TEKNIKA: JURNAL SAINS DAN TEKNOLOGI

Journal homepage: http://jurnal.untirta.ac.id/index.php/ju-tek/

Analysis resistance and flow patterns of hull catamaran axe bow for tourism boat

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ARTICLE INFO

Article history:
Submitted 28 September 2021
Reviewed 23 October 2021
Received 30 October 2021
Accepted 1 November 2021
Available online on 2 November 2021

Keywords:
Tourism boat, axe bow, resistance.

Kata kunci:
Kapal wisata, axe bow, hambatan.

ABSTRACT

The axe bow type catamaran is a ship used specifically for recreational purposes between Beting Island Aceh, with two hulls (catamarans). This analysis aims to see a more reductive resistance value that can be used in the Beting Island Aceh (Rupat) waters. To get the main size of the ship, namely the parent design approach method, which is to find data on the main ship and the same displacement to analyze the value of the ship's resistance. The main data of the ship, namely, $LOA = 12.20\text{ m}, B = 4.089\text{ m}, H = 1.48\text{ m}, T = 0.62\text{ m}$, and $\Delta = 7{,}243$ tons. The resistance value of the axe bow type catamaran is smaller than the non-axe bow type catamaran, with a difference of 5.92 %. Based on the results of running, the engine power of the axe bow type catamaran is 227 HP, while the non-axe bow type catamaran is 241 HP.

ABSTRAK

Catamaran tipe axe bow adalah kapal yang digunakan khusus untuk rekreasi antar Pulau Beting Aceh yang memiliki dua lambung (catamaran). Analisis ini bertujuan untuk melihat nilai resistansi yang lebih reduktif yang dapat digunakan di perairan Pulau Aceh Beting (Rupat). Ukuran utama kapal diperoleh dengan menggunakan metode parent design approach, mencari data kapal induk dan displacement yang sama untuk menganalisa nilai hambatan kapal. Dan didapatkan data utama kapal yaitu $LOA = 12.20\text{ m}, B = 4.089\text{ m}, H = 1.48\text{ m}, T = 0.62\text{ m}$, dan $\Delta = 7{,}243$ tons. Nilai hambatan kapal katamaran tipe axe bow lebih kecil dibandingkan dengan kapal katamaran tipe non axe bow dengan selisih sebesar 5,92 %. Berdasarkan hasil running, tenaga mesin catamaran tipe axe bow adalah 227 HP, sedangkan catamaran tipe non axe bow adalah 241 HP.

Available online at http://dx.doi.org/10.36055/tjst.v17i2.12552

1. Introduction

The tourism industry is one of the great and promising economic opportunities for the people of Indonesia. Based on the WTO, the mobility of world tourists reached 1.046 billion people in 2010 and 1.602 billion people in 2020 [1]. The increasing role of tourism depends on the quality of tourist objects and supporting infrastructure. Efforts to develop a tourist destination must pay attention to various factors that influence it. These factors relate to the five main elements in a tourist destination, including tourist objects, tourist attractions, infrastructure, management, and community or environmental conditions.

The government established Indonesia Indah, namely Wonderful Indonesia, as the branding of Indonesian tourism on January 1, 2011. The Indonesian tourism brand "Wonderful Indonesia" strengthens Indonesia's position on the world tourism map. At the regional level, the Riau Province Tourism and Creative Economy Agency carried the brand "Riau Tanah Air Melayu" on the 58th RIAU Anniversary in 2015. The brand aims to show and emphasize that Riau has an identity in Tourism Based on Malay Culture [2].

North Rupat Island, in Riau Province, is a RIPPARNAS tourism attraction. The island is a tourist destination in the National Tourism Strategic Area [3]. Rupat Island is located in the northern section of the Melaka Strait. Rupat Island consists of 2 sub-districts, namely Rupat and North Rupat, one of Indonesia's outer islands, which is directly adjacent to Malaysia. Rupat Island, which has the longest white sand in Indonesia, has a very exotic value because foreign ships passing through the Melaka strait can immediately dock there. The white sand beach stretches for ± 17 km from Teluk Rhu village, Tanjung Samak, to the Cingam river. The potential and tourist attractions in the North Rupat tourist area are described in Table 1 [4].

