REKAYASA 22 (1) (2024): 34-42

REKAYASA

Jurnal Penerapan Teknologi dan Pembelajaran

http://journal.unnes.ac.id/journals/rekayasa

Design and Construction of a Leisure Boat Bottom Glass Prototype as An Underwater Panorama Tourism Ride in Karimunjawa

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DOI: https://doi.org/10.15294/rekayasa.v22i1.13881
Submited: 2024-03-17; Revised: 2024-04-03; Accepted: 2024-05-01

Abstract

The lack of proper tourism infrastructure often limits the potential of marine ecotourism. In Karimunjawa, coral reef tourism is a major attraction. However, accessibility remains an issue, especially for visitors who cannot swim or dive. This research focuses on the design and construction of a glass-bottom leisure boat prototype to provide a safe and immersive underwater panorama experience. This study falls within naval architecture and marine engineering, addressing the challenge of designing a stable, efficient, and safe tourism vessel. A key concern in ship design is balancing hydrodynamic efficiency with stability. While monohull boats are common, their transverse stability is relatively low. To overcome this, a catamaran hull configuration was chosen for better stability, larger deck space, and reduced resistance. The prototype was constructed with dimensions of 21.81 m in length, 2.63 m in height, and 7.51 m in width, featuring a glass-bottom viewing area to enhance the tourism experience. Hydrodynamic performance analysis showed an average increase in resistance of 12.39307 N as speed increased, demonstrating the vessel's efficiency. The construction and testing process confirmed that the catamaran hull improves passenger safety, minimizes capsizing risk, and enhances the underwater viewing experience. This research contributes to sustainable marine tourism by introducing an innovative tourism ride that allows visitors to explore the underwater beauty of Karimunjawa without requiring diving skills. The successful design and construction of this prototype provide a model for future eco-friendly tourism vessels.

Keywords*:* catamaran hull, hydrodynamic performance, marine ecotourism, naval architecture.

INTRODUCTION

Indonesia is a maritime country with more than 17,000 islands, covering a marine area of 3.25 million km², of which 2.55 million km² is an Exclusive Economic Zone from the Ministry of Marine Affairs and Fisheries. The country has a coastline of 81,000 km and approximately 60,000 km² of coral reefs, home to one-eighth of the world's coral reef species (Marwan & Isnaeni, 2022). These factors present a significant opportunity for the development of marine tourism, particularly in coastal and coral reef areas, which attract both domestic and international tourists when properly managed.

The tourism sector is a key contributor to Indonesia’s economy, generating foreign exchange revenue (Hamonangan et al., 2020). Many stakeholders are interested in developing nature tourism, but inadequate infrastructure and a lack of supporting facilities often discourage visitors. One of Indonesia’s most promising marine tourism destinations is the Karimunjawa Islands.

Located in Central Java Province, the Karimunjawa National Park is geographically positioned at 5°40'39"–5°55'00" S and 110°05'57"–110°31'15" E (Sulisyati et al., 2014). Based on the Minister of Forestry and Plantation Decree the Karimunjawa Nature Reserve was designated as a national park covering 111,625 hectares. The Karimunjawa Islands possess rich marine biodiversity, including 400 species of marine life, with 242 ornamental fish species and several endangered species such as the white-bellied sea eagle (*Haliaeetus leucogaster*), hawksbill turtle (*Eretmochelys imbricata*), and green turtle (*Chelonia mydas*).

The Karimunjawa Islands play a crucial role in boosting Indonesia's marine tourism economy (Saragi, 2023). However, most boats used for tourism activities in Karimunjawa are converted fishing boats with monohull structures and small engine placements above the deck. These boats face significant safety risks during harsh weather conditions, limiting tourism accessibility (Adietya & Elvira, 2018). Additionally, current tourism boats in Karimunjawa generally lack specialized features beyond diving equipment and basic onboard amenities. Since the primary attraction of Karimunjawa is its underwater beauty, a more innovative and stable tourism vessel is required.

A catamaran hull design has become increasingly popular due to its wider deck area, enhanced stability, and greater safety and comfort for passengers (Piscopo & Scamardella, 2015). The catamaran’s slender hull shape also reduces wave-induced motion compared to traditional monohull vessels (Tamunodukobipi & Nitonye, 2019). To analyze the hydrodynamic resistance and stability of catamaran hulls, computational modelling was conducted using Maxsurf software (Lutfi et al., 2023). The catamaran hull form coefficient is generally higher than that of twin-hull vessels due to the Z-effect, which can result in a 10% difference (Sugianto et al., 2022). Structural strength considerations are also essential in ship design to evaluate the vessel’s response to combined loads.

