A Study into the Development of More Energy Efficient and Less Polluted Fishing Vessel

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Abstract— *The successful application of catamaran hull form as passenger carriers has been well-known since the last 30 years. It is later extended to the development of fishing vessels and the reason behind this is attributed to safety criteria and wider deck-space which can be offered by the catamaran. It is also in connection with the handicaps of monohull fishing vessels, in terms of stability and seakeeping performance which can be improved by the introduction of catamaran forms. Recent situation on the rare and expensive fossil fuels have caused the fishermen into deep trouble hence most of them tend to be deprived if there is no anticipation taken to help them. The current paper describes a systematic investigation into the way to reduce (if not possible to replace completely) the use of fossil fuels on a catamaran fishing vessel. The study is focused on the use of diesel engine, sail and solar power on individual application as well as the combination of them. The implication to the final cost of the vessel, however, is negligible. It is discovered that the use of diesel engine could be replaced by the use of sail and solar power for individual basis. A combination of those power sources is found to be more appropriate in terms of stability and capacity of fishing holds. The investigation is extended to the evaluation of energy efficiency design index (EEDI), a compulsory criterion for measuring marine pollution made by the international maritime organization (IMO) and applied for ocean-going vessels. It is considered for fishing vessels because this type of vessel is thousands in number and most of them use engine together with fossil fuels hence there is strong potency to pollute air and the environment.*

Keywords*— *Catamaran, fishing vessel, stability and seakeeping, power estimation, energy efficiency.

I. INTRODUCTION

In the last thirty years, there has been a great increase on the use of catamaran for various applications such as ferries, fishing vessels, sporting craft, and oceanographic research vessel [1]. The main advantages of catamaran compared to single hull are a wider deck space area, better transverse stability, and in certain case lower total resistance [2, 3]. Considering the resistance performance and wider deck space area for catamaran hull, it is a potentially good to apply for fishing vessel. Wider space area provides freedom of ship crews for fishing activities and to install fishing equipments on deck [4].

Factors driving fishing vessel operational, in general, are economic and environmental issues. The main economic concern, in particular, is fuel costs and the main environmental issue amounts to emissions and pollution [5]. Conventional Fishing vessel uses diesel engine and is found to be not economical in term of fuel spending and environmental issues. Recent situation on the rare and expensive fossil fuels have caused the fishermen into deep trouble hence most of them tend to be depressed if there is no anticipation taken to help them [6].

Development of environmental friendly vessels has become a major issue since the last twenty years. This occurs due to the scarcity and high cost of fossil fuels especially for ocean-going vessels in the world. Other reason relates to efforts to reduce the spread of toxic gases to the atmosphere such as CO, CO_2, SO_2 and NO_2 which is mainly caused by the use of fossil fuels [5, 6].

The powering of vessel without using engine and fuel oil has later become more popular considering environmental issues. There are several choices of power systems such as the use of sail, solar powered, diesel engine or the combination of those two and three power systems [6]. A combination of those power sources is found to be more appropriate in terms of stability and capacity of fishing holds. Overall, ship stability and seakeeping evaluation are considered for fishing vessels because of the placement of sail and (later) solar panel can affect ship stability and seakeeping qualities [7].

II. LITERATURE REVIEWS

2.1 Catamaran resistance

The most widely used estimation of catamaran resistance is the method proposed by Insel and Molland [2]. Catamaran hull consists of 2 isolated demihulls and creates wave and viscous resistance interference and formulated as follows:

$$C_T = (1+\phi k)\sigma C_F + \tau C_W \tag{1}$$

Where:

C_T is total resistance coefficient, C_F is frictional resistance coefficient and obtained from ITTC-1957 correlation line, C_W is wave resistance coefficient of isolated demihull, (1+k) is form factor value of isolated demihull, ø is used to estimate the change of pressure around demihull, σ represents additional velocity between demihulls and calculated from the summation of local frictional resistance around wetted surface area. In fact, the factors of ø and σ are difficult to measure hence for the practical purposes, the two factors can be combined to form viscous resistance interference factor β where $(1+\phi k)\sigma = (1+\beta k)$ hence:

$$C_T = (1+\beta k)C_F + \tau C_W \tag{2}$$

Where for monohull or demihull at isolation the value of β=1 and τ =1.

2.2 Powering

2.2.1 Conventional Engine

The overall concept of the powering system may be seen as converting the energy of the fuel into seful thrust (*T*) to match the ship resistance (*R*) at the required speed (*V*) [8], (see figure 1).

