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Stability and Power Resistance of a Multi-hull Tourism Boat

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ABSTRACT

This study is to analyse the stability and power resistance of a multihull of the catamaran variant tourism boat. Tourism boat has a design that can accommodate a number of passenger and cargo, and travel at a desired speed. A multihull type boat can improve the intended stability characteristic for the safety of the passengers and also the powering of the boat for economic considerations. This study was conducted using a 12-meter catamaran hull form with three different loading conditions, (i) boat only displacement, (ii) boat with half capacity passengers and (iii) boat with full capacity passengers. This study aims to find the total resistance value of the boat to obtain the power needed for the boat to move at certain speed that is suitable for tourism. The hull form was also analysed for its stability with three different loading conditions. The result showed that the boat at 12 knots had a resistance of 15.633 kN needing more than 130 kW to operate at the given speed with the usable maximum resistance of 18.935 kN at speed of 19 knots. The stability of the boat while operating was evaluated by comparing the results obtained by International Maritime Organization (IMO) criteria in A.749(18) and MSC.36(63). Based on the analysis, it was concluded that the maximum GZ that the boat can handle was 1.58 m at an angle of 25 degree with full loading parameter which met all the established standard.

Keywords: Stability, Power Resistance, Multihull boat, Catamaran, Safety

Nomenclature

EP	Effective Power (kW)
GZ	Righting lever (m)
Rt	Total Resistance (kN)
Vs	Vessel Speed (m/s)
Δ	Displacement (tonnes)

Abbreviations

CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
FEA	Finite Element Analysis
IMO	International Maritime Organization

1.0 INTRODUCTION

Nautical tourism is a tourism that combines sailing and boating with vacation and holiday activities. A tourism boat, which is one of the vehicles used in nautical tourism, must be safe and efficient to ensure the safety of the passengers and to be as cost effective for the owners. The comfort and safety of a vehicle or mode of transportation are determined by the ride quality or quality during the journey. Multihull vessels have gotten a lot of attention in the last thirty years because of their use as passenger ships, sports craft, and oceanographic research vessels [1]. Multihulls vessels have the advantage of providing lower drag [1] and are fast expanding to meet the demand for increased cargo capacity while consuming less fuel [2].

Resistance occurs when a ship is moving through a water medium at a given speed. Several factors influence a vessels' resistance, including the wet surface area, the ship's speed, and the fluid type [3]. The vessel resistance will increase as the Froude number climbs [4]. Ship resistance is described as a force that opposes the movement of a ship. Direct contact between the hullship and the fluid causes this force [5].

A ship's safety depends on its stability [3]. The capacity of a ship to recover to its former position after being tipped by external and internal factors which is referred to as stability. To ensure that the ship is safe and

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seaworthy, a comprehensive stability calculation is conducted. The length of the righting arm (GZ) can be used to assess the ship's stability [6]. The minimum value necessary for maximum GZ angle protects the boat from capsizing when floating on a steep wave [7].

Numerous studies have been carried out in finding the stability and resistance of numerous hull designs including multihull for different uses using different approaches. Ma and Sun [8] studied the resistance and seakeeping performance of a trimaran planning hull model conducted on a towing tank. Yanuar [2] conducted a hull resistance analysis of a pentamaran ship hull model and used the same towing tank test method. Windyandari and Yusim [9] studied the resistance and intact stability of an axe bow hull form conducted on marine CFD software. Ridwan [5] Medakovic [10] and Putranto [6] studied the resistance of catamaran hulled vessel through the simulation of naval architecture analysis software and Computational Fluid Dynamics (CFD) software to determine the resistance of the hull.

Catamaran boat is a variant of a multihull that is an alternative to tourism boat models that can utilize different types of seating arrangement and hold many more passengers and cargo. In terms of resistance and stability, a catamaran boat has numerous benefits over a typical single hull tourism boat. The goal of this study is to show a catamaran boat's resistance as well as its stability with different boat loadings required by IMO A.749(18) [11] and MSC.36 (63) [12].

2.0 METHODOLOGY

Multiple multihull boats as shown in Figure 1 were chosen as reference boats for this study. The design and specification of the boat reference are combined and used to design the catamaran in this study.

Figure 1. Multihull Boat Examples

Note that boats designed for this study have only its hull which excluded the shape of the roof and seats design. The principal dimensions of the boats are given in Table 1 with its 3D view shown in Figure 2.

