Design of Catamaran Electric-Powered Glass Bottom Boat as a Tourism Facility for Gili Noko Island

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(Received: 16 September 2023 / Revised: 18 September 2023 /Accepted: 18 September 2023)

***Abstract*— Gili Noko Island is one of the islands located in the Bawean archipelago, Gresik regency. The beauty of the beaches and underwater scenery on this island often captivates tourists but access to this island is quite limited. This research proposes the design of a tourist boat concept with a glass bottom route from Bawean to Gili Noko. In this research, there were several research design used those were the principal dimension, lines plan, general arrangement, construction calculation, stability analysis, ship motion analysis, and ship comfort. The selection of the engine is based on the calculated power required for the boat's resistance. The chosen engine is an electric propulsion system as a new environmentally friendly alternative. From the technical analysis, the boat's dimensions are found to be Loa: 11.83 m, B: 4.50 m, B1: 0.80 m, H: 1.50 m, T: 0.60 m, Cb: 0.611, and Vs: 7 knots. The engine power is 10.5 HP, and the battery capacity is 840 Ah. The construction calculation reveals that the boat weigths 4.8584 tons. The stability analysis complies with IMO standards, and the motion analysis and ship comfort meet the criteria set by Olson in 1987.**

Keywords— electric boat, gili noko island, glass bottom boat, ship design, tourist boat.

I. INTRODUCTION

Tourism is one of the important economic sectors for a country and region. With tourism, the economy and income of the area will increase. In addition, tourism is also used as a regional characteristic to be better known in the public eye [1]. In Indonesia, many places offer tourism with its natural and cultural beauty, one of which is Gresik Regency which has a lot of tourism potential.

Gresik Regency is one of the regencies in East Java province. Gresik Regency offers many tourism sectors, including natural tourism, artificial nature tourism, religious tourism, cultural tourism, historical tourism, and culinary tourism [2]. One of the places that offers beautiful marine tourism is Gili Noko Island.

Gili Noko Island is one of a group of islands located on Bawean Island which is administratively still included in the Gresik Regency area. Geographically, the Bawean Islands are located between 112 45' East Longitude and 5 45' South Latitude. The area is 196.27 km² [3]. Tourists can enjoy the beauty under the sea and a very beautiful expanse of beach sand in this island, as one of the tourist destinations that are a mainstay of tourists when visiting Bawean Island [4], tourists visiting Gili Noko Island can enjoy the sunset and sunrise are the best on the island, not only the beauty of the underwater in this destination to become an attraction that can attract a lot of tourists. The panorama and natural resources owned by the island of Gili Noko often tempt tourists to come to this island even after a long journey. Visitors who have a lot of guts can also swim or snorkel accompanied by dozens of sharks and witness the beauty under the sea.

Recently, the zero-emission movement has become increasingly popular among the public community, as well as various government pilot programs such as research and the development of renewable energy is also very intense in supporting it [5]. Electric-powered tour boats are very likely to be realized in several years. This is due to battery technology and electric motors increasingly sophisticated. The motor is combined with a Li-ion battery (Lithium-ion) which has a high discharge rate and long life longer and the current price is cheaper than in previous years.

Conducting repeated analytical procedures to achieve the best outcomes is essential in ship design. This is because crafting an ideal ship design necessitates adherence to relevant regulations, and achieving excellence in ship design is nearly impossible with just a single attempt but with immediate positive outcomes. Throughout the entire planning process, spanning from the initial phase to the final planning stage, multiple stages of calculations and analyses are involved. [6][7]. The ship design concept itself is typically similar to that of other ship design procedures. The design process commences by determining the primary measurements of the vessel, computing its resistance, creating the lines plan, and establishing the general arrangement of the ship. [8].

Based on the problems above, in this study, the authors wanted to design a glass-bottom tourist boat. This tourist boat will later be designed to use an electric motor or electric motor. The author chose to use an electric-powered boat engine to reduce pollution caused by exhaust gases from boats so as not to damage the beauty of the sea on Gili Noko Island. The results of this final project are expected to be a reference for tourism

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development on the island of Gili Noko so that it can become a new attraction for tourists.

II. METHOD

Numerous techniques are employed during the ship design process, with the spiral design method being the most widely utilized. [9] and the parent design approach. Specifically on this study, the spiral design was used by taking an example of a ship design that has almost the same shape and characteristics as the ship you want to design. The principal dimension of the boat used was obtained from linear regression of the parent ship data. The independent variable (x) used in the linear regression is the planned passenger's capacity from observations, data collection obtained from the official website of the Gresik department of tourism and culture [10], and interviews with local residents. After obtaining the principal dimension, proceed with planning lines plan, resistance calculation, determining machine, battery calculation, general arrangement design, construction calculation, weight calculation, stability analysis, seakeeping analysis, and ship comfort.

III. RESULTS AND DISCUSSION

The glass bottom boat design process begins with determining the principal dimension, planning line plans, calculating resistance, determining machine, calculating battery, planning general arrangement, calculating construction, calculating weight, analyzing stability, analyzing seakeeping, analyzing ship comfort and finally planning 3D model. The results of the full study can be traced below.

A. Determining the Principal Dimension

In this study, the principal dimension was determined using the linear regression method. The linear regression technique is a statistical tool employed to assess the impact of one or multiple variables on a single variable. The independent variable (X) used is the number of passengers of 24 people, while the dependent variable (Y) is the main size of the boat, namely, boat length (L), boat width (B), boat height (H), and boat draft (T). To determine the function of each pair of independent and dependent variables using the help of a comparison ship. Comparison vessel data and linear regression graph are shown in table 1 and figure 1 below.

