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# Design of River Tour Boat's Hull For Taman Nasional Tanjung Puting, Central Borneo

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**Abstract**

Tanjung Puting National Park is a natural wildlife park with a positively increasing trend in the number of visitors. The transportation which is utilized in Sekonyer river is 'klotok' boat, a traditional tour boat modified from a fishing boat. The design of a fiberglass-based tour boat is needed to accommodate the limitation of Kalimantan's logs, which become the main structural components of klotok and to comply with the technical characteristic of the river. The purpose of this study is to obtain the optimum main dimensions of the fiberglass-based tour boat and its hull form design. The method performed to obtain the main dimension of the boat is non-linear optimization with the help of solver in Microsoft Excel software. The process of boat's hull design is done by line distortion approach where the shape of a reference boat's hull is conformed to a particular size and hydrodynamical coefficients, which are obtained from the optimization process. The result of optimization process is the main dimension of the boat (Lpp = 12.23 m, B = 2.70 m, H = 1.14 m, T = 0.80 m and Cb = 0.55). By conducting a series of calculations, the obtained value of the total boat's resistance worths 2,427 N. Therefore, the number of boat's power needed is less than the power of existing boats. The boat's hull also complies with technical requirements and regulations, which are freeboard and intact stability.



## 1. Introduction

National Park is a natural conservation area that has a pure ecosystem, administered with a zonary system which utilized for research, science, cultivation, tourism, and recreational activity [1]. Tanjung Puting is one of Indonesia's national parks, which used for tourism activities, located in Central Kalimantan's peninsula. Tanjung Puting also well-known among international tourists, especially European tourists, for its endemic animals, Orangutan. There are some destinations which will be visited by tourists while going down to Sekonyer river. The activities included in the tour package are going down through Sekonyer river with a traditional boat, staying overnight in the traditional village, feeding Orangutan, visiting Orangutan Museum, and forest sightseeing [2].

The most popular attraction for international tourists in Tanjung Puting is feeding Orangutan. Hence, a buildup of tourists occurs during the period of high season in the three camps, which are Tanjung Harapan, Pondok Tanggui, and Camp Leakey. The only transportation used to go along the river is Klotok. It is a standard traditional boat used in Kalimantan rivers. The size of klotok varies from 13 to 20 meters in length and approximately 3 meters in breadth. Lately, most of klotok, which has been utilized, is a result of fishing boat's modification. The process of new hull production is rarely found due to the extinction of Ulin wood, which becomes the main structural component of klotok. Therefore, alternative material is needed to produce klotok boat.

Fiberglass is one of material that utilized to produce a boat besides wood, steel, aluminum, and ferro-cement. Nowadays, fiberglass is commonly used as it is obtained easily in stores, cheaper than other materials and the equipment needed is quite simple. The number of boats will grow proportionally as the number of tourists coming to keep increasing. Therefore, alternative material for boat structures and regulation regards to the traffics of the boats in high season are needed. Moreover, one of the previous research concluded that it is necessary to make improvements in terms of a transportation route, modernization, safety, and convenience of the boat besides uniformity of tour package's price [3].

This research is conducted to obtain boat hull's design, which suitable for Tanjung Puting environmental requirements. The first thing that must be determined is the optimum value of the main dimensions of the boat. The shape of the hull is designed based on the main dimensions that have been obtained. The resistance of the new hull design is expected to be smaller than the resistance of the ship that is now available so that the engine used can be smaller. The resulted boat's hull design is expected to be a reference for following boat's hull production in Tanjung Puting.

Hekkenberg stated that the optimization of boat size may escalate the economic benefit yet still restricted to an area of boat's navigation [4]. The maximum width of the river limits boat's length due to the boat maneuver radius when it reached the upstream of the river. There has been some research on the use of optimization methods to determine the main dimensions of the boat. The purpose of the generalized reduced gradient (GRG) method has been carried out to determine the main size of the Navy's LCU ship[5]. Research on catamaran ship design has also been carried out with optimization methods to determine the main size of the ship[6]. Basic Ideas of GRG, nonlinear program to be solved is assumed to have the form

$$\begin{gathered}\text{minimize } f(X) \\ \text{subject to } g_i(X) = 0\text{ , } i = 1, \ldots, m \\ l_i \leq X_i \leq u_i,\ i = 1,\ldots,n\end{gathered} \tag{1}$$

where $X$ is $n$-vector and $u_i$, $l_i$ are given lower and upper bounds $u_i > l_i$. The fundamental idea of GRG is to use the equalities (2) to express $m$ of the variables, called *basic variables*, in terms of the remaining $n$-$m$ *nonbasic* variables[7].

The main duty of a naval architect is to obtain the best hull shape based on integration among main dimension, hydrostatic coefficient, and several factors such as [8]:

1. Resistance and propulsion;
2. Stability;
3. Seakeeping;
4. Boat's maneuver;
5. Cargo space;
6. Construction aspect; and
7. Building cost.

The shape of the boat's hull cross-sectional area is divided into several types as shown in Figure 1:

a) U shape;
b) V shape;
c) Square (midship sections);
d) Round;
e) Hard-chine (one or two chines); and
f) Bulbous (fore and aft part of boat).

