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Study of Incorporating Kite or Balloon Technology to UMT Research Boat

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Abstract: *Rising oil prices, increasing competition in the maritime industry, climate change and pollution are significantly more prevalent among the causes of the search of alternative energy other than the use of crude oil. One of the energy that is suitable to use is wind energy because it is easily found, especially at the ocean. The large kite has been used by several types of ships as one of the propulsion system to move the ship. This study is done for the feasibility of incorporating kite technology to move the UMT boat in Terengganu waters that have been selected to save the consumption of diesel. The amount of power saving was calculated using the formulae from the previous research. Then, economic assessment was carried out based on amount of power saving. Using kite propulsion technology, fuel consumption can be reduced thus resulting in lower and operation costs on the particular routes. The results of the economic assessment indicate that, annual average cost for boat with kite sail is lesser than annual average cost for boat without kite sail. It is expected that the capital investment in the new device will be recovered within 9 years.*

Keyword: Kite Ship, Power Saving, Economic Assessment

1. Introduction

Increasing oil prices in 2008 have started a world-wide discussion among experts on how to reduce the fuel consumption of ships. Since 1970s, many researches had done to develop any alternatives energy to cover the use of fuel especially in transportation. In maritime industry, the alternatives energy is used as ship propulsion to reduce the fuel consumptions [8].

One of the alternative energy that had been used is wind energy. Wind energy is one of the useful energy for the ship propulsion when it is sailing. This is because the wind can be getting easily and very friendly to the environment. This paper studies on the kite technology as wind assisted propulsion for UMT Research boat.

The objectives of this study is the feasibility of using kite as a sailing device on UMT Research boat in order to reduce oil usage in the operation cost and at the same time can safe our environment from pollutions.

UMT boat is 16.5 m length, used for fishing research, discovery purpose and transportation. The boat is fitted by propeller by one single screw in engine board and equipped with all necessary facilities for 10 researchers/passengers and 3 crews. The speed of the boat during the first trial is 20 knots. The principal dimension of boat is shown in Table 1.

Table 1: UMT research boat principal dimensions

Properties	Dimensions
Length Overall	16.5 meter
Length Water Line	13.40 meter
Breadth	3.65 meter
Draft	0.6 meter
Speed	20 knots
Propulsion	1 x 360 HP Marine Engine
Block Coefficient	0.75
Fuel	1000 Liter
Water	500 Liter
Passenger and crew	13 Person

2. Methodology

2.1 *Kite Parameters*

The basis ship is used to calculate the scale of the kite that will be attached to the candidate ship. The ship is chosen from the previous research to make sure that the area scale of kite would be suitable for the candidate ship. The Table 2 has shown the principle dimension for the basis ship [6].

Table 2 Principle Dimension of Basis Ship (Name: 36 m, T.S. Landing Craft) [1]

Properties	Dimension
Length Overall	36.25 meter
Length Waterline	31.90 meter
Depth	2.44 meter
Design Draught	2.00 meter
Fuel Oil	150 / 200 MT
Fresh Water	150 MT
Crew / Passenger	20 men
Main Engine	3 x Yanmar Diesel Ghute 3 x 350 hp / 2300 rpm each
Speed	15 knots
Kort Nozzle	2 MT
Displacement	582.19 tonnes
Deadweight	355.71 tonnes
Block Coefficient	0.7198
Kite Area, A	200 m^2

By using scale ration equation the new parameters of kite can be determined as shown in Equation (1) (M.Azlan, 2009). Details of new area of UMT boat are shown in Table 3.

$$\left[\frac{S_M}{\Delta^{2/3}}\right]_{BK} = \left[\frac{S_M}{\Delta^{2/3}}\right]_{NK} \qquad S_{NK} = \frac{S_{BK} \times \Delta_{NK}^{2/3}}{\Delta_{BK}^{2/3}} \quad (1)$$

Where, S_{NK} = Kite Area (New Kite), S_{BK} = Kite Area (Basis Kite), Δ_{NK} = ρ x L x B x T x CB (New Kite), Δ_{BK} = ρ x L x B x T x CB (Basis Kite)

Table 3 Sample of kite data

Kite Data	Value
Kite Area, A	8.59 m^2
Aspect Ratio, AR	0.043

2.2 Propulsion Force Analysis

A force may be thought of as a push or pull in a specific direction. Figure 1 shows an example of forces that act on the Wright 1900 aircraft when flown as a kite. [8]

