Resistance and Stability Analysis for Catamaran Fishing Vessel with Solar Cell in Calm Water

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Abstract. The use of solar cell as the moving force for the ship's tour seems to be an important theme in action to create a sea transportation that is environmentally friendly as contribution of the Energy Efficiency Design Index (EEDI) for the decrease of pollutant levels. The electrical energy produced by solar cell is not as much energy from fuels so that the solar energy powered ship that can only be followed with a limited range and speed. This type of multi hull design like catamaran that has two symmetrical hull which is possible to have an more expansive main deck, small boat boundaries and good stability. The ship deck shape is going to contribute the extension of solar panels that can be used as a generator of power needed at the time of calculation of powering the ship. The analysis of the stability of the ship carried out numerically bu using references from the IMO regulations which require minimum value stability arm at certain angles. Load cases are definitely varied in 2 (two) conditions and compared in full and light load. The goal of this research is catamaran fishing vessel that have battery, solar panel, electric motor and all of supporting solar energy moving with speed 5 knots.

1 Introduction

By the topic of efficient energy uses, the world of shipbuilding is currently vying to conduct more studies on the ship design which is believed to have a small resistance compared with monohull [1]. One of the conceptual design is a type of catamaran which is often used by passenger ship for example as a tourism vessel in the area Sarangan, Bedugul Lake and other water attractions with calm water conditions. As shown in Figure 1, the environmental conditions in the unspoiled tourist spot that needs to be kept preservation of natural way in order to reduce or eliminate air pollution occurred. International Maritime Organization (IMO) has published some of regulations on the limitation of air pollutants produced by a ship called the Energy Efficiency Design Index (EEDI).

All ship types which is either single or double hull have a good stability if only metacenter point is above the center of gravity [2]. However, if the righting arm of stability is smaller or even negative, then the ship will not have a reserve moment so that the ship will be sink.

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Therefore, IMO regulations already require the magnitude of arms that have to be had a ship so that safety and comfortable of passenger can be secured [3].

In calm wates, the determination within demihull on the small vessel appeared to have a significant effect on the total resistance of ship. The volume of the submerged hull on the catamaran and single hull is assumed in the same weight. One of the factors that affect the ship weight is the material used where Fiber Reinforced Plastics (FRP) have lightweight material and is suitable for vessel moving in the low speed [4]. The use of a catamaran hull for tourist ships can increase speed by 30% of the speed of the single hull ships. It certainly would have an effect on driving energy use [5].

Fig. 1. Sarangan Lake.

Energy obtained from fuel had started to be decreased by considering the pollution aspect. Natural resources cannot be upgraded so that it is necessary to look for the environmentally friendly renewable energy [6]. A small passenger vessel using solar panels as an energy for propulsion can be seen in Figure 2.

Although the ship dynamics is not considered later on, the ship design have to be analyzed the fluid structure interaction. It means that the shear force and bending moment caused by still water condition can influence the dimension of stiffener and thickness of ship structure [7].

Fig. 2. Catamaran vessel with solar cell energy.

The popular types of ship hull, for example usually monohull and catamaran, have been proven to provide some of advantages in the sea transportation. For the ship that needs more space or area in main deck as payload but the displacement of ship is small precisely, the design of catamaran vessel can be used to be applied for the ship design. The study of symmetrical and asymmetrical of catamaran vessel had been described that the magnitude of resistance does not significantly affect in the low speed ship. For the high speed ship, the effect of fluid interference along hulls does relatively affect the magnitude of total resistance. If it is reviewed in aspect of the ship draft, the symmetrical hull draft is smaller than the asymmetrical hull [8].

2 Theory

This research is generally carried out by using numerical method for the stability and resistance analysis. This vessel has solar panel, battery, electric motor, and propulsion system which support for the sustainable energy. The source of energy comes from the solar energy that is converted to be electric energy to rotate the propeller.

2.1 Catamaran Vessel Model

Catamaran vessel have 2 (two) hull types which are symmetrically or asymmetrically. In this research, the ship model uses catamaran symmetrically type because from the previous research, this model give some advantages in aspect of stability and resistance.

