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Analyzing The Total Resistance and Wave Pattern of Modification Hull Form Design Catamaran Fishing Vessel

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ABSTRACT

Indonesia is located between the Pacific Ocean and the Indian Ocean. In addition, Indonesia is a maritime country, with data stating that Indonesia’s sea proportion is 64.97% of the total territory of Indonesia. Diverse marine resources exist in Indonesia, and the country produces 8.02 million tons of fish annually. In Indonesia, the traditional fishing vessel serves as both a mode of transportation and an element of livelihood. It was built using techniques passed down from generation to generation. Therefore, it is necessary to investigate the fishing vessels in order to determine their resistance profile and wave pattern. This analysis is done to take the catamaran-hull fishing vessel design into reference. The performance of ship design can be quickly predicted using a computational approach. The Slender Body approach and Savitsky's mathematical model are used to investigate the resistance analysis. The primary method used to describe the efficacy of the methodology is study comparison. This research will discuss the three variations of the fishing vessel design. According to the results, the chine increases the Froude number, reducing overall resistance; for this design, the single chine is the lowest resistance value.

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INTRODUCTION

Indonesia is located between the Pacific Ocean and the Indian Ocean. In addition, Indonesia is a maritime country, with data stating that Indonesia’s sea proportion is 64.97% of the total territory of Indonesia. The Indonesian oceans that are located in tropical climates seem to be carrying the consequences of species wealth and potential fishery resources, for example fish is estimated to have 6,000 species and only 3,000 species have been identified (Sasvia 2019). With the area of Indonesia’s seas, there are differences in wave conditions in each region, especially in the rainfall. During the rainy season, the conditions of the high sea waves and making fishermen cannot be fishing in the sea (Ngurah, Yogiswara, and Sutrisna 2021).

The flooding that occurs in Indonesia is one of the most complicated conditions in the world, due to the rough topography of the seabed, the complex coastline, and the interaction of the wave freezing of the Pacific Ocean, the Indian Ocean, and the South China Sea. These wave differences result in an adjustment of the shape of the vessel to match the waves in a particular region. Traditional fishing vessels are manufactured in Indonesia using skills passed down from generation to generation and are one of the ways of transportation and livelihood (Bahatmaka and Kim 2019). Therefore, in this particular case, it is important to measure and assess the fishing vessel model's shape in terms of the characteristics of the Indonesian Sea.

When a ship is above sea level, it will always gain strength from the outside of the ship which causes the ship to move. This movement of the ship is caused by external factors mainly by waves (Aldias Bahatmaka et al. 2023). Excessive movement of the ship during operation causes uncomfortable conditions for the ship's crew, such as being drunk or bouncing and disturbing the crew while doing activities on the ship. This problem will limit the capability and duration of operations of the vessel, especially when there is a considerable wave (Afdhal, Budiarto, and Mulyatno 2019). When the ship is above the wave, it will experience the worst hogging load at the moment when the middle position of the ship's body is over the peak of the wave crest, while on the bow and the stern it is in the wave trough. Therefore, it is necessary to design a ship that can survive in all conditions of the type of catamaran hull.

Catamaran vessels are widely used due to the availability of a wider deck area and a more comfortable and safe level of stability (Julianto et al. 2020). In addition, a catamaran with a thin body shape (slender) can reduce the appearance of a wave wash compared to a monohull ship. To find out the interference of the barrier ship on the catamaran hull, calculations, and computations are carried out using the Maxsurf program (Pratama et al. 2023). The shape coefficient of the catamaran is greater than its demi hull due to the presence of z effects, where the difference between the two can reach 10%. Another factor that needs to be considered in the design of the ship is in terms of strength due to the presence of combined loads aimed at knowing the reaction of structures on the ship (Michael, Zakki, and Iqbal 2020).

In addition, the catamaran has a more attractive accommodation layout, improved transversal stability and in some cases able to decrease the propulsion of the ship to a certain service speed. The size of the catamaran ship can make it easier for designers to make it more convenient to arrange the accommodation space of the ship (Iqbal et al. 2020). Because the generated obstacles are smaller depends of monohull, catamaran ships have higher speeds and lower ship loads. Small resistance results in small operating costs. The guaranteed safety

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impact of the reversed ship factor can also be found on catamaran ships (Shi et al. 2021). Both demihulls on the catamaran ship are arranged with bridging networks. This bridging structure is a catamaran advantage because it increases the height of the hull (freeboard), so the likelihood of deck wetness can be reduced, the ship is also able to operate on shallow waters (ANANTA 2022).

