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Design and Modeling of Catamaran Flat Plate Ship with Bottom Glass Concept to Improve Tourism Underwater in Bangsring Banyuwangi

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Abstract

Bangsring is underwater tourism which is one of the favorite destinations in Banyuwangi Regency. Unfortunately, the underwater charm of Bangsring Underwater can only access by diving and snorkeling, which is considered quite inconvenient and tiring for some tourists. So, the concept of bottom-glass in this design is offered as a problem-solving in this paper. The concept of flat plate and flat-bottom is carried out to the time efficiency and cost-efficiency of shipbuilding because the concept of the flat plate is no need for rolling and other material bending processes. The design of the main dimensions is made based on owner requirements, were obtained based on field study and referring to the research Optimum Hull Spacing of a Family of Multihulls. The research showed optimum spacing between hulls of 6.293 m, from LOA = 19.1 m and breadth each hull = 1.47 m. Then, a scaling of 1.592 is carried out, to get the size that suits the needs. Then, the main dimensions for this paper are LOA = 12 m, total B = 5.6 m, breadth each hull = 0.94 m, hull spacing = 3.72 m, T = 0.7 m, H = 1.85 m, Vs = 10 knots. In order to get the lowest ship resistance, 4 ship models were designed with these primary parameters. Based on the resistance analysis, model 4 with a maximum resistance of 4.3 kN was chosen, which tend to be more effective than model 1, model 2, and model 3, which have a maximum resistance of 8 4.9 kN and 5.3 kN. Stability analysis was carried out with load cases of 100%, 80%, 60%, 40%, and 20%. Based on the analysis results, it is shown that the stability analysis that has been carried out has fulfilled all the stability requirements of IMO MSC.36 (63) for HSC multihull Annex 7.

1. Introduction

Bangsring Underwater is a beach located in Krajan Hamlet, Bangsring Village, Wongsorejo District, and Banyuwangi. The main destination of Bangsring beach is the beauty of the beach and underwater, which makes it one of the leading tourist destinations in Banyuwangi Regency, with a total of 1.140.341 visitors in 2015-2017 [1].

However, based on the author's observations and previous research, it is discovered that Bangsring tourism had problems in the aspects of infrastructure to support its tourism activities [2]. To enjoy the beauty of the Bangsring Underwater can exclusively be done by diving or snorkeling. That method is quite troublesome and exhausting, especially for tourists who want to enjoy and look at entertainment more simply. Besides that, snorkeling and diving require a license from an authorized institution to do so. So this problem reduces the interest of travelers to visit this place.

This paper will focus on overcoming the problem above that, "There is no transport mode that can provide services to see the beauty of the underwater in Bangsring without having to dive or snorkel." So the concept of bottom-glass is offered as a problem solution in this paper. The catamaran was chosen because it has a very slim hull waterline to obtain low resistance [3] and has a wider deck compared to the monohull type, making it suitable for this design. The concept of flat plate and flat-bottom is carried out to efficiently time and cost of shipbuilding because, with this flat plate concept, there is no rolling and other material bending process [4]. The study of the catamaran has been conducted for traditional fishing vessels [5,6]. The study of catamaran hull form has been carried out both experimentally and numerically in the past, and it was showed catamaran has benefited both structural and hydrodynamics [7]

Catamaran hull forms have many models, but generally, there are three standard forms of a catamaran, three standard forms of catamaran hull as shown in Figure 1, namely: 1) Asymmetrical with a flat outside. 2) Symmetrical. 3) Asymmetrical with flat insides [8]. The study of catamaran hull form has been carried out.

The purpose of selecting this hull type is to determine the ship's resistance when maneuvering, significantly affecting the comfort and power requirements when operating at sea. Which is owned by the type asymmetrical with flat insides is greater than the asymmetric hull type [9]. Moreover, the symmetrical type was chosen in this design. Therefore, with this design, it is expected to be able to produce a catamaran ship design with a bottom glass concept that can be used to support tourism activities in Bangsring by providing facilities to be able to see the underwater beauty without the need for snorkeling or diving and produce a safe tourist boat design, convenient and efficient in the production process.

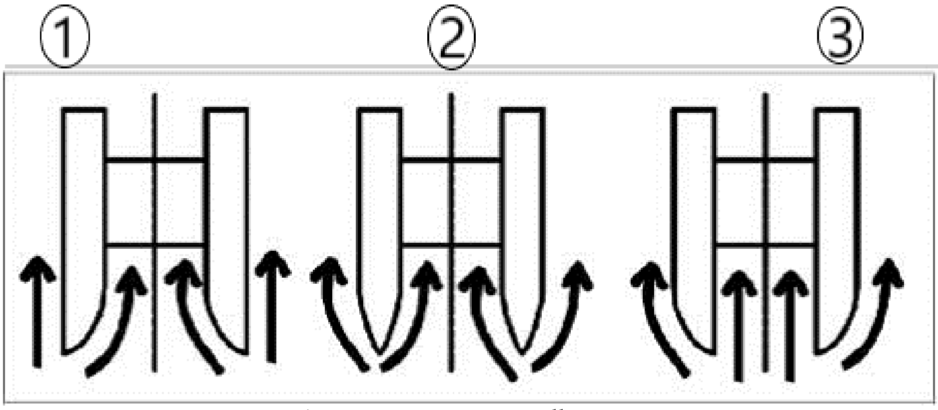

Figure 1. Catamaran Hull Form

2. Methods

2.1. Field Study and Study of Literature

In this study, a literature review has been conducted. The source is taken through scientific papers such as books, journals, thesis, and the internet, which is related and can support completing the ship's research and design. A field study is intended to be carried out by surveying and identifying technical matters in the field related to the research [10], which was held on the Bangsring beach, Banyuwangi.

