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Computer-Based Simulation on LCB Positions in Indonesian Traditional Wooden Ship

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Abstract*— A Traditionl Wooden ship in North Penajam Paser is built without initial calculation to predict the resistance that will occur based on the shape of the hull. The ship is built solely based on the main dimensions and the number of engines to be installed, without considering the optimal hull shape. The hull shape is an important component in supporting the hydrostatic performance of a ship. Planning the hull's shape affect the ship's resistance value and ultimately impacts the ship's engine power requirements. The purpose of this research is to obtain the resistance value of the existing ship and determine the hull shape with a lower resistance value through computer-based simulations. The computer simulation approach based Holtrop method is used to determine the position of the LCB point based on the hull shape. Then, it examine the effect of the LCB position on the ship's resistance of the hull shape. The hull shape simulation was conducted without changing the ship's main dimensions. The simulation result show that the position of the LCB on the existing hull shape is 8.514 m from the AP, with a ship resistance value is 7.4 kN. Meanwhile, the optimum hull shape was found when the location of the LCB point was moved 0.1 m forward from its initial position (model 4). The resistance value in Model 4 decreased by 3.8% compared to the initial resistance value. In addition to model 4, models 2 and 3 also reduced the ship's resistance value, with changes of 0.9% and 2.1%, respectively. Furthermore, this optimal hull shape can be developed in the next analysis stage, such as ship structure planning and other design analyses.

Keywords—*Computational, Hull Shape, Wooden Vessel, LCB, Resistance*

I. INTRODUCTION

The International Maritime Organization (IMO) is actively promoting the Energy Efficient Design Index (EEDI) program. The EEDI standard, established by the IMO, is outlined in Regulation 22 of the MARPOL Annex VI Convention for the prevention of pollution from Ships. In this regulation, the IMO sets two standards for ship fuel efficiency: the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) [1]. This program aims to control the amount of CO^2 that contributes to greenhouse gas emissions, as well as other harmful emissions from ship operations, particularly in Indonesia. By implementing the EEDI, the design of the hull shape becomes one of the key factors in achieving energy efficiency and reducing excessive exhaust emissions.

A hull shape with low resistance provides better fuel efficiency for the engine. Therefore, the design of the ship's hull should undergo a more technical design process, adopting the concept of a spiral ship design diagram. Increasing environmental concerns and regulations on emissions are driving shipbuilders and owners to choose to design environmentally friendly ships [2]. In addition, to reduce the greenhouse gas effect, very

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fuel-efficient fishing vessels are needed [3] especially in the North Penajam Paser area.

In Indonesia, ships are constructed using two distinct approaches: modern and traditional. Modern construction involves shipbuilding that starts with a detailed and measurable engineering design process. In contrast, traditional construction relies on experience to determine the size and performance of the structure. This traditional approach can result in inconsistencies in performance, particularly regarding ship speed and engine efficiency, which significantly affects fuel consumption. Thus, to design an environmentally friendly ship, the hydrodynamic behavior of the ship's hull must be estimated accurately [4]. Where, the ship's resistance and propulsion are the most important hydrodynamic performance [5].

Traditional fishing boats like Figure 1 are made of wood and are typically built using traditional methods, without following the concept of a spiral ship design diagram. The planning and construction of the ship are based on knowledge and information passed down through the families of the craftsmen. These craftsmen do not conduct technical or economic studies regarding the shape of the ship's hull. As a result, the resistance value of traditional wooden ships cannot be determined in advance. This issue leads to the installed engine power being ineffective. Consequently, there is a potential for the installed engine to be over power compared to the actual requirements. The large engine power on a ship will result in greater fuel consumption, leading to a lower energy efficiency index value. The aim of this research is to obtain the resistance value of the existing ship and its engine power requirements. In addition, the shape of the new ship hull based on LCB position that has a small resistance value will be obtained in this paper.