Resistance is a key aspect of ship analysis that determines how effectively a vessel can function hydrodynamically. The water that goes through the hull as it moves forward and crosses the sea will provide resistance. Raj did research to determine that the ship should be built to go through the water with the least amount of external force possible (Raj 2019). Resistance is affected by factors including ship speed (Vs), displacement, and hull type. There are two types of resistance force: normal and tangential. Eq. (1) can be used to characterize the total resistance.

$$RT = RF + RV + RW \tag{1}$$

The force used to press the surfaces together is usually directly proportional to the frictional resistance. The portion of the applied force that works perpendicularly or normally to the surface is the force that will affect frictional resistance. The International Towing Tank Conference (ITTC) of 1975 (ITTC, 1975) provided the friction coefficient as Eq. (3) and the friction resistance formula is displayed on Eq. (2).

$$R_f = \frac{1}{2}\rho.\ C_f.\ S.\ V^2 \tag{2}$$

$$C_f = \frac{0.075}{(LogRe-2)2} \tag{3}$$

Viscous resistance, as described by Zeng et al. (Zeng, Hekkenberg, and Thill 2019), is the resistance caused by the viscous forces that a fluid places on a ship's body. The amount of viscous resistance is typically based on the form factor (1+k) for mono-hulls and (1+βk) for multi-hulls. Eq. (4) shows the viscous resistance coefficient.

$$Cv = (1 + k)\, C_f \tag{4}$$

Wave resistance is a type of drag that affects surface vehicles like boats and ships. Due to minimal resistance values, the wave resistance is taken to be zero at high speed (Vs). It is seen in Equation (5).

$$Rw = C_1\, C_2\, C_5 \nabla \rho g e \chi p\ \{m_1\, f_r^{d} + m_4 \cos(\lambda F_r^{-2})\} \tag{5}$$

Reynold's number will determine the fluid's shape, its make acrucial factor in determining the laminar or turbulent behavior of a fluid. The ratio between the force of inertia and viscosity is represented by Reynold's number equation. It is evident in Eq. (6). Laminar flow has Reynold's number value of between 2300 and 400.

$$R_n = \frac{V\ .\ L}{v} \tag{6}$$

The Froude number indicates the speed compared to the mass displaced. In hydrodynamics, the Froude number represents a specific model that works for a system. A Froude number can be called a semi-displacement if its value is around 0.4 to 1 (Matafi, 2015). However, if the value is above 1, it is called a planning hull. This can be seen in the equation. (7).

$$F_n = \frac{V}{v} \tag{7}$$

The wetted surface area can be computed using Mumford's formula to suggest an error rate of around 7% (Poundra, 2017). Utilizing the setups for measuring the type of ships can increase accuracy. The wetted surface area has an impact on the resistance. Equation (8) can be used to compute the wetted surface area.

$$S = 1.025.\ L_{pp}.\ (Cb.\ b + 1.7T) \quad (8)$$

Savitsky's mathematical model is utilized in calculations to determine the wet areas, drag, pressure, stability, and also the resistance (Qin, 2021) which may be employed as a function of speed, deadrise angle, and trim in the hydrodynamic parameters for numerical approach. Eq. (9) contains the empirical formula for prismatic planning hull.

$$R_T = \Delta \tan \tau \quad \frac{\frac{1}{2}\rho V^2 \lambda b^2 C_f}{\cos \tau} \quad (9)$$

The slender body approach takes the vessel's slenderness consideration by assuming high length-to-beam or slenderness ratios. Although the slenderness ratio should ideally be as high as feasible, in practical terms, slenderness ratios between 5.0 and 6.0 might produce satisfactory outcomes. The minimal slenderness ratio to which the approach is applicable likewise decreases as the vessel's Froude number increases. The vessel's slenderness ratio determines the largest Froude number for which reasonable results can be achieved. It has been discovered that the slender body approach may get accurate findings for Froude values as high as 1.0 for very slender vessels (slenderness ratios greater than 7.0). Round bilge and chine hull types are equally amenable to the low-profile approach. Transom stern hulls are handled by a "virtual appendage" being automatically added. The demihull slenderness ratio, $L/\nabla^{1/3}$ to calculate the form factor in following equation (10).

