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The Configuration of Solar Sail Catamaran Fishing Vessel

By PI Santosa

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I. Introduction

The mission of a fishing boat is to catch fish from the sea to get fish that meet the quality in appropriate ways and deliver the fish to land or to another vessel for further processing,[1]. The fishing activities have an impact on the increase of air pollution levels (such as CO_2, SO_2 and NO_X) in the atmosphere, especially on fish boats that use diesel engines. The impact of the activities is one of the most crucial problems in the world, thus many efforts have been done to look for solutions that the operation of fishing vessels become environmentally friendly, [2].

In general, the operation of a fishing vessel is always associated with economic and environmental issues. Economic factor is the cost of fuel, while the environmental factor is related to the level of pollution produced. Economic problems and strong environmental pressures forcing the ship designers and owners to create more efficient vessels to minimize the use of ship propulsion. Reduced magnitude of ship propulsion (and fuel requirements) can be fulfilled since the ship design stage by creating more efficient hull design and propulsion systems as well as ship operational activities including ship operations, such as: Solar Sail Vessels (SSV), [3].

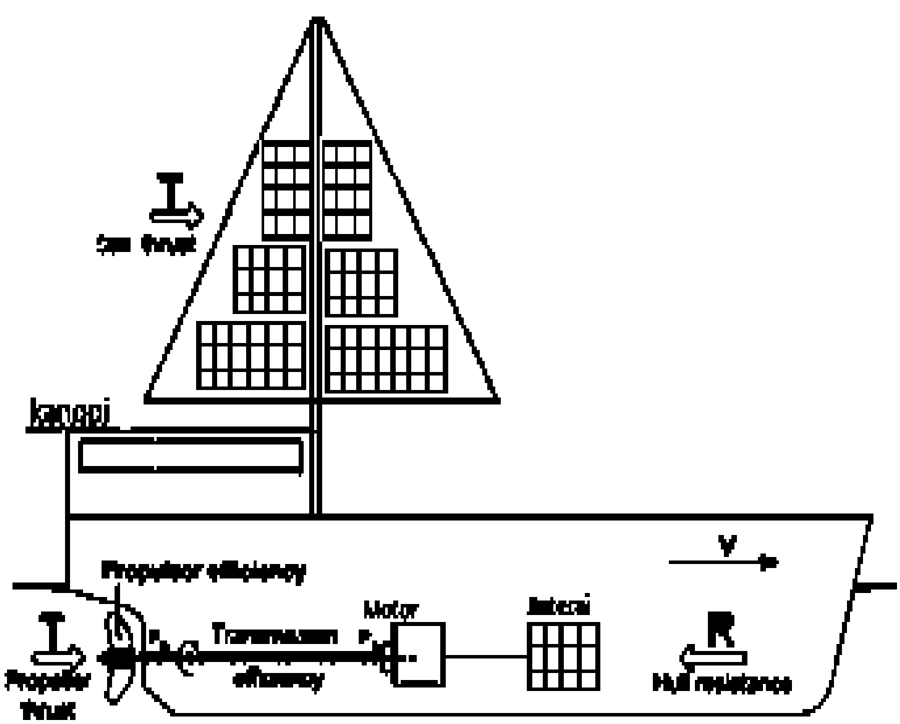

Figure 1: Configuration of Solar-sail Vessels (SSV),[1].

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Figure 1. shows the configuration of the vessel with the solar-sail driver. The concept of energy conversion in the ship's configuration is to convert wind and solar energy into the required thrust force of the ship through the propeller (electric motor) and sail. The thrust (*T*) force generated from one or more of the ship's propulsion sources operates simultaneously or together known as the hybrid system [1].

