Tersedia online di: http://ejournal.undip.ac.id/index.php/teknik

TEKNIK, 45 (3), 2024, 313-325

Design of a Glass Bottom Catamaran as a Tourist Attraction on Aceh's Banyak Island

Deddy Chrismianto, Ahmad Firdhaus*, Hassan Al Muhshi, Kiryanto

Department of Naval Architecture, Diponegoro University, Jl. Prof. Soedarto, SH, Kampus UNDIP Tembalang, Semarang, Indonesia 50275

Abstract

Aceh's Banyak Island has become a tourist hotspot due to its vast ocean areas and fascinating islands that retain the beauty of their sea and beaches. Traditional fishing boats are still the primary mode of transportation for tourists. The Glass Bottom Catamaran is a novel and engaging method to explore Banyak Island's seas while capitalizing on Indonesia's marine tourism potential. The study aims to develop an optimal glass-bottom catamaran that meets legal and regulatory norms. These ships offer underwater attractions, as well as passenger comfort and safety. This vessel was built using basic linear regression calculations, a ship's line plan, a General Arrangement design, and software 3D model design. Motion analysis follows Nordfork 1987, stability calculations follow IMO, and resistance calculations use the Slender Body technique. Thus, the vessel's main dimensions are 20.25 m length overall (LOA), 7.04 m breadth catamaran (B), 1.8 m breadth demi hull (B1), 2.4 m height (H), 1.55 m draught (T), 17 knots service velocity (Vs), and 54 passengers. This experiment discovered 42.3 kN resistance when hauling 60 tons at 17 knots. The stability study complies with IMO requirements, whereas the motion analysis satisfies Nordfork 1987.

keywords: *ship design; glass bottom catamaran; ship resistance; ship stability; ship seakeeping*

1. Introduction

Aceh Singkil Regency is known for its natural beauty, plentiful resources, diverse cultural and social environment, and rich historical past, making it a popular tourist destination—this tourist location has various boat attractiveness (Firman et al., 2024). Traditional boats (modified fishing boats) and traditional speedboats are available for rental at Banyak Island, each having pros and cons. Classic boats are ideal for transporting people between Banyak Island and Singkil. Companies, clubs, and organizations over 25 employ these traditional boats. They average 8 to 9 knots, 17 to 19 meters long, and 3.8 to 4 meters wide. Singkil to Banyak island takes 3–3.5 hours.

Banyak Island tourist potential highlights catamaran boats' benefits. In marine transportation, ship operations are usually linked to economic variables like operating expenses and environmental problems like pollution (Koilo, 2019; Moon & Woo, 2014). Creating an efficient hull and propulsion system during design may reduce engine power and fuel consumption. Due to their broad deck, low resistance, superior stability, and excellent ship agility (seakeeping), catamaran hulls may reduce propulsion power and emissions (Firdhaus & Suastika, 2022; Santosa & Pranatal, 2021).

The glass bottom catamaran is a good alternative for Banyak island tourism since it provides comfort and safety for inter-island marine transit. The boat's tempered glass bottom lets passengers see underwater life. According to a Banyak Island marine transit user study, safety and comfort are paramount. Fast boats affect satisfaction, especially in safety and security, since buyers anticipate more significant standards (Bahattab et al., 2023; Hanafiah & Asyraff, 2022; Purboyo, 2021). Fast boats also affect satisfaction, especially departure times, because customers want improved timeliness (Dewi, 2022). The study shows that Banyak Island transit options for crossing and tourism lack safety, security, and punctuality.

There are only a few glass-bottom boats available in Indonesia, each adapted to its specific tourist location. Hidayat et al. focus on designing a catamaran with a glass bottom to enhance underwater tourism in Bangsring, Banyuwangi. Their study proposes a flat plate and flat-bottom design to optimize shipbuilding time and costs (Hidayat et al., 2021). Alam and Birana present a general plan for a glass-bottom catamaran in the Derawan Islands,

*) Corresponding Author
E-mail: ahmadf@lecturer.undip.ac.id

doi: 10.14710/teknik.v45i3.60019

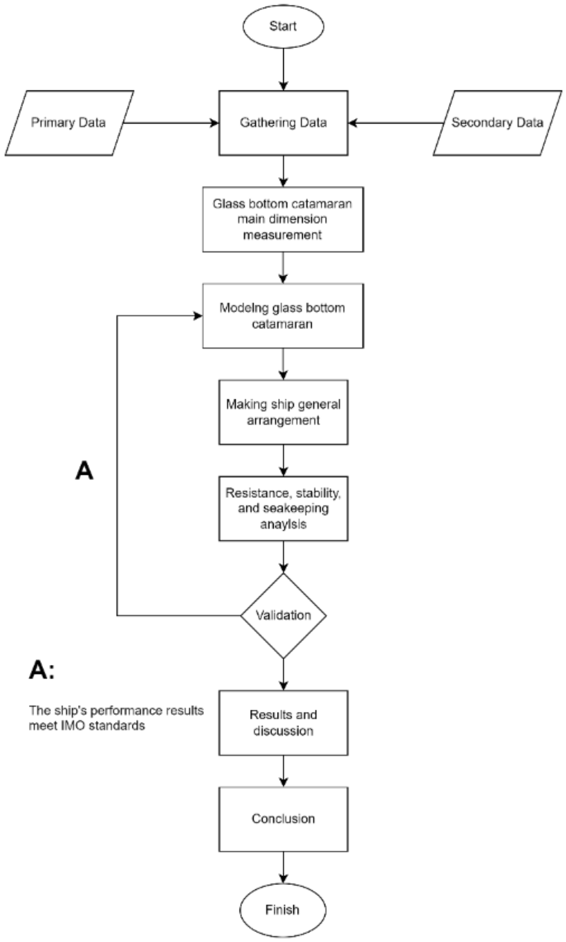


Figure 1. Research flowchart diagram

emphasizing the need for suitable sea transportation for tourists (Alam & Birana, 2019). Their study provides the principal dimensions and design parameters for the vessel. Trisyaldi et al. explore the design of a catamaran hull for tourism in Maninjau Lake, stressing the importance of innovation and efficiency (Trisyaldi et al., 2019). Rahmat et al. developed an electrically powered catamaran with a glass bottom, motivated by the goal of building a shipbuilding-compliant tourist craft to boost tourism on Banyak Island in Aceh Singkil (Rahmat et al., 2023). Each glass bottom boat in Indonesia is tailored to the unique characteristics of its target region.