2.2 Stability Calculation Analysis

Intact stability calculation is carried out to make sure the evidence that the ship is safe in seaworthiness condition [9]. The calculation of righting arm which is used as parameter of stability does produce a metacenter point. In order to obtain this result, the Krylov I provides the equation to calculate it. The length of righting arm (GZ) could be used to check whether the ship stability is accepted or rejected which it is definitely regulated in the Intact Stability Code, IMO Regulation A. 749 (18).

2.3 Resistance Calculation

Because ship moves in low speed, the van oortmerssen calculation for ship resistance can be used. The ship speeds are varied in 0, 1, 2, 3, 4, and 5 knots. The Van Oortmerssen formula is usually used by condition the ship resistance in low speed. Beside it, the total resistance of ship could be calculated by using Holtrop and Mennen equation. This method can be divided in viscous and wave making resistance consideration. The Holtrop and Mennen equation is generally used to calculate the ship resistance in any ship type and speed.

Two methods are used to verify the total resistance of ship obtained from those methods. The magnitude of resistance could be used to estimate the magnitude of main engine power of ship which the efficiency of shaft propeller is neglected because of the simply of propulsion system . So that the Effective Horse Power (EHP) obtained from multiplication between resistance and ship speed is same as the Break Horse Power (BHP).

3 Result and Discussion

The catamaran vessel worked in this research have main dimension as follow:

Length of Water Line (LWL)	= 4.35 m
Breadth (B)	= 2.55 m
Draft (T) at full load	= 0.45 m
Freeboard (Fb)	= 0.35 m
Depth (H)	= 0.85 m
Capacity of Passenger	= 8 persons

The location of solar panel is put above the catamaran fishing vessel because it considers the absorb of solar energy. Figure 3 shows the catamaran fishing vessel for this research.

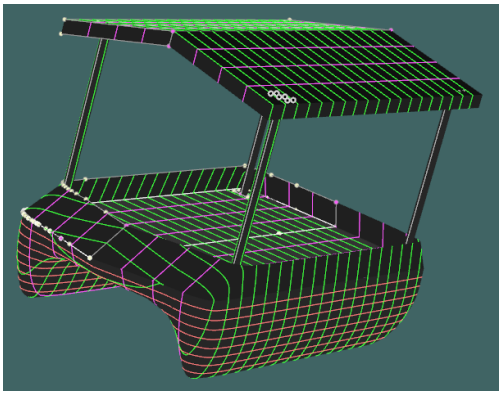

Fig. 3. Surface view of catamaran vessel using solar panel.

3.1 Intact Stability Analysis

Intact stability can be approached by the length of metacenter to gravity (MG) because this length is always affected the reserve moment of ship when the ship is in heel condition. Figure 4 shows graph of statics stability of this catamaran fishing vessel. At the initial position with heel 0 degree, the GZ length is zero. At the moment where heel is about 40 degrees, the GZ length is in the maximum value of 0.35 m and the empty condition is provided such result.

Figure 5 shows the graph of GZ curve for full load condition. The GZ maximum is occurred in the heel angle about 33 degrees. After 33 degrees, the GZ length decreases significantly to zero value. This is exactly critical point where the ship stability changes to be an unstable condition and it is very dangerous.

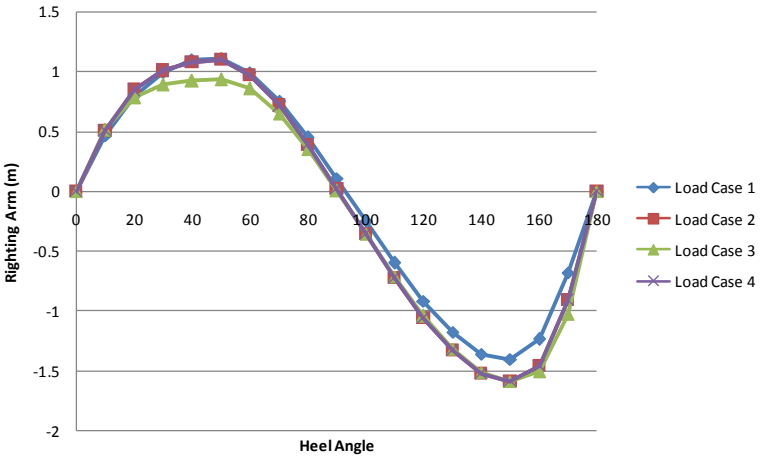

Fig. 4. The GZ curve at no passenger condition.