2.2. Conceptual Design

The conceptual design represents the design of the ship design concept, which is carried out after the owner requirements stage is completed. One part of the conceptual design is the mission requirements and design modeling, which the author uses with the help of Maxsurf software. There are four main parameters behind the conceptual design, namely as follows [11]:

1. Transport Capacity

Transport capacity is ship deadweight, cargo capacity, the number of containers that can be carried, or if on a tourism ship, it is the type of ship and the capacity of the ship's passengers and crew that can be accommodated.

2. Speed in Trial Condition

The speed in the trial condition is 100% maximum continuous rating (MCR) of the ship's power which we routinely call BHP MCR.

3. Range or Endurance

Range or endurance represents the distance of the voyage (which usually uses nautical miles) that can be covered by the ship without refilling (fuel) for a specific route at the speed of service speed.

4. Class

This class is a classification that will be used routinely to be recognized on an international scale or recognized by the classification society.

In this conceptual design stage, 4 ship models will be designed with the same variables obtained from the owner and mission requirements implemented by the Maxsurf Modeller software. The resistance analysis will be analyzed using the Holtrop Method on Maxsurf Resistance software in order to obtain the most efficient model that will be used in the subsequent design.

2.3. Preliminary Design

After obtaining the best design, the second stage in the design process is the preliminary design. Preliminary design is the initial design stage that is carried out after the conceptual design. The part of the preliminary design is the lines plan, hydrostatic, bonjean, and general arrangement.

2.4. Advance Analysis on Ship Design

Advance analysis on ship design here is an analysis of the stability of the ship. It was performed using Maxsurf Stability software. The stability standard uses regulations from the International Maritime Organization (2008) [12], on the international code on intact stability in – chapter 5B criteria – alternative comprehensive criteria of general application to catamarans as follows:

1. The area from 0 to 30

The area (A1) under the righting lever (G_FZ) curves up to an angle θ shall be at least:

$$A_1 = 3.15\frac{30^O}{\theta} \quad (1)$$

Where A_1 is the area under the righting lever (G_FZ) curve, in meter degrees. θ is the least angle, in degrees, of the following: a) The down flooding angle ϑ_f in degrees. b) The angle θ at which maximum G_FZ occurs in degrees. c) 30 degrees.

2. The angle of maximum GZ

The angle of maximum righting lever ϑ_{max} shall occur at an angle of heel not less than 10 degrees.

3. Wind heeling (Hw)

a) The angle of heel θ_h shall not exceed θ_s degrees when any of the individual heeling moments due to person crowding, wind, or turn is applied. b) The resultant angle of heel θ_h shall not be greater than 16 degrees.

4. The area between GZ and HA

The effect of rolling in a seaway upon the vessel's stability shall be demonstrated mathematically (this can be done using software such as Maxsurf Stability, Hydromax). The residual area under the righting lever G_FZ curve $A_{1,}$ between the angle of the heel (ϑ_h) and the angle of roll (ϑ_r) shall be at least 1.61 meter-degrees.

3. Results and Discussion

The results obtained from field surveys and discussions with Bangsring beach tourism managers, for ship's design requirements are as follows: the distance of Bangsring beach voyage to the Tabuhan island is 2.21 Nautical miles, tour package maximum 10 people, the average sea wave is sea state 2-3 with a maximum wave height of 1.25 meters, the number of crew is three people.

3.1. Conceptual Design

Once the data owner requirements have been obtained, the ship's main dimensions were sketched, referring to the research [13], which obtains optimum spacing between hulls of 6.293 m and an overall length of 19.1 m, with the two hulls that have a beam1.47 m. To achieve the main dimensions of the design with the specifical reference for the length of 12 meters, as a result, LoA is divided by 12 = 1.591667, which completely gets a scale factor of 1.591667. In most cases, the difference in the obtained scale model compared to the original model using this scaling on all factors starts at around 10-20% [14]. After scaling and adjustments, the primary dimensions of the design ship were obtained in Table 1:

Table 1. Principal Dimension

Principal Dimension	Value
Length of all	12 meters
b' (Breadth for each hull)	0.94 meters
B (Breadth of all)	5.6 meters
Hull Spacing	3.72 meters
H (Height)	1.85 meters
Vs (Service speed)	10 knot

To maximize the design of the ship, an analysis of the rear shape of the ship was carried out by making 4 different models using the same parameters referring to Table 1. The four models represent as follows: a. Model 1 (Form the back of the transom ship parallel to midship), b. model 2 (The shape of the back of the transom ship is not parallel to the midship), c. model 3 (transom with a width of 100 mm), d. model 4 (transom with a width of 150 mm), as in the following Figure 2.