TABLE 1.
COMPARATION SHPS DATA

Ships name	Passangers capacity	Length	Breadth	Heigth	Draft
Surf Cat 850	20	7,85	3,00	1,43	0,50
Aquila 36 Excursion	26	9,94	4,45	1,25	0,60
Blu Anda 121	30	11,49	4,36	1,35	0,55
HD-1160W	30	11,65	4,55	1,45	0,61
Whitsunday Bullet	43	12,05	4,70	1,7	0,55

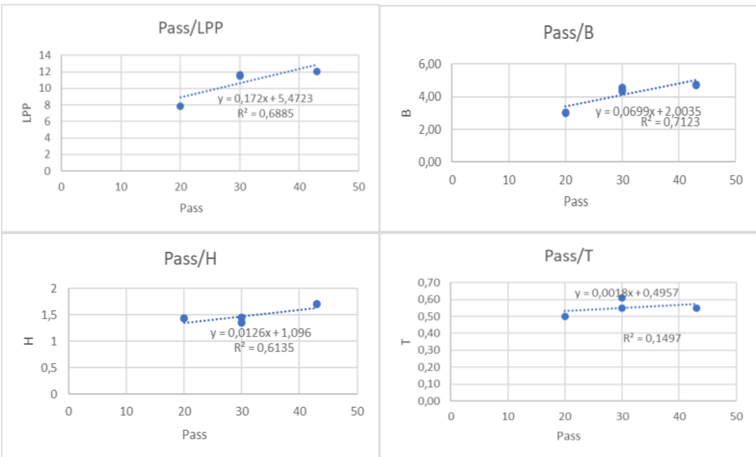

Figure 1. Linear Regression Graph

The results of the linear regression above are used as an approach in determining the main dimensions of the ship. However, if the dimensions of the ship produced do not meet the specified requirements, then these dimensions cannot be used and must be re-planned by taking into account the applicable requirements.

Therefore, the following is the main ship dimension data used in the design of this tourist ship.

Length Between Perpendicular (LPP) = 11 meters
Breadth Moulded (B) = 4.5 meters
Beam of Side Hull (B_1) = 0.8 meters
Depth (H) = 1.5 meters
Draft (T) = 0.6 meters

To ensure the optimal main dimensions of the ship, there are limitations that must be met, which includes comparisons of B/L, H/L, B_1/T, L/B_1, and B/B_1[11]. Each component of the comparison has a range or limits that must be met. The results of the comparison of the limits that have been determined and the final principal dimension are shown in table 2 and table 3 below.

TABLE 2.
PRINCIPAL DIMENSION COMPARASION

Items	Type	Value	Requirement	
	B/L	0.409091	Range 0.3-1.0	Accepted
Principal	H/L	0.1636363	Range 0.1-0.3	Accepted
Dimension	B_1/T	1.66667	Range 0.5-2.5	Accepted
Comparasion	L/B_1	11	Range 2-30	Accepted
	B_1/B	0.178	Range 0.15-0.3	Accepted

TABLE 3.
PRINCIPAL DIMENSION BOAT

Parameters	Dimension
Length Overall (LOA)	11.83 m
Length Water Line (LWL)	11.45 m
Length Between Perpendicular (LPP)	11 m
Breadth/Beam (B)	4.5 m
Depth (H)	1.5 m
Draught/Draft (T)	0.6 m
Beam of Side Hull (B_1)	0.8 m
Cruising Speed (Vs)	7 knot

B. Linesplan

The lines plan is commonly described as a two-dimensional representation of a ship's hull section, projected either transversely or longitudinally. In typical lines plans, we come across three distinct designs: the body plan, the sheer plan, and the half-breadth plan. The LinesPlan serves as the initial foundation for ship design and plays a crucial role in the design process. [8].

In making the Ship Hull Design Line Plan, used Maxsurf Modeller and AutoCAD software. The first step is to model the ship's hull in the Maxsurf Modeller software according to the predetermined principal dimensions. Then set the grid design by adding a station, waterline, and buttock line. After the hull model is finished, then export the file to AutoCAD in a two-dimensional form so that it becomes a line plan view as shown in figure 2 and figure 3 below.

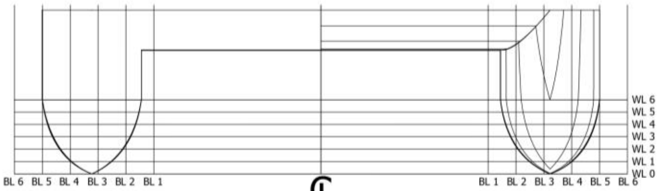

Figure 2. Ship's Body Plan

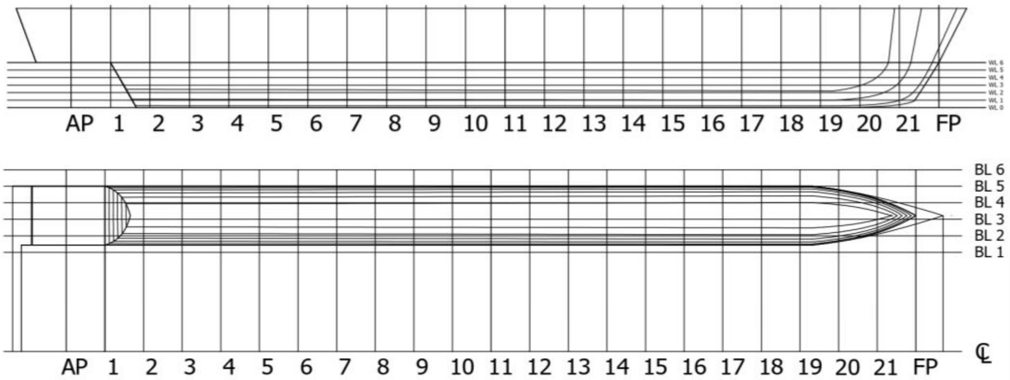

Figure 3. Sheer and Half Breadth Plan

C. Determining Machine and Battery

1. Ships Resistance

Calculation of hull resistance was carried out using Maxsurf Resistance software. The approach used to analyze obstacles is the Slender Body method. Each drag analysis method is selected based on the type and shape of the hull. The Slender Body method was chosen because according to the Maxsurf Resistance User Manual, this method can be applied to various hull shapes, including multihull which has a slender and symmetrical design.