This condition can cause the ship capsize. Because this catamaran fishing vessel does not sail in the wave water condition, the ship capsize caused by wave is impossible occurred. The possibility of ship sinking is caused by the position or distribution of passenger focused on the one side of ship. Table 1 shows that the ship stability analysis of two load cases. The load cases consists of no passenger (LC1) and full passengers (LC2). From the result, each of parameter has accepted criteria for each load cases. If there is a parameter that is not fulfills

the IMO regulation, the criteria would be definitelyrejected because it means that the catamaran fishing vessel would be fail.

Table 1. The ship stability analysis based on the load cases compared by IMO criteria.

Parameter	LC1	LC 2	IMO	Criteria
$e_{0.30}o$	0.21	0.63	≥ 0.055	Accepted
$e_{0.40}o$	0.28	0.83	≥ 0.09	Accepted
$e_{30,40}o$	0.07	0.20	≥ 0.03	Accepted
$h_{30}o$	0.40	1.20	≥ 0.2	Accepted
ϕmax	30^0	33^0	≥ 25^0	Accepted
GM_0	1.26	4.20	≥ 0.15	Accepted

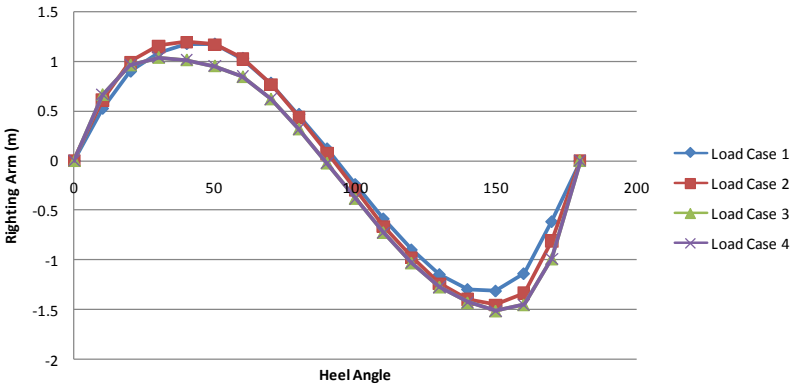

Fig. 5. The GZ curve at full load condition.

3.2 Resistance Analysis

There are some methods for calculating the catamaran fishing vessel resistance. One of method for calculating the resistance is Van Oortmerssen Method. This method is suitable for small displacement ships especially for catamaran fishing vessel which have involved the main resistance components such as viscous resistance and wave making resistance. This method is like as Holtrop Method. The result of two methods is compared to show that the pattern of graph is relatively same and ensure that the methods is recommended to be used. The greater resistance is occurred in the faster of ship speed. The maximum of total resistance of catamaran fishing vessel is about 1.8 kN in ship speed 5 knots.

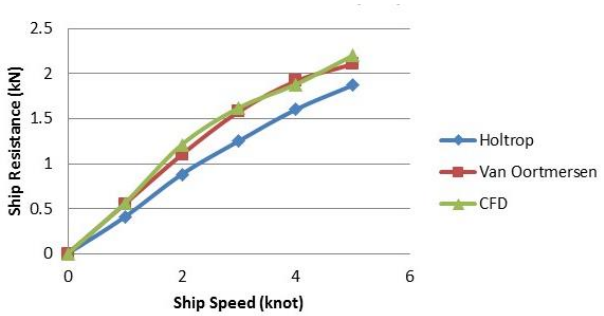

Fig. 6. Total resistance in various of speed at catamaran vessel.

Need main engine power depends on the total resistance of ship. For the total resistance is 1.5 kN, the main engine power needed for ship speed 5 knots is 3.75 kW. The specification of main engine is by using the electric motor because the power is produced from solar energy. The magnitude of electric motor power is 2000 Watt so that is needed two electric motors precisely.

4 Conclusion

The conclusions of this research can be concluded as follows:

1. The positions of metacenter that indicate the stability of ship is still located above gravity point either the full load condition or the empty condition. The maximum GZ at full load condition is about 1.2 m and one at empty load condition is about 0.4 m;
2. The vessel can be operated because electric motor power is greater than resistance. From the result and discussion, the resistance is about 2.043 kN in maximum speed, but the electric motor is about 2000 Watt;

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