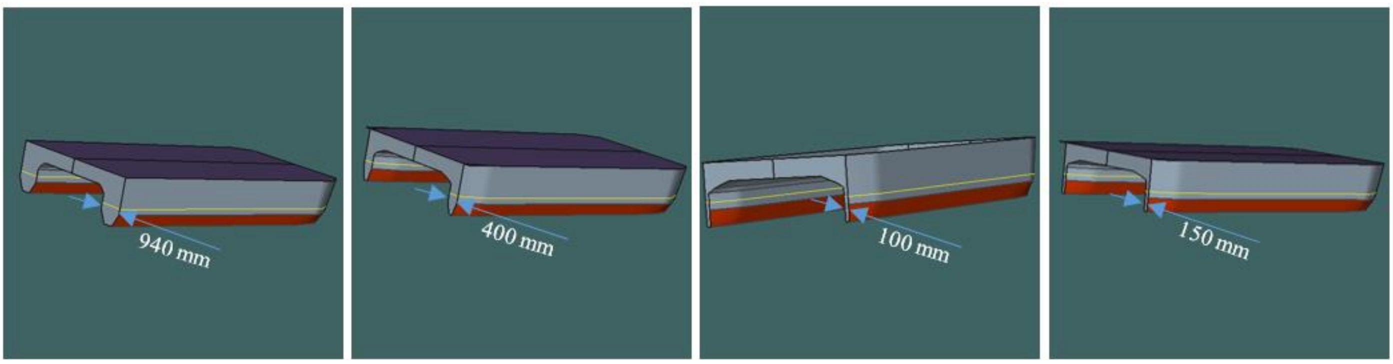

Figure 2. Ships Model 1-4 (from left to right)

3.2. Resistance Analysis

An understanding of ship resistance components and their behavior is important. Because of these components are used in scaling the resistance of one ship to another size or in other words: it can perform resistance analysis from testing at model size to its original size [15]. After the ship modeling is completed, the next stage is to analyze the resistance on each hull model using Holtrop Method on Maxsurf software. In accordance with the owner requirements that have been determined, Calculation with the speed of 10 knots and Fr 0.48 is carried out, then the results of the resistance analysis shows in the Figure 3.

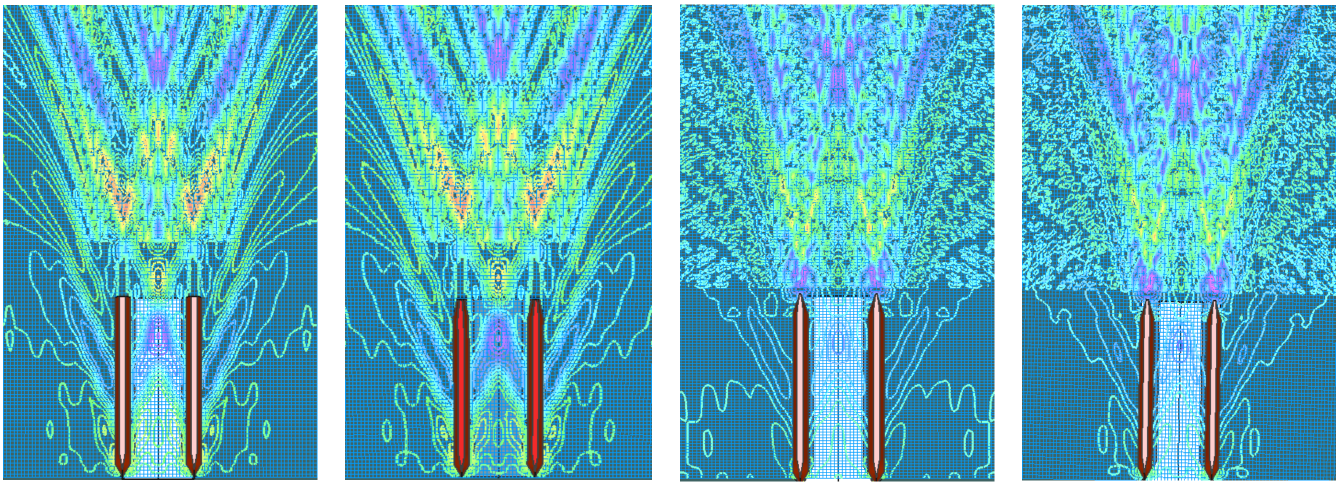

Figure 3. Resistance Analysis for Ship Models 1-4 (from left to right)