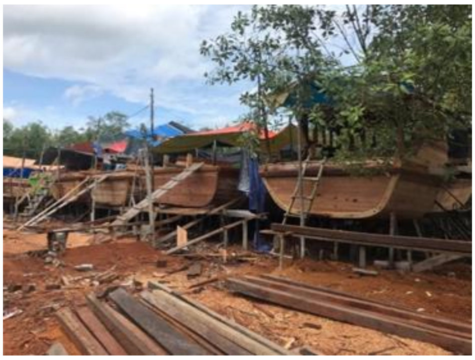

Figure 1. Traditional Wooden Ships in North Penajam Paser

In fact, the population of traditional fishing boats in East Kalimantan is quite large, making it suitable for conducting technical studies on ship resistance performance. According to data from the East Kalimantan Central Bureau of Statistics in 2020, there were a total of 19,992 traditional fishing boats operating in the waters of East Kalimantan, including 3,212 non-motorized boats, 14,584 outboard motor boats, and 2,196 motorized boats [6]. Therefore, to encourage efficient hull design on new fishing vessels, computer simulation is needed to analyze it. This method allows for rapid determination of ship performance values, thus allowing for more precise conclusions regarding the hull design of traditional fishing vessels. Holtrop's equation will be applied to a computer program to analyze the resistance of fishing vessels.

So far, most research on ship hull shape optimization has focused on steel and fiberglass ships. The hull shape optimization process is predominantly carried out using numerical simulation methods. This method is implemented with the aid of a computer to analyze the underwater characteristics of the ship's hull shape. Cheng et al. (2018) optimized a cargo ship hull using numerical methods combined with towing tank experiments. The results showed that the optimized hull shape had a better ship resistance figure when compared to the initial shape of the ship's hull, where at a speed of 1.9 m/s, the resistance reduction rate reached 11.93% [7]. Choi (2015) optimized the shape of container ship hull using numerical methods, achieving a 4.6% reduction in ship resistance [8]. Huang et al. (2016) optimized the shape of a cargo ship hull using numerical equations by obtaining a ship resistance reduction value of 6.42% [9]. Liu et al. (2021) conducted hull shape optimization on a single ship and obtained a 14% reduction in ship resistance using a numerical method [10]. Liu et al. (2021) conducted hull optimization by comparing the performance of a single ship with and without bulbous bow, achieving a 25% reduction in drag [11]. Tian et al. (2021) optimized the hull shape of a semi-submersible medical platform using numerical simulation, resulting in an improved ship motion response [12]. Zha et al. (2021) conducted numerical simulations on a ship hull, achieving 5.74% reduction in resistance in calm water [13]. Park et al. (2015) showed a 3.7% reduction in using the KSUEZMAX ship engine using the RaPID-HOP Program numerical method [14].

In addition to studies on large ships, similar research has been conducted on smaller vessels. For example, Tezdogan et al. (2018) studied high-speed fishing vessels and optimized the hull shape using the CFD method [15]. Kang et al. (2007) optimized the hull shape of a 4.99 GT fishing vessel using an experimental method. Achieving a more efficient design compared to the original hull shape [16]. Similarly, Abramowski et al. (2017) optimized the hull shape of a fishing vessel by incorporating features such as a bulbous bow with a ducktail, cylindrical bulbs, and streamlined bulbous bow shapes, using the CFD method. The study demonstrated the potential for reducing ship resistance with each variation in the addition of bulbous shapes [17]. T Basil et al. (2022) modified the bow of a ship by replacing the conventional design with an X-bow using computer simulations, resulting in decreased resistance values [18]. Oh et al. (2005) optimized a 12-meter trimaran with V-type and Wigley-type hulls using an experimental method. The results showed that the V-type hull exhibited better resistance performance compared to the Wigley-type [19]. Based on the study, it is possible to modify the hull shape of a traditional wooden ship to improve its performance. Howefer, Construction carried out without proper planning may prevent the ship from achieving optimal performance. Thus, the hull shape of a fishing boat built in North Penajam Paser will be modified to achieve minimum resistance.

II. METHOD

A. Data

The ship used as the object of this research is a traditional wooden ship of the fishing boat type. This ship will operate in Indonesian waters, carrying 4-6 crew members. The engine power of this ship is 2 x 30 Hp.

The main dimensions of the ship are shown in Table 1.

The initial hull shape ordinates obtained from direct measurements in the field are as follows in Table 2.