From the simulation results using the Maxsurf Resistance software with the Slender Body method, the resistance and power values of the ship are obtained. The recorded resistance value of the ship is 2.3 kN, the operational speed is 7 knots. This resistance value will be used as a reference in selecting the machine. The simulated results of the calculation of the hull resistance show the results of the resistance and power calculations listed in the resistance graph shown in Figure 4 and Table 4 below.

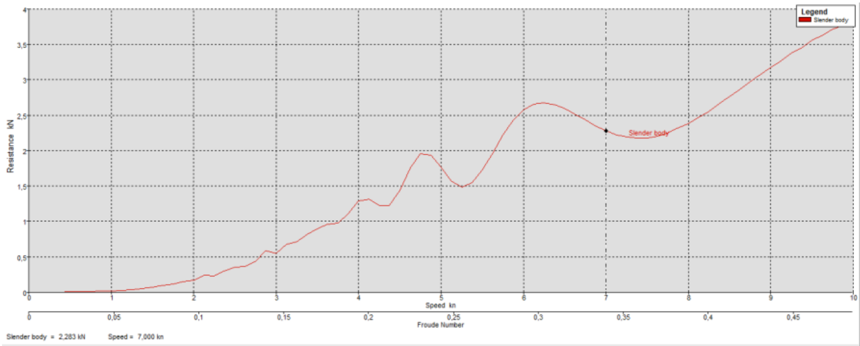

Figure 4. Resistance vs Speed Graph

TABLE 4.
CALCULATE RESISTANCE DATA

Speed (kn)	Froud No. LWL	Froude No. Vol.	Slender body Resist. (kN)
2.250	0.109	0.270	0.2
2.500	0.121	0.300	0.4
2.750	0.133	0.329	0.4
3.000	0.146	0.359	0.6
3.250	0.158	0.389	0.7
3.500	0.170	0.419	0.9
3.750	0.182	0.449	1.0
4.000	0.194	0.479	1.3
4.250	0.206	0.509	1.2
4.500	0.218	0.539	1.4
4.750	0.231	0.569	2.0
5.000	0.243	0.599	1.8
5.250	0.255	0.629	1.5
5.500	0.267	0.659	1.7
5.750	0.279	0.689	2.2
6.000	0.291	0.719	2.6
6.250	0.303	0.749	2.7
6.500	0.316	0.779	2.6
6.750	0.328	0.809	2.4
7.000	0.340	0.839	2.3

2. Power Calculation

After the value of the ship's resistance is known, namely Rt = 2.3 kN, then the ship's engine power is calculated. The power of this engine is used as a reference in selecting ship engines. Next, the calculation of engine power is carried out based on the book "Ship Resistance and Propulsion"[12].

a. Efective Horse Power (EHP)

EHP = Rt ×V (1)
= 2,3 ×3,6011 m/s
= 8.221 kW or 11.025 HP

b. Wake Friction (W)

W = 0,5 Cb-0,05 (2)
= 0,261

c. Trush Deduction Factor (T)

T = k ×W (3)
= 0,2084

d. Speed of Advance (Va)

Va = (1-W) × Vs (4)
= (1-0.261) × 3.6011 m/s
= 0.2663

e. Rotative Relative Efficiency (ηrr)

The value of ηrr for ships with twin screw propellers ranges from 0.97 to 1.07. In planning the propeller and propeller shaft tube, the value of ηrr is 1.07.

f. Propulsion Efficiency (ηp)

The value is between 40 – 70%. Taken the value of 60%.

g. Hull Efficiency (ηH)

ηH =((1-t))/((1-W))
=1,0704

h. Propulsive Coefficient (Pc)

Pc = ηrr × ηp × ηH
= 0,687

i. Delivery Horse Power (DHP)

DHP =EHP/Pc
=11.963 kW or 16,043 HP

j. Shaft Horse Power (SHP)

SHP = DHP/ηsηb
=12,207 kW or16,370 HP

k. Brake Horse Power (BHP) Scr.

BHP Scr = SHP
=12,207 kW or 16,370 HP

l. Brake Horse Power (BHP) Mcr.

BHP Mcr = (BHP Scr)/0,85
=14,361 kW or 19,259 HP

In this design two machines are used, so that the BHP per machine is 7.1805 kW or 9.6295 HP. BHP is used as a reference to determine the machine to be used.

After calculating the resistance and power for glass bottom boats, the next step is to choose the appropriate engine. The selected machine must have specifications according to the calculation results. Complete information regarding machine specifications can be found in the selected machine catalog. In general, the selected machine specifications can be explained in table 5 and figure 5 below.

TABLE 5.
ELECTRIC MOTOR SPECIFICATIONS

Specification	Units
Brand	Bellmarine Drive Master 10 W (Liquid Cooler)
Intermittent kW	10 kW
Nominal kW	8 kW
HP equiv	10.5 HP
Voltage	48 vdc
Current	208 A
Dimension	L:408 mm W:240 mm H:240 mm
Weight	35 kg
Motor RPM	1500 rpm

Sources : Bellmarine engine catalog [13]

Figure 5. Bellmarine Drive Master (Liquid cooler)

3. Battery Calculation

The power in the battery depends on how much energy can be stored, the energy stored in a battery is in units of Ah (Ampere hours) or power per hour, so that you can find out the total current capacity with the working voltage of the battery [14].

. The battery used as a power source for driving the electric motor of this tour ship is adjusted to the working voltage of the DC motor used, which is 48 Vdc and also the power that works on one motor is 10 kW or 10,000 watts (peak power is used). In the design requirements, it is planned that this tour ship will operate at 08.00-17.00 for 3 trips with an estimated time of 60 minutes for each trip. Total ship operating time = 60 minutes x 3 = 180 minutes or 3 hours.