Therefore, this research aims to develop a tourism vessel with a catamaran hull that can accommodate more tourists while ensuring enhanced stability and lower hydrodynamic resistance, ultimately improving passenger safety. Additionally, bottom glass innovation is integrated into the design, a feature that remains rarely applied in catamaran-type tourism vessels. The bottom glass feature allows non-swimming tourists to enjoy the beauty of coral reefs in the Karimunjawa

Islands without diving. This research aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 14 (Life Below Water) by promoting marine biodiversity appreciation and conservation, and SDG 12 (Responsible Consumption and Production) by encouraging sustainable tourism practices that minimize environmental impact. Furthermore, by providing a safer and more inclusive marine tourism experience, this study also supports SDG 9 (Industry, Innovation, and Infrastructure) in advancing maritime transportation technology.

METHODS

This research focuses on improving tourism vessels in the Karimunjawa Islands by developing a catamaran hull design that can accommodate more tourists while incorporating bottom glass innovation, allowing passengers to observe the underwater beauty without the need for diving. The ship analysis process follows the regulations of the 2023 National Unmanned Fast Boat Competition to determine the vessel's dimensions. The tourism boat dimensions in this study were determined using linear regression based on selected reference vessels. The reference ships used in this study are listed in Table 1. The Comparison method will be used to obtain the main size of the ship and the main dimensions of the ship are obtained, namely, length (L) = 20.152 meters, beam (B) = 5.5 meters, depth (H) = 2.939 meters, draft (T) = 1.5129 meters (Harsi & Arif, 2021).

During the dimensioning process, several key hull ratios were obtained, including the Length-to-Beam Ratio (L/B), Length-to-Height Ratio (L/H), and Beam-to-Draft Ratio (B/T). The main dimensions of the tourism vessel, derived from the regression of reference ships, are presented in Table 2, while the main dimensions of the prototype vessel are provided in Table 3. Additionally, the line plan of the vessel can be seen in Figure 1. The pre-design of the catamaran hull is based on using the comparative method as the dimension ratio of the ship, so that the dimensions of the ship are LWL = 4 m; LPP = 3.96 m; B = 1.7 m; B1 = 0.36 m; D = 0.7 m; d = 0.307 m (Trisyaldi et al., 2019).

RESULTS AND DISCUSSION

To estimate the required power, several elements need to be considered, including the amount of power needed and the resistance experienced by the vessel. The reference source for calculating the power required by the ship's motor is the resistance acting on the vessel.

Table 1. Comparative Ship Data, Length, Breadth, Depth, and Draft

Ship name		Breadth, (B)	Depth, (H)	Draft, (T)
Pringle 18	19.3	6.9	3.2	1
Pulau Seribu	25.95	9.9	2.5	1
Spirit Of Victory	27.4	13.02	4.1	1.74
Captain Korsac	31	8.4	3.8	1.5
Super Jet-30	31.5	9.8	3.8	1.9
Tusa 5	24.5	7.66	2.5	1.75
Pure Dive	15.6	5.36	1.75	1.25
Black Gold	20.65	6.75	2.45	1.65
Cat Balou	16.01	6.36	2.03	1.2
JC 1435	14	3.5	1.4	0.45
JC 1450	14	5	1.4	0.45

Table 2. Main Ship Dimensions (unit m)

Measurement	Value
Length	21.81
Breadth	7.51
Depth	2.63
Draft	1.26

Table 3. Prototype Ship Sizes (unit cm)