Table 1. Main Dimension of Catamaran Boat

No.	Item	Size	Unit
1	Length Overall	12	m
2	Length at Waterline	11.9	m
3	Maximum Breadth	5	m
4	Breadth at Waterline	5	m
5	Draught	0.8	m
6	Δ (Displacement)	14.5	tonnes

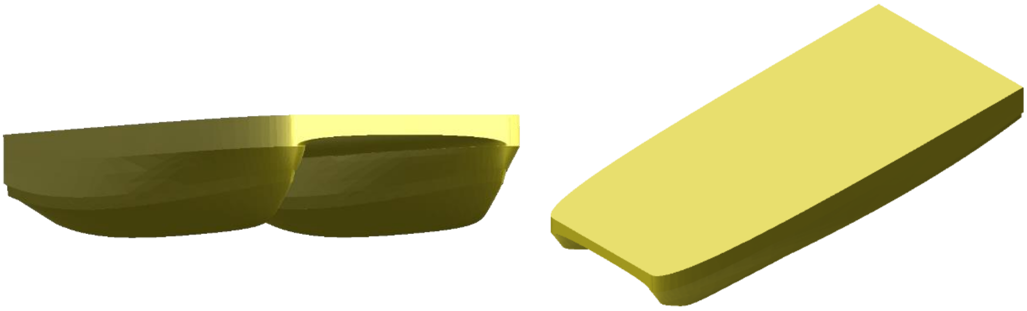

Figure 2. *Catamaran Boat Design 3D Isometric View of Different Angles.*

The catamaran boat design was modelled using a combination of boat modeler and CAD software, FreeShip and SolidWorks respectively. Resistance, stability, and seakeeping performance were all assessed using naval architect software, PolyCAD and then confirmed using IMO A.749(18) and MSC.36(63) for stability. Stability of the boat was tested with 3 different boat displacements to represent 3 different conditions of boat loadings as elaborated in Table 2.

Table 2. *Stability Parameters*

No.	Condition	Displacement (tonnes)
1	Boat only	14.5
2	Boat with Half Passengers (20 Person)	16.35
3	Boat with Full Passengers (40 Person)	18

The methodology flowchart of the project is shown in Figure 3.

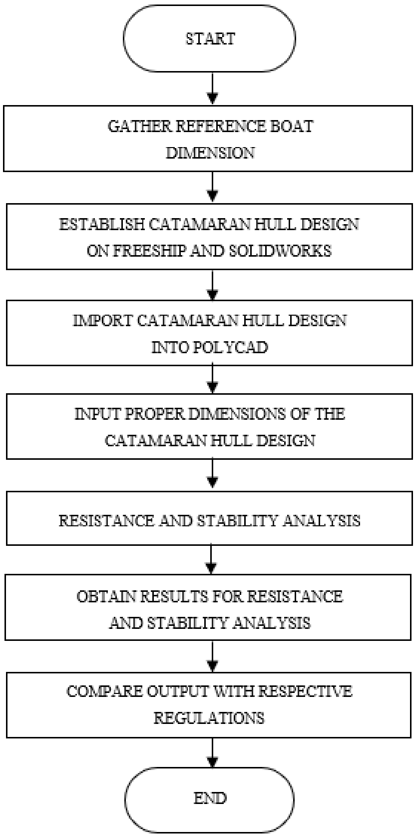

Figure 3. *Methodology Flowchart*

3.0 RESULTS AND DISCUSSION

3.1 Total Resistance

Ship resistance can be defined as a force that works against ship movements. This force is caused by direct contact between the hull ship and the fluid [5].

The total resistance value of the analysis can be seen in Table 3. This value is the total resistance in the actual size of the catamaran boat based on the resistance calculation of Molland series formula using excel. Molland et al. [13] summarized a calm water resistance investigation into high speed semi-displacement catamarans, with symmetrical hull forms based on experimental work carried out at the University of Southampton. The result of the resistance analysis is shown in Table 3.

Table 3. *Catamaran Hull Design Resistance Results*

No.	Speed [Knots]	Speed [m/s]	R Total [kN]
1	5	2.572	0.804
2	6	3.087	1.441
3	7	3.601	2.598
4	8	4.116	4.372
5	9	4.630	7.698
6	10	5.144	11.065
7	11	5.659	13.892
8	12	6.173	15.633
9	13	6.688	16.257
10	14	7.202	16.125
11	15	7.717	16.157
12	16	8.231	16.219
13	17	8.746	17.156
14	18	9.260	17.976
15	19	9.774	18.935
16	20	10.289	19.942

From Table 3, the total resistance of the catamaran hull at average cruising speed of 12 knots is 15.633 kN. This design has a usable max resistance of 18.935 kN at the speed of 19 knots. To determine the amount of power required to propel the catamaran hull at its average cruising speed, an effective power equation (1) is used.

$$EP = Rt \times Vs \qquad \text{(kW)} \qquad (1)$$

Where *Rt* is the total resistance (kN) and *Vs* is the vessel speed (m/s).