Taking into account the voltage and power of the engines and the operating time of the ship, it was decided to use 8 Lithium Iron Phosphate (LiFePO4) batteries with a voltage of 48 V and a capacity of 105 Ah, which will be connected in parallel. So, in total, there will be 16 batteries to be used, with each machine having its own individual battery. LiFePO4 material is a material for the cathode in Lithium Ion batteries and has a number of advantages such as low cost, high working voltage (voltage curve is nearly linear at 3.4 V compared to lithium materials), high specific capacity, good stability at high temperatures , long service life (more than 1000 usage cycles), and environmentally friendly [1]. The selected battery and specifications are shown in Table 6 and Figure 6 below.

TABLE 6.
BATTERY SPECIFICATIONS

Specification	Units
Brand	Power Brick+
Voltage	10 kW
Capacity	8 kW
Stored Energy	10.5 HP
Voltage	48 vdc
Current	208 A
Dimension	L:408 mm W:240 mm H:240 mm
Weight	35 kg
Motor RPM	1500 rpm

Sources : Power Brick+ Battery catalog [15]

Figure 6. LiFePO4 48 V 105 Ah Battery

D. Electric Propulsion System

Generally, electric ship systems have lower complexity than non-electric ships. In an electric ship system, the electric motor is used as the main propulsion source, while the battery functions as a power storage or "fuel" for the motor. In an electric ship system, there is a motor controller which acts as a controller for all systems operating on the ship. This controller is connected to the throttle and also the display on the ship. The components in an electric ship include:

1. DC motors

A direct current motor (DC motor) is a device that converts direct current electrical energy into mechanical energy. This motor serves as the prime mover that sends energy to the ship's shaft and propeller.

2. Battery

The battery is a place to store electrical energy after charging (charge), which later this electrical energy will be distributed to the engine.

3. Motor Controller

The function of this motor controller is to control all systems on an electric ship. Such as the battery power delivery system, engine cooling system (colling system), as an indicator on the display, and connecting to the throttle.

4. Battery Charger

This is a tool to recharge the battery, this tool converts the incoming current from the shore connection (AC) to DC current.

5. Throttles

The function of this Throttle is as a stabilizer or controller of the ship. This throttle is connected to the controller as the main system controller on the ship.

6. Displays

Display is a monitor that can display information, such as battery state, capacity, etc. The information displayed on the display is obtained from the motor controller.

7. Cooling system

This device consists of a valve, filter to filter water, and also a pump to suck up water as engine coolant. The cooling system is connected to the motor controller which will then be channeled to the main engine.

8. Shore Power Connector

Shore Power Connector is a cable that connects land current with battery charging on board.

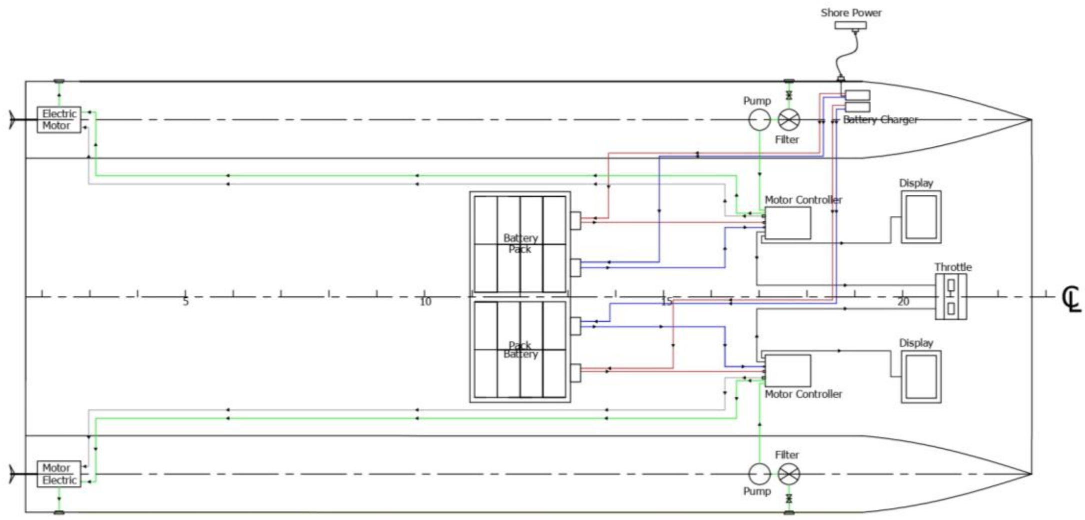

Figure 7. Electric Propulsion System

E. General Arrangement

By considering the lines plan drawings that have been prepared and various related plans, a general plan or General Arrangement of this glass bottom boat can be compiled. This general Arrangement drawing refers to the planning of the room layout on the boat. The layout plan of this room is located above the boat's deck.

This general plan shows the layout of the seats for passengers as well as the outer design of the ship which can be seen in the side view, deck view, front view and back view. The arrangement of the passenger seats is arranged as many as 11 seats on each side of the ship or a total of 22 seats, these seats are arranged facing the glass bottom area. The wheelhouse is located at the front of the ship and there are two seats for the crew.