TABLE 1.
PRINCIPLE MAIN DIMENSION

Item	Dimension
LoA	21.90 m
Lwl	19.06 m
B	4.00 m
T	1.40 m
H	2.00 m
V	9 knot

TABLE 2.
OFFSET OF HALF BREATDH

Waterline	Station																				
	a	b	Ap	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Fp	c	d
Wl 0	-	-	-	-	-	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	-	-	-	-
Wl 1	-	-	-	-	-	0.13	0.62	0.76	0.79	0.77	0.75	0.67	0.59	0.50	0.39	0.15	0.15	-	-	-	-
Wl 2	-	-	-	-	0.55	1.23	1.42	1.47	1.47	1.46	1.46	1.36	1.26	1.11	0.91	0.65	0.41	0.11	-	-	-
Wl 3	-	-	-	0.77	1.43	1.62	1.66	1.68	1.68	1.68	1.68	1.64	1.58	1.48	1.29	1.01	0.69	0.3	-	-	-
Wl 4	-	-	0.95	1.50	1.65	1.73	1.76	1.77	1.77	1.77	1.77	1.75	1.71	1.64	1.51	1.28	0.97	0.55	0.20	-	-
Sheer	1.88	1.93	1.94	1.96	1.99	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.98	1.96	1.928	1.84	1.58	1.20	0.1

From the ship hull shape offset data above, the next step is to model the ship's hull shape using a computer based on Maxurf software. Modeling the hull shape using maxurf for ship resistance testing has been widely carried out by various researchers, such as Utama et al. (2020), who modeled the rescue boat hull shape using maxsurf and looked at the ship's resistance value in calm water conditions [20]. Luthfi et al. (2023) modeled a patrol boat using maxsurf to analyze the internal design factor in calculating ship resistance [21]. Bahatmaka et al. (2023) used the Holtrop method to predict fishing boat resistance using variations in Fn, Rn, and Ship Speed values [22].

B. Holtrop Method

After obtaining the ship's hull data, ship resistance calculations were performed using computer software. The method employed is the Holtrop method, which is suitable for fishing vessels, as demonstrated by Xhaferaj (2023), who used computer software to assist in the process. In this study, they experimented with variations in the ship's hull shape by adjusting the position of the LCB point [23]. Hertaria et al. (2021) applied this method to a tuna fishing vessel using a towing tank [24]. The Holtrop (1984) equation used in this study is as follows [25] :

Total Resistance (R_T) ;

$$R_T = (1 + k) R_F + R_{APP} + R_A + R_W + R_B + R_{TR} + R_{AA}$$

Where,

R_F = frictional resistance

R_{APP} = appendage resistance

R_A = model-ship correlation resistance

R_W = wave resistance

R_B = resistance due to bulbous bow near the water surface

R_{TR} = pressure resistance due to immersed transom

R_{AA} = air resistance

The details of the equation for each component of the total resistance in the Holtrop equation are described as follows:

$$R_F = \tfrac{1}{2} \rho V_S^2 S C_F$$

$$R_{APP} = \frac{1}{2} \rho V_S^2 (1 + k_2)_{eq} C_F \sum_i S_{APPi} + \sum R_{TH}$$

$$R_A = \frac{1}{2} \rho v_S^2 (C_A + \Delta C_A)[S + \sum S_{APP}]$$

$$R_W = R_{Wa}(0.4) + \frac{(20Fr-8)}{3}[R_{Wb}(0.55) - R_{Wa}(0.4)]$$

$$R_B = 0.11 \rho g \left(\sqrt{A_{BT}}\right)^3 \frac{Fr_i^3}{1 + Fr_i^2} e^{(-3.0 P_B^{-2})}$$

$$R_{TR} = \frac{1}{2} \rho v_S^2 A_T c_6$$

$$R_{AA} = \frac{1}{2} \rho_A v_S^2 C_{DA} A_v$$

For the details of the components in each of the equations above, you can see the book Fundamentals of Ship Hydrodynamics**.**

III. RESULT AND DISCUSSION

The change of the ship's hull model is done without changing the main dimensions of the ship, namely length (L), width (B), and Draft (T). The form of change made is to change the shape of the area of each station so that it affects the position of the center of gravity in a longitudinal manner. Based on the results of data analysis, the position of the initial ship's LCB point is 8,514 m measured from station a. Furthermore, the LCB value will be shifted towards the forepeak (+) and afterpeak (-) with an increment of 0.05 m. The ship's hull LCB position will vary, as seen in Table 3.

