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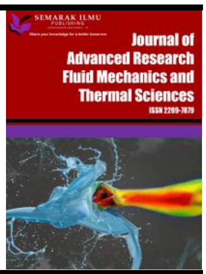

Numerical Approach of Fishing Vessel Hull Form to Measure Resistance Profile and Wave Pattern of Mono-Hull Design

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ABSTRACT

Indonesia is a maritime country with two-thirds of its territory is the ocean. Indonesia has a diversity of marine resources with a total fish production continuing each year to reach 8.02 million tons. The traditional fishing vessel is one of transportation and livelihood support in Indonesia and the vessel was made based on the knowledge from generation to generation. Thus, the investigation of the fishing vessels must be conducted to measure the resistance profile and wave pattern. This analysis is conducted to consider the mono-hull fishing vessel design. The use of a numerical approach is rapid to predict the performance of ship design. The resistance analysis is investigated using Savitsky's mathematical model and Holtrop's regression method. Comparing studies is the main focus to describe the effectiveness of the methodology. The research will present the three variations of the hull for the mono-hull design. By comparing both methods, the best design makes the methods well enough to be used for resistance analysis, especially in the fishing vessel design.

1. Introduction

Indonesia is marine country which has much natural potential and also as the largest country which has 17,499 islands with total beach length of ± 81,000 km as great potential for marine tourism in its territory [1]. The traditional fishing vessel is one of transportation and livelihood in Indonesia and the vessel was made based on the knowledge gained from generation to generation [2]. Therefore, in this case it needed to measure and analyze the hull of fishing vessel model that fits with the coastal characteristic. Since these studies are focused on the mono-hull type of fishing vessel, there are a lot method to analyze the hull form resistance.

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The numerical investigation is one of strategy to make the effectiveness calculation compare to analytic and experimental method [3-5]. Another study was conducted by Bahatmaka and Kim [6] investigated resistance on the hull form by using numerical approach, especially by using CFD. Jena and Gairola [7] applied the novel boundary condition into the numerical simulation, it concluded that the use of k-omega SST ensure effective near wall treatment from the simulation. The numerical and parametric studies which were conducted by Hind *et al.,* [8] considering the effect of Fly-Ash and Micro-PVA Fiber accompanying the boundary are solved numerically with assistance of using the solver in the simulation. The validation for comparison of numerical simulation to experimental studies have been conducted and produced the result slight difference and in a good agreement results by previous researches [9-13].

The ship resistance is one of the problems should be solved to produce the good performance especially in the ship design industry. There is some strategy to reduce the ship resistance. Budiyanto *et al.,* [14] reduced the high-speed vessel by application of stern foild using CFD simulation. The result concluded from the model simulation by stern foil worked optimally to reduce the resistance. Yanuar *et al.,* [15] investigated the hull water resistance calculation of seaplane twin float with clearance ratio variation configuration in the numerical simulation, from the result explained that the interference factor has a slight difference trendine between the numerical investigation and the experimental.

In this research used two kind of methods which is Holtrop method and Savitsky formula to measure the resistance of the hull form on several fishing vessel designs. The improved analysis of hull form has been conducted [16-18]. By using mono-hull fishing vessel design due to the existing data as comparison and other designs are proposed by modify the simple hull to investigate the resistance performances of each hull form and the best hull performances will be selected.

2. Theoretical Basis

2.1 Resistance Definition

Resistance is part of important ship analysis to perform the ability of hydrodynamic performance from the vessel. The hull operates and cross the sea water moving forward then will have resistance from the water which passes through. The ship must be designed to move the efficiently through the water with minimum of external force was conducted by Raj [19]. Several parameters are investigated by Hafez and El-Kot [20] explained effect to the resistance such as the ship speed (Vs), displacement, and hull type. The force of the resistance is divided into normal and tangential forces. The total of resistance can be described as Eq. (1).

$$R_T = R_F + R_V + R_W \tag{1}$$

2.2 Frictional Resistance

Sridhar *et al.,* [21] explained Frictional resistance typically proportional to the force which presses the surfaces together. The force which will affect frictional resistance is the component of applied force which acts perpendicular or normal to the surface. The formula of friction resistance is shown on Eq. (2) and the coefficient of friction is given by the International Towing Tank Conference (ITTC) 1975 as Eq. (3).