Environmentally friendly vessels that have ever been built in the world

- Foscat32 catamaran tourism boat, the concept of a hybrid drive that combines diesel motors, sail and solar panels (Foscat32,2015)

Figure 2: Foscat32 catamaran tourism boat hybrid (Foscat32, 2015)

Figure 2. shows the configuration of the Foscat32 catamaran tour boat equipped with hybrid propulsion which, in this case, the screen and solar panel are placed vertically above the ship's navigation space as the screen whose placement is adjusted according to: stability, load space requirements, vessel operations and energy requirements to drive the ship. Foscat32 (Folding Solar Catamaran) is a folding sailboat utilizing natural energy from wind and sun, has a length of 32 meters and a height of 52 meters with a solar panel (95 m2) placed on the main pole and has two electric motors placed on the hull. This ship has high performance because it uses a lightweight system, which is a combination of the power of the sun and wind by reducing CO2 to almost zero during sailing.

- Greenpeace Rainbow Warriors, this eco-friendly vessel is actively carrying out a campaign to save the environment by sailing around the world (Greenpeace, 2015).

Figure 3: Greenpeace Rainbow Warriors ship (greenpeace, 2015)

Figure 2. shows the configuration of the Greenpeace Rainbow Warriors Ship, which is equipped with a driving force of sail combination, hybrid engine. While what is meant by a hybrid engine is a diesel engine that is equipped with an electric motor that can work alternately or simultaneously. Hybrid engine and sail will work alternately or simultaneously. The thrust force used to drive this ship is generated from the propeller and sail. The New York Horn blower passenger vessel, the "San Francisco Horn blower Hybrid" ship made in 2008 and the "New York Horn blower Hybrid" vessel in April 2011, is a passenger vessel with a capacity of 600 passengers equipped with a combination of diesel engines, solar power and power turbines. wind (New york Horn blower, 2015).

Figure 4: Hybrid passenger ship (Newyork hornblower, 2015)

Figure 4: shows the configuration of a hybrid passenger ship by utilizing natural energy from wind and solar because this ship will run its diesel engine if needed as additional power. The wind will drive wind power turbines to produce electricity, while solar power will be converted into electricity as well.

- Norwegian fishing boats, Eld by, (2014), in their article writing about the collaboration of Norwegian fishermen and SINTEF researchers, have succeeded in simulating small fishing boats equipped with a battery-driven electric (as shown in Figure 5, the results show that the energy consumed about 60 to 70% of total energy during the time of operation of the fishing vessel.

Figure 5: Fishing boats equipped with a battery-driven electric engine, (Eldby, 2014)

Furthermore, the idea of developing an innovative hybrid catamaran fishing vessel design is intended to produce a fuel-efficient, environmentally friendly and well-performing vessel, which is a proposal for the concept of a future fishing vessel. Whereas the relevance of this research is related to efforts to create an efficient ship and save fuel and the possibility of its contribution to the layout of the catamaran vessel space which is more flexible in the application of fishing vessels.

II. Literature Review

- *Ship Moving Theory*
  The vessel may move forward due to a sufficient thrust to resist ship resistance at a certain service speed [4]. Based on the above concept, then requirement of ship can move.

$$T \geq R_T \quad \text{or} \quad T - R_T \geq 0 \qquad (1)$$

where: T is Thrust (kN), R_T is Resistance (kN)

- *Ship Resistance*
  The total vessel resistance (R_T) is calculated according to Equation (2) where ρ is the sea water mass, *CT* is the total resistance coefficient, WSA is the wet surface area, and V is the velocity of the vessel, [4]

$$R_T = \frac{1}{2}\rho\, C_T\,(WSA)\,V^2 \qquad (2)$$

- Thrust
  Thrust (T) is the energy or force required to drive the vessel and can be expressed as Eq. (3), [4].

$$\text{Thrust } (T) = R_T/(1-t) \qquad (3)$$

where: t is thrust deduction factor

For double screw [3]: $t = k_R$ (4)

where: k_R is 0.5 for thin rudder.

$$wt = -0.0458+0.3745C_B^2+0.1590D_w0.8635Fr+1.4773Fr^2$$

$$D_w = \frac{B}{\nabla^{1/3}}\sqrt{\frac{\nabla^{1/3}}{D}}$$

To move itself, the thrust (T) force generated through the propeller and the sail must be greater than the existing total vessel resistance (), mathematically expressed in (5), [4].