Table 1. Name of Rupat Island tourism object.

No	Attraction name	Types of attractions
1	Pesona Beach	Nature tourism
2	Tanjung Lapin Beach	Nature tourism
3	Beting Aceh Beach	Nature tourism
4	Ketapang Beach	Nature tourism
5	Putri Sembilan Grave	Cultural tour
6	Tourist Safar Baths	Artificial tour
7	Festival Pantai Rupat	Artificial tour

Rupat Island has a very promising natural tourism, namely the whispering sand of Aceh Beting Island. Tourists will be presented with a view of a beautiful stretch of white sand. One of the innovations supporting Rupat Island Nature Tourism is a tourist boat. [5]. However, the current condition to get to the island of Beting Aceh must use an existing boat or fishing boat. The long journey to Beting Island Aceh is about 20-30 minutes from Teluk Rhu. The boat rental fee is IDR 750,000 – IDR 800,000 per group. The Rupat Island is one of the outermost islands directly opposite the Melaka Strait, with water/wave conditions as high as 1 to 2 meters.

In general, the design of tourist boats uses a rounded hull hard chine planing hull, monohull or, double hull (catamaran). Another aspect that is no less important in planning a tourist ship is the aspect of motion (performance). Ships that are planned with poor maneuverability will result in accidents at sea. In the field of seakeeping, four subjects need to be considered, namely ride quality, speed and power, sea load, and extreme effects. Ride quality or quality during the trip indicates the comfort and safety of transportation. Ride quality is related to motion and speed, so it is clear that movement and bulk cause uncomfortable conditions for passengers [6-7].

One of the targets for optimizing design efficiency is ship speed, namely designing ships with the least engine power but having efficiency in fuel use. The design planning must take into account the magnitude of the drag on the ship and the minimum desired speed. Displacement conditions are very important requirements [8] to overcome the problems of achieving ship speed. Many ways are used to overcome these problems, including modifying the engine, hull, and propulsion. One solution to overcome this problem is to make a catamaran hull (double hull) type axe bow [9-10]. The design reduces the wet surface area (water surface area) due to turbulence under the hull and increases the ship's compressive strength (lift force). So that by itself will reduce resistance and increase efficiency, it will produce different power. The engine speed is smaller, and the fuel requirements are reduced from the above in this study to design a ship supporting tourism on Rupat Island. The ship will be designed using the axe bow and as comfortable as possible to affect the passengers' emotions to help them enjoy the sea atmosphere and the stunning panorama of natural beauty. With this research, it is hoped that it can assist relevant agencies in designing more optimal and efficient tourist boats on these shipping routes to increase the flow of natural tourists on the island of Beting Aceh.

2. Research Methodology

The steps in this research are divided into three stages, namely the design process using Maxsurf and AutoCAD, making miniatures according to the design, and preparing reports related to the planning of making miniature tourist boats Tanjung Medang–Beting Aceh (Rupat Island).

2.1. Axe Bow

Tourist boats are ships used specifically for recreational purposes between islands [11]. Passengers board the tour boat to enjoy the time spent on board. At the same time, the axe bow is a type of hull that pierces the waves at the bow of the ship, characterized by a vertical rod and a relatively long and narrow entry (front hull) or shaped like an axe. The forelegs are deep, and the freeboard is relatively high, with a little flare, so the bow's profile resembles that of an axe. And a catamaran is a ship with two hulls tied together with a larger carrying capacity, making it more stable than a one-hulled ship. A catamaran is a multi-hull marine vessel, usually consisting of two hulls (three hulls are called trimarans). The axe bow is a narrow, pointed bow at the bow, characterized by a vertical bar and a relatively long and narrow entry (forehead hull) or an ax-like shape. The concept was developed in the Netherlands by Lex Keuning of Delft University of Technology, Damen Shipyards Group, Marin (Maritime Research Institute Netherlands), Damen Schelde Naval Shipbuilding, and the United States Coast Guard [12].