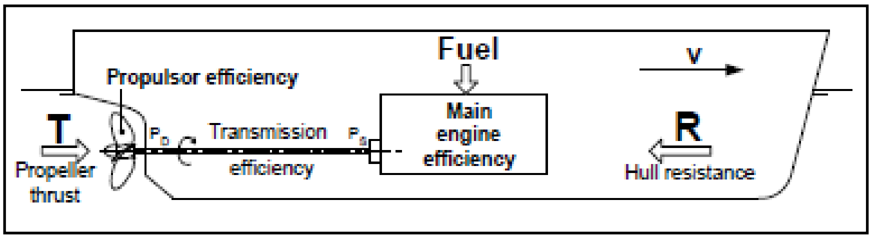

FIGURE 1: OVERALL CONCEPT OF ENERGY CONVERSION [8]

It is seen that the overall efficiency of the propulsion system depends on: fuel type, properties and quality; the efficiency of the engine in converting the fuel energy into useful transmittable power; and the efficiency of the propulsor in converting the power (usually rotational) into useful thrust (*T*). The present study concentrates on the performance of the hull and propulsor, primarily considering, for a given set of constraints, how resistance (*R*) may be reduced and thrust (*T*) may be increased.

2.2.2 The Use of Sail

A sail is defined as a surface, typically made of fabric and supported by a mast with purpose to propel a sailing vessel [9,10]. Recently, as fuel costs increase, particularly when fast journey time is not critical, there is a renewed interest in the commercial use of sail propulsion either as a primary source of propulsion with usually a back-up diesel-propeller for safety or as a means of providing additional power when wind is available [9]. The choice of sail arrangement and underwater hull and appendage design can make a large difference in available speed for given wind directions and magnitudes.

2.2.3 Solar panels

Solar panel as a powered boats get their energy from the sun. By using electric motors and storage batteries charged by solar panels and photovoltaic cells, solar powered boats can significantly reduce or eliminate their use of fossil fuels. Solar boats are uniquely suited to transform light energy into movement. Environmental friendly solar energy is an energy efficient way to power commercial oceangoing vessels as well as leisure boats [5].

2.2.4 Development Hybrid Vessel in the World

Several power systems have been developed such as combination of engine and sail which is later known as sail assisted engine. The powering vessel without using engine and fuel oil has later become more popular considering environmental issues. Successful application of catamaran type of vessel as passenger carrier with hybrid power has been well-known such as Foscat32, Greenpeace Rainbow Warriors and New York Hornblower [5].

2.3 Stability and Seakeeping Evaluation

Catamaran vessel has better transverse stability compared to monohull. Catamaran has been applied successfullly as passenger carriers, oceanographic research vessels, and leisure boats [1, 2]. Recent work shows that catamaran is feasible as fishing vessel, particularly for coastal waters operation [5]. Seakeeping ability is a measure of how well-suited a watercraft is to conditions when underway [7]. A ship or boat has good seakeeping ability is said to be very seaworthy and is able to operate effectively even in high sea states. Ship stability and seakeeping evaluation are considered for fishing vessels because of the placement of sail and solar panel can reduce the ship stability and seakeeping qualities. Also, fishing vessels are usually operated in more open sea hence this vessels are prone to capsize. Several surveys indicated that fishing vessel has reached the highest accident rates among othe types of vessel. Under United Kingdom Regulation every fishing vessel of 12 m registered length and over is required to satisfy as fairly specific minimum stability aggregate [12]. The specific requirement in relation to the static stability curve is given below (see figure 2):

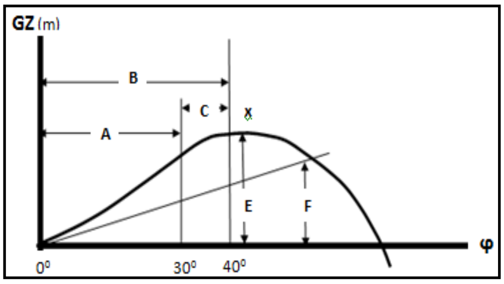

FIG.2 STATIC STABILITY CURVE [12]

A - area under curve up to 30 degrees to be not less than 0,055 meter-radians

B - area under curve up to x degrees to be not less than 0,09 meter- radians

C - area between 30 degrees and x degrees to be not less than 0,03 meter-radians

x - 40 degrees or any lesser angle at which the lower edges of any openings in the hull, superstructure or deckhouses which lead below deck and cannot be closed, will be immersed.

E - maximum GZ to occur at angle not less than 25 degrees and to be at least 0,20 meter at an angle equal to or greater than 30 degrees

F - Initial GM to be not less than 0,35 meter.

2.4 Criterion for measuring CO_2 environmental impact

The emissions from ships include NOx, SOx and CO_2. CO_2 emissions have a global climate impact and a concentrated effort is being made worldwide towards their reduction. In order to monitor and quantify CO_2 emissions, the International Maritime Organization (IMO) has developed an Energy Efficiency Design Index [13, 14].

The general form of the Energy Efficiency Design Index, as proposed by IMO, is as follows:

$$\text{EEDI} = \frac{P \times sfc \times C_F}{C \times V} \text{ gm } CO_2\text{/tonne mile}$$

Where P is power (kW), sfc is specific fuel consumption (gm/kW.hr), C_F is a CO_2 conversion (tonne CO_2/tonne fuel), C is the capacity of the ship (DWT or GT) and V the speed (knots). As such, EEDI can be seen as a measure of a ship's CO_2 efficiency.