This research aims to construct a Glass Bottom Catamaran to attract visitors to Banyak Island. In the introduction, it is important to highlight the significance of resistance analysis, seakeeping, and stability in ship design to ensure the vessel's efficiency, safety, and passenger comfort. The ship is designed to provide a complete tourist experience in one trip. Its glass bottom feature allows underwater exploration and access to uninhabited islands for island hopping, diving, and snorkeling. The author analyzed resistance, stability, and seakeeping and developed 3D models of the vessel. The researcher presumes that the Glass Bottom Catamaran may solve tourist transportation problems safely and efficiently and become a future standard.

2. Research Methods

This study will use a numerical methodology to determine the performance of a ship. Figure 1 displays the study flowchart diagram. The research process starts by gathering and scrutinizing both secondary and primary material. Secondary data is collected from several sources, such as journals, papers, articles, conversations, and online sources. Primary data collection encompasses two primary activities: quantifying the length and breadth, comparing the measurements of ships, and examining the properties of the waters in the designated region.

After the data-gathering phase is over, the next step is data processing, which involves computing the primary measurements of the vessel. Afterward, a replica of the ship is generated using specialist software. Subsequently, a comprehensive ship plan is created.

During the subsequent phase, a range of studies are performed to verify the feasibility and effectiveness of the ship's design. The analyses include stability, hydrostatics, resistance, and motion analysis. The findings of these studies are subsequently verified to guarantee their precision and dependability.

After being verified, the results undergo a comprehensive discussion, and the findings are then presented in the results and discussion section. The investigation culminates with a concise review of the findings in the conclusion section, offering a thorough overview of the procedure and its results.

2.1. Ship Main Dimension

This extensive study employs the linear regression method to determine the main dimensions, utilizing a reference vessel's primary dimensions (Cepowski, 2018; Harsi & Arif, 2021; Hou et al., 2011). The linear regression method, utilizing a mathematical equation known as a regression line as written in equation 1-3, predicts the Y value based on a given X value, which is fundamental in regression analysis (Smadi & Abu-Afouna, 2012).

$$Y = a + bX \quad (1)$$

$$b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2} \quad (2)$$

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{n(\Sigma x^2) - (\Sigma x)^2} \quad (3)$$

2.2. Ship Resistance

Resistance is a pivotal factor in determining the choice of engine to use. Consequently, resistance is the

doi: 10.14710/teknik.v45i3.60019

Table 1. Stability Criteria Code A.749 (IMO A. 749 (18), 1998)

Criteria	Value	Unit
All Ship		
Area 0 to 30; (>)	3,151	m.deg
Area 0 to 40; (>)	5,157	m.deg
Area 30 to 40; (>)	1,719	m.deg
Max GZ at 30 or greater; (>)	0,2	m
Angle of Maximum G.Z.; (>)	25	deg
Initial GMt; (>=)	0,15	m
Passenger Crowding: Angle of equilibrium (>=)	10	deg
Angel of Steady Heel (<=)	16	deg

Table 2. Stability Criteria MSC.36(63) HSC Code Annex 7 Multihull (The Maritime and Coastguard Agency, 2008)

Criteria	Value	Unit
All Ship		
Area 0 to 30; (>)	4,932	m.deg
The angle of Maximum G.Z.; (>=)	25	deg
The area between G.Z. and HTL (>=)	1,604	deg
Passenger Crowding Heeling Arm (<=)	10	deg

Table 3. Ship Motion Criteria (Jamal et al., 2020)

No	Criteria	RMS	Unit
1	Vertical acceleration at forward perpendicular	0,275	g(m/s)
2	Pitch	4,0	deg
3	Roll	8,0	deg
4	Vertical acceleration at Bridge	0.15	g

Table 4. Main Dimensions of the Reference Ship

No.	Vessel Name	LPP (m)	B (m)	H (m)	T (m)
1	Sea Cat 74	21,28	8	2,24	1,5
2	Nirmala Bahari 1	20,80	8	3	2,22
3	Nirmala Bahari 2	23,05	8	3	2,22
4	Baswara Bahari 1	22,06	8	3	2,22
5	Baswara Bahari 2	23,05	8	3	2,22
6	Fantasea	18	6,2	1,94	1,4
7	IC15109	20,2	6,5	2,2	1
8	Bue Marine	17,75	6,24	2,05	0,9
9	IC17224	19,5	6,5	2,2	1,05
10	Quick Cat	17	6,5	2	1,35

critical determinant of the vessel's operational speed in this context. The resistance value for this vessel is computed using dedicated software, employing the Slender Body method as written in equation 4, which is well-suited for catamaran-hulled ships.

$$R_W = \frac{4}{\pi}\rho V^2 \nu^2 \int_1^\infty \frac{\lambda^2}{\sqrt{\lambda^2 - 1}} |A(\lambda)|^2 d\lambda \qquad (4)$$

The slender body technique is used to determine wave resistance R_W, which is produced by waves created by body motion in a fluid. Several things affect wave resistance. The fluid density ρ represents the mass density of the medium in which the body flows. The body's kinetic energy in the fluid is calculated by multiplying this factor by the square of its velocity V^2.