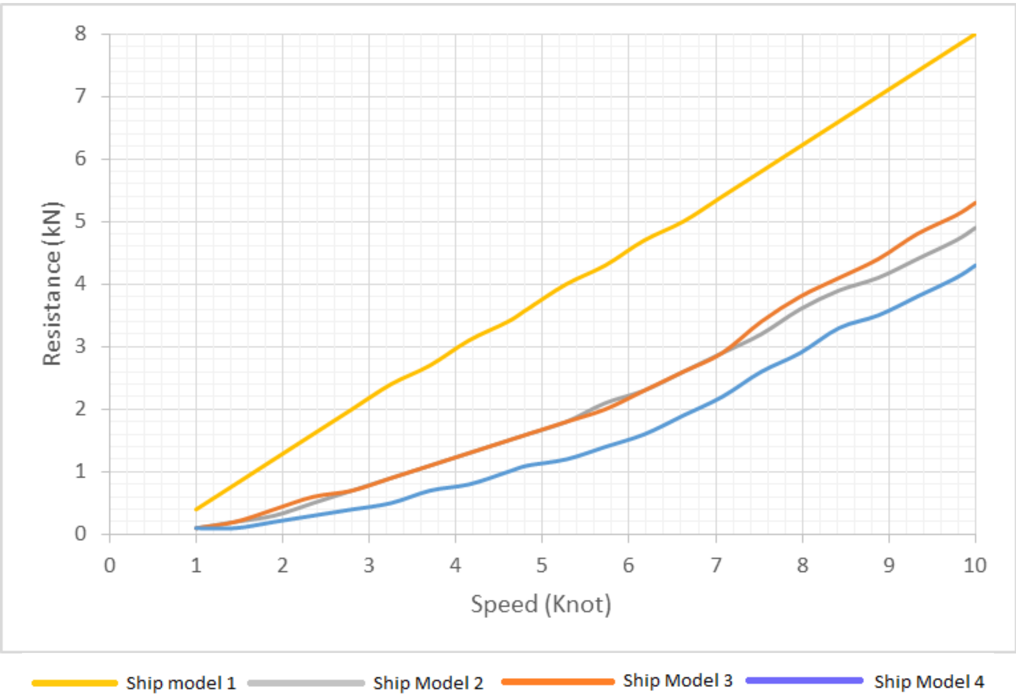

Figure 4. Resistance vs Speed Comparison Graph of 1-4 Models

Table 2. Total Resistance of Each Model

Model/Resistance	Model 1	Model 2	Model 3	Model 4
Maximum Resistance (kN)	8	4,9	5,3	4,3

Based on the Table 2 and Figure 4, the design of the hull model 4 was chosen, with a maximum resistance value of 4.3 kN which tends to be more effective than the designs of model 1, model 2, and model 3 which have a maximum resistance of 8 kN, 4.9 kN, and 5.3 kN. The characteristic data of the selected design are shows in Table 3.

Table 3. Characteristics of Ship Hull

Measurement	Value	Units
Displacement	11,51	t
Volume (displaced)	11,232	m^3
Wetted Surface Area	44,115	m^2
Max sect. area	1,058	m^2
Waterpl. Area	20,366	m^2
Prismatic coeff. (Cp)	0,907	
Block coeff. (Cb)	0,726	
Max Sect. area coeff. (Cm)	0,8	
Waterplane. area coeff. (Cwp)	0,921	

After obtaining the total resistance value at a speed of 1-14 knots from the Maxsurf Resistance software, then the calculation of resistance is carried out using the Empirical equation method at each speed of the ship, while the formula for the calculation of the Empirical method used is as follows [15]:

$$RT = \tfrac{1}{2} .WSA .v^2. \rho. Ct \quad (2)$$

Where WSA is Wetted Surface Area. v is speed. ρ is density. Ct is the Total Resistance Coefficient.

Table 4. Result of Validation Analysis of Resistance

Speed (*knot*)	Speed (m/s)	Total Resistance Coefficient (Ct)10^{-3}	Resistance (RT *Maxsurf*) (kN)	(RT Empirical) Resistance (kN)	Margin Error
1	0,514	10,231	0,061	0,0607	0,429%
2	1,029	9,188	0,217	0,2182	-0,547%
3	1,543	8,527	0,459	0,4556	0,740%
4	2,058	8,003	0,762	0,7602	0,238%
5	2,572	7,593	1,126	1,1269	-0,083%
6	3,087	7,314	1,569	1,5632	0,372%
7	3,601	7,324	2,135	2,1305	0,209%
8	4,116	7,799	2,963	2,9632	-0,008%
9	4,630	7,517	3,613	3,6147	-0,048%
10	5,144	7,21	4,289	4,2804	0,201%
11	5,659	6,976	5,013	5,0112	0,037%
12	6,173	6,924	5,917	5,9192	-0,038%
13	6,688	6,939	6,975	6,9619	0,187%
14	7,202	6,865	7,995	7,9881	0,086%

The results of the Holtrop method uses the Maxsurf Resistance software (RT Holtrop) and comparison is made with the Empirical equation method (RT Empirical) at a speed of 1-14 knots. The maximum error of 0.74% was obtained at a speed of 3 knots, while the minimum error was obtained at 0.008% which was obtained at a speed of 8 knots (see Table 4). The maximum error of 0.74% is still very far from the specified margin of error of 5% [16].

3.3. Preliminary Design

3.3.1. Lines Plan

The next stage is the designing of the lines plan, in order to design the initial preliminary design drawing. Lines plans are lines that project the intersection of the hull of the ship with a series of planes. Three fields/points of view are usually designed in this line's plan, namely: sheer plan, body plan, and half breadth plan (Figure 5).