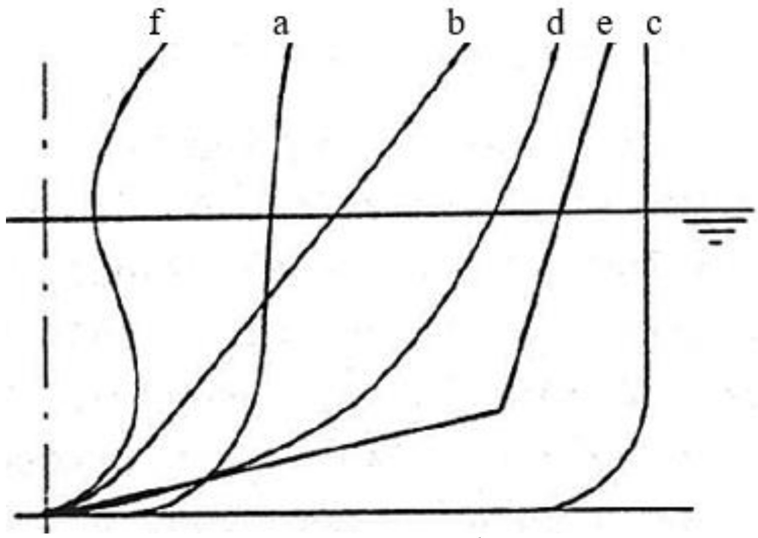

Figure 1. Boat Cross Sectional Area Types

The shape of the boat hull influences the performance of boat's stability. U shape generates less waterplane area than V shape; thus, the boat with U shape has a shorter metacenter radius (BM). Meanwhile, the vertical center of buoyancy of U shape is lower than V shape. On the same initial stability (same value of GM), a boat with U type hull needs a greater value of B/T (lower L/B) than a boat with V type. On the same amount of displacement, the vertical center of gravity for V shape hull is higher than another one as the weight distribution of steel tends to be above the waterline. Nevertheless, for V shape hull, the position of metacenter above baseline (KM) is higher. Therefore it can maintain the position of metacenter above the center of buoyancy.

## 2. Methods

The whole sequence of this research, as shown in Figure 2 and will be explained comprehensively stage by stage as follows.

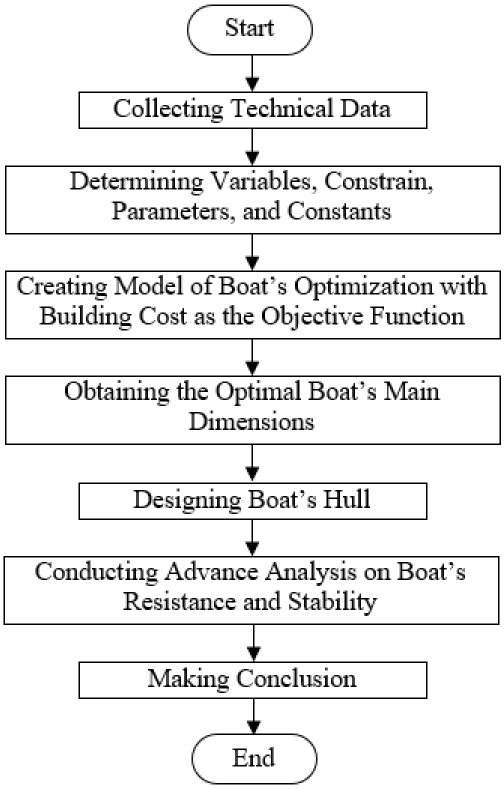


Figure 2. Research Flow Chart

### 2.1. Determining The Technical Requirements

This stage is done by processing given data from Tanjung Puting National Park administrator, which collected by conducting a direct field survey to Tanjung Puting National Park. The information contains the number of tourists coming, the number of tour boats, and Sekonyer river dimension (total length, width, and depth). After collecting data from Tanjung Puting National Park, the next stage is analyzing passengers' capacity, operational mileage, service speed, and boat consumable's endurance during the trip.

### 2.2. Determining the Main Dimension of the Boat

The important thing that needs to be done before making a design of the hull is a ship's main dimension. The determination of the main dimension of the vessel is done by the optimization method. Optimization of the main dimension of the ship is made in an optimization model of the data that has been obtained by involving the calculation of technical requirements and applicable regulatory provisions. There are five components of optimization method which are objective function, variables, constraints, parameters and constants which are as follows

1. Objective Function
   The objective function of this research is the total building cost of a tour boat.
2. Variables
   Variables on this research are boat length (Lpp), breadth (B), depth (H), draft (T) and block coefficient (Cb).
3. Constraints
   Constraints on this research are based on technical requirements and regulations, which are displacement correction, freeboard, trim, and stability.
   - Displacement
     The total weight of the boat, Deadweight (DWT) + Lightweight (LWT), to be closer to the value of Displacement (L x B x T x Cb x ρ) by a margin of 1% to 3%.
   - Freeboard
     Ship freeboards at full load must meet the minimum values required in the Minister of Transportation Regulation No. PM 39 of 2016 concerning freeboard and ship loading.
   - Trim
     The trim value of the boat must be between - 2% Lwl to 2% Lwl.
   - Stability

Ship stability criteria that must be met in the analysis are based on the Intact Stability Code (IMO, 2008)[9].

4. Constants

Constants on this research are freshwater density, gravitation, fiberglass density, etc.

5. Parameters

Parameters on this research are the number of passengers, width, and depth of Sekonyer river.

- The planned number of passengers is assumed to be the owner's requirement.
- River width and depth
- The width of the river affects the planned boat's width, while the depth of the river affects the maximum draught ship.

### 2.3. Designing Boat's Hull

Boat's hull is designed after the optimal main dimension is obtained. The line distortion approach is utilized for designing the boat's hull [10] with the help of maxsurf modeller software. The process of designing boat's hull considers two main aspects, which are the boat's resistance and stability. The value of the boat's displacement and hydrostatic coefficients also must comply with the calculation result, which previously done during the boat's main dimension optimization process.