Also, the amplitude of the longitudinal oscillatory velocity ν and its square ν^2 indicate the body's oscillation intensity. The equation comprises an integral from $\lambda = 1$ to infinity, where λ is a dimensionless wavelength parameter. The factor $\frac{\lambda^2}{\sqrt{\lambda^2-1}}$ shows how wavelength characteristics affect resistance, while $|A(\lambda)|^2$ shows the energy distribution of waves in a spectrum, calculated as

doi: 10.14710/teknik.v45i3.60019

Table 5. Main Dimensions of the New Designated Ship

No.	Dimension	Value	Unit
1	Length Over All (LOA)	20.25	m
2	Length Between Perpendicular (LPP)	19,50	m
2	Breadth (B)	7,03	m
3	Depth (H)	2,4	m
4	Draught (T)	1,55	m
5	Speed (Vs)	17	m
6	Displacement	60	Ton

Table 6. Main Dimension Ratio Parameters

Items	Value	Parameters range (Metelitsa, 2020)	Status
BWL/L	0,35	0,3 – 1,0	PASS
L/B1	11,11	2 – 30 10 – 15	PASS
L/H	8,33	5,9 – 11,1	PASS
B/H	2,94	0,7 – 4,1	PASS
H/L	0,12	0,1 – 0,25	PASS
S/L	0,26	0,19 – 0,51	PASS
S/B1	2,94	0, 9 – 4,1	PASS
B1/T	1,16	0,5 – 2,5	PASS
B1/B	0,25	0,15 – 0,3	PASS

the squared modulus of the amplitude distribution function. The integral sums the contributions from the full wave spectrum to get the overall wave resistance R_W. The result shows how a slim body impacts wave generation resistance on the fluid surface.

2.3. Ship General Arrangement

The arrangement of ship compartments to suit various activities, aligned with their functions and equipment requirements, considering their positioning and access pathways, is known as the ship's general arrangement (Kawahara et al., 2010). The primary aim of the general arrangement is to ensure that all spaces on the planned vessel are designed for maximum efficiency (Pragada et al., 2021). This encompasses plans for cargo areas and auxiliary equipment to aid the crew in their work for enhanced efficiency

2.4. Ship Stability

Ship stability pertains to the ship's capacity to revert to its original condition after being subjected to forces, whether they arise from internal factors or external influences affecting the ship's hull. Ship stability encompasses both static and dynamic stability. In this research, the ship's stability is assessed using ship stability analysis software, in compliance with the criteria outlined in the International Maritime Organization (IMO) Intact Stability Code (I.S. Code) 2008 Code A.749 (IMO A. 749 (18), 1998) Chapter 3-design criteria applicable to all ships (Table 1) and IMO MSC.36(63) HSC Code (The Maritime and Coastguard Agency, 2008) Annex 7 Multihull (Table 2).

2.5. Ship Motion

The response amplitude operator (RAO) shows the connection between wave and response amplitude. The RAO's horizontal axis represents frequency, while its vertical axis represents motion amplitude to wave amplitude in a mode (Wang et al., 2019). The reaction is lowest in ship motion when the RAO peak is lowest as written in equation 5.

$$RAO = \frac{Z_0}{\xi_0}(m/m) \tag{5}$$

The equation 5 for the Response Amplitude Operator (RAO) expresses the dynamic behavior of a structure under external excitation. In this equation, ξ_0 represents the response amplitude of the structure, such as its motion in heave, pitch, or roll. ξ_0 denotes the amplitude of the external excitation, typically the wave height or force causing the response. By dividing ξ_0 by ξ_0, the RAO provides a dimensionless measure (m/m) of how the structure reacts to the excitation.

In this research, ship motion analysis is performed using specialized software, considering the relevant ship motion criteria. The criteria used for ship motion in this study are based on the NORDFORSK 1987 criteria (Table 3). These NORDFORSK 1987 criteria can be applied in future studies of cruise ships. The developed method is expected to be suitable for establishing

doi: 10.14710/teknik.v45i3.60019 p-ISSN: 0852-1697, e-ISSN: 240-9919

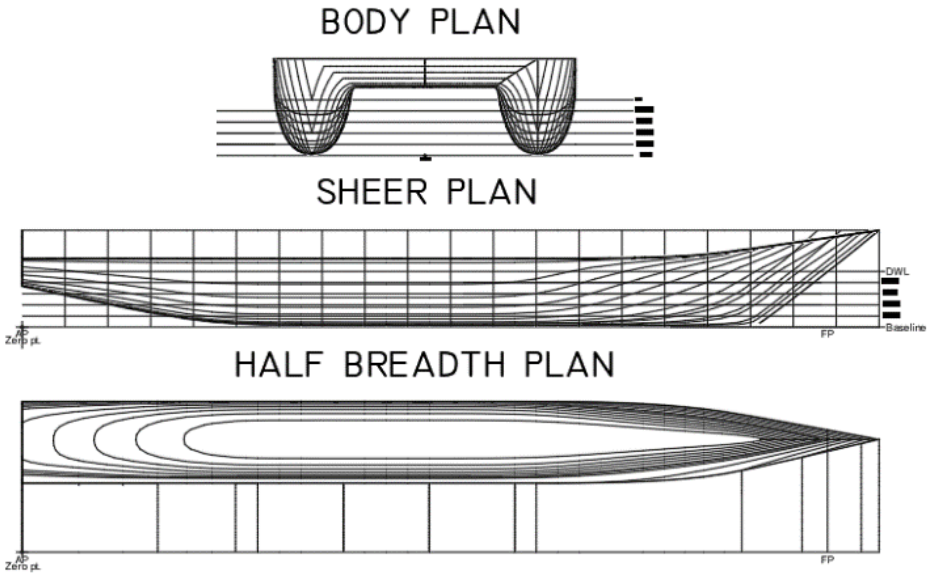


Figure 2. Designated Glass bottom catamaran linesplan

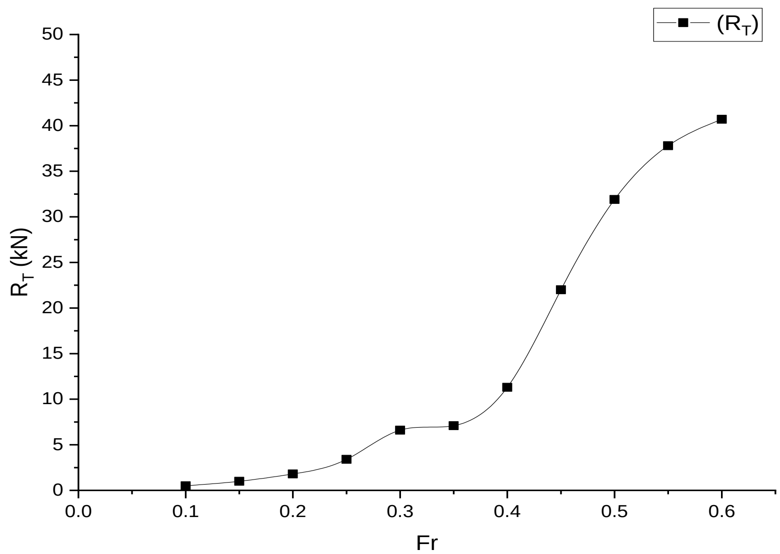


Figure 3. Ship resistance ($R_{.T.}$) value against ship speed (Fr) curve

navigation criteria for passenger ships operating in Indonesian waters (Jamal et al., 2020).

