case study, the total fuel savings on a chosen route can be determined as well as the emission of $CO_2$ can be reduced and furthermore an investment appraisal will be also discussed. Finally, in Chapter five, the conclusion on the objective of the study will be explained in brief and recommendations and suggestions for the improvement of the study or future research will be provided.