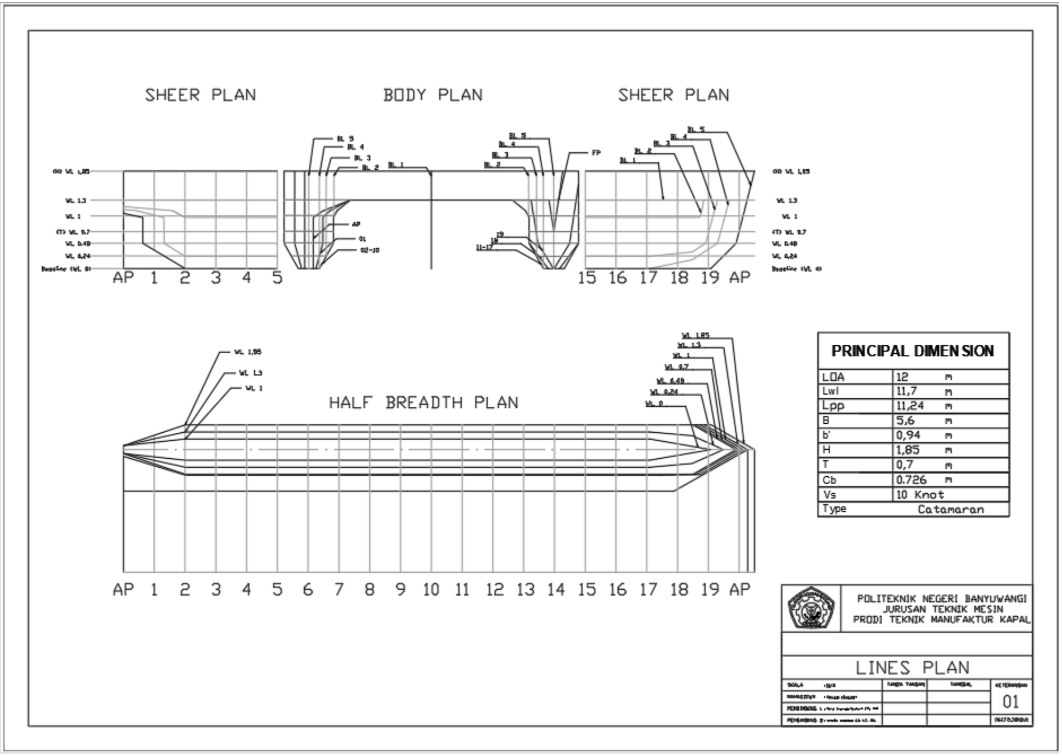

Figure 5. Lines Plan

3.3.2. Hydrostatic Curve

The next step is hydrostatic. Hydrostatic curves were obtained through the help of Maxsurf software analysis. The data from the hydrostatics curve obtained from Table 5.

Table 5. Hydrostatics Data (Cont.)

Waterlines (m)	Displacement (Ton)	Max Sext area (MSA) (m²)	Wetted area (WSA) (m²)	Water plan area (WPA) (m²)	LCB (m)	LCF (m)
0	0	0	0	0	0	0
0,175	1,848061	0,174453	17,234118	12,450475	5,58057	5,65717
0,35	4,474251	0,417812	26,451615	16,843572	5,66673	5,78336
0,525	7,872487	0,727836	35,525313	20,218558	5,73992	5,86762
0,7	11,513305	1,057654	43,755674	20,366305	5,78438	5,89064

Table 5. Hydrostatics Data

Waterlines (m)	KB (m)	TKM (m)	LKM (m)	TPC (t/cm)	Cp (m)	Cb (m)	Cm (m)
0	0	0	0	0	0	0	0
0,175	0,093556	37,774914	63,65818	0,127617	0,91098	0,76074	0,83508
0,35	0,195278	21,334984	36,865791	0,172647	0,90691	0,68197	0,75197
0,525	0,301087	14,772481	25,908703	0,20724	0,90487	0,6667	0,7368
0,7	0,39959	10,356026	18,180499	0,208755	0,90706	0,726	0,80038

While to simplify the reading data from this hydrostatics table, we made curves that were then named the hydrostatics curve. Each of the lines on the hydrostatics curve was formed using various scales at each curve with the aim of fineness and ease of reading. The hydrostatics curve is shown in Figure 6.