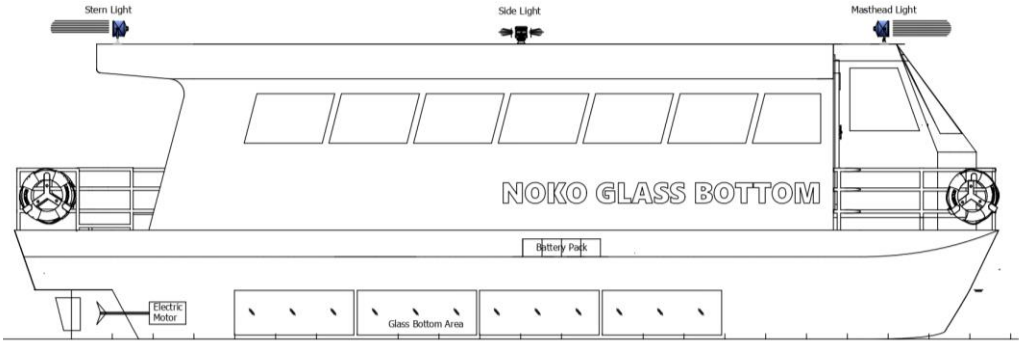

Figure 8. General Arrangement (Side View)

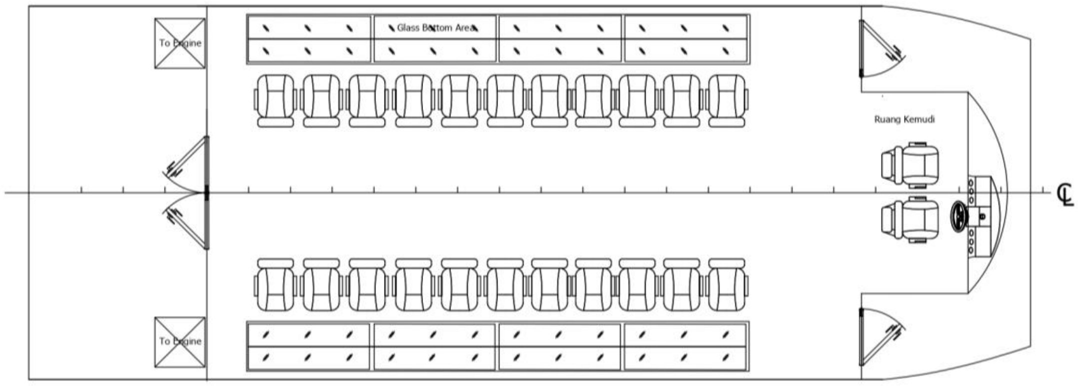

Figure 9. General Arrangement (Main Deck)

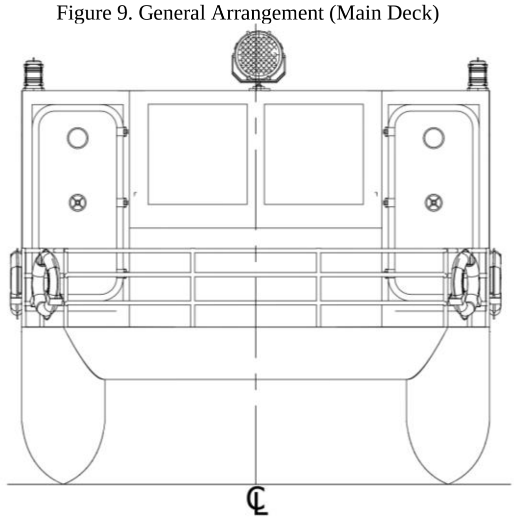

Figure 10. General Arrangement (Front View)

F. Construction Calculation

Construction calculations are carried out using aluminum material. In this construction calculation, load, material thickness and modulus calculations will be carried out, which are then used to obtain the LWT ship weight. For construction calculations on aluminum material, refer to BKI regulation part 3 Special Shps Vol.VII Rules for Small Vessels Up to 24 m [16].

1. Aluminium Type Determination

In the market, there are various series of aluminum alloy plates, from 1000 series to 8000 series and so on. However, in shipbuilding, the commonly used aluminum materials are in the 5000 and 6000 series. In the 5000 series, there are two types of aluminum that are often used for making ship hulls, namely the 5083 and 5086 series. Meanwhile, in the 6000 series, the types of aluminum that are often used are 6061 series and 6082 series.

The aluminum used in the planning of this ship uses aluminum series 5083. Because the aluminum alloy series has many positive properties given in its content. In addition, the 5083 series aluminum alloy has also been widely sold in the market, so that in the shipbuilding process there will not be any problems in procuring the aluminum alloy series material for a long time.

2. Frame Spacing

The planned frame spacing on this boat is:

a = (350 + 5 .L) (mm)
= 408.9 mm

So that the Frame spacing used is 500 mm

3. Construction Summary

recapitulation of calculations can be seen in Table 7. below

TABLE 7.
CONSTRUCTION CALCULATION

Item		for : ≥ 0.4 L		for : < 0.4 L	
		Min. BKI	Used	Min. BKI	Used
Keel Plate	Width	106.03 mm	110 mm	106.03 mm	110 mm
	Thickness	11.563 mm	12 mm	11.563 mm	12 mm
Bottom Plate		6.175 mm	7 mm	5.523 mm	7 mm
Floor	Modulus	7.5 cm^3	9 cm^3	6 cm^3	7 cm^3
	Dimension		I65x7mm		I50x7mm
Bottom longitudinal		2.3 cm^3	5 cm^3	2.7 cm^3	5 cm^3
			I50x5mm		I50x5mm
Side Shell		4.954 mm	5.00 mm	4.426 mm	5.00 mm
Side longitudinal	Modulus	3.4 cm^3	5 cm^3	3.4 cm^3	5 cm^3
	Dimension		I50x5 mm		I50x5mm
Web Frame	Modulus	15.466 cm^3	16 cm^3	12.343 cm^3	16 cm^3
	Dimension		L 60x40x5mm		L 60x40x5mm
Gading Biasa	Modulus	7.5 cm^3	9 cm^3	6 cm^3	7 cm^3
	Dimension		I65x6mm		I50x7mm
Collision Bulkhead				4.851 mm	5 mm
Collision Bulkhead Girder					
	Modulus				
	Dimensi	2.3 cm^3	5 cm^3	2.7 cm^3	5 cm^3
			I50x5mm		I50x5mm
Other Bulkhead		3.195 mm	4 mm	3.195 mm	4 mm
Other Bulkhead Girder					
	Modulus				
	Dimensi	4.3 cm^3	5 cm^3	4.3 cm^3	5 cm^3
			I50x5mm		I50x5mm
Deck Plate		3.244 mm	4 mm	3.244 mm	4 mm
Deck Beam					
	Modulus	7.5 cm^3	9 cm^3	6 cm^3	7 cm^3
	Dimensi		L65x6mm		I50x7mm
Deck Girder					
	Modulus	2.90 cm^3	5 cm^3	2.90 cm^3	5 cm^3
	Dimensi		I50x5mm		I50x5mm
Superstructure Plate		3.521 mm	4 mm	3.521 mm	4 mm
Deck beam deckhouse					
	Modulus	2.508 cm^3	5 cm^3	2.90 cm^3	5 cm^3
	Dimensi		I50x5mm		I50x5mm
Deck Girder deckhouse					
	Modulus	2.90 cm^3	5 cm^3	2.90 cm^3	5 cm^3
	Dimensi		I50x5mm		I50x5mm