$$(1 + \beta k) = 3.03\ (L/\nabla^{1/3})^{-0.40} \quad (10)$$

METHODS

In this study, the focus was on improving fishing vessel catamaran hull design and hull comparative analysis by selecting the most effective designs and having the best performance among those designs. This analysis process follows the rules applicable at MARINESIA 2023 (Indonesian Marine Innovation Festival) to measure the size of the ship (MARINESIA, 2023). The fishing vessel is selected as the research object using linear regression of the selected reference vessel. The reference vessels selected can be seen in Table 1. In this process, the ratio of the vessels of the Long/Breadth ratio (L/B), Long/Height ratio, and Breadth/Draft (B/T) ratio is found. The size of the vessel obtained for the new design is presented in Table 2, and the design of its vessel lines plan shown in Figure 1.

Table 1. Reference Dimension of Ship

Type of Ships	Dimension				
	LOA	LPP	B	H	T
MAREEL VERDIGRIS	76.50	69.00	22.50	9.00	4.59
MAREEL VIOLET	75.00	67.50	22.50	10.50	4.50
MARINER	78.00	69.00	25.50	12.00	6.00
MASTER	78.60	72.00	26.79	12.00	6.00
SEACAT COURAGEOUS	78.90	66.00	26.85	10.80	4.50
SEACAT INTREPID	78.00	67.50	26.85	10.80	4.50
WEM 3	81.00	72.00	24.00	12.00	8.40

Table 2. Main dimension of the new design of fishing vessel

Dimension	Notation	value (m)
Length Overall	L_{OA}	78
Length Between Perpendicular	L_{BP}	69
Breadth	B	25
Height	H	11
Draft	T	5.5

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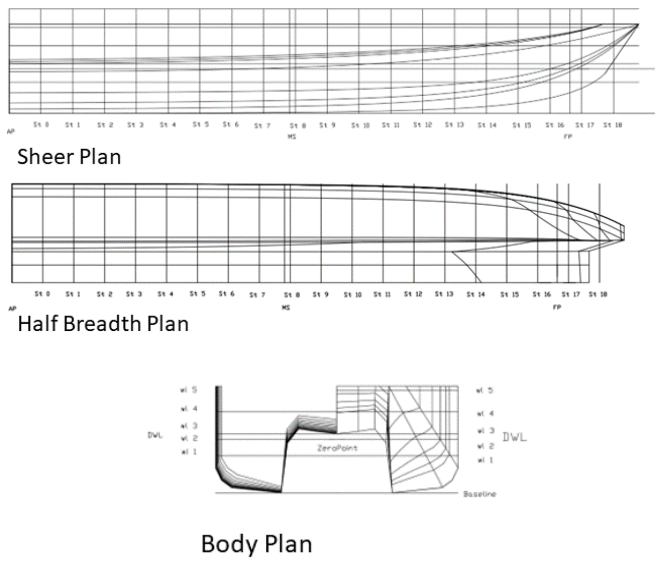


Figure 1. The Ship Design

2.1. Numerical Configuration and Benchmarking Study

The ship's hydrostatic data is used in this chapter as a configuration variable. Table 3 shows the characteristics of the new design. With an 8 knots minimum speed and a 14 knots maximum speed, the change ship's speed is variably controlled. Seawater must have a salinity of 3.5%, a kinematic viscosity of 0.0000011 m^2/s, a density of 1025.9 kg/m^3, a gravity of 9.8 m/s^2, and a temperature of 15°C, according to the ITTC 1975.

