KITE SHIP: PRELIMINARY INVESTIGATION ON POWER GENERATION

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To my great Father and Mother, Brothers and Sisters, my Dear Wife and my Sons and Daughter, whose prayers always afforded me the power to accomplish this work. To all I dedicate this work with great respect and love.

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ABSTRACT

This research project is carried out with the purpose of investigating the application of kite ship system operating within Malaysian water and weather environment. This study began with the analyzing of the weather characteristic such as wind speed, wind direction and frequency in selected South China Sea area based on the data given by the Malaysian Meteorological Department. It then followed with the study on technical knowhow in determining the additional propulsive force generated to the ship by the flying kite. The additional propulsive power was then translated into the amount of fuel saving that a ship can achieved. This has in turns enabled the economic analysis to be carried out. To investigate the techno economic feasibility of the kite ship system, a case study was made to a typical medium size vessel operating within the selected area. The result of this study indicated that, the average speed and frequency of wind in South China Sea is capable for launching and modestly operating the kite ship system. The most suitable local shipping route to apply kite ship system is when the prevailing wind direction is coming from Northeast from January until March and winds direction coming from Southwest from July to September. In this study, the shipping route selected for an analysis is Sepangar – Singapore - Sepangar. Based on the techno economic analysis, with the investment cost of kite systems at around Euro 495,000.00 and the fuel saving due to wind force at 16 %, the break even of total investment can be achieved within four to six years depending on fuel price.

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ABSTRAK

Kajian penyelidikan ini dijalankan adalah untuk menyiasat mengenai aplikasi sistem layang-layang kapal yang beroperasi di perairan dan keadaan cuaca di Malaysia. Kajian ini dimulakan dengan penganalisaan keadaan cuaca seperti halaju , arah dan kekerapan angin di kawasan yang terpilih di Laut Cina Selatan berdasar kepada data yang diberikan oleh Jabatan Meteorologi Malaysia. Seterusnya, ia disusuli dengan kajian pengetahuan teknikal untuk mencari kuasa rejangan tambahan yang dihasilkan oleh sistem layang-layang terhadap kapal. Kuasa tambahan ini kemudiannya akan diterjemahkan kepada jumlah penjimatan bahan api kapal yang boleh dicapai. Ini seterusnya membolehkan kajian ekonomi dijalankan. Untuk menyiasat keboleh laksanaan secara tekno ekonomi untuk sistem layang-layang kapal ini, kajian kes dijalankan keatas kapal yang bersaiz sederhana dan beroperasi di lingkungan kawasan yang dipilih. Hasil keputusan daripada kajian ini menunjukkan, purata halaju dan kekerapan angin di Laut Cina Selatan adalah berupaya untuk melancar dan beroperasi secara sederhana untuk sistem layang-layang kapal ini. Laluan kapal tempatan yang paling sesuai untuk menggunakan sistem layang-layang ini adalah apabila arah angin lazim bertiup dari arah Timur Laut bermula daripada Januari hingga Mac dan arah angin lazim datang daripada arah Barat Daya yang bermula daripada Julai hingga September. Di dalam kajian ini, laluan kapal yang dipilih adalah Sepangar – Singapore –Sepangar. Berdasarkan kepada kajian tekno ekonomi, dengan kos pelaburan untuk sisstem layang-layang kapal lebih kurang Euro 495,000.00 dan jumlah penjimatan bahan api disebabkan oleh daya angin adalah 16% , pulangan untuk jumlah pelaburan boleh dicapai antara empat hingga enam tahun bergantung kepada harga minyak.

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Abbreviation

FE	-	Flight Envelope
NE	-	Northeast
S	-	South
SW	-	Southwest
BP	-	British Petroluem

Symbols

Re	-	Reynolds number
C_L	-	Lift coefficient
C_D	-	Drag coefficient
C_M	-	Moment coefficient
Γ	-	Circulation
F_L	-	Lifting Force
F_D	-	Drag Force
T_a	-	Traction force
V	-	Airflow at the towing kite

A	-	Surface area of the towing kite
ρ_a	-	Air density
AR	-	Aspect ratio
C_{Lo}	-	Lift slope coefficient
C_{Do}	-	Drag slope coefficient
α	-	Angle of attack
α_L	-	Zero lift angle of attack
s	-	Kite span
W	-	True wind speed
$W_{(z)}$	-	Wind speed at altitude *z* above (sea) surface
u_{ref}	-	Wind speed at reference level
z_{ref}	-	Reference level
z_o	-	Surface roughness (depending on wave height)
$V_{(A)}$	-	Propeller pitch
V_{rel}	-	Relative velocity
V_t	-	Tangential velocity
V_{r-z}	-	Radial velocity at Z direction
V_{t-x}	-	Tangential velocity at X direction
V_{t-y}	-	Tangential velocity at Y direction
V_{x-k}	-	Kite speed at X direction
V_{y-k}	-	Kite speed at Y direction
V_{y-w}	-	True wind at Y direction
V_k	-	Kite's own speed
γ	-	Kite flying direction
$\dot{\theta}, \dot{\phi}$	-	Kite's own speed in term of circular motion