G. Weight Calculation

Ship weight calculation is divided into 2, namely dead weight or DWT (Dead Weight Tonnage) and empty ship weight or LWT (Light Weight Tonnage). The weight of the DWT ship consists of the weight of passengers, luggage and crew. The weight of the LWT ship briefly consists of the total weight of the material and the weight of the machinery. The weight of the material is obtained by multiplying the total area by the thickness of the plate on the ship. Then the multiplication result is multiplied by the density of the material. For aluminum the density is 2.7 tons/m^3. Calculation of construction weight can be seen in table 8, table 9, and table 10 below.

TABLE 8.
LWT CALCULATION

Item	Value	Unit
Hull Construction Weight		
Plate weight	2.028	Ton
Construction Weight	0.843	
Total weight Aluminum hull construction	2.871	Ton
Superstructure Weight		
Total Upper Building Area	70.91	m^2
Superstructure Plate Thickness	0.004	m
Volume	0.284	m^3
Aluminum specific gravity	2.7	Ton/m^3
The total weight of the superstructure	0.766	Ton
Glass Weight		
The surface area of the glass is obtained from the sketchup software which uses a thickness according to the calculation, which is 9 mm		
Thick glass	9	mm
Glass surface area	13.324	m^2
Volume of glass = area x thickness	0.0972	m^3
Glass density	1.18	Ton/m^3
Total weight of glass	0.1147	Ton
Railing Weight		
The length of the railing is obtained from the measurement of the railing from the general plan of the railing material using an aluminum pipe with a thickness of 2 mm		
Pipe Diameter	40	mm
Pipe thickness	2	mm
Railing surface area	13.324	m^2
Railing volume = area x thickness	0.0267	m^3
Density of Aluminum	2.7	Ton/m^3
Railing Total Weight	0.072	Ton
Machine Weight		
Taken from machine catalog		
Inboard Electric Engine	0.07	Ton
Propeller Shafts	0.0074	Ton
Propeller Blades	0.004	Ton
Rudder	0.024	Ton
Total Machining Weight	0.1054	Ton
Battery Weight		
Taken from the battery catalog		
Number of batteries	16	Pcs
Battery Weight	0.0375	Ton
Total battery weight	0.6	Ton
Other Equipment Weight		
Passenger Seat	209	Kg
Crew seats	20	Kg
Navigation and steering equipment	100	Kg
total weight	329	Kg
	0.329	Ton

TABLE 9.
DWT CALCULATIONS

Item	**Value**	**Unit**
Weight of Passengers and Luggage		
Total passenger	22	Person
	80	Kg
	3	Kg
Weight per passenger	1760	Kg
	66	Kg
Weight of luggage per passenger	1826	Kg
	1.826	Ton
Total passenger weight		
Total weight of passengers' luggage	2	Person
	80	Kg
	5	Kg
Total weight of passengers and	160	Kg
luggage	10	Kg
Ship's Crew Weight and Luggage	170	Kg
	0.17	Ton
	1996	Kg

TABLE 10.
TOTAL SHIP WEIGHT

Item	Weight (Ton)
DWT	1,996
LWT	4,8584
Total Ship Weight	6,8544

H. Stability Analysis

Ship stability shows the ability of the ship to be able to return to its original position after experiencing shaking caused by external forces that affect it (Manik & Hadi, 2008). Stability analysis for the design of this tourist ship uses the help of Maxsurf Stability. The stability analysis of this ship refers to the IMO MSC.36(63) HSC Code Annex 7, Multihull criteria. These criteria are most suitable for passenger ships and catamaran hulls.

This stability analysis was carried out on several loadcase conditions, namely on variations in the number of passengers. while loadcase 1 is a full passenger, loadcase 2 is a half-full passenger, loadcase 3 is an empty passenger, and loadcase 4 is a half-full passenger on one side. The result of stability analysis is shown in figure 11 until figure 14 below.