Measurement	Value
Length	119.95
Breadth	41.32
Depth	14.47
Draft	6.94

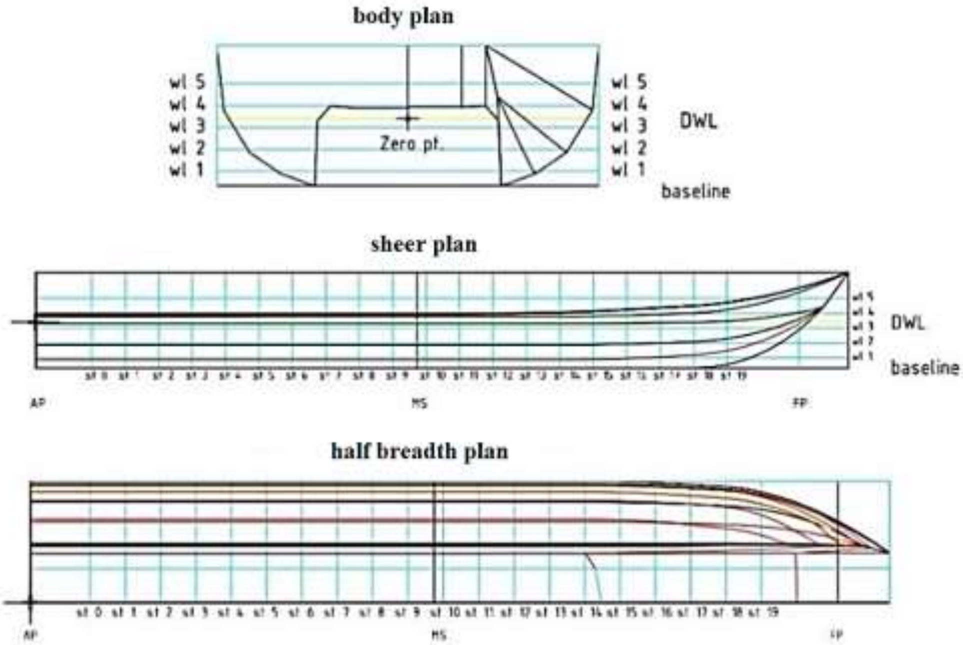


Figure 1. Ship Plane Linen

This resistance value is determined using Maxsurf Resistance software, which employs the Slender Body method. The Slender Body method illustrates the variation in resistance caused by different hull structure configurations.

A comparison between the ship's resistance and the power generated at the same Froude number. Additionally, Figures 2 and 3 display the graphical comparison of resistance and power against the Froude number. Putra, I. N., Susanto, A. D., & Suharyo, O. S. (2017). Comparative analysis results of towing tank and numerical calculations with harvald guldammer method. *Int. J. Appl. Eng. Res*, *12*, 10637-10645.

The resistance analysis in this study compares the characteristics resulting from the design effects to estimate the power required for the ship's design. A low resistance projection is targeted. Various parameters and scenarios have been explored using different ship speeds and Froude numbers. Table 4 provides a detailed comparison of resistance values.

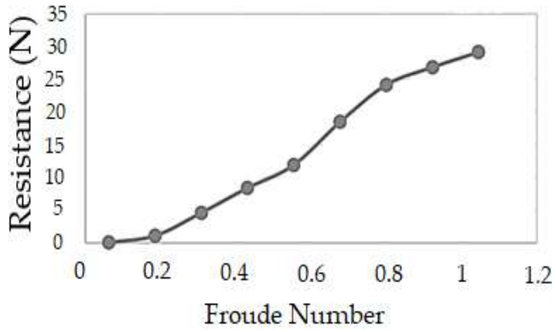


Figure 2. Grafik Froude Number vs Resistance

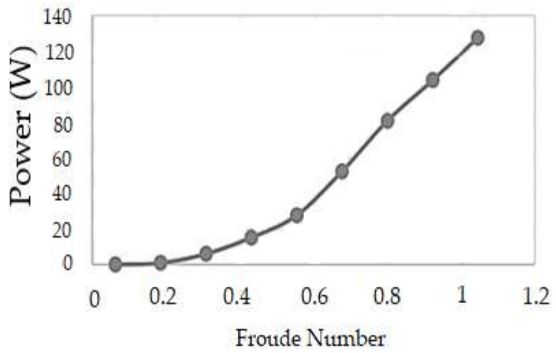


Figure 3. Grafik Froude Number vs Power

Table 4. Comparison of Froude Number vs Resistance vs Power

Froude Number vs Resistence vs Power		
Froude	Number Resistance (N)	Power (W)
0.062	0.06	0.02
0.185	1.09	0.84
0.308	4.60	5.92
0.431	8.40	15.12
0.554	11.91	27.57
0.677	18.48	52.30
0.800	24.15	80.74
0.923	26.84	103.56
1.045	29.14	127.43