Figure 1. Axe bow ship [13].

2.2. Resistace Calculation

The calculation of resistance in this study used the gastric velocity with the Savitsky method [14]. According to Daniel Savitsky, the coefficient of speed is expressed by:

$$Cv = \frac{v}{b\sqrt{g}} \tag{1}$$

Where:

Cv = Speed coefficient

v = Vessel speed

g = Gravitation speed (9,80 m/s²)

b = Maximum beam over chine (m)

When there is a deadrise angle condition that is formed equal to zero [14], (β = 0), then the lift coefficient is expressed by the equation:

$$Clb = \frac{\Delta}{0.5 \times \rho \times V^2 \times B^2} \quad (2)$$

Where :

Clb = *Lift coefficient*

ρ = Density sea water (Slug/Cu.ft)

V = Vessel speed (ft/sec)

B = Maximum chine beam (ft)

Δ = Displacement (lb)

The value λ is the average value of the ratio between length and width in the wet area of the ship. Savitsky assumed the prismatic hull form. This assumption has consequences in the form of the deadrise angle value constant along the ship's hull [15], so the equilibrium planning graph is used to determine the trim angle (τ) acting on the ship. Furthermore, Savitsky approached to find out the Reynolds number with the equation:

$$Rn = \frac{V_1 \lambda b}{v} \quad (3)$$

Where:

Rn = Reynold number

λ = The average value of the ratio between length and width in the wet area of the ship

b = Maximum chine beam (m)

V_1 = Vessel speed (m/s)

v = Viscosity sea water (m²/s)

The determination of the coefficient of frictional resistance Savitsky using the Schoenherr method [14]. Schoenherr estimated that the coefficient of frictional resistance is expressed by:

$$Cf = \frac{1}{(3{,}5 \log Re - 569)^2} \quad (4)$$

Where :

Cf = Viscos coefficient

The total resistance is calculated by [3]:

$$RT = \Delta \tan\tau \; \frac{1/2\rho^2 \lambda b^2 Cfo}{cos\tau \; . \; cos\beta} \quad (5)$$

Where :

RT = Resistance total (KN)

3. Result and Discussion

3.1. Main Size Determination

Determination of the main size of the ship using the Parent Design Approach method. In the parametric design approach method, the main data for the new vessel has been obtained, and some of the main data for the comparison vessel have been taken first. The comparison ship data in Table 2. From the comparison of the main ship data that has been obtained and calculated, the main size of the new unmanned surface vehicle is obtained, while the main sizes of the ship are in Table 3.

Table 2. Comparison ship data.

No	Ship name	LPP	B	H	T	VS	JP
1	GPC 1500	15	4.5	1.4	0.5	30	30
2	GP 1100P	11	4	134	0.5	25	30
3	GPP 1500	15	4	1.7	0.85	40	31
4	GPC 110	11	4	1.73	0.85	20	30
5	AL-1180	11.78	3.85	1.45	0.61	35	30

Table 3. Main data of catamaran type axe bow and non-axe bow.

Principle dimension							
Ship type	LOA	LWL	B	H	T	VS	Δ
Axe bow	12.20	12.2	4.09	1.48	0.62	27.5	7243
Non axe bow	12.2	11.68	4.09	1.48	0.62	27.5	7.243

3.2. Coefficient Calculation

The coefficient calculation includes the calculation of Froude number (Fn), block coefficient (Cb), midship coefficient (Cm), prismatic coefficient (Cp), waterline field coefficient (Cwp), and displacement (Δ) [16]. The calculation of the coefficients is as follows:

1. Calculation Froude Number (Fn)

$$Fn = \frac{Vs}{L\sqrt{g}} \tag{6}$$

$$Fn = \frac{14.4}{12.2\sqrt{9.81}} = 0.37$$

2. Block Coefficient (Cb)

$$C_B = \frac{\blacktriangledown}{L \times B \times T} \tag{7}$$

$$C_B = \frac{7.066}{12.2 \times 4.089 \times 0.62} = 0.235$$

3. Midship Coefficient (Cm)

$$C_M = \frac{A_M}{T \times B_M} \tag{8}$$

$$C_M = \frac{0.837}{0.62 \times 3.98} = 0.33$$

4. Prismatic coefficient (Cp)

$$C_P = \frac{C_B}{C_M} \tag{9}$$

$$C_P = \frac{0.235}{0.33} = 0.801$$

5. Water prismatic coefficient (Cwp)

$$C_{WP} = \frac{A_{WP}}{B_{WL} \times L_{WL}} \tag{10}$$

$$C_{WP} = \frac{18.713}{3.98 \times 12.2} = 0.385$$

6. Space frame calculation (Hpp)

$$H_{PP} = \frac{L_{PP}}{20} \tag{11}$$

$$H_{PP} = \frac{12.2}{20} = 0.62 \text{ M}$$

7. Displacement (Δ)

$$\Delta = \blacktriangledown \text{t} \times \rho_{\text{air}} \tag{4}$$

$$\Delta = 7.066 \times 1{,}025 = 7.243 \text{ ton}$$

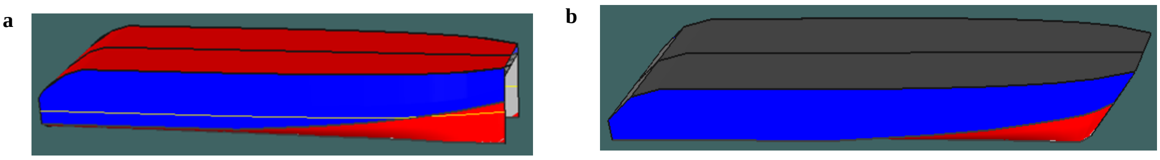

Figure 2. (a) Axe bow catamaran (b) Conventional catamaran.

Figure 2(a) and 2(b) are models of conventional catamaran and axe Bow type catamaran planned for tourist boats using maxsuft software. The value of the ship's resistance is analyzed to determine the model's engine speed. The smallest value of ship resistance on tourist ships is chosen to reduce fuel consumption.

3.3. Analyst Resistance Total

Numerical resistance prediction is done using the Savitsky method. The method was carried out based on statistical data for several hydrostatic parameters for the hull [17, 18]. Figure 2 shows the total resistance for the two hulls of the axe wow and non axe bow catamarans. The numerical results in the Maxsurf Hullspeeed program is from the comparison of the two models. The total resistance of the axe bow type catamaran is smaller than the non axe bow type catamaran. At a speed of 27.5 knots, the resistance value of the axe bow type catamaran is 169.618 kN. While the non axe bow type catamaran is 179.666 kN. With a difference of 5.92%, the axe bow type catamaran is more reducing than the non axe bow type catamaran. The pattern of water flow can be seen in Figures 3 and 4.

Figures 3(a) and 3(b) show the results of modeling the flow pattern of the ship using the hull speed method in the condition of the ship at full speed, from this image it is clear that the flow pattern caused by the hull of the conventional catamaran and axe Bow catamaran is shown. The desired flow pattern is to have a greater speed so as not to block the flow of water entering the hull's surface. Therefore, based on resistance analysis and flow pattern modeling. The axe model has a more regular flow influenced by the axe bow shape. The shape is more penetrating to the incoming waves approaching the hull so that the catamaran axe model is the most optimal.

Table 4. Evaluation of the resistance of the axe bow and non axe bow catamaran models.

VS	Savitsky resistance (kN)		Difference
	Non axe bow	Axe bow	
19	90,217	90,208	0,01%
20	100,195	99,032	1,17%
21	110,595	108,197	2,22%
22	121,512	117,823	3,13%
23	127,195	122,844	3,54%
24	139,077	133,369	4,28%
25	151,724	144,618	4,91%
26	165,226	156,675	5,46%
27,5	179,666	169,618	5,92%