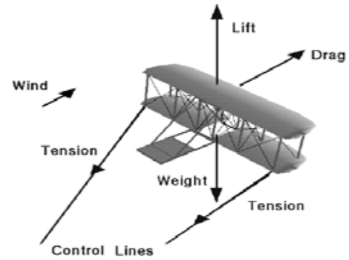

Figure 1

First step on determining the propulsion force is to determine the values of true wind speed at require altitude using Equation (2) [6]. From the calculation of the scale ratio, the required altitude is 15 meter above the sea level.

$$W_{(z)} = C_{log} \ln\left(\frac{z}{z_o}\right) = \left(\frac{u_{ref}}{\ln(z_{ref}/z_o)}\right) \ln\left(\frac{z}{z_o}\right) \quad (2)$$

Where, $W_{(z)}$ = wind speed at altitude z above sea surface

$$C_{log} = \left(\frac{U_{ref}}{\ln(z_{ref} / z_o}\right)$$

Where; u_{ref} = known wind speed at reference level, z_{ref} = reference level (10 m), z_o = surface roughness (depending on wave height).

Several theories have been applied to determine the magnitude and direction of apparent wind [6, 1]. Equation (3) shows one of theory that was used on this project.

$$V_{(A)} = \sqrt{W^2 + V_s^2 - 2.W.V_s \cos(\varphi)} \quad (3)$$

Where, $V_{(A)}$ = apparent wind ,W = Wind Speed at some latitude, Vs = Ship speed, φ = Ship course angle (Ship heading – wind direction angle).The stronger of apparent wind speed will produce larger relative velocity, Equation (4-8) shows the formula to determine relative velocity (V_{rel} ,V_{t-y}, V_{t-x}, V_t, V_{r-z}).
Kite's own speed, ø

$$\ddot{\theta}^2(r^2 sin^2(\theta)(1 - tan^2\gamma)) - \dot{\theta}(Wr sin^2(\theta)\tan(\gamma))$$
$$= -W^2 sin^2(\theta) - \left(\frac{W cos(\theta)}{\tan(\alpha)}\right)^2 \quad (4)$$

Where; α = Angle of attack, r = Tow line straight length, β = Tow line drift angle, γ = Kite flying direction , θ = Tow line inclination angle.

Tangential velocity at Y direction, Vt-y can be determined

$$V_{t-y} = -r\dot{\theta} + V_A sin(\theta) \quad (5)$$

Tangential velocity at X direction, Vt-x,

$$V_{t-x} = -r sin\theta . \dot{\theta} \quad (6)$$

Tangential velocity V_t

$$V_t = \sqrt{(V_{t-x})^2 + (V_{t-y})^2} \quad (7)$$

Total radial velocity at Z direction Vr-z

$$V_{r-z} = V_A cos\theta \quad (8)$$

By using Foil Design Program, the NACA 4415-63 was designed to obtain the Lift coefficient, C_L and Drag coefficient, C_D at difference relative wind speed. Then, Lift and Drag forces were calculate by using following Equation (9) and (10).

$$F_L = C_L \times \frac{\rho_a}{2} \times V_{rel}^2 \times A \quad (9)$$

$$F_D = C_D \times \frac{\rho_a}{2} \times V_{rel}^2 \times A \quad (10)$$

Where, F_L = Lift force, F_D = Drag force, C_L = Lift coefficient, C_D= Drag coefficient, ρ_a = Density of the air ,V_{rel} = Airflow relative velocity at the towing kite, A= Surface area of the towing kite. Otherwise, the traction force, T and the vertical component of traction force in X axis in ship sailing direction, F_S was calculate by using Equation (11) and (12).

$$T = \sqrt{F_L^2 + F_D^2} \quad (11)$$

$$F_s = T cos\theta . cos\beta \quad (12)$$

There are interrelationship between horsepower, boat resistance and speed; therefore, traction force in X axis, Fs can be connected to engine horsepower. This is because, resistance to boat is reaction force which opposite forward movement of boat, while Fs is reaction force which helps forward movement of boat [7, 8]. Equation (13) is relationship between Fs and boat resistance.

$$R_{T(new)} = R_T - F_S \quad (13)$$

Where, R_T = Ship Resistance, F_P = Resultant Force and R_{Tnew} = New Ship Resistance. Thus, we can compare the new/old break horse power

by using general power prediction theory,

$$P_{HP(old/new)} = \frac{R_{T(old/new)} V_S}{\eta_T} \quad (14)$$

P_{Hp} = Brake Horsepower, R_T = Ship Resistance and V_S = Ship Speed, η_T = Total Efficiency.