3. Results and Discussion

In designing a glass bottom catamaran, the process begins with the determination of the primary dimensions, followed by the formulation of line plans, the computation of resistance, the development of a general arrangement, the estimation of weight, a stability study, an evaluation of seakeeping qualities, and finally the creation of a 3D model. The succeeding subchapter will explain the overall conclusions obtained from the inquiry that was carried out.

3.1. Ship Main Dimension

The Glass Bottom Catamaran was created utilizing linear regression calculations and software to analyze data from the measurements of a reference ship. The following are the resultant values: enhanced rigidity and stability of the frame, thereby dispersing the applied load more uniformly over the tank structure. The measurements of current tourist boats on Pulau Banyak, which are modified 30 G.T. fishing vessels, are used to determine the most appropriate glass-bottom catamaran

doi: 10.14710/teknik.v45i3.60019

for the needed requirements. These dimensions are similar to the Kapal Inka Mina 30 G.T., with LOA = 18.05 m, B = 4.8 m, D = 1.7 m (Soeboer et al., 2018), and an estimate of 60-70 tons displacement. The first step in determining the appropriate glass-bottom catamaran that meets the criteria is to identify a reference ship that closely matches the design objectives in Table 4.

Through a straightforward linear regression analysis (Smadi & Abu-Afouna, 2012), displacement is treated as the dependent variable X, with LPP, B, and H serving as independent variables Y. This analysis yields the main dimensions of the new ship, as presented in Table 5.

The main dimensions of the new ship have been designed to match the ideal characteristics of a catamaran vessel, as confirmed by the size ratio parameters outlined in Table 6, as demonstrated in the referenced journal (Metelitsa, 2020)

3.2. Ship Linesplan

The Lines Plan is obtained from the design modeler and refined using specialized 2D software.Figure 2 illustrates the ship's lines plan, consisting of the body, half-breadth, and sheer plans. The body plan represents a 2D frontal view of the ship, the half-breadth plan portrays a 2D top view, and the sheer plan depicts a 2D side view.

3.3. Ship Resistance

This study's resistance analysis employs the Maxsurf Resistance software and uses a slender body analysis based on the Molland method. Using the slender body method in the Molland approach at 17 knots, the resistance analysis resulted in a resistance force of 42.3 kN, requiring 496 hp, as depicted in Figures 4 and 5. A method based on formulas from M. Insel and A.F.

Table 7. Ship resistance results

Metode	R_T (K.N.)	Percentage Difference
Maxsurf Resistance	42,3	1%
Empiris	42,4	

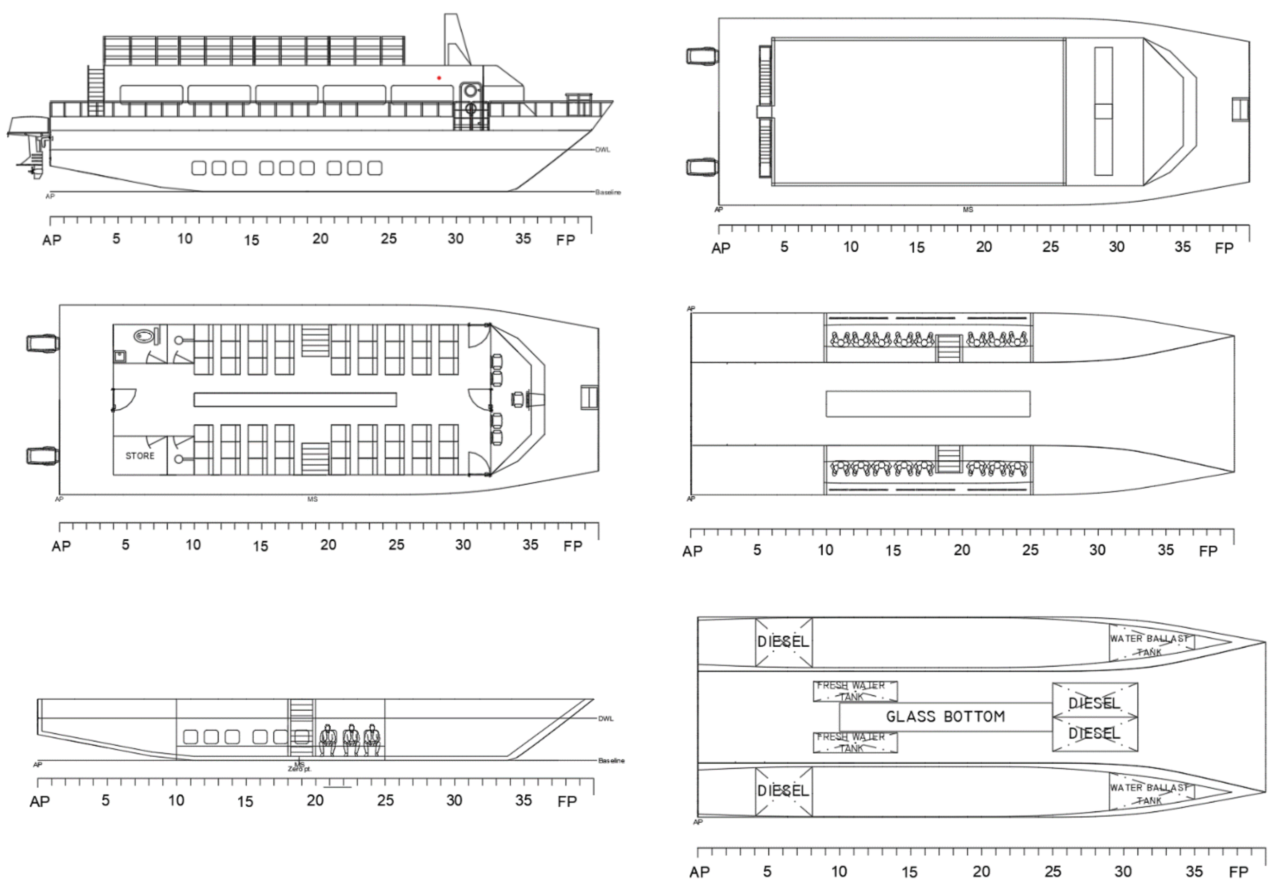


Figure 4. Designated Glass Bottom Catamaran general arrangement plan

doi: 10.14710/teknik.v45i3.60019

Figure 5. Designated 3D Glass Bottom Catamaran general arrangement plan

Molland (Insel & Molland, 1992) was employed to verify the total resistance calculation. The formula used in this method is written as equation 6.