III. RESULT AND DISCUSSION

When considering the overall form of the Energy Efficiency Design Index it is clear that in order to reduce the index for a given ship at a given speed, a decrease in propulsive power must be achieved and/or improvements made in engine efficiency with a reduction in *sfc*. Improvements in efficiency of propulsion will lead directly to improvements in the economic return and a decrease in GHG emissions. This means that there is now a double incentive to pursue such efficiency improvements. There are, however, some possible technical changes that will decrease emissions, but which may not be economically viable [8]. Potential savings in resistance can be achieved throughout hull form selection and enhanced hull coatings, are likely to come into this category.

3.1 Improvement in Resistance

The experimental work was conducted using towing tank and a symmetrical catamaran model (S/L=0.4) were tested and the results are given in Table 1. The particular of vessel is 14.5 m LWL, 7.118 m B, 1.44 m H, 0.694 m d and 11.8 t Displacement. The models were tested at speed equal to speed of real vessel at open sea from about 5 to 10 knots and the Froude numbers were about 0.24 to 0.48 or from low speed to medium speed condition and the details can be found in [4].

TABLE 1
RESISTANCE RESULT OF TOWING TEST

Run Number	V (knots)	R_T (kN)	EHP	C_F	C_T
1	5.7	1.66	6.596	0.0023	0.0077
2	6.2	2.06	8.930	0.0023	0.0081
3	6.6	2.35	10.896	0.0023	0.0080
4	7.1	2.95	14.562	0.0022	0.0089
5	7.5	3.55	18.513	0.0022	0.0096
6	7.9	3.77	20.767	0.0022	0.0091
7	8.5	4.34	25.768	0.0022	0.0091
8	9.0	4.66	29.322	0.0022	0.0087
9	9.4	5.51	36.210	0.0022	0.0094
10	9.8	6.14	42.172	0.0021	0.0096

3.2 The use of Conventional Engine

If the catamaran is powered by engine at the speed of 9.8 knots, it requires effective power (PE) about 42 HP and breaking power (P_B) about 70 HP presumably the total eff. is 60%. The conventional engine thus contributes 0.2218 g CO_2 /ton mile of CO_2 index. Thrust (T) = R_T/(1-t) [11], (given T: 4.12 kN). *Thrust deduction fraction* (t) = k_R . *wt*, for twin screw [11], where: k_R is 0.5 for thin rudder, *wt* = $-0.0458 + 0.3745C_B^2 + 0.1590D_w - 0.8635Fr + 1.4773Fr^2$, $D_w = \frac{B}{\nabla^{1/3}}\sqrt{\frac{\nabla^{1/3}}{D}}$, (given t : -0.49).

3.3 Improvement in Powering

To identify key areas where changes and improvements in powering might be made and decreases in power and hence CO_2 index, suggestions that emissions trading for ships may be introduced in the future are given below:

3.3.1 The use of Solar Panels and Sail (Solar Sail)

To achieved thrust power (T) of about 4,12 kN and speed (Vs) = 9,8 knots, the boat required 52 kW to move produce by 289 solar panels (180 WP) with 298 m^2 areas and 0.825 ton weight devices and Sail areas = 140 m^2 with 0.378 ton weight devices [9, 10].

3.3.2 The use of combination powering

All means of improvement in powering and reduction in greenhouse gas emissions should be explored and assessed, even if such improvements may not be directly economically viable. The following combinations are possible: (i) engine – solar panels, (ii) engine – sail, (iii) solar panels – sail, and (iv) engine – solar panels – sail (See figure 3 and 4).

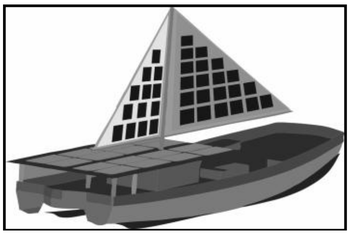

FIG.3 HYBRID CATAMARAN FISHING VESSEL [7]

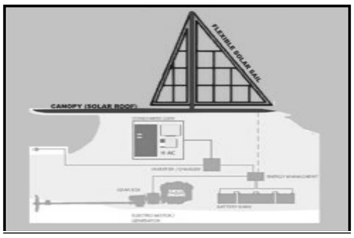

FIG.4 HYBRID POWER SYSTEM CONFIGURATION [7]

Many efforts to reduce the use of fuel and GHG effect have been made worldwide. The use of alternative energy to complement or replace the use of fuel is actively conducted around the world. The combination or hybrid of engine and sail has been done in many places in Indonesia especially by fishermen. The combination use of engine, solar powered and sail has become other promising answer.

IV. CONCLUSION

The present work apparently portraits a study into the development of more energy efficient and less polluted fishing vessel. Application of hybrid technology is very useful when applied to catamaran fishing vessels. The development of hybrid vessel gives a promising expectation in order to reduce the use of fossil fuels. It has been found that the use of sail or solar sail and solar panel in combination with the operation of electric engine is to be very useful.

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