Table 5. Hydrostatic Data of Ship Prototype

No.	Measurement	Value	Unit
1	Displacement	9.214	kg
2	Volume (displaced)	8989.51	cm^3
3	Draft Amidships	6.95	cm
4	Immersed depth	6.94	cm
5	WL Length	113.98	cm
6	Beam max extents on WL	38.75	cm
7	Wetted Area	4111.40	cm^2
8	Max sect. area	87.39	cm^2
9	Waterpl. Area	2070.83	cm^2
10	Prismatic coeff. (Cp)	0.902	
11	Block coeff. (Cb)	0.580	
12	Max Sect. area coeff. (Cm)	0.643	
13	Waterpl. area coeff. (Cwp)	0.927	
14	LCB length	51.78	from zero pt. (+ve fwd) cm
15	LCF length	53.23	from zero pt. (+ve fwd) cm
16	LCB %	45.431	from zero pt. (+ve fwd) % Lwl
17	LCF %	46.696	from zero pt. (+ve fwd) % Lwl
18	KB	4.33	cm
19	KG fluid	6.95	cm
20	BMt	49.06	cm
21	BML	221.03	cm
22	GMt corrected	46.43	cm
23	GML	218.41	cm
24	KMt	53.38	cm
25	KML	225.36	cm
26	Immersion (TPc)	0.002	tonne/cm
27	MTc	0.000	tonne.m
28	RM at 1deg = GMt.Disp.sin(1)	7.47	kg.cm
29	Length:Beam ratio	5.817	
30	Beam:Draft ratio	2.822	
31	Length:Vol^0.333 ratio	5.482	
32	Precision	Highest	213 stations

The ship's hydrostatic data obtained serves as a configuration variable. Table 5 presents the new design characteristics. With speeds from 8 to 16 knots, variations are controlled accordingly. Seawater conditions for calculations must meet ITTC 1975 parameters: salinity 3.5%, kinematic viscosity 0.0000011 m^2/s, density 1025.9 kg/m^3, and gravity 9.8 m/s^2.

The new design developed according to the Slender Body and Savitsky method yields resistance values as shown in Table 6. This shows that the data study can be used to calculate resistance profiles and wave patterns.

The resistance analysis of this study compares the characteristics resulting from the design effect. For the purpose of estimating the power required by the ship design. low resistance can be projected. The results. various parameters and scenarios have been explored using different ship speeds and Froude numbers. Tt is found that as the ship speed increases. the resistance value also increases with an average resistance increase of 12.39307 N.

Hull design variations

This study focuses on the number of tourists that can be accommodated on the ship and aims to provide an interesting impression because they can enjoy the underwater panorama without having to surf. Therefore, this study chooses a catamaran-type hull as shown in Figure 4 which can accommodate more tourists.

The two hulls on a catamaran are connected by a bridging structure. namely a deck located between the two hulls which has the function of providing transverse strength to the ship. Catamaran ships are considered to have many advantages when compared to monohulls. where the ship's deck is wider. and has good stability. By using a catamaran hull, it can provide comfort and safety to tourists (Nugraha & Hasanudin. 2017). The type of catamaran hull used is an asymmetric catamaran type hull design variations, including Flat Inside Symmetry, Flat Symmetry Outside, and Asymmetry, were analyzed to determine the most efficient catamaran model for Lake Maninjau, with test results indicating that the Flat Inside Symmetry design offers optimal performance for tourism applications (Esmailian & Steen, 2022). Hull design variations, including monohull and catamaran types with deadrise angles ranging from 10° to 30°, were analyzed to determine their impact on resistance reduction in high-speed patrol boats (Prabowo et al., 2022).

Table 6. Resistance Values of the Savitsky and Slender Body Methods

Speed (kN)	Savitsky Resistance (N)	Selender Body Reistance (N)
8	17.71	28.86
9	20.47	33.23
10	23.6	38.74
11	27.16	44.58
12	31.13	51.69
13	35.51	58.87
14	40.3	66.27
15	45.49	73.72
16	51.06	82.60

Ship Hull Wave Pattern

During this procedure, the ship's Froude number is initially determined, and although relatively unimportant, there is little change in the wave pattern as shown in Figures 5. Even when the Froude number is low or the ship enters the planing stage, the waves surrounding the ship appear smoother. The Impact of Froude Number on Ship Waves is shown in Figure a that the ship's wave pattern at low Froude number (Figure 5a) and high Froude number (Figure 5b). At low speed, the waves produced are smaller and smoother, thus increasing passenger comfort. At high speed, the wave pattern becomes more complex and larger, which can cause discomfort due to shaking or vibration. When the Froude number is low, the ship experiences minimal wave-breaking, but as the ship enters the planing stage at higher Froude numbers, more violent bow wave breaking occurs (Roshan et al., 2022). The ship hull wave pattern is influenced by the Froude number, with low Froude numbers producing waves outside the Kelvin wake cusps and high Froude numbers generating primarily divergent waves within the cusps (Wu et al., 2019). There is little change in the wave pattern across different configurations, but at maximum Froude number, the trimaran models exhibit minimal interference factors of 0.02-0,022 (Yuliora et al., 2022).