2.3 Economical Analysis

Economy is the task of allocating a finite supply of investment funds in the face of infinite possibilities and it is an approach to determine whether the project will be economic or not. This study used the annual average cost (AAC) and net present value (NPV) methods to compare the total cost between with kite and without kite. Equations (15) and (16) shows formula related to calculating NPV. Life time of the UMT boat was assumed as 20 years and interest rate (i) is 10%. Table 4 is shows the present costs of the system elements.

NPV (without kite) = ∑PV (maintenance cost)+ PV (operation cost) - PV (salvage value) (13)

NPV (with kite) = ∑PV (maintenance cost) + PV (operation cost) + PV (investment cost in kite) - PV (salvage value) (14)

Operation cost; Fuel saving = operating time × [$P_{B(old)}$-$P_{B(new)}$] × specific fuel consumption.

Table 4 Overall Cost Estimation

3. Results and Discussions

3.1 Wind Speed

There are two different wind speeds that had been recognized. First is the true wind speed which is getting from Malaysian Meteorology Department. Second is the apparent wind speed that is calculated using the formula to get the wind speed at required altitude to force the kite for towing the FMSM boat.

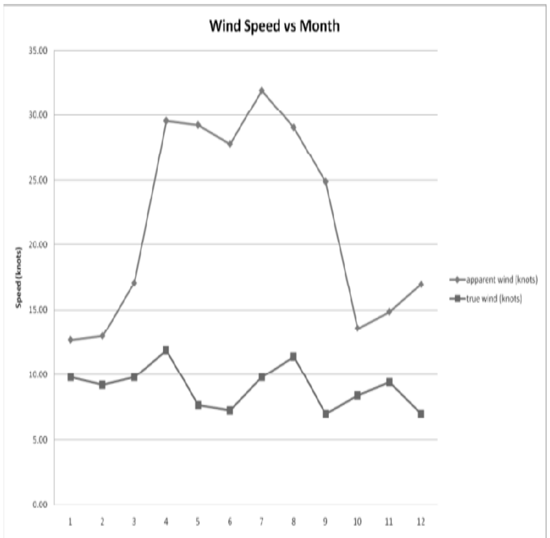

Figure 2 Result on Wind Speed versus Month at required altitude.

From the Figure 2 above, the different between wind speed at 10 meters and 15 meters above the sea level had been determined. The graph shows that, the higher the level above the sea, the higher the wind speed.

3.2 Result of Power Generate by Kite

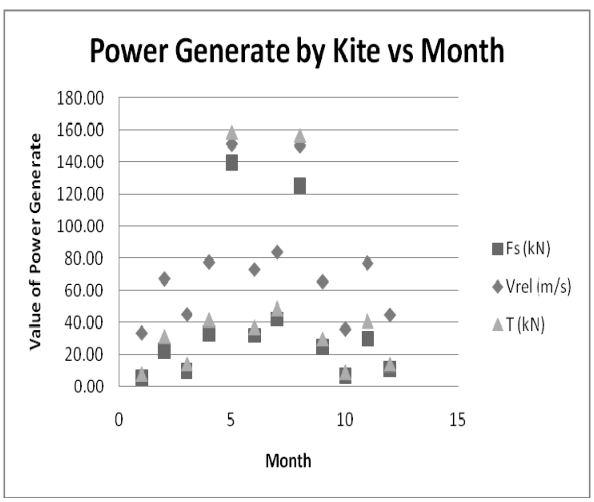

Figure 3 Result of Power Generate by Kite versus Month

The power generated by using flying kite on the assumptions, the ship moving forward at constant speed and heading angle. From Figure 3, it is clearly indicated that, the Traction depends on the apparent wind speed. Therefore, by increasing the apparent wind speed, the kite velocity relative also will increase and the traction force generate by flying kite will be higher.

Cost	Properties	With Kite (RM)	Without Kite (RM)
Investment cost	Boat cost	-192,000	-192,000
	Total investment on kite	-55736.84	Non
Maintenance cost (increase 2% each year)	Machinery & Hull	-19,200 per year	-19,200 per year
	Kite	-4,241 per year	Non
Operation cost (assume constant each year)	Fuel oil	-5,716.28 per year	-20,376 per year
Salvage value (after 20 years, decrease 5% each year)		+88810.17	+68,829.30