$$C_T = (1 + \beta k).C_f + \tau C_W \tag{6}$$

The total resistance coefficient $C_T$of a ship is here, $(1 + \beta k)$ represents the frictional resistance, with C_f as the frictional resistance coefficient, k as the form factor, and β as a correction factor. The term τC_W accounts for wave resistance, where C_W is the wave resistance coefficient, and τ is a scaling factor. This equation combines both frictional and wave resistance to determine the total resistance acting on a ship.

Upon obtaining the coefficients from interpolation, the parameters were determined as follows: (1 + βk) = 1.345, Cf = 0.00112, τ = 1.160, and Cw = 0.0025039. With these coefficients in hand, the resistance can be calculated using equation 7.

$$R_T = \frac{1}{2}.\rho.S.V^2.C_T \tag{7}$$

This equation consists of several key components. The total resistance R_T is calculated as a function of the fluid density ρ, the wetted surface area of the hull S, the square of the ship's velocity V^2, and the total resistance coefficient C_T. The term $\frac{1}{2}$ is a constant that arises from the dynamic pressure in fluid mechanics. Together, these factors describe how the ship's geometry, speed, and fluid properties contribute to the total resistance experienced during motion. Hence, a contrast of resistance values is displayed in Table 7, utilizing both the slender body method and the M. Insel and A.F. Molland formula.

The ship resistance analysis in this study employs slender body analysis using Maxsurf Resistance software, and the graph of the function of ship speed in Froude number against ship total resistance (kN) can be seen in Figure 3.

3.4. Ship General Arrangement

The general plan for the catamaran fishing boat was developed after creating the lines plan, as shown in Figure 4. This vessel is designed for the marine environment in the southern area of the Aceh Sea.

The models of the line plan and general layout are used as references to build a 3D model. All auxiliary components employed aboard the ship are considered throughout this modeling phase to improve the realism of the model portrayal.

The objective is to provide a realistic representation of the ship's design. The 3D model shows

doi: 10.14710/teknik.v45i3.60019

Table 8. DWT and LWT Components

Items	Weight(ton)	LCG (m)	TCG (m)	VCG (m)
LWT	47,30	8,80	0	1,80
FWT (Str)	0,42	15,35	2,63	15,53
FWT (Port)	0,42	15,35	-2,63	15,53
DOT (Str)	0,49	13,24	0,60	1,93
DOT (Port)	0,49	13,24	-0,60	1,93
DOT (Str) Generator Set	0,36	13,24	0,60	1,93
DOT (Port) Generator Set	0,36	13,24	-0,60	1,93
Passengers 1 (Port)	0,76	6,52	0,00	2,26
Passengers 2 (Str)	0,76	9,32	0,00	2,26
Passengers 3 (Port)	0,76	12,20	0,00	2,26
Passengers 4 (Str)	0,76	-6,52	0,00	2,26
Passengers 5 (Port)	0,76	-9,32	0,00	2,26
Passengers 6 (Str)	0,76	12,20	0,00	2,26
WB (Port)	1,12	4,75	0,45	1,75
WB (Str)	1,12	4,75	-0,45	1,75

Note: Str = Starboard FWT = Fresh Water Tank
Port = Portside DOT = Diesel Oil Tank
WB = Water Ballast

Table 9. Stability Conditions

Item	Payload Condition		
	100%	50%	10%
DOT Main Engine	100%	50%	10%
DOT Generator set	100%	50%	10%
Freshwater	100%	50%	10%
Passengers	100%	100%	100%
Ballast	50%	50%	100%

Note: DOT = Diesel Oil Tank

Table 10. Results of Stability Analysis Code A.749

Criteria	**Value**	**Actual**			**Status**
		100%	**50%**	**10%**	
Area 0 to 30; (>)	3,15	48,49	49,27	49,96	**PASS**
Area 0 to 40; (>)	5,15	72,72	73,62	74,41	**PASS**
Area 30 to 40; (>)	1,71	24,22	24,34	24,45	**PASS**
Max GZ at 30 or greater; (>)	0,2	2.49	2,515	2,52	**PASS**
Angle of Maximum G.Z.; (>)	25	26,5	25,5	25,5	**PASS**
Initial GMt; (>=)	0,15	7.16	7,278	7,38	**PASS**
Passenger Crowding: Angle of equilibrium (>=)	10	0	0	0	**PASS**
Angel of Steady Heel (<=)	16	2	2	2	**PASS**

the vessels from multiple perspectives, including front, back, side, and perspective views, as seen in Figure 5.

3.5. Ship Stability

The vessel is assigned specific tasks for each situation. Besides the predetermined conditions, the ship's stability is affected by its loading. The ship's lightweight tonnage (LWT) accounts for 47.76 tons of its total displacement, while the deadweight tonnage (DWT)

Makes up 12.24 tons of the ship's displacement. The ship's payload is approximately 9.61 tons without any water ballast. Stability analysis is performed using specialized software, and the position of the ship's center of gravity is presented in Table 8 as follows:

The stability analysis is performed under three distinct conditions, as outlined in Table 9. The 100% condition signifies the ship's initial departure state, assuming all weight components are fully loaded. In the

doi: 10.14710/teknik.v45i3.60019

50% condition, the vessel is presumed to be seafaring, with consumable weight estimated at 50%. Lastly, the 10% condition emulates the ship's status as it returns from tourism operations, with just 10% of the cargo on board and full water ballast for stability.