Implications for passenger stability and experience: Large waves may cause visual distortion or discomfort for passengers viewing underwater through the glass due to ship vibrations. Thus, the design must ensure an optimal speed for stability. This study compares long-term hydro-structural computations with Classification Society Rules (Tilander et al., 2020).

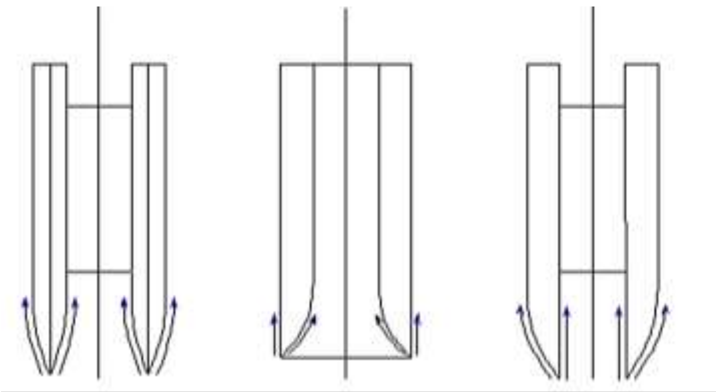
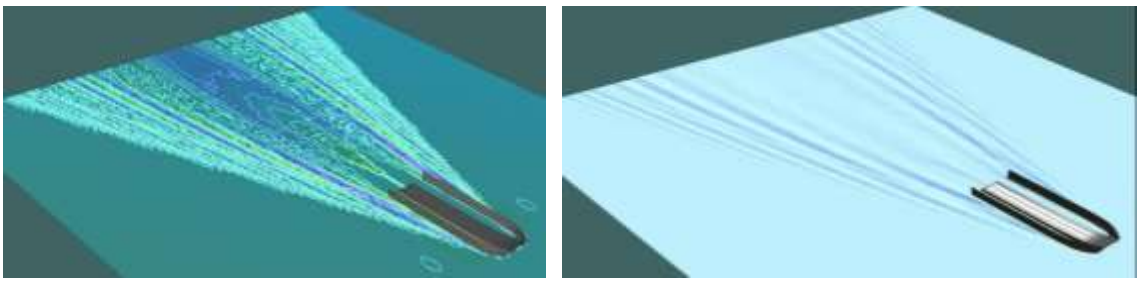


Figure 4. Catamaran Hull Type
(a) Simetris (b) asimetris type-a (c) asmtris type-b



(a) (b)

Figure 5. Ship Hull Wave Pattern
(a) at low (b) at high froude number

On the other hand, the optimization of the underwater hull design, it is considered that the catamaran hull can be selected because it produces less resistance than a monohull, thus reducing the impact of waves and increasing fuel efficiency. The ship design must minimize the effects of waves while maintaining optimal cruising range for underwater conditions (Wang et al., 2020). The ship hull wave pattern plays a crucial role in the bottom-glass vessel design, influencing stability, passenger comfort, and energy efficiency, with Model 4 being selected for its lower resistance and better hydrodynamic performance (Hidayat et al., 2021).

CONCLUSION

The computational results indicate that the Slender Body method successfully aligns with the Savitsky method in terms of resistance characteristics. The trend lines also exhibit a consistent pattern, and a good agreement is observed across all recommended dimensions. Based on the findings, the hull design increases the Froude number, thereby reducing overall resistance. Computational analysis using Maxsurf software shows that the average increase in hull resistance is 12.39307N as the ship's speed increases. Although a clear flow pattern is observed around the hull, modifications to the hull's front section alter the wave pattern. This study can be further enhanced by comparing different computational approaches to better understand water interactions with the hull. Additionally, this research holds potential for further development, as the bottom glass innovation in catamaran-type vessels remains limited in shipyard production.

ACKNOWLEDGEMENT

This research work is supported by DPA FT UNNES Year of 2024 with number of 125.22.3/UN37/PPK.05/2024 and Creativity and Research Club Department of Mechanical Engineering of Universitas Negeri Semarang. Indonesia for helping authors in this research.

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