### 2.4. Conducting Advanced Analysis

Advanced technical analysis is a detailed process of technical calculation, which previously done in the boat's main dimension optimization. This analysis is performed based on the hull model from the previous stage, and the analysis consists of boat resistance and stability simulation. Resistance simulation of boat's hull model is performed by using maxsurf resistance. The Holtrop method is applied to obtain the total resistance, and the estimated minimum boat's powering to fulfill service speed as the owner requirements. The stability simulation of the boat's hull model is performed by using maxsurf stability. Previously on the optimization stage, Barnhart & Thewlis method is applied and only in one load case, that is, full load condition. At this stage, the load cases will be comprehensive on every possibility refer to the real condition of daily boat operation.

## 3. Results and Discussion

A field survey to Tanjung Puting National Park has been accomplished. Tourism condition and operational boat scheme have already been known. Tourists mostly from abroad and travelled with a spouse or along with family. Tour package is available for minimum of 2 people. The sailing distance to the last camp (Camp Leakey) is around 45 kilometers, which the average service speed of tour boar is 5 knots. The narrowest width of the river is approximately 5 meters with minimum depth 2 meters. According to tour boat owners, the seabed consists of muds and some transverse logs from dead trees. After discussing with Tanjung Puting National Park administrator and analyzing the given data, then technical requirement which has to be fulfilled on this design process is arranged. The technical requirements, as shown in Table 1. The process of determining a boat's main dimension is begun with collecting the existing boat's main dimension. These data will be employed as a comparison in the optimization process. The number of an existing boat is determined to be 20 boats, as shown in Table 2.

Table 1. Tour Boat Technical Requirement

| Technical Requirement | Value |
|---|---|
| Type of boat | River tour boat |
| Operational route | Kumai Port - Camp Leakey |
| Route distance | 45 kms |
| Service speed | 5 knots |
| Number of crews | 4 people |
| Number of passengers | 4 people |

Table 2. Existing Tour Boat Data

| No | Boat's Name | Lpp (m) | B (m) | H (m) | T (m) |
|---|---|---|---|---|---|
| 1 | Zulfikar | 16.50 | 2.85 | 1.47 | **1.10** |
| 2 | Yeni Rahma | 17.60 | 3.10 | 1.13 | **0.85** |
| 3 | Usaha Baru 211 | 18.00 | 4.00 | 1.47 | **1.10** |
| 4 | Duta Pariwisata | 15.80 | 2.40 | 1.60 | **1.20** |
| 5 | Kelinmutu | 19.00 | 4.20 | 1.73 | **1.30** |
| 6 | Ogreen | 18.30 | 3.80 | 1.73 | **1.30** |
| 7 | Belantara | 19.30 | 4.00 | 1.40 | **1.05** |
| 8 | Fiqri II | 17.60 | 3.10 | 1.13 | **0.85** |
| 9 | Bima Sakti | 16.60 | 2.70 | 1.47 | **1.10** |
| 10 | Borneo Eco Tour | 14.00 | 3.00 | 1.87 | **1.40** |
| 11 | Batavia I | 14.20 | 3.00 | 1.33 | **1.00** |
| 12 | Bim Sakti II | 15.90 | 3.00 | 1.47 | **1.10** |

| | | | | | |
|---|---|---|---|---|---|
| 13 | Spirit Ading | 16.80 | 2.30 | 1.47 | **1.10** |
| 14 | Bahuma | 16.00 | 3.40 | 1.33 | **1.00** |
| 15 | Horbil | 15.80 | 3.10 | 1.07 | **0.80** |
| 16 | Sean | 16.00 | 2.92 | 1.87 | **1.40** |
| 17 | Tiana II | 17.70 | 3.10 | 1.20 | **0.90** |
| 18 | Tiana I | 16.00 | 3.00 | 1.07 | **0.80** |
| 19 | Princess Kumai | 17.33 | 3.70 | 1.40 | **1.05** |
| 20 | Oto | 14.83 | 3.30 | 1.60 | **1.20** |
| **Minimum Size** | | 14.00 | 2.30 | 1.07 | **0.80** |
| **Maximum Size** | | 19.30 | 4.20 | 1.87 | **1.40** |

The optimization model to obtain the main dimension is created with the help of solver tool on Microsoft excel software, where generalized reduced gradient (GRG) is applied. The add-in installation of solver is required to activate solver function on the software because solver has not been installed by default settings.