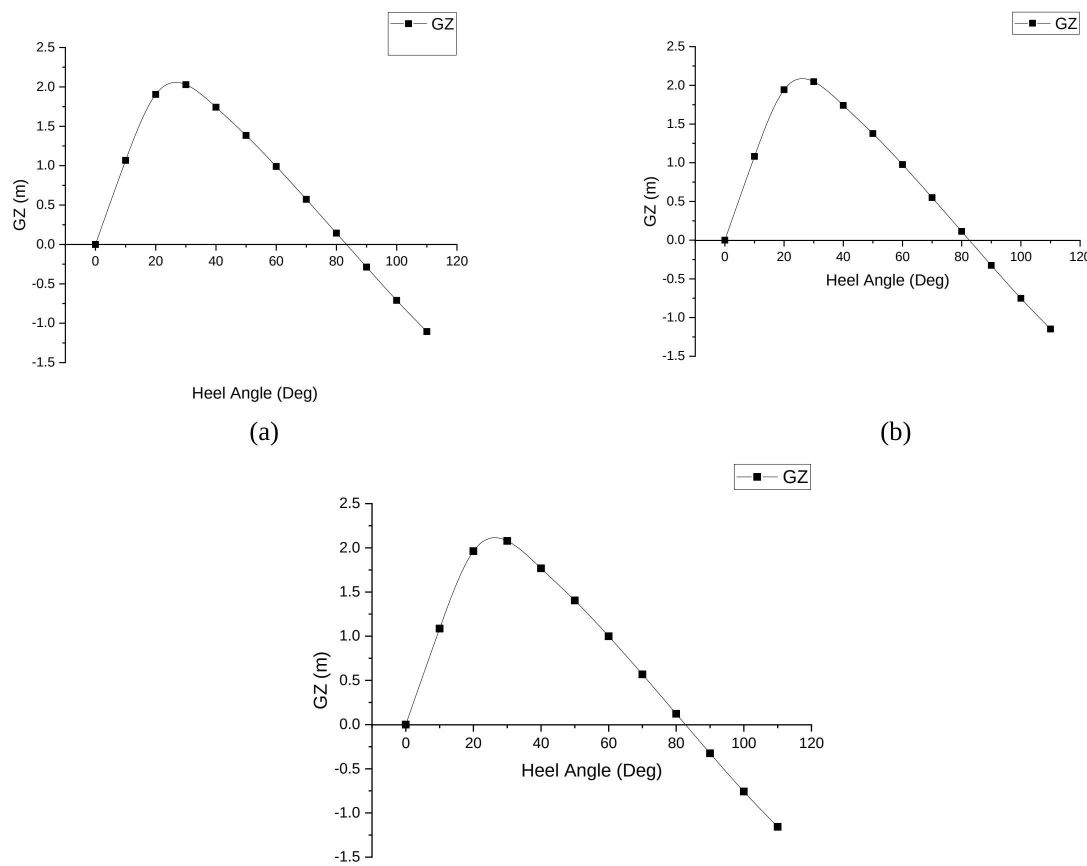
Figure 6 details the stability outcomes for these three situations based on the stability scenarios listed in Table 10. Figure 6 demonstrates alterations in the ship's stability across different conditions. Table 10 and Table 11 provide a breakdown of stability calculations for condition 3, showing positive values within the range of righting levers (G.Z. Curve) (Yaakob et al., 2015), signifying substantial stability and equilibrium for the ship under this condition. According to these calculations, the vessel meets IMO criteria, as the maximum G.Z. value and initial GMt comply with the prescribed standards.

3.6. Ship Motion

The ship motion analysis in this study is assessed using motion analysis software. According to the Indonesian Maritime BMKG's Wave Height Forecast, the waters in the southern part of Aceh are categorized as having moderate waves (Setiawan et al., 2021). The JONSWAP wave spectrum is employed for this analysis, considering four different heading angles at a cruising speed of 15 knots. Subsequently, these four heading

Table 11. The results of the Stability Analysis according to MSC.36(63) HSC Code Annex 7 Multihull

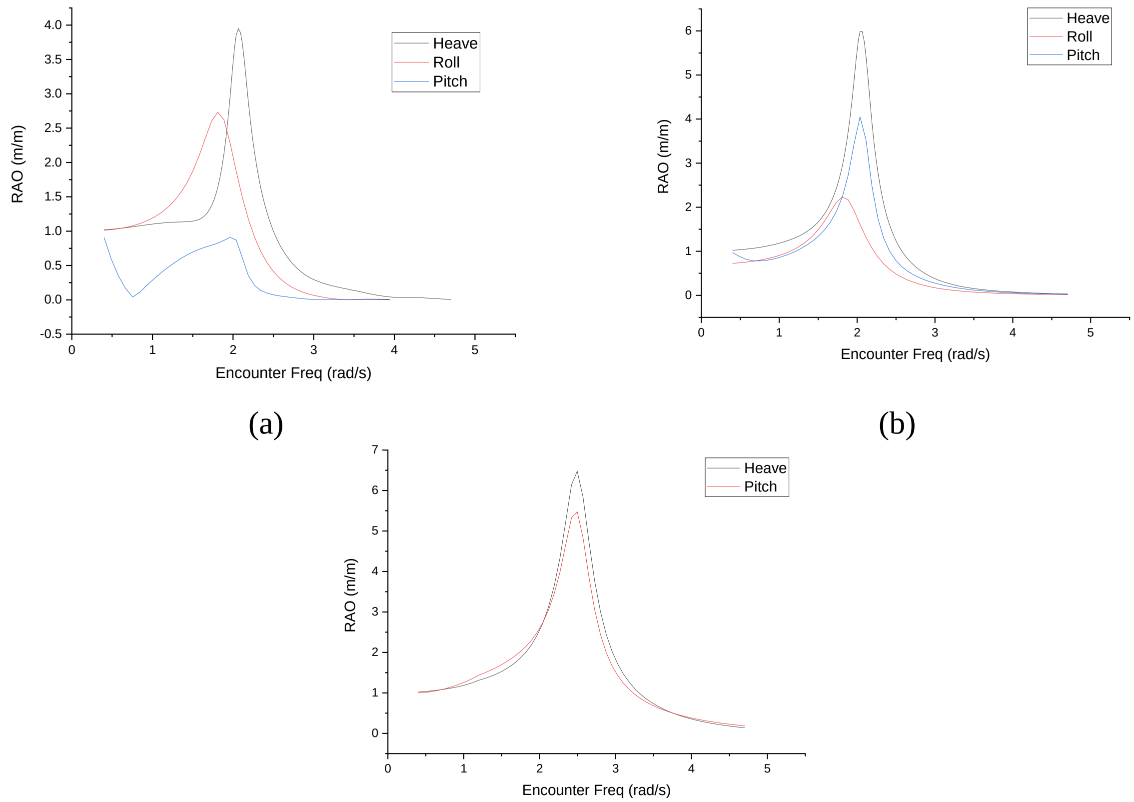
Criteria	Value	Actual			Status
		100%	**50%**	**10%**	
Area 0 to 30; (>)	3,15	44.69	46.22	43,04	**PASS**
Angle of Maximum G.Z.; (>=)	10	28,2	29,1	27,30	**PASS**
The area between G.Z. and H.A. (>=)	1,60	13,85	13,85	14,30	**PASS**
Angle of equilibrium (<=)	16	0,3	0,3	0,3	**PASS**