From equation (1), to propel the catamaran hull at the speed of 12 knots, the hull will need a power of 128.68 kW. An engine of more than 130 kW is preferred to power this hull design.

3.2 Ship Stability

This study used the Large Angle Stability Analysis method available in PolyCAD software, which allowed the stability curve or righting lever (GZ) curve for a range of particular angles to be calculated and the vessels' stability to be assessed against the IMO stability requirements. The positive range of righting levers is the parameter from this curve (GZ). The defined areas beneath the GZ curve represent the amount of energy required to heel the ship from an upright position or a 30° initial heel [7]. The IMO stability criteria used to assess the stability are GZ maximum values and their corresponding angles, initial metacentric height, and other parameters.

The stability analysis was carried out with the 3 conditions from Table 2, namely (1) the condition of the boat with no passengers; (2) the condition of the ship with half capacity of the passengers which is 20 people; and (3) the condition of the ship with full capacity of passengers which is 40 people. The result of the stability analysis can be seen in Figure 4, Table 6 and Table 7 in the form of GZ curves and area under the curve from the 3 (three) conditions and stability criteria according to IMO A.749(18) and MSC.36(63) in Table 4 and Table 5 respectively. A visual representation to the GZ curves graph is shown in Figure 5.

Table 4. *Stability Criteria in IMO A.749 (18) [10]*

No.	Criteria	Value
1	Area under the GZ curve up to 30° heel angle	≥0.055 m.rad
2	Area under the GZ curve up to 40° heel angle	≥0.09 m.rad
3	Area under the GZ curve at 30° to 40° heel angle	≥0.03 m.rad
4	The GZ at 30° and greater heel angle	≥0.20 m
5	Maximum GZ	≥25°
6	Initial Metacentric Height, GMo	≥0.15 m

Table 5. *Stability Criteria in IMO MSC. 36 (63) [11]*

No.	Criteria	Value
1	Area under the GZ curve at 0° - 30°	≥0.055 m.rad
2	Maximum GZ	≥10°