$T\,propeller + T\,sail \geq R_T$

Propeller thrust, $T\,propeller = K_T.\rho.n^2.D^4$

where: thrust coefficient (K_T), Salt water density (ρ), Propeller Rpm (n), Propeller diameter (D) . wt

Sail thrust, $T\,sail = q \,.\, As$

where: Dynamic wind pressure (q) = ½ x ρ x £ x V_w^2) (ton/m^2), Air mass density (ρ) = γ/g, Weight per unit volume (γ) = 1.2265 t/m^3, g = 9.81ms^{-2}, £ = wind pressure coef. (1.1), wind speed (V_w), sail area (As).

- Powering
  Engine conventional is the prime mover of the vessel which works by converting the fuel energy to rotate the blades thereby producing sufficient thrust to resist ship resistance at certain service speeds. One of the most fundamental methods of power sharing in this conventional driving force is to distinguish between the effective power (*PE*) required to drive the ship and power delivered (PD) on the ship propulsion unit, [4].

The formulations used according to [4] are as follows:

Effective power (PE) = R_T x V_s (8)

Delivered power (PD) = PE/ Hd (9)

Quasi propulsive coefficient (ηD) = ηP. ηH. ηR (10)

Service power (Ps) = PD/ ηT

where: ηT is 0.98 with gearbox, 0.95 without gearbox

Installed power (*PI*) = Ps + Margin

Margins (*roughness, fouling, weather*) 15 – 20% depend ship route.

The concept of solar vessel energy conversion is converting solar energy into the driving force required by vessels through solar panels, batteries, electric motors, transmissions and propellers at a certain speed. In detail can be explained as follows: Solar panels function to capture solar energy and convert it into electrical energy, then stored in a battery. Power stored in the battery will be used to supply the electric motor and rotate the propeller. So that the vessels can move forward due to the thrust force produced by the propeller (*Tp*).

Since 2002 research on the technology of combined use of wind and solar power in the form of a Solar sail has been developed in the USA, (Her beck et al., 2002). Solar sail is made of thin Mylar or Kapton films with a thickness of 7.6 mm and has a broad density (defining the weight of the material divided by the area of material) about 11 g / m^2 as shown in Fig.7. The solar sail has 2 functions, namely: 1) As a propeller vessel, 2) As a system of Photovoltaic technology that converts sunlight into electrical energy. The existence of an efficient combination between the use of the sail and the solar panel if applied to the ship will be able to save the use of the deck of the ship.

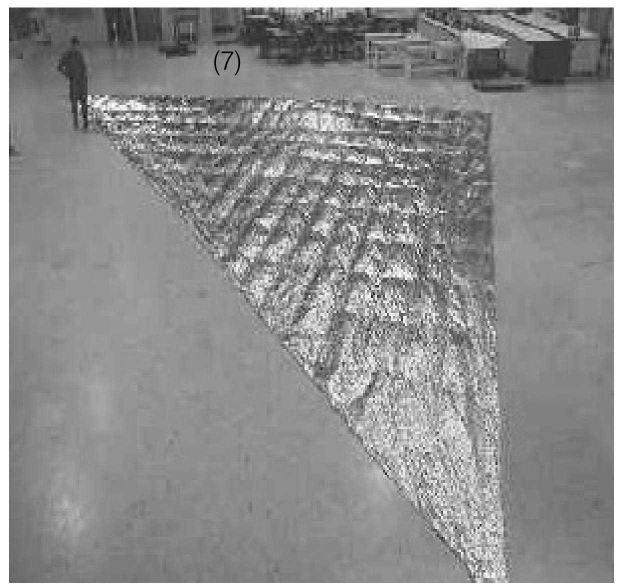

Figure 6: Solar sail NASA JPL Type

Besides functioning as a booster of vessel (in the form of sail), Solar Sail can also function as a solar panel that collects electrical energy and is very suitable to be applied as an environmentally friendly vessel. Sail is one of the propeller props without a propeller on the ship that can work due to the wind force (catch the wind) on the surface of the screen, resulting in a drifting force on the ship at a certain speed. The Sail is one of the propulsion devices on the ship. As with other propulsion devices such as propellers, the sail is attempted to produce an optimal thrust force, in order to produce maximum velocity of the ship. The forces on the Sailing Ship, as the ship moves due to the thrust of the propeller or sail there will be a lift that will lift the hull from the water. In addition, obstacles caused by the aerodynamic resistance of the sail are the forces acting on the sailboat, [5].