(a) (b) (c)

Figure 6. G.Z. Value Curve for each ship condition (a) 100% payload, (b) 50% payload, and (c) 10% payload

doi: 10.14710/teknik.v45i3.60019



(a) (b)

(c)

Figure 7. RAO at heading angles of (a) 90°, (b) 135°, and (c)180°

angles are evaluated using slight, moderate, and rough wave characteristics with heights of 0.5 m, 1.25 m, and 2.5 m.

The information in Figure 7 enables us to illustrate how the vessel reacts to sea waves (represented as the Ship Response Amplitude Operator or RAO). This data reveals that the ship's rolling movement is notably influenced when waves approach from the beam seas (the ship's sides) and bow quartering seas (the front part of the ship). However, the rolling motion remains unaffected when waves approach from the head seas (the front of the vessel). Conversely, the pitching motion displays a significant response to waves from head seas and bow

Table 12. Ship motion analysis

Item	Wave Heading (deg)	RMS			unit	Max Value
		0,5 (m)	**1,25 (m)**	**2,5 (m)**		
Heaving	45	0,10	0,27	0,56	m	
	90	0,14	0,36	0,71	m	
	135	0,25	0,60	1,13	m	
	180	0,30	0,65	1,29	m	
Rolling	45	0,43	1,01	1,88	deg	
	90	1,74	3,88	6,14	deg	6°
	135	1,01	2,27	4,13	deg	
	180	0	0	0	deg	
Pitching	45	0,78	1,77	3,22	deg	
	90	0,58	1,28	2,28	deg	6°
	135	1,35	3,06	5,16	deg	
	180	1,76	3,11	6,18	deg	

doi: 10.14710/teknik.v45i3.60019

quartering seas, while its response to waves originating from the beam seas (the ship's sides) tends to be minimal.

Table 12 illustrates the ship's motion response while operating at 15 knots. The analysis indicates that the ship's design meets the NORDSFOK 1987 criteria. Nevertheless, when facing rough wave conditions (2.5 meters), there is a noticeable increase in the values for heaving, rolling, and pitching motions. This suggests the tourist vessel should not sail in challenging wave conditions (2.5 meters). Thus, the design proposed in this research is suitable.

4. Conclusion

A study on the analysis of the Design of a Glass Bottom Catamaran as a Tourist Attraction on Aceh's Banyak Island using numerical and analytical approaches was conducted. The Glass Bottom Catamaran has the following ship principal dimensions: Length Between Perpendiculars (LPP) of 19.50 meters, Breadth (B) of 7.07 meters, Draft (T) of 1.55 meters, Height (H) of 2.4 meters, Block Coefficient (Cb) of 0.55, Service Speed (Vs) of 17 knots, and Displacement of 60 tons. The resistance study reveals a resistance of 42.3 Newtons at a maximum speed of 17 knots, with a negligible calculation error of 0.1%. The stability parameters adhere to the design standards outlined in the Intact Stability Code and the HSC Code for Multihull boats, as the International Maritime Organization stipulated. Analysis of motion at a speed of 15 knots reveals significant enhancements in surging, rolling, and tilting when encountering extreme sea conditions with wave heights of 2.5 meters. This indicates that operating under such circumstances is not advisable. Nevertheless, the vessel complies with all necessary stability and motion criteria.

Acknowledgment

Thanks to all contributors for participating in this research, which has received no external funding.

References

Alam, A., & Birana, B. F. (2019). Rencana Umum Kapal Katamaran Tipe Glass Bottom Untuk Sarana Pariwisata di Kepulauan Derawan, Kabupaten Berau, Kalimantan Timur. JURNAL SAINTIS, 19(02), 41. https://doi.org/10.25299/saintis.2019.vol19(02).3455

Bahattab, S., McCain, S.-L. C., & Lolli, J. (2023). Cruise ship safety measures and their influence on passenger sense of security and purchase intention. Consumer Behavior in Tourism and Hospitality. https://api.semanticscholar.org/CorpusID:258781882

Cepowski, T. (2018). Determination of regression formulas for main tanker dimensions at the preliminary design stage. Ships and Offshore Structures, 14, 320–330. https://api.semanticscholar.org/CorpusID:115995511

Dewi, I. (2022). Faktor-Faktor Yang Mempengaruhi Pergerakan Dari Singkil ke Pulau Banyak Dengan Transportasi Air. Jurnal Ilmiah Telsinas Elektro, Sipil Dan Teknik Informasi, 5(2), 92–104. https://doi.org/10.38043/telsinas.v5i2.3805

Firdhaus, A., & Suastika, I. K. (2022). Experimental and Numerical Study of Effects of the Application of Hydrofoil on Catamaran Ship Resistance. The International Conference on Marine Technology (SENTA), 104–110. https://doi.org/10.5220/0010854400003261