TABLE 3.
LCB VARIATION ON EACH MODEL

No.	Model	Difference	LCB
1	A	-0.10	8.414
2	B	-0.05	8.464
3	C (initial)	0	8.514
4	D	+0.05	8.564
5	E	+0.10	8.614

From the results of the hull shape changes according to the LCB set as in Table 4, it was found that there were differences in the wet area in each variation of the ship's hull model. The distribution of changes in the wet area value in each model can be seen in the curve in Figure 2.

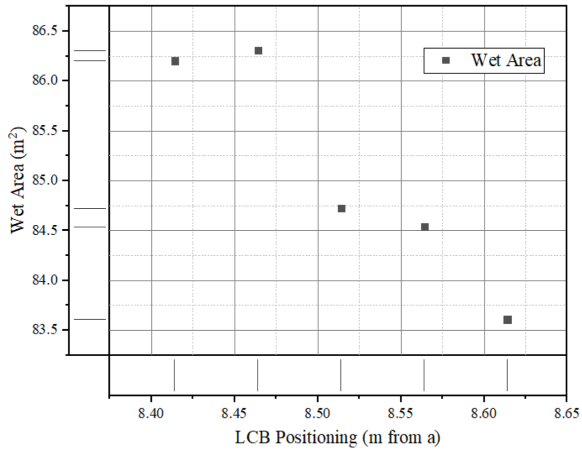

Figure 2. Wetted Surface Area Every LCB Variations

The changes in the wet area in the LCB (+) and LCB (-) model variations show the same changes, around ± 1 m2. Based on the general equation of ship resistance, the value of the wet area is one of the components that influences the magnitude of ship resistance. In addition to changes in the wet area value, the ship shape coefficient component also changes in each model variation. However, the changes that occur do not show significant changes in numbers. The changes in the coefficient do not even reach ± 0.1. The distribution of changes in the shape coefficient for each LCB value can be seen in Figure 3.

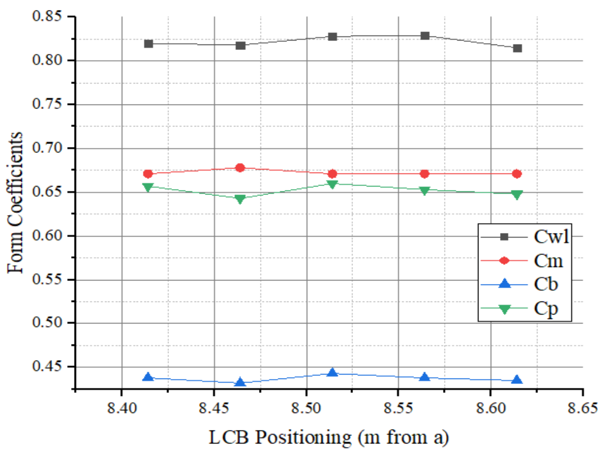

Figure 3. Form Coefficient Every LCB Variations

Shape variation also shows differences in the volume and displacement of each ship. The volume value of the model shows a change of ± 0.6 - 1 m^3. Similar to other components, the displacement figures for each ship model also change with a range of 0.7 - 1 ton. The trend of differences in each ship's volume and displacement values can be seen in Figure 4. In models A and B, the ship volume is shown to increase due to the addition of the station area on the hull behind the midship. While in models D and E, the ship volume is shown to decrease due to the reduction of the station area on the hull behind the midship. Changes in the volume value in each model also affect the ship displacement value that occurs as seen in Figure 4.