$C_{L,c}$	-	3D lift coefficient of curved wing
ζ	-	Angle of curvature
ε	-	Angle of between kite centerline and kite edge
R	-	Length of lines between gondola and kite
b	-	Constructed span
$C_{D,l}$	-	Drag coefficients of lines between gondola and kite
d	-	Diameter of individual lines
α_l	-	Angle of attack between relative speed and kite line
$C_{D_{ZL}}^{s}$	-	Zero lift surface irregularities and fabric roughness drag coefficient
$C_{D_{ZL}}^{n}$	-	Zero lift inlet drag coefficient due to open airfoil nose
h	-	Height of the inlet
c	-	Chord length of the kite or wing profile
F_s	-	Verical component of traction force acting on ship
β	-	Tow line drift angle
V_a	-	Speed of advance
R_T	-	Ship resistance
T	-	Thrust
P_E	-	Effective power
P_T	-	Thrust power
P_D	-	Delivered power
P_B	-	Brake power
η_H	-	Hull efficiency
η_R	-	Relative rotative efficiency

η_O	-	Propeller efficiency –open water
η_B	-	Propeller efficiency- behind hull
η_S	-	Shaft efficiency
η_T	-	Total efficiency

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Today, fuel costs become sufficiently high and governmental air and water quality regulations became sufficiently odious. The latest price increases have placed tremendous cost pressure on the commercial shipping industry. There is strong evidence that recent fuel cost increases aren't going to be temporary, and environmental restrictions will become increasingly in law implementation. In April 2008, IMO approved a reduction in sulfur emissions for the shipping industry [1]. Meaning, if no fuel is combusted, there are no emission. Obviously, the commercial shipping industry need to look forward alternative power as an assist to petroleum powered vessels towards to year 2020.

One of the most recent inventions of renewable energy concept for ship is the use of kite as sailing power. Recent demonstration on the application of kite as an additional power generator for a medium size bulk carrier ship has indicated that it could reduce up to 30 percent of the vessel's fuel consumption [2]. Hence it has a great potential to be applied to local (locally operated) vessel especially during monsoon season.

However, kite ship concept is very new hence the theoretical background and experimental studies have not been widely available. This research is therefore intends to study the physics and mechanics of forces generated by the kite, taking into consideration local weather (wind) conditions. The result of the study will then be translated into potential source of additional power generation of a vessel that could reduce the fuel consumption and green house effects. The potential of its application for local ship (such as Fishing Vessel, Passenger Ferry etc) can also be explored. One of the important parameters on which fuel consumption utilize is dependent on type of local weather the vessels encounters during its voyage. The cost of fuel saved as a result of weather and ship routing are the main criteria to be analyze.

1.2 Problem Statement

In the carrying out the investigation on power generation by kite ship, several issues will be addressed as follow:

1. How forces from the sailing kite can provide additional power to ship?

2. How feasible is this concept to be implemented in vessels operating local environment?

1.3 Objectives

In addressing the above issues, this project work is therefore carried out with the following objectives:

1. To study the technical know how (physic and mechanics) on how aerodynamics forces of a flying kites is converted to propulsion forces of a ship.

2. To investigate the feasibility of this concept to be implemented for ships operating in local environment.

1.4 Scope of the Research

The scopes of this project are listed as follows:

1. Conduct literature research on Kite Ship
2. Study the technical know how (physics and mechanics) on how aerodynamics forces behind the kite flight.
3. Study mathematical modelling of kite flight and traction force calculation
4. Analysis of local weather condition in order to determine suitable shipping route.
5. Techno economic analysis for potential fuel saving.

Limitations of this research are:-

1. Theoretical analysis with no experiment.
2. Only local wind data from South Chinese Sea will be use in feasibility study.

1. 5 Expected Benefit

The result of this study will be useful for knowledge and understanding on the relationship between aerodynamics forces (physics and mechanics) of flying kite with additional forces or power generated to the ship. Then, the result of this study can be translate into potential source of additional power generation for vessels operating in local environment that could reduce the fuel consumption and green house effect such as fishing vessel, general cargo, yacht , etc.

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