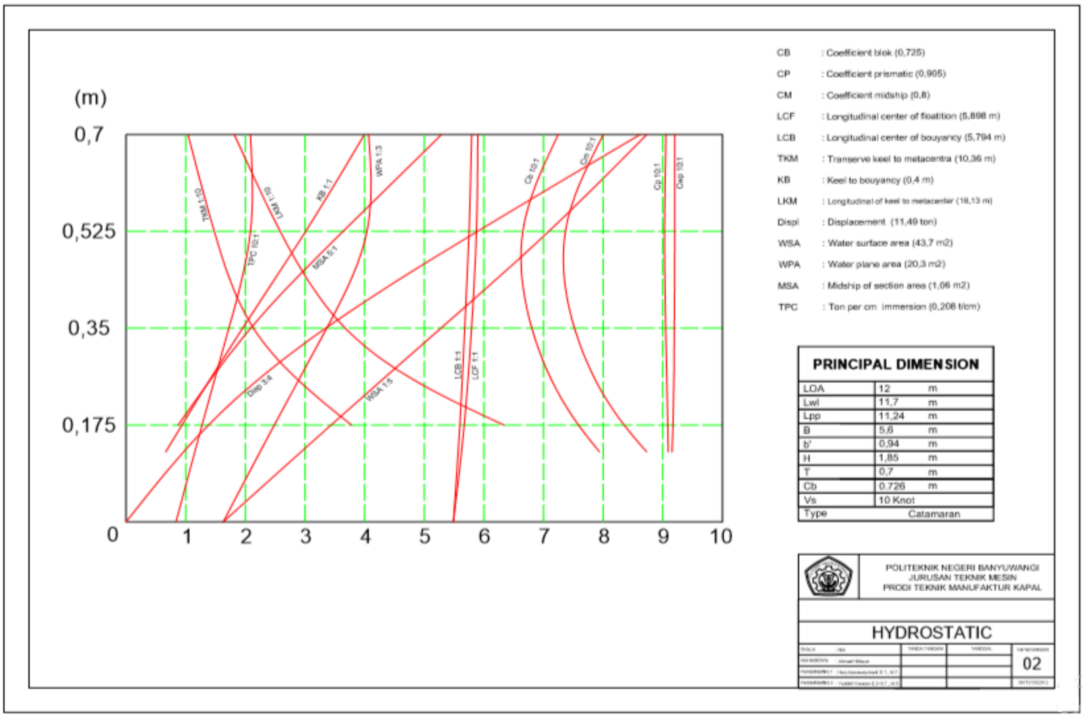

Figure 6. Hydrostatics Curve

3.3.3. Bonjean Curve

The following stage is Bonjean. A Bonjean curve is a curve/graph that shows the area of a station as a loaded function. So to calculate the area of the station to the desired height, it can be defined on the Bonjean arcs. Data and Bonjean curves are gained through the help of Maxsurf software shows in the Figure 7.

In order to get the Bonjean curve, the graph is carried out by drawing a Bonjean curve on the side of the hull with 20 stations [17]. Additionally, to receive the optimal shape, a different sketch scale is used. The length of the ship (X-axis) uses a scale of 1: 100, while for waterlines (Y-axis) uses a scale of 1:32, and for area uses a scale of 1: 5. Then the area value is obtained at each station with the results of the scale as follows.

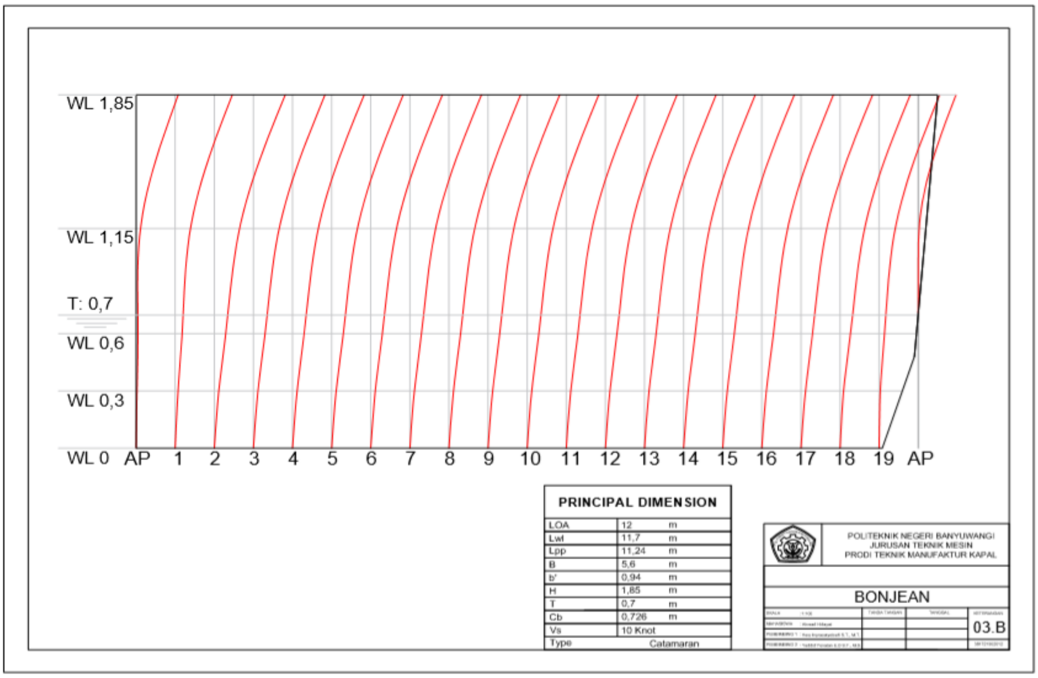

Figure 7. Bonjean Curve

3.3.4. General Arrangement

After designing the general arrangement, the main engine was obtained with 2 engines. The Engine has a specification: The maximum power is 14.6 kW, the number of cylinders is 4. At the same time, the frame spacing is planned 400 mm. The general arrangement design can be seen in the Figure 8 [18]. The 3D model of ship shows in the Figure 9.