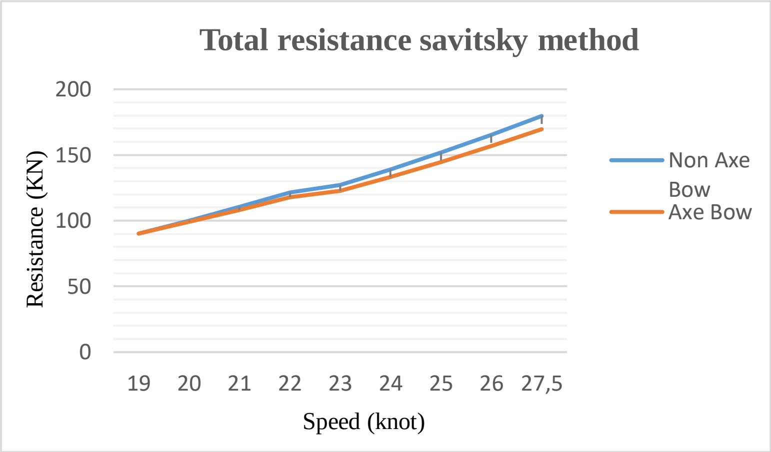

Figure 3. The graph of the total resistance of the axe bow and non axe bow hull models.

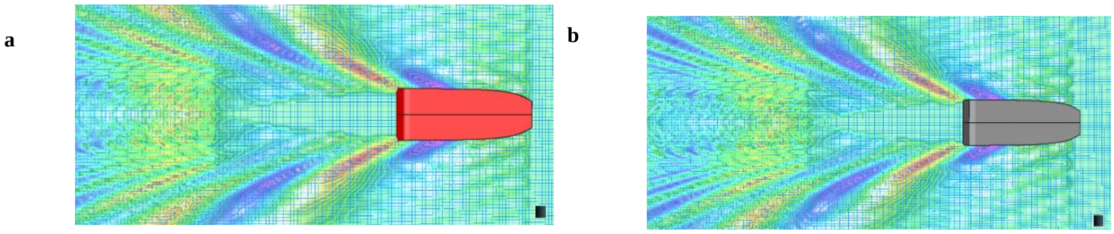

Figure 4. (a) Axe bow catamaran (b) Conventional catamaran.

3.4. Engine Power Calculation and Specification

Based on the results of calculations and the results of running on the hull speed software to move the tourist ship to sail at the desired speed. The power generated is the output power in service conditions, the amount of 80% of the maximum power produced is at a speed of 27.5 knots, the axe bow type is 169.618 kW while the non axe bow type is 179.666 kW. The formula for converting kW to HP is:

Axe bow : 1 kW = 1.341 HP
: 169.618 kW × 1.341 HP
: 227 HP

Non axe bow : 1 kW = 1.341 HP
: 179.666 kW × 1.341 HP
: 241 Hp

Based on the data, the axe bow catamaran's engine power is 115 HP, against 150 HP for the non-axe bow catamaran. Using an axe hull may lower a ship's resistance by 10-20% and save fuel.

Table 5. Evaluation of the engine power axe bow and non axe bow catamaran models.

Specification	Non axe bow	Axe bow
2-Tak	150 HP	115 HP
Engine	150 AETX	E 115 AE
Engine type	90 degree - V6	90 degree - V4
Transom height	Extra long 25.3 Inch	Long 20.3 Inch
Volume cylinder (cm^3)	2,596 cc	1,730 cc
Diameter × step	90.0 mm × 68.0 mm	90.0 mm x 68.0 mm
Maximum operating range	4,500 – 5,000 rpm	4,500 – 5,500 rpm
Compression comparison	6.2 : 1	5.7 : 1
Fuel induction system	3 Carburettor dual throat	2 carburettor dual throat
Fuel consumption	72 litter/hours	47 litter/hours
Weight	178 - 186 kg	147 - 160 kg

4. Conclusion

The main size of the ship was designed to analyze the resistance of the axe bow and non-axe bow catamarans, LOA: 12.20 m, breadth: 4,089 m, draft: 0.62, m, height: 1.48 m. The resistance value of the axe bow type catamaran is smaller than the axe bow type catamaran, with a difference of 5.92%. Based on the results of running, the engine power required for the axe bow type catamaran is smaller than the non-axe bow type catamaran.

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