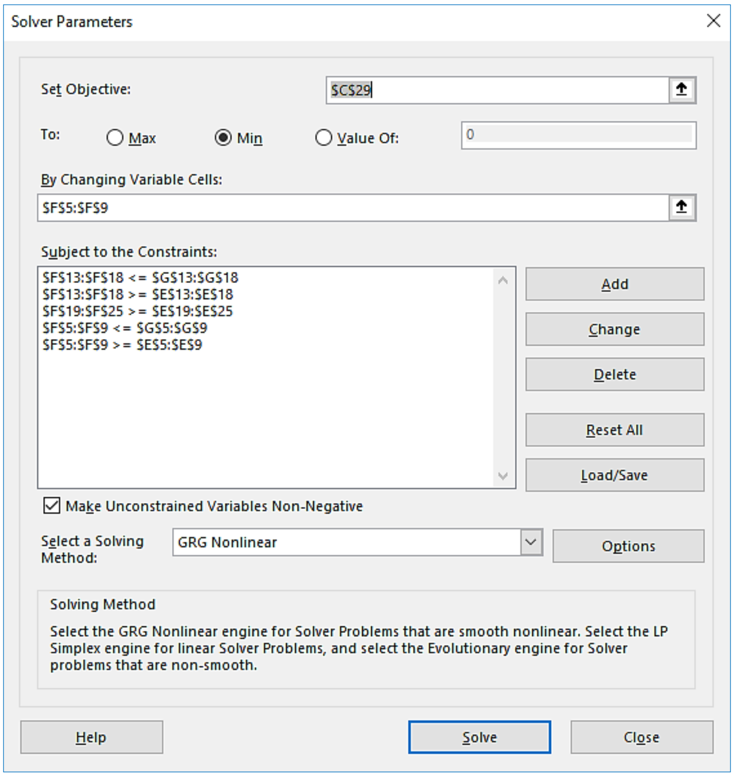

Figure 3. Solver Dialog Box

On the dialog box, as shown in Figure 3, Set Objective is filled with a target cell, which will be minimalized or maximized, or in the optimization process is called objective function. The purpose of the optimization of this research is to minimize the overall building cost. In other words, the best decision for the main dimension will be based on the cheapest building cost, which complies with the technical requirements and regulations. By Changing Variable Cells, the column is filled with variables that are the main dimension of the boat, such as boat's length between perpendicular (Lpp), breadth (B), depth (H), draft (T) and block coefficient (Cb). Subject to the Constraints is filled with technical constraints from every single type of technical calculations, which are stability, trim, and displacement. The result from the optimization process which obtained on Microsoft excel is the main dimension of the boat as follows:

1. Length (Loa) : 14.00 m
2. Breadth (B) : 5.00 m
3. Height (H) : 1.14 m
4. Draft (T) : 0.90 m
5. Cb : 0.6

### 3.1. Archimedes Law Compliance

Lightweight of tour boat consists of boat hull and superstructure, equipment and outfitting, and machinery components. Boat hull and superstructure is estimated by pos per pos method with size of hull construction, which previously calculated in compliance to BKI regulation of fiberglass boat [11], as the initial input. Equipment and outfitting's weight are obtained from identification of boat needs and specification. Machinery and component's weight are obtained from catalogue in compliance to technical requirements such as powering requirement, area of top deck, area of machinery space and etc. Lightweight (LWT) components shown in Table 3.

Table 3. Lightweight Components of Tour Boat

| No. | Item | W (ton) | KG (m) | LCG (m) |
|---|---|---|---|---|
| 1 | Hull Construction | 4.64 | 0.97 | 6.55 |
| 2 | Equipment & Outfitting | 1.27 | 1.54 | 6.76 |
| 3 | Machinery | 1.05 | 0.87 | 1.83 |
| | **Total** | **6.96** | **1.06** | **5.87** |

Deadweight is a maximum weight which allowed to be transported by a boat and consists of passengers, crews, provision, diesel oil for generator, lubricating oil, freshwater, and sewage. Deadweight (DWT) components shown in Table 4.

Table 4. Deadweight Components of Tour Boat

| No. | Item | W (ton) | KG (m) | LCG (m) |
|---|---|---|---|---|
| 1 | Crews | 0.40 | 1.00 | 7.57 |
| 2 | Passengers | 0.40 | 1.90 | 6.11 |
| 3 | Provision | 0.12 | 1.00 | 5.34 |
| 4 | Freshwater | 2.40 | 0.25 | 7.26 |
| 5 | Diesel oil (reserve) | 1.50 | 0.57 | 3.46 |
| 6 | Sewage | 0.50 | 0.57 | 0.92 |
| 7 | Margin | 2.34 | 0.33 | 7.26 |
| | **Total** | **7.66** | **0.50** | **6.03** |

Archimedes' law stated that "if something is thrown into a liquid, then it will have the same buoyancy as the mass of displaced liquid." The application of this law in boat design is the total weight of the boat (lightweight & deadweight) must be equal with the displacement of boat. Total calculation of boat's weight shown in Table 5. The total of boat weight is 14.614 tonnes meanwhile the displacement of boat is 14.761 tonnes. Therefore, the difference between boat weight and displacement is 1%, which is acceptable according to the allowance margin.

Table 5. Total of Lightweight & Deadweight

| No. | Item | W (ton) | KG (m) | LCG (m) |
|---|---|---|---|---|
| 1 | DWT | 7.656 | 0.497 | 6.029 |
| 2 | LWT | 6.957 | 1.056 | 5.872 |
| | **Total** | **14.614** | **0.763** | **5.954** |

### 3.2. Minimum Freeboard Compliance

Freeboard requirement, which has to comply, refer to PM No. 39 Tahun 2016 [12]. For type B vessel, the regulation gives a minimum freeboard value of 150 millimeters for a boat that has a length less than 15 meters and sails in the riverway, lake, or reservoir. Meanwhile for the boat which has length more than 15 meters in such circumstances, need to have further corrections on the calculation. The corrections of freeboard for a boat with length more than 15 meters are as follows:

a) Coefficient block correction;
b) Depth correction;
c) Superstructure and trunk correction;
d) Sheer correction;
e) Hatchway correction;
f) Minimum bow height correction; and
g) Freshwater correction.

According to the calculation which has been completed, the value of the minimum freeboard is 150 millimeters, and the actual freeboard is 342.9 millimeters, which means the actual freeboard fulfills the requirement for minimum freeboard.

### 3.3. Boat's Hull Design

The main dimensions of the boat that obtained from the optimization process have met the technical and applicable regulatory requirements. The next process is designing the hull shape of the boat. The hull design process is carried out using the Line Distortion Approach method using the "Maxsurf Modeller" software. The design of the hull, as shown in Figure 4. From the design or model of the ship's hull that has been made, it can be made a lines plan of the ship. The lines plan is a 2-dimensional drawing of the ship's hull consisting of the front, top, and side views of the ship. Lines plan of the boat can be seen in Figure 5. Boat hull design which has been made has the basic characteristics are presented in Table 6.