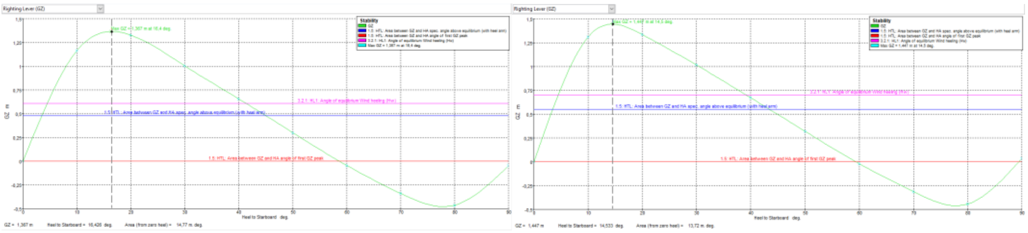

Figure 11. GZ curve on Loadcase 1 and Loadcase 2

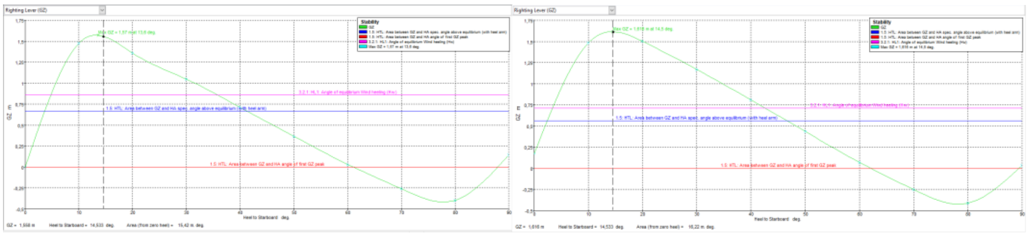

Figure 12. GZ curve on Loadcase 3 and Loadcase 4

TABLE 11.
COMPARASION OF STABILITY VALUE

Code	Units	Loadcase 1	Loadcase 2	Loadcase 3	Loadcase 4	Req. Value	Status
Area from 0 to 30	m.deg	14.6577	13.7337	14.0191	16.2428	5.774	Pass
Angle of maximum GZ	Deg	16.4	14.5	13.6	14.5	10	Pass
Angle of maximum GZ and heeling arms							
Hpc + Hw	m.deg	9.5190	10.0619	10.3621	11.5394	1.604	Pass
Ht + Hw	m.deg	12.8285	14.3907	16.1466	6.9924	1.604	Pass
Angle of equilibrium due to the following Shall not be greater than Wind Heeling (Hw)	deg	4.5	4.5	4.8	3.4	16	Pass

I. Seakeeping and Ship Comfort Analysis

1. Seakeeping

The ship's motion is analyzed under the condition of a 100% passenger ship or full load of passengers operating at a service speed of Vs = 7 knots. Ship motion was analyzed using maxsurf motion software. To analyze the ship's motion, refer to the JONSWAP wave spectra which match the Indonesian waters which are islands. Referring to wave height data based on the BMKG, the Bawean – Gili Noko sea is included in calm to slight waters with wave heights of 0.1 – 1.25 meters.

Based on seakeeping criteria stated in Olson [17]. general criteria as a limitation for seakeeping analysis on passenger ships. The general criteria used in this analysis are summarized in a summary of the seakeeping analysis results obtained with the help of the Maxsurf Motion Advanced software. Seakeeping Analysis Results Referring to the results of the response spectra analysis which includes heave, roll and pitch movements with the position of the following wave directions, beam sea and headsea. With a ship speed of 7 knots and wave heights of 0.1 m, 0.5 m and 1.25 m.

average roll amplitude should not be more than 12 degrees, average pitch amplitude should not be more than 3 degrees, and significant heave acceleration should not be more than 2 m/s^2, seakeeping analysis results can be seen in the table below.

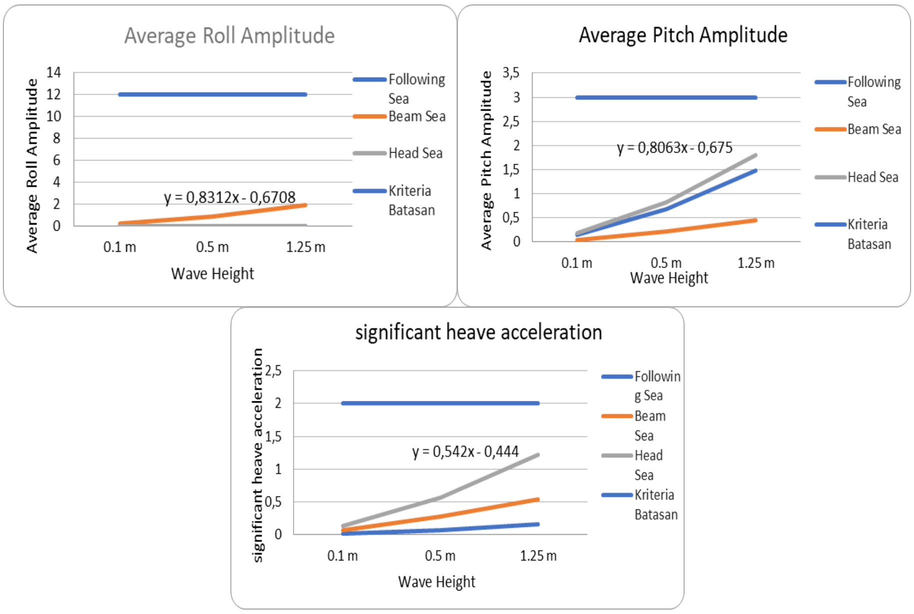

Figure 13. Seakeeping Graph

TABLE 12.
SEAKEEPING RECAPITULATION

Wave Direction	Wave Hright.	Average Roll Amplitude (degree)	Average Pitch Amplitude (degree)	Significant Heave Acceleration (m/s^2)
Following Seas	0.1 m	0 (Pass)	0,15 (Pass)	0,016 (Pass)
	0.5 m	0 (Pass)	0,675 (Pass)	0,072 (Pass)
	1.25 m	0 (Pass)	1,4875 (Pass)	0,164 (Pass)
Beam Seas	0.1 m	0,2125 (Pass)	0,04875 (Pass)	0,068 (Pass)
	0.5 m	0,8875 (Pass)	0,2125 (Pass)	0,272 (Pass)
	1.25 m	1,875 (Pass)	0,45 (Pass)	0,54 (Pass)
Head Seas	0.1 m	0 (Pass)	0,1875 (Pass)	0,134 (Pass)
	0.5 m	0 (Pass)	0,825 (Pass)	0,568 (Pass)
	1.25 m	0 (Pass)	1,8 (Pass)	1,218 (Pass)

2. Ship Comfort

Passenger comfort is important in the passenger ship design process, where the level of comfort Passengers are determined by the index value of the number of passengers experienced seasickness during the wave period of ship operations passenger. Calculations and simulations are performed at one point on the ship namely the passenger deck / passenger room to see the acceleration happening vertically. From the simulation results using the help Maxsurf Motion software is known to have the influence of the measurement location, duration and direction of the waves on the percentage of the number of passengers who experience symptoms of seasickness or motion sickness Incidence (MSI).