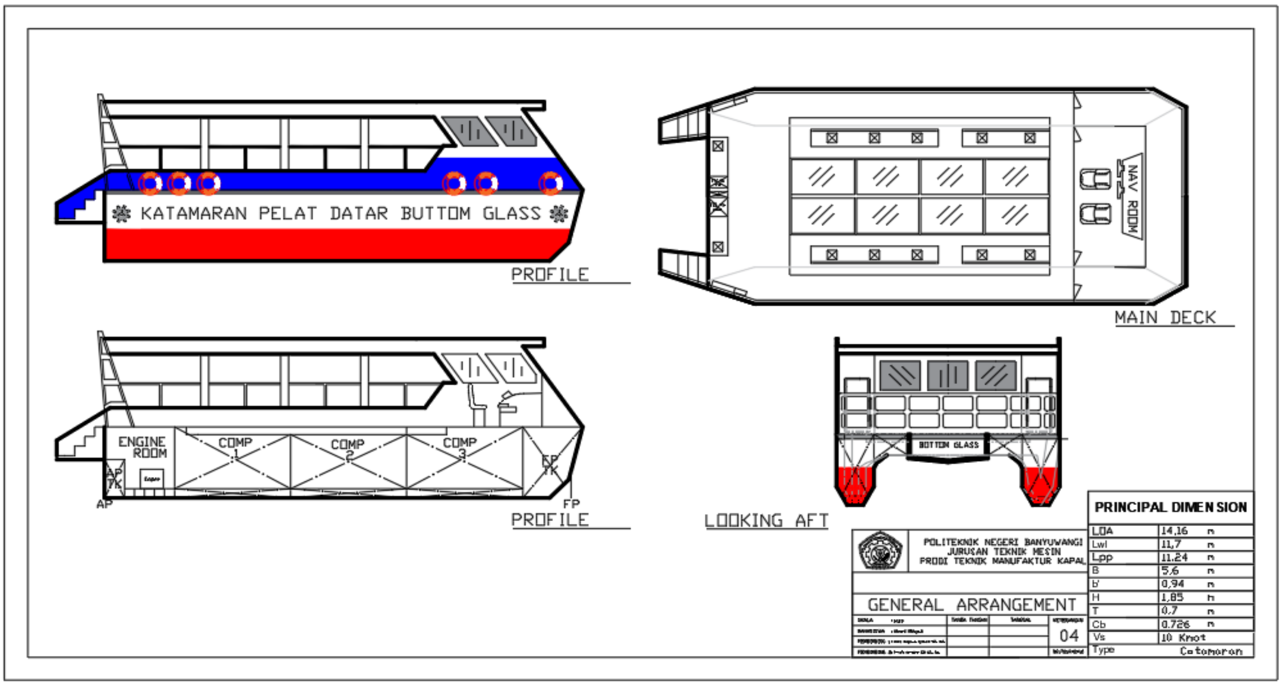

Figure 8. Ship general arrangement

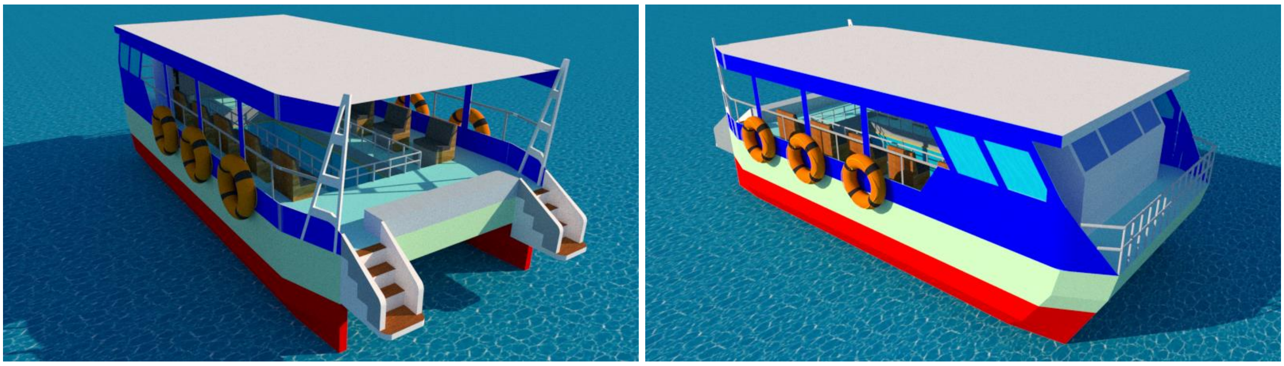

Figure 9. 3D Modelling Design

3.4. Ship Stability Calculation.

Using Maxsurf stability software, the design ship is using 5 load-case criteria. The waves at sea state 3 (maximum wave height 1.25m) is using the standard IMO MSC.36 (63) criteria for HSC multihull Annex 7 [19]. It was found that this ship meets all standards that apply to all loading criteria, as for the details are as follows.

a) Departure / Load Case 1
Load-case 1 or departure, uses a load-case value of 100%, with waves in sea state 3 (maximum wave height 1.25m), using the IMO MSC.36 (63) standard criteria for HSC multihull Annex 7 shows in Table 6.