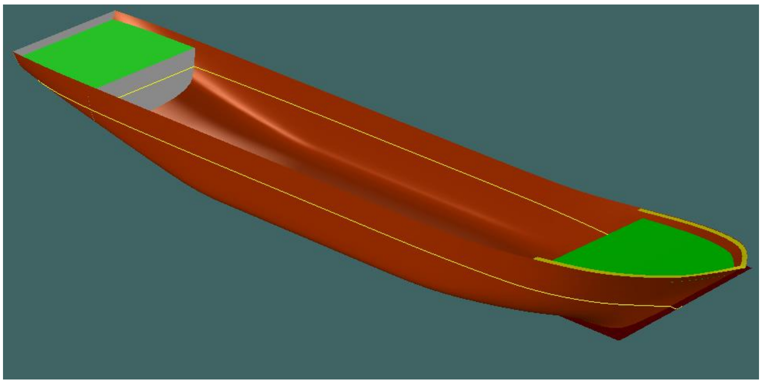

Figure 4. 3D Modelling of Tour Boat Hull

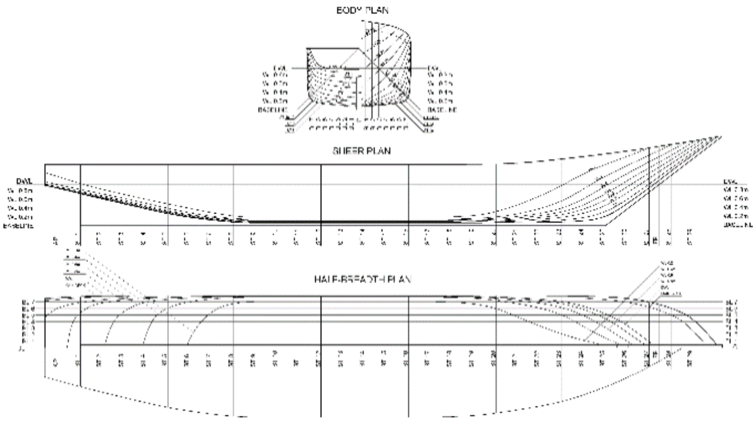


Figure 5. Design of Tour Boat Lines Plan

Table 6. Characteristics of Tour Boat Hull

| Item | Value | Unit |
|---|---|---|
| Displacement | 14.78 | t |
| Draft Amidships | 0.80 | m |
| Prismatic coeff. (Cp) | 0.71 | |
| Block coeff. (Cb) | 0.55 | |
| Max Sect. area coeff. (Cm) | 0.77 | |
| Waterpl. area coeff. (Cwp) | 0.86 | |
| LCB (from AP) | 6.215 | m |
| KB | 0.496 | m |
| KMt | 1.537 | m |

### 3.4. Hydrostatic Data of The Hull

Hydrostatic curves are curves that show the state of the hull below the waterline for each increment loaded. Some components that can be known from the hydrostatic curve include moulded displacement, shell displacement, total displacement, block coefficient, prismatic coefficient, water plan coefficient, LCB, and LCF. The hydrostatic curve of the tour boat hull that has been made can be seen in Figure 6.

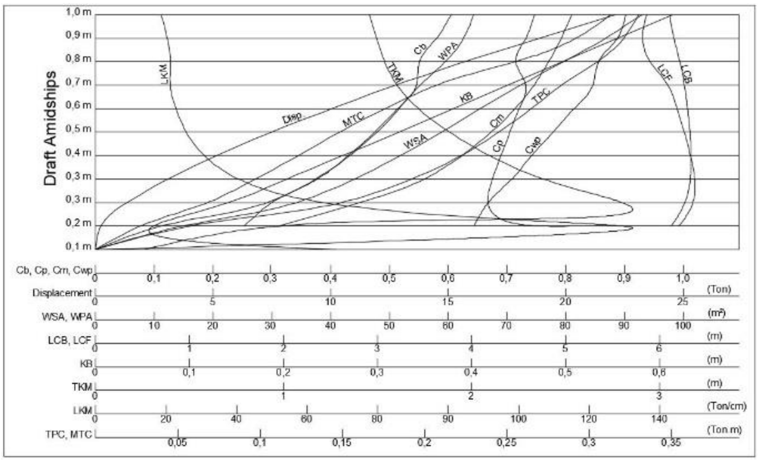


Figure 6. Hydrostatic curves

### 3.5. Resistance Calculation

Resistance and powering (BHP) calculation on boat model is performed by using the Holtrop method in maxsurf resistance software and calculated from 3 to 7 knots of service speed. After finishing the simulation, the total resistance of the tour boat on 7 knots of service speed is 2.427 kN, as shown in Figure 7. From the chart of ship resistance vs. ship speed, it can be seen that ship resistance is significantly increasing at speeds above 6 knots. Whereas at speeds below 6 knots the ship's resistance rises slowly as the ship's speed increases. From the calculation of the ship's power vs. service speed, it can be seen that for 7 knots, the engine power is 11.733 HP, as shown in Figure 8.