Table 3. Data and design characteristics of the new design

Parameters	**Value**	**Unit**	**Savitsky**	**Slender Body**
LWL	74,21	m	74,21	74,21
Beam	25	m	25	25
Draft	5,5	m	--	5,5
Displaced volume	4145,53	m^3	4145,53	4145,53
Wetted area	2190,44	m^2	--	2190,44
1/2 angle of entrance	38,4	deg.	--	38,4
LCG from midships (+ve for'd)	-4,14	m	-4,14	--
Deadrise at 50% LWL	8,7	deg.	8,7	--
Kinematic viscosity	0,0000011	m^2/s	0,0000011	0,0000011
Water Density	1025.90	kg/m^3	1025.90	1025.90

The new designs were developed in accordance with the Savitsky and Slender Body methods and along the same trend line (see Figure 2). It indicates that the study of the data can be used for calculating the resistance profile and wave pattern.

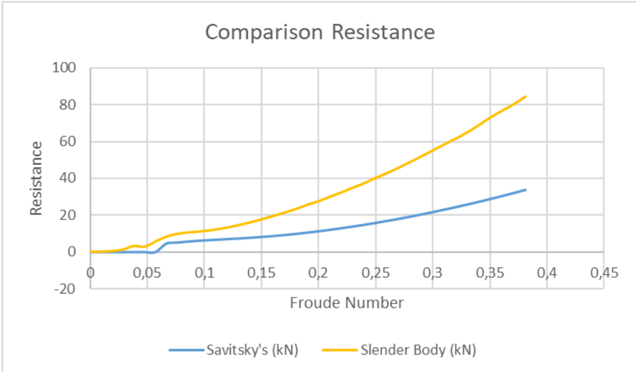


Figure 2. Comparison method of total resistance Savitsky vs Slender Body

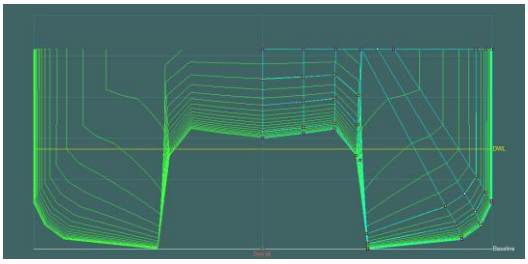
This research's analysis of resistance compares the characteristics that result from the effects of the designs. For the purpose of estimating the power required by the ship design, low resistance may be projected. As a result, a variety of parameters and scenarios have been explored using different ship speeds and Froude numbers. Table 4 provides a summary of the resistance comparisons in detail.

Table 4. Total resistance comparison

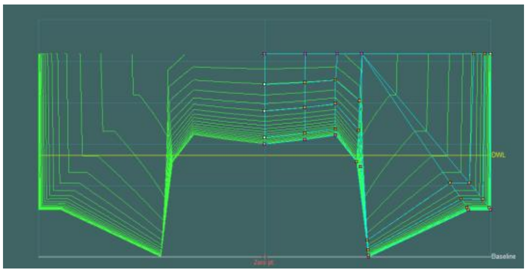
Fn (-)	**V (knot)**	**Savitsky (kN)**	**Slender Body (kN)**
0,153	8	8,28	18,04
0,191	10	10,54	25,61
0,229	12	13,66	34,49
0,267	14	17,56	44,65

2.2. Design Variation

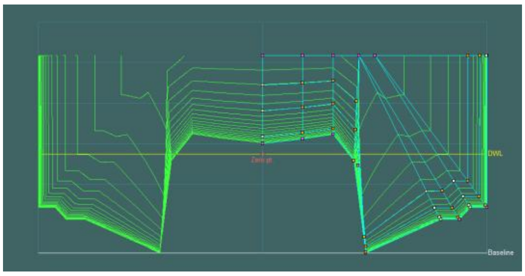
The study focused on the variation of chine numbers in 4 variations of speed. The study aims to determine whether the increase in chine amounts impacted fixing the total resistance on fishing vessels. The variations of the chine can be seen in Figure 3 (a-c).



a. Barehull



b. Single Chin 0°



c. Double Chine 0°

Figure 3. Variation of Chine Design

RESULT AND DISCUSSION

3.1. Total Resistance

Here is the result of the total resistance ship hull Chine variation on each Froude number with kN units.

Table 5. Result of the total resistance from variations of Chine

Fn	Total Resistance from variations of Chine (kN)		
	Barehull	Single Chine	Double Chine
0.153	18.04	15.78	16.08
0.191	25.61	23.05	23.42
0.229	34.49	31.52	31.97
0.267	44.65	41.19	41.74

The results of the analysis showed that the designs with the lowest resistance values were the single-chine models, while the double-Chine models had greater resistance than the single-chine. Figure 4 shows a graph of the total resistance comparison of each model.