Determination of Sail Area almost as a comparison of sail area (As) with wetted surface area (WSA) is between 2.0 and 2.5. Comparison of sail area (As) with wetted surface area (WSA) known as sail ratio (SR), [6]. There is another way according to [7], where the determination of SR depends on the LWL of the ship by using the graph shown in Fig.7.

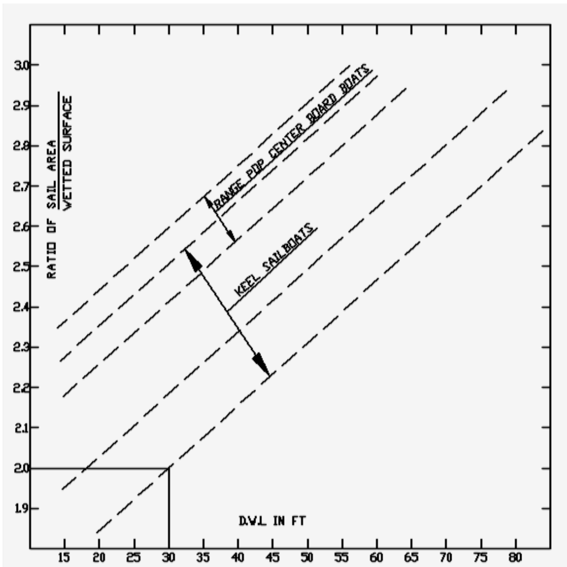

Figure 7: Graph of *SR* – *LWL* Relationship

Figure 8. shows graph of relation between SR with LWL which can be used to determine Sail Area with 15 - 80 feet or 5 - 25 m LWL limitation.

- Fishing Vessel
  In general, the normal voyage profile of fishing vessels according to [9], are as follows: a) The ship departs and operates in the port (Departure from port), b) The ship goes to the location of the fishing ground (Outward bound), c) The ship arrives at the location fishing ground and fishing (On fishing ground), d) When the ship leaves the location of the fishing ground to the port (Homeward bound :), e) when the ship arrives at the port and docked at the port (Arrival at Port).

In its operation a fishing vessel must be completely safe (very seaworthy indeed), in bad weather even the ship must work. All work on the fishing boat must be done quickly, starting from the process of catching until the processing of the catch is a function of time. The slow catching process causes the fish to run all (migration), while the sluggish processing of the catch causes the fish to be damaged, [1].

III. Material and Result

This research is a continuing research that has been done in [3]. All material data and information using the results of previous research to support scientific / academic and its application.

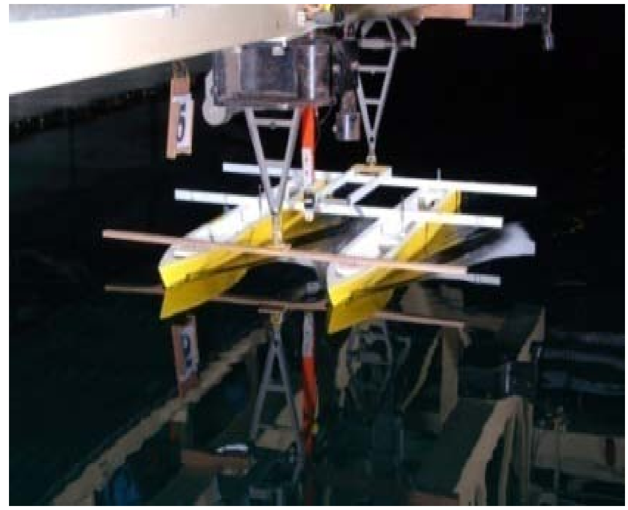

Figure 8: Towing Tank Experiment of Ship Resistance, [3]

Table 1: Dimension of Ship, [3]

Parameter	*Catamaran*	*Demihull*
LWL (m)	14.5	14.5
B (m)	7.118	1.318
H (m)	1.44	1.44
D (m)	0.694	0.694
C_B	0.434	0.434
Displ. (ton)	11.8	5.9

Figure 9. Demonstrate the Catamaran Hull Resistance Model Test through experiments in the hydrodynamic Tank, while Table 1 shows the ship dimension data as the model.