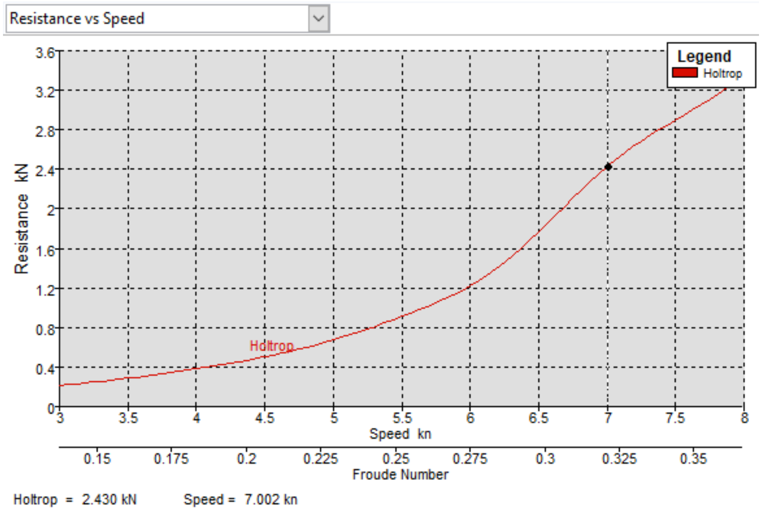

Figure 7. Resistance vs Service Speed

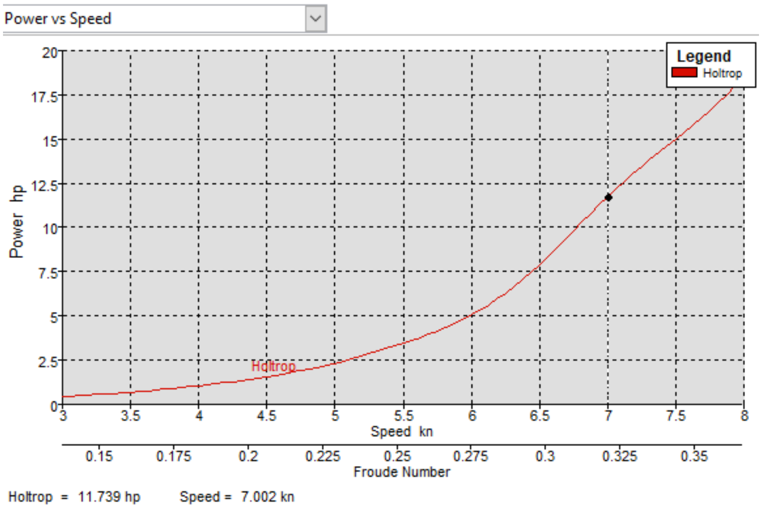

Figure 8. Power vs Service Speed

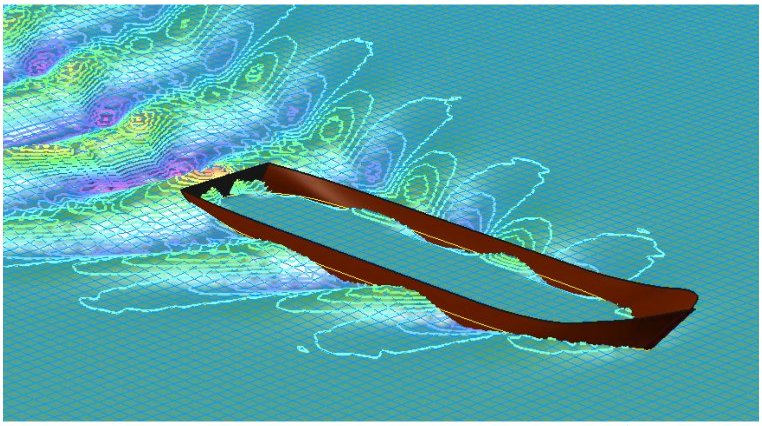
Figure 9. Wave Pattern on Boat Service Speed

The power needed by this design is lower than the average engine power on tour boat currently used in Tanjung Puting National Park. The power calculation is done with the assumption that the efficiency of the entire propulsion equipment is 50%. With the Maxsurf Resistance software, it also can be analyzed the estimated wave excitation that occurs in ships moving at a certain speed. The boat is analyzed at 5 knots speed. It can be seen in Figure 9 that the highest water waves due to the movement of the boat at 5 knots speed occur in the middle of the boat. This phenomenon needs to be considered because the waves that occur will cause boat freeboards to be getting smaller. This condition will make water enter the boat's hull. After water passes through height of the bow, water forms a wave with a height that slowly decreases to the stern of the boat.

### 3.6. Stability Compliance

Stability calculation is performed by using maxsurf stability software. The hull model is made first with the Maxsurf Modeller software, and then the model is analyzed with the Maxsurf Stability software. Ship stability criteria that must be met in the analysis are based on the Intact Stability Code (IMO, 2008)[9], for boats in general. Boat's hull model is analyzed by five times regarding five load cases that conform to the operational condition. Variations of loading condition scenarios are made by differentiating cargo and consumables on the ship during the tour.

#### 3.6.1. Load Case 1, Empty Ship Condition

Load case 1, the ship is analyzed in an empty condition, without passengers, without crew, and without consumables. The result of this stability calculation is the stability arm curve, as shown in Figure 10. The GZ arm curve has a positive value with a maximum value of 0.296 m at a heeling angle of 37.3°. The value of GZ is close to the minimum value required. The height of the transverse metacenter point of the ship is 0.904 m. The metacenter height has a positive value indicating that the ship has positive stability so that if the boat is tilted due to external forces, the ship can still return to its original position after the external force has disappeared. The fulfillment of stability criteria in load case 1 can be seen in Table 7.