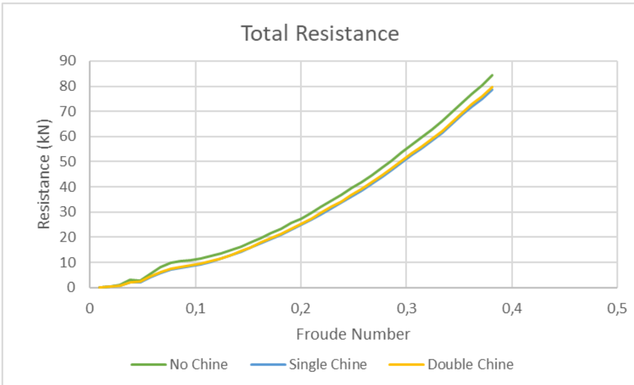


Figure 4. Total Resistance Each Model Variation

3.2. Wave Pattern Contour

During this procedure, the ship's Froude number was initially assigned, and despite being relatively unimportant, there was a slight alteration in the wave pattern. The chine arrangement is detailed in Figure 5 (a-c). While the Froude number was low or the ship entered the planning phase, the waves surrounding the ship seemed to be smoother.

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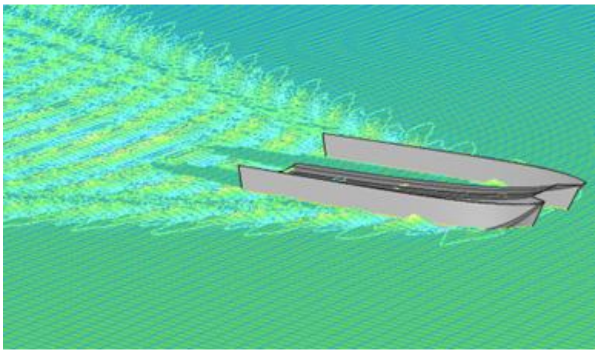
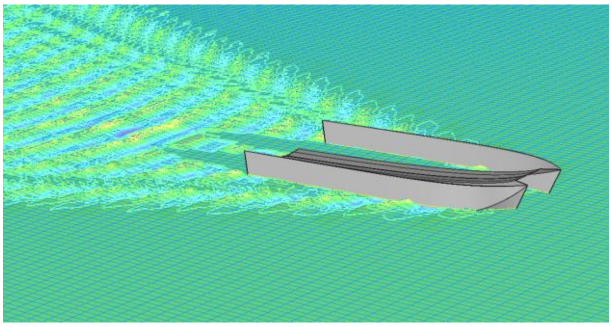
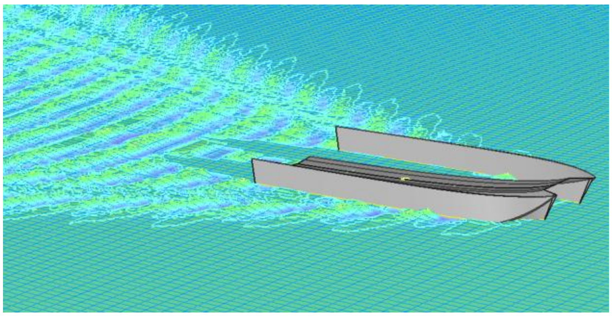


a. Barehull



b. Single Chine 0°



c. Double Chine 0°

Figure 5. The wave pattern of variations hull chine

CONCLUSION

The computational result shows that the Slender Body method's approval of the resistance characteristics in comparison to the Savitsky method was successful. The trend line is also in identical circumstances, and good agreement is shown for all suggested dimensions. Several chines for the catamaran fishing vessel designs were suggested in order to measure the resistance profile and wave pattern. According to the results, the chine increases the Froude number, reducing overall resistance; for this design, the single chine is the lowest resistance value. Despite a clean pattern surrounding the hull, a change in chine modifies the wave pattern. This research can be strengthened by contrasting a different computational approach to determine how the water interacts with the hull.

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