Table 6. Stability Criteria of Departure/Load Case 1.

Criteria	Value	Units	Actual	Status
Area from 0 to 30	3,2498	m.deg	40,9399	Pass
The angle of maximum GZ	10	deg	29,1	Pass

HTL: Area between GZ and HA				
Hpc + Hw	1,6043	m.deg	8,7883	Pass
Ht + Hw	1,6043	m.deg	12,8734	Pass
HL1: Angle of equilibrium				
Wind heeling (Hw)	16	deg	1,5	Pass
HL4: Area between GZ and HA				
Hpc + Hw	1,6043	m.deg	10,6186	Pass

b) Load Case 2
Load-case 2, uses a load-case value of 80%, with waves in sea state 3 (maximum wave height 1.25m), using the IMO MSC.36 (63) standard criteria for HSC multihull Annex 7 shows in Table 7.

Table 7. Stability Criteria of Load Case 2

Criteria	Value	Units	Actual	Status
Area from 0 to 30	3,3546	m.deg	37,9521	Pass
The angle of maximum GZ	10	deg	28,2	Pass
HTL: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	7,79	Pass
Ht + Hw	1,6043	m.deg	12,2556	Pass
HL1: Angle of equilibrium				Pass
Wind heeling (Hw)	16	deg	1,7	Pass
HL4: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	9,7837	Pass

c) Load Case 3
Load-case 3, uses a load-case value of 60%, with waves in sea state 3 (maximum wave height 1.25m), using the IMO MSC.36 (63) standard criteria for HSC multihull Annex 7 shows in Table 8.

Table 8. Stability Criteria of Load Case 3

Criteria	Value	Units	Actual	Status
Area from 0 to 30	3,586	m.deg	32,4563	Pass
The angle of maximum GZ	10	deg	26,4	Pass
HTL: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	6,0827	Pass
Ht + Hw	1,6043	m.deg	11,4059	Pass
HL1: Angle of equilibrium				Pass
Wind heeling (Hw)	16	deg	2	Pass
HL4: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	8,4376	Pass

d) Load Case 4
Load-case 4, uses a load-case value of 40%, with waves in sea state 3 (maximum wave height 1.25m), using the IMO MSC.36 (63) standard criteria for HSC multihull Annex 7 shows in Table 9.

Table 9. Stability Criteria of Load Case 3

Criteria	Value	Units	Actual	Status
Area from 0 to 30	3,9997	m.deg	23,167	Pass
The angle of maximum GZ	10	deg	23,6	Pass

HTL: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	1,6424	Pass
Ht + Hw	1,6043	m.deg	9,3178	Pass
HL1: Angle of equilibrium				Pass
Wind heeling (Hw)	16	deg	2,4	Pass
HL4: Area between GZ and HA				Pass
Hpc + Hw	1,6043	m.deg	4,9926	Pass

e) Arrived/ Load Case 5

Load-case 5 or arrived, uses a load-case value of 20%, with waves in sea state 3 (maximum wave height 1.25m), using the IMO MSC.36 (63) standard criteria for HSC multihull Annex 7 shows in Table 10.

Table 10. Stability Criteria of Arrived / Load Case 5

Criteria	Value	Units	Actual	Status
Area from 0 to 30	4,5214	m.deg	30,3339	Pass
The angle of maximum GZ	10	deg	20,9	Pass
HTL: Area between GZ and HA				
Hpc + Hw	1,6043	m.deg	7,3645	Pass
Ht + Hw	1,6043	m.deg	14,6994	Pass
HL1: Angle of equilibrium				
Wind heeling (Hw)	16	deg	1,8	Pass
HL4: Area between GZ and HA				
Hpc + Hw	1,6043	m.deg	11,0816	Pass

4. Conclusion

Based on the present study results, the design of a flat plate catamaran with a bottom glass concept is obtained. Which can present underwater charm without having to snorkel or dive. Conclusions can be drawn from the results of the design as follows:

1) Based on the concept design, a ship model 4 is gained with the most effective resistance, namely 4.3 kN with the back of the transom of 150 mm on each hull. The main dimension of the ship is LOA: 12 m, b ': 0.94 m, B: 5.6 m, hull spacing: 5.6 m, T: 0.7 m, H: 1.85 m, Vs: 10 knots.

2) Based on the preliminary design, it was discovered that this ship has a displacement of 11.51 tons, with two engines of 19.6 hp. Moreover, it can accommodate 10 passengers and three crew members within a voyage radius of 2.2 nautical miles, carrying as many as 3 times its daily journey.

3) The stability analysis results on a ship designed with waves in sea state 3 with a maximum wave height of 1.25m using the IMO MSC.36 (63) standard for HSC multihull Annex 7 complied. The result shows it fulfilled the IMO MSC criteria.36 (63) for the HSC multihull Annex 7.

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