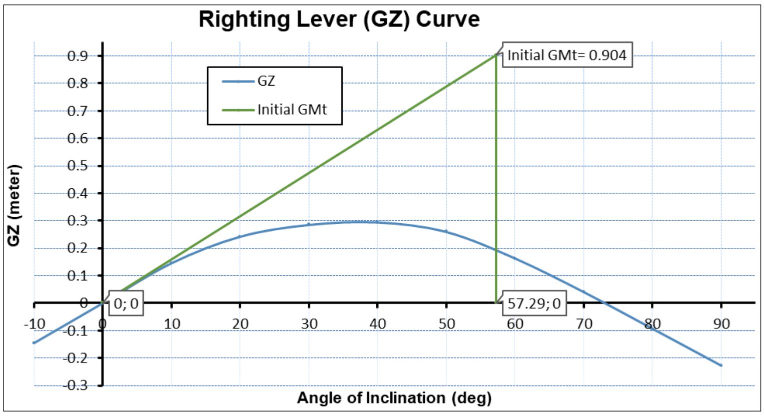


Figure 10. Righting arm curve in Load Case 1

Table 7. Stability Criteria of Load Case 1

| Criteria | Value | Unit | Actual | Status |
|---|---|---|---|---|
| Area 0 to 30 | 3.151 | m.deg | 5.422 | Pass |
| Area 0 to 40 | 5.157 | m.deg | 8.354 | Pass |
| Area 30 to 40 | 1.719 | m.deg | 2.932 | Pass |
| Max GZ at 30 or greater | 0.2 | m | 0.296 | Pass |
| Angle of maximum GZ | 25 | deg | 37.3 | Pass |
| Initial GMt | 0.15 | m | 0.904 | Pass |

#### 3.6.2. Load Case 2, Full Load Condition

This load case represents the condition when the boat is on its way from starting point to the first camp. A ship is carrying passengers, luggage as well as all the consumables during the tour. In this condition, consumables are assumed to be 100% full. The result of this stability calculation is the stability arm curve, as shown in Figure 11. The evaluations of criteria are shown in Table 8.

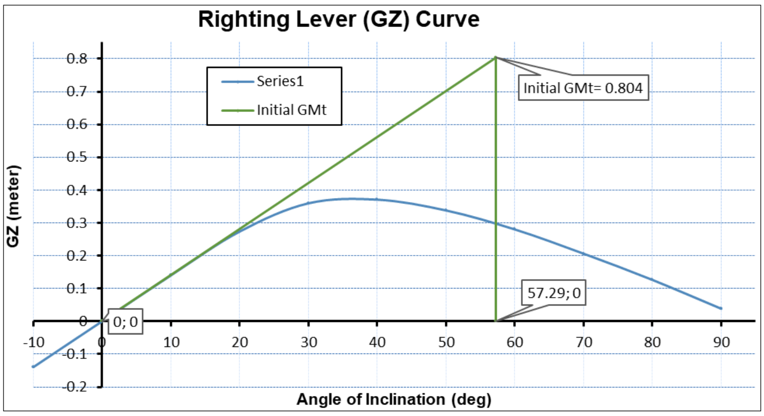


Figure 11. Righting arm curve in Load Case 2

Table 8. Stability Criteria of Load Case 2

| Criteria | Value | Unit | Actual | Status |
|---|---|---|---|---|
| Area 0 to 30 | 3.151 | m.deg | 6.014 | Pass |
| Area 0 to 40 | 5.157 | m.deg | 9.721 | Pass |
| Area 30 to 40 | 1.719 | m.deg | 3.707 | Pass |
| Max GZ at 30 or greater | 0.2 | m | 0.374 | Pass |
| Angle of maximum GZ | 25 | deg | 36.4 | Pass |
| Initial GMt | 0.15 | m | 0.804 | Pass |

### 3.6.3. Load Case 3, Ship Leaves Without Passengers

Load case 3 is analyzed to accommodate the condition of the ship when the ship is leaving for the trip, assuming the passenger of the boat has not yet boarded the ship. In this condition, all the crew and all the needs (consumables) during the tour have been 100% on the boat. In this load case 3, the ship is in a better stability condition with a maximum stability arm of 0.401 m, higher than load case 1 and load case 2. The righting arm curve of load case 3 can be seen in Figure 12. The fulfillment of stability criteria in load case 3 can be seen in Table 9.

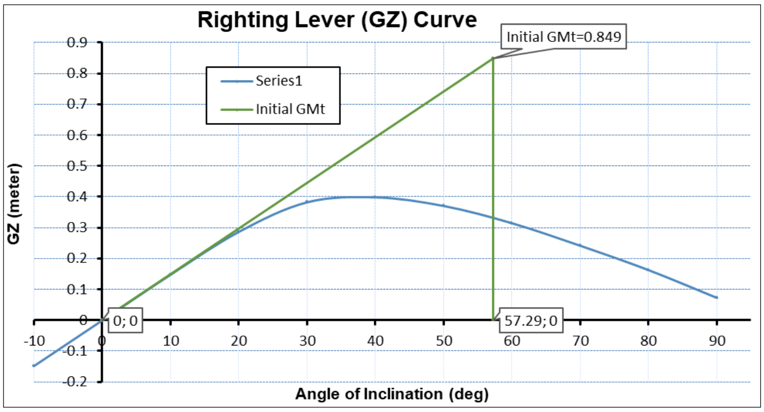


Figure 12. Righting arm curve in Load Case 3

Table 8. Stability Criteria of Load Case 3

| Criteria | Value | Unit | Actual | Status |
|---|---|---|---|---|
| Area 0 to 30 | 3.151 | m.deg | 6.342 | Pass |
| Area 0 to 40 | 5.157 | m.deg | 10.306 | Pass |
| Area 30 to 40 | 1.719 | m.deg | 3.965 | Pass |
| Max GZ at 30 or greater | 0.2 | m | 0.401 | Pass |
| Angle of maximum GZ | 25 | deg | 37.3 | Pass |
| Initial GMt | 0.15 | m | 0.849 | Pass |

### 3.6.4. Load Case 4, Full Passengers With 50% Consumables

This load case represented the condition when the boat reached last camp (Camp Leakey) with half of the consumables left. This condition is named load case 4, where the stability of the ship is still positive, as seen from the stability arm curve in Figure 13. The maximum value of GZ is not higher than GZ in load case 3. The fulfillment of stability criteria in load case 4 can be seen in Table 10.