In addition to MSI, MII (motion induced interruptions) is a situation where the crew will stop the activity or task they are doing and then hold on to any part of the ship, with the aim of maintaining balance[18]. The criteria and results of the MSI and MII simulations can be seen in table 13 to table 15 below.

TABLE 13.
MSI SAFETY RATING RANGE

Range	Status	Passenger Condition
0 – 5 SM	*Moderate*	The shock still feels safe.
5 – 10 SM	*Serious*	Shaking causes dizziness.
10 – 15 SM	*Severe*	The shaking causes vomiting.
15 – 20 SM	*Hazardous*	Shock is dangerous for passengers.
>20 SM	*Intolerable*	The shock is not tolerable.

TABLE 14.
MII RISK LEVEL

MII per *Hour*	MII *Risk Level*	Passenger Condition
6	*Possible*	Can hold or not
30	*Probable*	Holding on is recommended
90	*Serious*	Must hold on
180	*Severe*	Must hold on
300	*Extreme*	Must hold on

TABLE 15.
MSI & MII RESULTS

Wave direct.	Wave height	MII/jam	MII Risk Level	MSI %	MSI SM	MSI *status*
Following Seas	0.1 m	0	*Possible*	0	0,00	*Moderate*
	0.5 m	0,0000	*Possible*	0,0000	0,04	*Moderate*
	1.25 m	0	*Possible*	0	0,108	*Moderate*
Beam Seas	0.1 m	0,000	*Possible*	0	0,046	*Moderate*
	0.5 m	0,000	*Possible*	0,074	0,353	*Moderate*
	1.25 m	0	*Possible*	1	0,951	*Moderate*
Head Seas	0.1 m	0	*Possible*	0	0,107	*Moderate*
	0.5 m	0,0000	*Possible*	0,337	0,87	*Moderate*
	1.25 m	0	*Possible*	5	2,67	*Moderate*

J. 3D Model

The 3D design of this tourist ship is planned based on the planning results that have been completed in the previous discussion. From previous planning discussions, it will be applied in 3D form so that the visualization of the ship can be known, and a more realistic picture form is obtained in planning this ship design.

The results obtained in this design planning are obtained in the form of 3D shapes using the help of the SketchUp software. obtained a layout that is designed in accordance with the results of planning a general plan that has been planned.

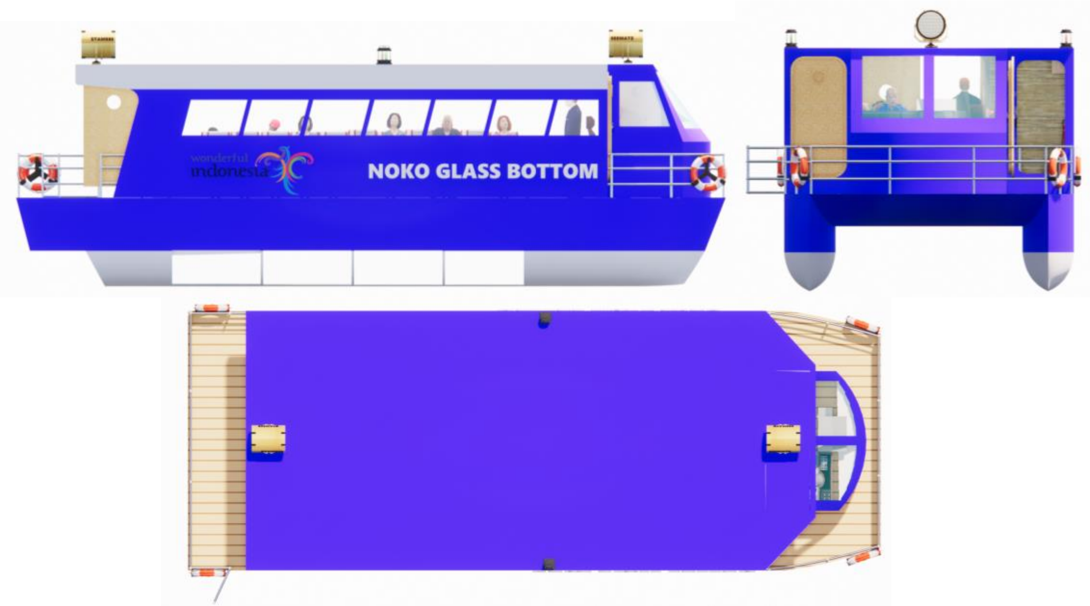

Figure 14. Side, Front, and Top View

Figure 15. Isometric view and interior

IV. Conclusion

Based on analysis and technical calculations of glass bottom boat, the boat's dimensions are found to be Loa: 11.83 m, B: 4.50 m, B1: 0.80 m, H: 1.50 m, T: 0.60 m, Cb: 0.611, and Vs: 7 knots. The engine power is 10.5 HP, and the battery capacity is 840 Ah. The construction calculation reveals that the boat weigths 4.8584 tons. The stability analysis complies with IMO standards, and the motion analysis and ship comfort meet the criteria set by Olson in 1987. The Glass Bottom Boat, designed with a focus on tourism, is anticipated to become a captivating attraction, enticing tourists to enjoy vacations on Gili Noko Island.

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