Firman, F., Nadirsyah, & Ridwan. (2024). The Influence of Amount Traveler's Regional Original Income Through Entertainment Tax, Hotel Tax, and Restaurant Tax Regency/City in Aceh Province. International Journal of Economics, 3(1), 159–170. https://doi.org/10.55299/ijec.v3i1.624

Hanafiah, M. H., & Asyraff, M. A. (2022). Effects of post-pandemic perceived safety and security and service quality on ferry service's image, satisfaction, and loyalty. Anatolia, 34, 280–284. https://api.semanticscholar.org/CorpusID:247948622

Harsi, R. B., & Arif, N. (2021). Defining Ship Principal Dimensions Using Comparison Method. Journal of Applied Sciences, Management and Engineering Technology. https://api.semanticscholar.org/CorpusID:245716750

Hidayat, A., Prasetyobudi, H., Yonatan, Y., & Darma, E. (2021). Design and Modeling of Catamaran Flat Plate Ship with Bottom Glass Concept to Improve Tourism Underwater in Bangsring Banyuwangi. Kapal: Jurnal Ilmu Pengetahuan Dan Teknologi Kelautan, 18(3), 140–150. https://doi.org/10.14710/kapal

Hou, Y., Huang, S., Wang, W. Q., & Hu, Y. L. (2011). Regression Analysis of Ship Principal Dimensions Based on Improved PSO-BP Algorithm. Advanced Materials Research, 308–310, 1029–1032. https://api.semanticscholar.org/CorpusID:110472973

IMO A. 749 (18). (1998). Code on Intact Stability for All Types of Ships. 749(November), 1–103.

Jamal, Sulisetyono, A., & Aryawan, W. D. (2020). Review of the seakeeping criteria for the study of a passenger ship criteria in Indonesian water. IOP Conference Series: Materials Science and

Engineering, 982(1). https://doi.org/10.1088/1757-899X/982/1/012041

Jamaluddin, A., Aria, I. K., Utama, P., & Arief, M. (2002). ' Slender Body Method '. Balai Pengkajian Dan Penelitian Hidrodinamika, 1–9.

Kawahara, Y., Yoshiho, I., & Yasunori, N. (2010). Optimization of Ship-Compartments Arrangement on the Basis of the New Damage Stability Criteria. https://api.semanticscholar.org/CorpusID:113224854

Koilo, V. (2019). Sustainability issues in maritime transport and main challenges of the shipping industry. Environmental Economics. https://api.semanticscholar.org/CorpusID:203335225

Metelitsa, S. S. (2020). The Rational Main Dimensions in The Design of High-Speed Passenger Catamarans Choice Justification. Russian Journal of Water Transport. https://api.semanticscholar.org/CorpusID:225230472

Molland, A. F., Turnock, S. R., & Hudson, D. A. (2011). Ship resistance and propulsion: Practical estimation of ship propulsive power. In Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power (Vol. 9780521760). https://doi.org/10.1017/CBO9780511974113

Moon, D. S.-H., & Woo, J.-K. (2014). The impact of port operations on efficient ship operation from both economic and environmental perspectives. Maritime Policy & Management, 41, 444–461. https://api.semanticscholar.org/CorpusID:153811416

Pragada, V. A. D., Banerjee, A., & Venkataraman, S. (2021). Optimisation of Naval Ship Compartment Layout Design Using Genetic Algorithm. Proceedings of the Design Society, 1, 2339–2348. https://api.semanticscholar.org/CorpusID:238818415

Purboyo. (2021). Analysis of Need for Fast Vessels in Ferries. KnE Social Sciences, 272–283–272–283. https://api.semanticscholar.org/CorpusID:234288427

Rahmat, M. Z., Tiyasmihadi, T., & Abdullah, K. (2023). Design of Catamaran Electric-Powered Glass Bottom Boat as a Tourism Facility for Gili Noko Island. International Journal of Marine Engineering Innovation and Research, 8(3), 2548–1479.

Santosa, P. I., & Pranatal, E. (2021). Study of Catamaran Fishing Vessel Based on Solar Energy. Journal of Physics: Conference Series, 2117(1), 012023. https://doi.org/10.1088/1742-6596/2117/1/012023

Setiawan, I., Yuni, S. M., Ulfah, M., Purnawan, S., Haridhi, H. A., Masri, S. R. R., Muhammad, M., & Ilhamsyah, Y. (2021). Wave height and period on 16 March, 21 April, and 22 September 2019, in the Ujung Batee coastal waters and Lampanah coastal waters, Aceh Besar District, Indonesia. IOP Conference Series: Earth and Environmental Science, 869. https://api.semanticscholar.org/CorpusID:244191732

Smadi, A. A., & Abu-Afouna, N. H. (2012). On Least Squares Estimation in a Simple Linear Regression Model with Periodically Correlated Errors: A Cautionary Note. In AUSTRIAN JOURNAL OF STATISTICS (Vol. 41, Issue 3).

Soeboer, D. A., Iskandar, B. H., Imron, M., & Ardiyani, W. J. (2018). Utilization Of The Inka Mina In PPP and PPS Tegalsari Cilacap, Central Java. ALBACORE: Jurnal Penelitian Perikanan Laut, 2(3), 357–368.

The Maritime and Coastguard Agency. (2008). International Code of Safety for High-Speed Craft. MCA Maritime and Coastguard Agency, July, 380.

Trisyaldi, A., Purwantono, P., Waskito, W., Primawati, P., & Syahril, S. (2019). Study of Ship Design Maninjau Lake Tourism by Using Catamaran Hull Type and Fiberglass Material. Teknomekanik. https://api.semanticscholar.org/CorpusID:243718569

Wang, D., Liu, K., Huo, P., Qiu, S., Ye, J., & Liang, F. (2019). Motions of an unmanned catamaran ship with fixed tandem hydrofoils in regular head waves. Journal of Marine Science and Technology, 24(3), 705–719. https://doi.org/10.1007/s00773-018-0583-x

Yaakob, O., Hashim, F. E., Jalal, M. R., & Mustapa, M. A. (2015). Stability, seakeeping and safety assessment of small fishing boats operating in southern coast of Peninsular Malaysia. Journal of Sustainability Science and Management, 10(1), 50–65.

doi: 10.14710/teknik.v45i3.60019