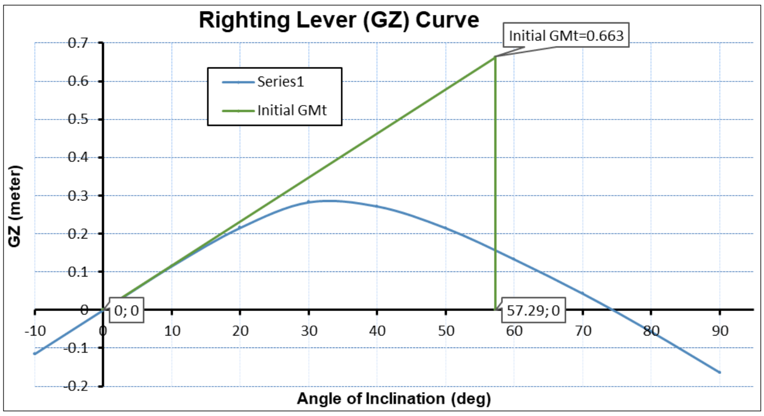


Figure 13. Righting arm curve in Load Case 4

Table 9. Stability Criteria of Load Case 4

| Criteria | Value | Unit | Actual | Status |
|---|---|---|---|---|
| Area 0 to 30 | 3.151 | m.deg | 4.792 | Pass |
| Area 0 to 40 | 5.157 | m.deg | 7.627 | Pass |
| Area 30 to 40 | 1.719 | m.deg | 2.835 | Pass |
| Max GZ at 30 or greater | 0.2 | m | 0.288 | Pass |
| Angle of maximum GZ | 25 | deg | 33.6 | Pass |
| Initial GMt | 0.15 | m | 0.663 | Pass |

### 3.6.5. Load Case 5, the Condition of Full Cargo Ship Arriving at the Port of Origin

Load case 5 is when the ship arrives back at the original port after completing the tour. In this condition, it is assumed that all consumables have been used up, leaving only 10%. The sewage tank is assumed to be full after completing the tour. The stability of the ship in this condition is still positive, with a maximum value of GZ is 0.24 m at a heeling angle of 32.7°. The righting arm curve of load case 5 can be seen in Figure 14. The fulfillment of stability criteria in load case 5 can be seen in Table 11.

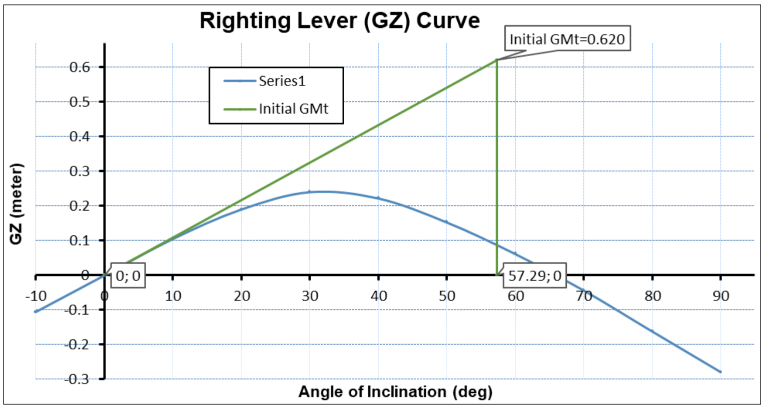


Figure 14. Righting arm curve in Load Case 5

Table 10. Stability Criteria of Load Case 5

| Criteria | Value | Unit | Actual | Status |
|---|---|---|---|---|
| Area 0 to 30 | 3.151 | m.deg | 4.223 | Pass |
| Area 0 to 40 | 5.156 | m.deg | 6.593 | Pass |
| Area 30 to 40 | 1.718 | m.deg | 2.370 | Pass |
| Max GZ at 30 or greater | 0.2 | m | 0.242 | Pass |
| Angle of maximum GZ | 25 | deg | 32.7 | Pass |
| Initial GMt | 0.15 | m | 0.62 | Pass |

## 4. Conclusion

The result of the optimization process of main dimension of the boat are Lpp = 12,23 m, B = 2,70 m, H = 1,14 m, T = 0,80 m and Cb = 0,55. The ship's resistance has been obtained from the analysis and the ship requires a smaller propulsion engine than the propulsion engine on ships currently available at the Tanjung Puting National Park tourist site. The designed hull meets technical and regulatory requirements regarding freeboard and stability. Technically the ship meets the Archimedes' principle (LWT + DWT = Displacement). The value of the actual freeboard is 342.9 millimeters, greater than the minimum freeboard required (150 millimeters).

All stability criteria have been met in each loading condition. It is also necessary to conduct further research on the accommodation room's design and propulsion system, which complies with the special characteristic of Sekonyer river and Tanjung Puting National Park environmental condition. Accommodation room design is important to ensure all passengers feel comfortable during the trip.


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