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

$$C_{f}=\frac{0.075}{(LogRe-2)^2} \quad (3)$$

2.3 Viscous Resistance

Zeng *et al.,* [22] explained the resistance due to the viscous stresses that the fluid exerts on the body of ship named viscous resistance. Generally, the value of viscous resistance depends on the form factor (1+k) for the mono-hull, (1+βk) for the multi-hull. The coefficient of viscous resistance can be seen in Eq. (4).

$$C_v = (1 + k)C_f \quad (4)$$

2.4 Wave Resistance

Wehausen [23] explained that a form of the drag that affects the surface watercraft, such as a boat or ship named wave resistance. The wave resistance considers zero at high speed (Vs) due to minimum resistance values. It can be seen on Eq. (5).

$$R_w = C_1C_2C_5\nabla\rho g exp\{m_1{F_r}^d + m_4 \cos(\lambda {F_r}^{-2})\} \quad (5)$$

2.5 Reynold's Number

The form of fluid will be created by the Reynold's number. The Reynold's number is part of important point used to measure the different of fluid such as laminar or turbulent. This Reynold's number equation is ratio from the force of inertia and the viscosity. It can be seen at Eq. (6). The laminar flow is the Reynold's number value around 2300 and 400 of flow. The Reynold's number value above 4000 is the turbulent flow which explained by Min and Kang [24].

$$R_n = \frac{V.L}{v} \quad (6)$$

2.6 Froude Number

The froude number indicates the speed compared to the displacement mass. In the hydrodynamics represent a particular model works for a system. Explained by Ogilvie [25]. The Froude number can be said semi-displacement if the value about 0.4 and 1. But if the value above 1, it will be called as the planning hull. It can be seen at Eq. (7).

$$F_n = \frac{V}{\sqrt[2]{g.L_{wl}}} \quad (7)$$

2.7 Wetted Surface Area

The wetted surface area can be calculated by using Mumford's formula to indicate an error rate about 7%, explained by Kristensen and Lützen [26]. The accuracy can be improved by using the configurations for measure the type of ships. The resistance is affected by the wetted surface area. If the number is small, the resistance will be reduced. Explained by Vitiello *et al.,* [27]. The wetted surface area can be calculated by using Eq. (8).

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

2.8 Savitsky Total Resistance

In the hydrodynamic characteristics for numerical approach, Savitsky's mathematical model is using in calculation to find the wet areas, drag, pressure, stability and also the resistance which can be used as function at speed, deadrise angle and trim. Explained by Savitsky and Brown [28]. The empirical formula on prismatic planning hull can be seen in Eq. (9).

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

2.9 Deadrise Angle

A ship's deadrise is angle accounted for the section plane between the hull and baseline (horizontal) at midship section [29]. It can be seen in Figure 1.

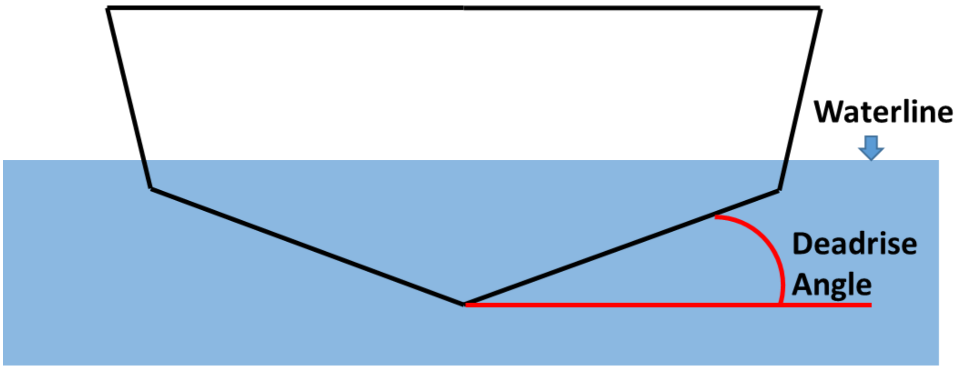


Fig. 1. Deadrise angle positioning on the ship

3. Design and Numerical Configuration

3.1 Main Dimension and Hull Ratio

In this study, the focus is addressed to improve design of mono-hull of fishing vessel and comparison analysis of the hull by selecting the effectiveness design and best performances among the designs. This analysis process, by following the rules that apply to MARINESIA 2022 (Indonesian Marine Innovation Festival) to measure the dimension of the ship. The Fishing vessel is selected as the object of the research by linear regression from the selected reference ship [30]. The selected ship references can be seen in Table 1. In this work process, finding the ratio of the ships from Length/Beam ratio (L/B), Length/Height ratio (L/H), and Beam/Draught ratio (B/T). The obtained ship dimension for the new design is performed in Table 2 and the lines plan designs are presented in Figure 2 to Figure 4.