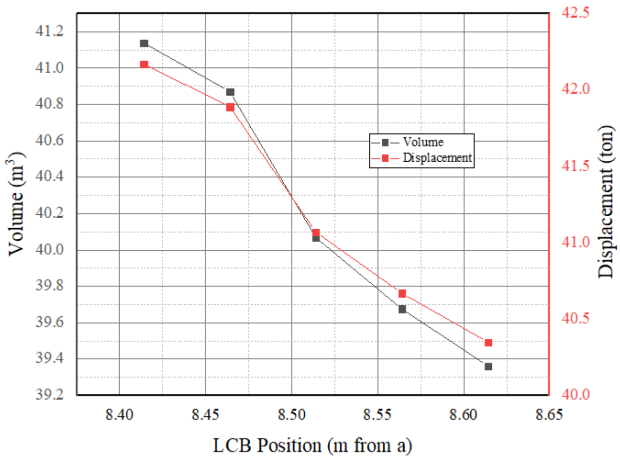

Figure 4. Volume and Displacement Every Model

The results of this study show that the effects of changes in hydrostatic components, such as Figure 2 to Figure 4, are changes in the ship's resistance value. This change phenomenon occurs at the LCB position, which shifts to the front and rear of the midship. The difference in ship resistance values can be seen in the graph in Figure 5. The ship's engine power requirements for each model can be seen in Figure 6.

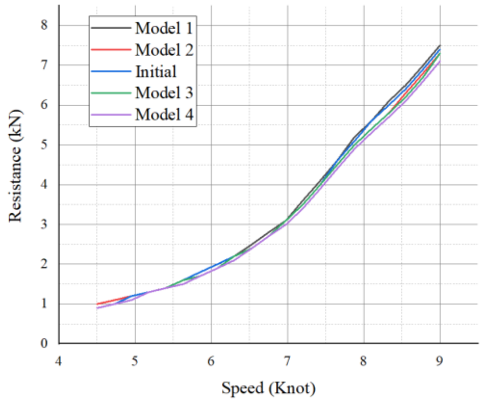

Figure 5. Ship Resistance Every Model

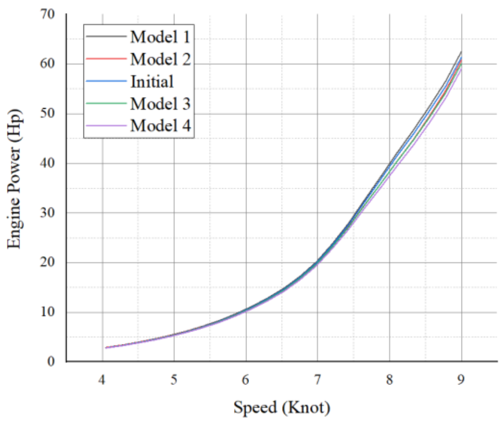

Figure 6. Engine Power Every Model

Based on the computer simulation results, showed the ship resistance figure obtained from the existing ship model (C) is 7.4 kN at a speed of 9 knots. Models B and D show the same figure, namely 7.3 kN. Model A showed a resistance figure of 7.5 kN. While model E showed a resistance figure of 7.1 kN. Model 4 has a small resistance value at a speed of 9 knots. The same thing happens to the ship's engine power requirements; model 4 showed a smaller engine power requirement than other models.

Based on the graphic display of Figure 5 and Figure 6, it has been illustrated that changes in the shape of the hull affect changes in the ship's resistance value and engine power requirements. Based on the Holtrop equation, the possible resistance components that experience changes are Frictional Resistance (R_F), appendage resistance (R_{APP}) and model-ship correlation resistance (R_A). The numbers for these three components are greatly influenced by the value of the wetted surface area, ship speed and ship shape coefficient.

From the simulation results, the offset of the new traditional ship hull shape is obtained with a smaller resistance value than the initial shape. The difference in the offset number of the station width between model E and the existing model is in the upper hull section along the maximum waterline of the ship.

IV. CONCLUSION

The traditional wooden ship hull shape was modeled using computer simulation. Based on the simulation results, the effect of the LCB point's position on the ship's hull is demonstrated. The simulation also shows how the volume, area and form coefficient are related in determining the position of the LCB. The effect of changing the LCB position is a modification in the ship's resistance value and the engine power requirements for a given speed. The method used to calculate the resistance is the Holtrop equation. The initial model obtained a resistance figure of 7.4 kN. Model 4, with 0.1 m shift in the LCB point, shows the minimum resistance value compared to the other variations and the initial models with the resistance number 7.1 kN. The comparison of ship resistance between model 4 and the initial model shows a decrease of 3.8%. Models 2 and 3 also experienced reductions in ship resistance, with values of 0.9% and 2.1%. Only model 1 saw an increase in resistance of 1.9%. The ship hull shape Modeling, with various variations, should be physically tested using a towing tank or other methods to obtain accurate results.

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