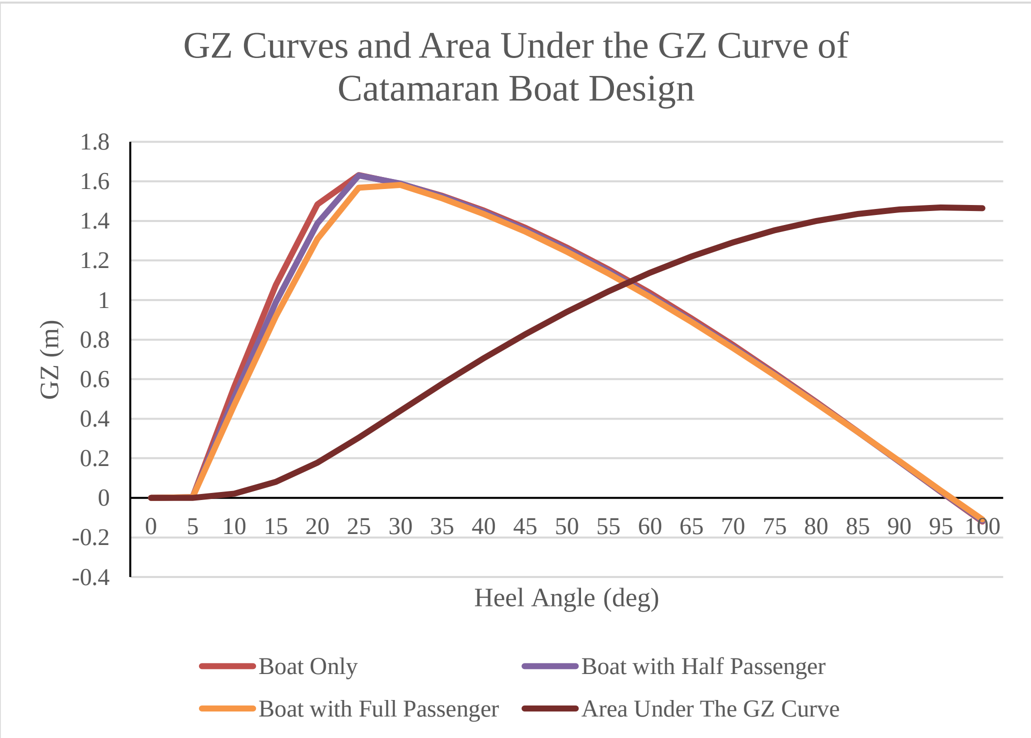

Figure 4. *GZ Curve of Catamaran Hull Design*

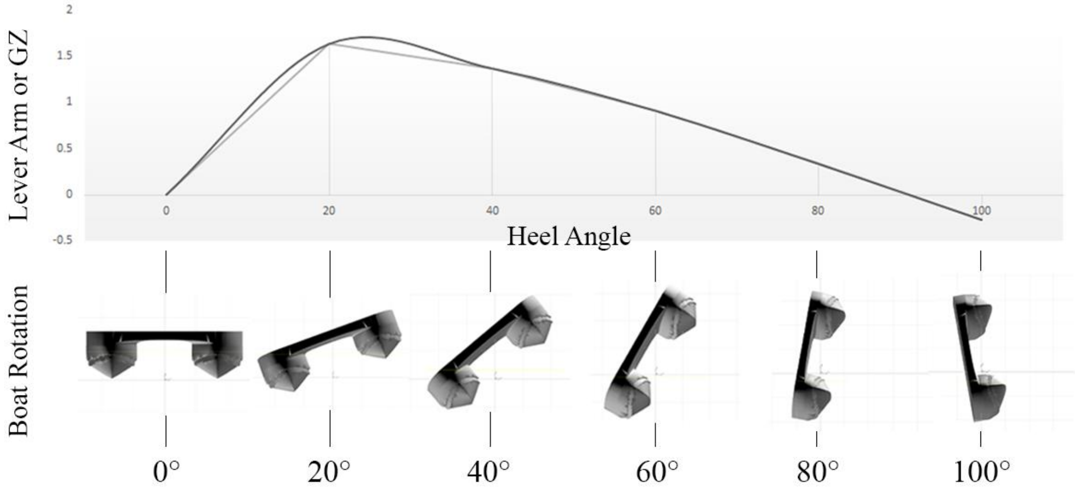

Figure 5. *Visual Representation of Boat Rotation Relative to the GZ Curve*

Table 6. *Stability Results and IMO A.749 (18) Criteria of Catamaran Hull Design*

No.	IMO A.749 (18)	Value	Loading Condition			Result
			Boat only	Boat with Half Passengers (20 Person)	Boat with Full Passengers (40 Person)	
1	Area under the GZ curve up to 30° heel angle	≥0.055 m.rad	0.484 m.rad	0.464 m.rad	0.441 m.rad	Pass
2	Area under the GZ curve up to 40° heel angle	≥0.09 m.rad	0.750 m.rad	0.730 m.rad	0.705 m.rad	Pass
3	Area under the GZ curve at 30° to 40° heel angle	≥0.03 m.rad	0.620 m.rad	0.600 m.rad	0.576 m.rad	Pass
4	The GZ at 30° and greater heel angle	≥0.20 m	1.587 m	1.589 m	1.582 m	Pass
5	Maximum GZ	≥25°	25°	25°	25°	Pass
6	Initial Metacentric Height, GMo	≥0.15 m	6.436 m	5.798 m	5.336 m	Pass

Table 7. *Stability Results and IMO MSC.36 (63) Criteria of Catamaran Hull Design*

No.	**IMO MSC.36 (63)**	**Value**	**Loading Condition**			**Result**
			Boat only	Boat with Half Passengers (20 Person)	Boat with Full Passengers (40 Person)	
1	0° - 30° of area under curve	>0.055 m.rad	0.484 m.rad	0.464 m.rad	0.441 m.rad	Pass
2	Angle of Max. GZ	>10°	25°	25°	25°	Pass

All conditions of the catamaran hull design met the IMO A.749(18) and MSC.36 (63) criteria. The hull design fulfilled all the criteria limits for each loading condition and was stable and safe to operate in all loading conditions.

4.0 CONCLUSION

Based on the results of the resistance and stability analysis towards the catamaran hull design, it is concluded that the hull design has a total resistance of 15.633 kN at average tourist boat cruising speed of 12 knots and a power of at least 130 kW is needed to power this hull design. The maximum resistance that this hull design can be subjected is 18.935 kN at a speed of 19 knots. The catamaran hull design in each loading condition of the boat meets the stability criteria of IMO A.749(18) and MSC.36 (63) for a multihull vessel. This catamaran hull design is safe to operate and carry tourist with its efficient powering.

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