3.3 Result of Power Saving

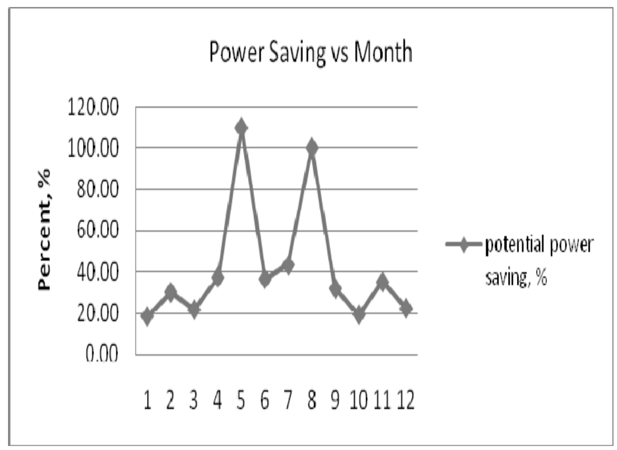

Figure 4 Result of Percentage of Power Saving for year 2008

Figure 4 shows the percentage of power saving throughout the whole year of the research. The route is from mouth of Sungai Terengganu to Bidong Island. From the figure, it shows that, the highest saving can be had on May, and August. The month of January, March, October and December, present the lowest percentage potential power savings.

3.4 Cash Flow Diagram

Cash flow diagram shows the flow of costs for one project. The positive direction shows the profit (debit) and negative direction shows the expenditure (credit). The involving cost of economic analysis can be shown by Figure 5 until Figure 6.

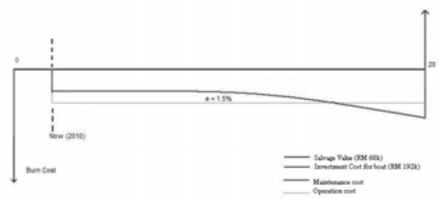

Figure 5 The costs for without kite sail (including burn cost)

The involving cost in Figure 6 shows the different way of the costs for without kite sail (including bum cost) in simplified form. The inertia cost for UMT boat is removed. While in Figure 7, shows the involving costs for boat with kite technology sail.

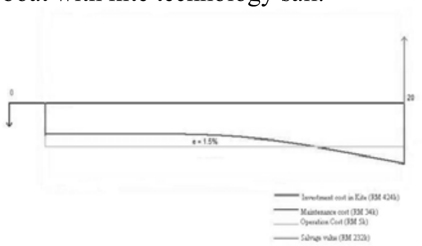

Figure 6 Cash Flow Diagram (without kite sail)

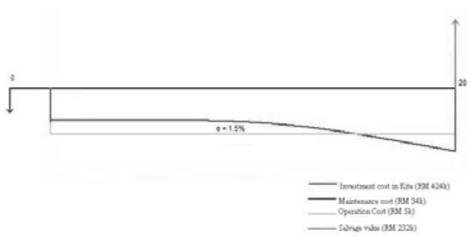

Figure 7 Cash Flow Diagram (with kite sail)

From calculation for both cases which are, with kite sail and without kite sail, the AAC is negative, which means that, the both alternatives are not profitable. This is due to the function of this boat which is only used for research purpose. The result finds that, the total annual average cost without kite is higher than total average cost with kite. Whereas, AAC without kite sail is – RM 45618.80 per year, while AAC with kite sail – RM 39623.7per year. This *result proved that the boat which has been fitted with kite sail is more economical compared to the boat without the kite sail.*

3.5 Return Investment

Assuming that, the oil price, interest rate (i), and others value that influence on calculation of economic analysis is constant each year. Therefore, the capital investment recovery that has been determined is 9 year.

4. Conclusion and Recommendation

The major presented analyses are introduced by three previous researches. Meaning, the kite position on flight envelope and calculation of apparent wind speed are based on many assumptions. Without promising data from experiment or simulation for kite flying altitude, it is difficult to predict the velocity calculation.

The accuracy of this calculation is mainly depends on relative velocity, lift and drag coefficient. In this project, the wind speed at any height from sea level is calculated using the formula developed by previous research. Using kite propulsion technology, fuel consumption can be reduced thus resulting in lower and operation costs on the particular routes.

The results of the economic assessment indicate that, annual average cost for boat with kite sail is lesser than annual average cost for boat without kite sail. It is expected that the capital investment in the new device will be recovered within 9 years. Thus, the actual condition of wind speed at different height is about 90% accurate and directly reflects the overall calculation and estimation in this project.

This lead to the conclusion of the fuel saving value that was calculated is purely theoretical value and several uncertainties involved in the analysis of the kite force estimation and ship powering. Hence, further validation of the kite force calculation is desired as well as research on the optimization of the ship routing and behavior.

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