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- Test result:

Table 2: Result of Resistance Test, [3]

Run No.	V (knots)	Fr	Catamaran Resistances (kN)		
			S/L=0.2	S/L=0.3	S/L=0.4
1	5.788	0.250	1.821	1.659	1.659
2	6.218	0.268	2.141	1.851	2.061
3	6.677	0.288	2.443	2.239	2.348
4	7.051	0.304	2.852	2.678	2.947
5	7.560	0.326	3.460	3.568	3.547
6	8.032	0.347	4.467	3.954	3.766
7	8.384	0.362	4.844	4.345	4.341
8	8.818	0.380	5.149	4.790	4.662
9	9.233	0.398	5.807	5.592	5.515
10	9.813	0.423	7.101	6.448	6.138

Table 2 shows the experimental results of catamaran Resistance in towing tanks. Furthermore, from this data will be developed as a basis for designing the concept of catamaran fishing boat with a combination of engine-sail, [1], [8].

Powering calculation result: Effective power (PE) 32,435 kW, quasi-propulsive coefficient (ηD) 0.664, delivered power (PD) 50.21 kW, transmission losses (ηT) 0.98 without gearbox, service power (Ps) 51.235 kW and installed power (PI) of 60 kW with total efficiency (PE / PI) is 54%. Engine specifications used 2 x 43 hp or 2 x 30 kW as shown in Fig. 9.

The result of Sail Area determination: Boats with 14.5 m LWL (47.56 feet) obtained approximately 125 m^2. The calculation results of Thrust is obtained for 6.685 kN with thrust deduction factor (t) of 0.038. Propeller thrust (*Tp*) is achieved at the speed of the ship's service (*Vs*) of 9.8 knots while the thrust force (*Ts*) is reached at wind speed (*Vw*) of 19.2 knots. The results of the above calculation are then used to create *Hybrid Curve Charts* as shown in Figure 5. This curve can be used to calculate ESV efficiency.

Figure 9: The Layout of SSV

Fig.6 shows the arrangement of fish holds and area for crew activities on the main deck, The wider space area for fishing activities on main deck is the main concern for the commercial fishing industry now. The Data's of Solar sail Catamaran Fishing Vessel (SSCFV) is LWL=14.5m, B=7.118 m, H=1.44 m, T=0.694 m, Tonnage 15 GT, Fish hold 1.723 ton, Electric power 2 x 30 kW at 2800 rpm.

The relationship between propeller thrust (T_P), see Equation (3) and sail thrust (T_S), see Equation (7) is shown in Figure 11, namely T_P–T_S curve. Meanwhile, the relationship between wind speed (V_W) with the sail thrust (T_S) is shown in Figure 6, namely the V_W–T_S curve. Likewise, the relationship between ship service speed (V_S) and propeller thrust (T_P) is also shown in Figure 6, namely the V_S–T_P curve. The relationship between wind speed (V_W) and ship service speed (V_S) is called the V_W–V_S curve.

Table 3: The Hybrid System work at *Vs* 9.813 knots

Sail		Propeller		Prime mover
Vw (Knots)	*Ts (kN)*	*Tp (kN)*	*Electric motor Rpm*	
0.0	0	6.685	1700	Propeller
4.0	0.5	6.185	1550	Propeller-sail
8.0	1.2	5.485	1480	Propeller-sail
12.0	2.4	4.285	1300	Propeller-sail
16.0	5.4	1.285	1000	Propeller-sail
19.2	6.685	0	0	Sail

Table 4 shows the Hybrid System (ESV) work, the propeller and sail can work individually/separately or together as a hybrid system when the ship moves.

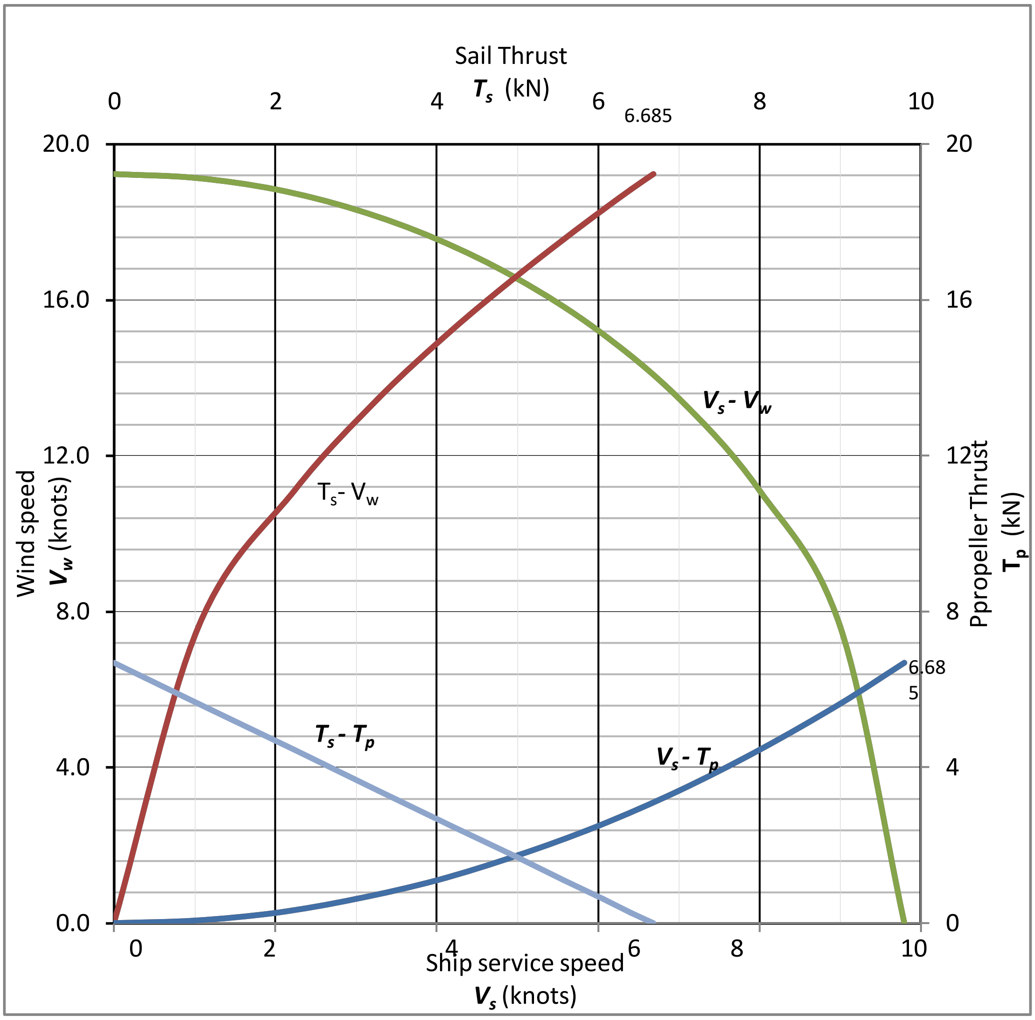

Figure 10: Hybrid Curve Chart, [1]

IV. Discussion

Service speed (Vs) on fishing boats is a major requirement because fishing vessels must arrive at the fishing ground as quickly as possible so as not to lose the right time to catch fish. This fishing vessel operates with service speed of around 9.8 knots. At this speed the ship will experience a drag force (RT) of 6,423 kN with the need for thrust (*T*) of 6,685 kN. To meet the needs of the thrust force is supplied from propeller propulsion (Tp) with a 2x30 kW electric motor and sail (Ts) with an area (As) 125 m^2.

V. Conclusion

Application of hybrid technology use a combination Solar-Sail has potency to save fuel usage until 90%. It is very useful when applied to catamaran fishing vessels and hence reduce emission of greenhouse gases. The present work apparently portraits of study into the development of more energy efficient and less polluted fishing vessel.

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