Table 1
Comparison dimension of the fishing vessel's references

No.	Type of Hull	Dimension of hull				
		LOA (m)	B (m)	H (m)	T (m)	Speed (knot)
1	ALBACORA CARIBE	77.80	13.60	9.05	6.60	14.40
2	TXOPITUNA	77.30	13.60	9.05	6.60	13.50
3	EMERAUDE	74.40	16.00	9.55	6.50	17.10
4	GEVERED	77.00	13.60	9.20	6.70	16.50
5	GUAYATUNA DOS	77.30	13.60	9.05	6.69	14.60

Table 2
Main Dimension for the new design

Parameters	Unit	Dimension
LOA	m	77.59
LWL	m	70.03
LPP	m	67.34
B	m	13.50
H	m	9.12
T	m	6.70

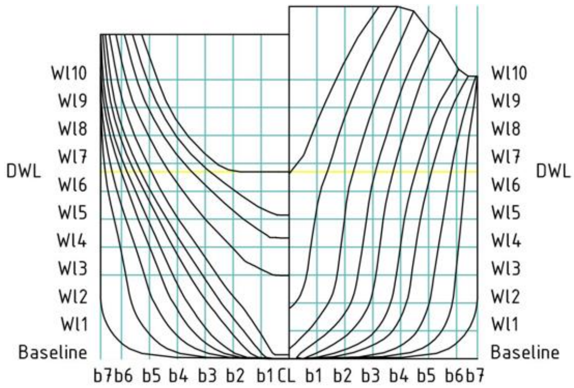


Fig. 2. Body plan of the design

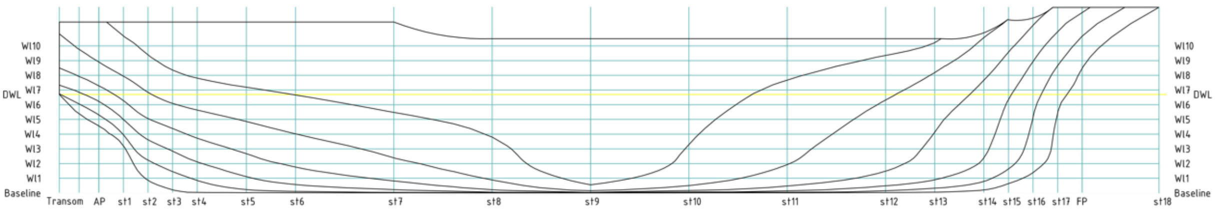


Fig. 3. Sheer plan of the design

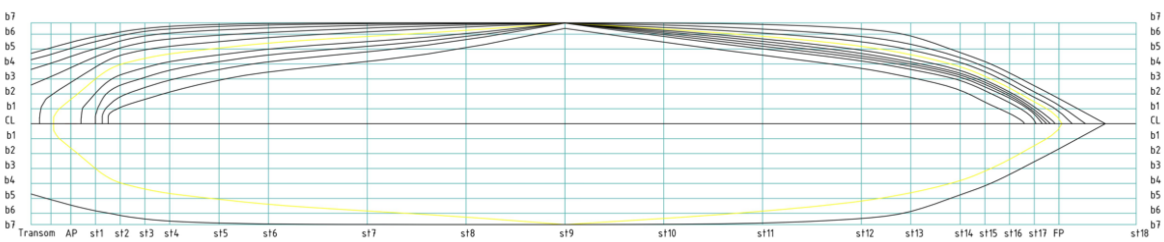


Fig. 4. Breadth plan of the design

3.2 Numerical Configurations and Benchmarking Study

This chapter performs the hydrostatic data of the ship as a variable of the ship's configuration. The characteristics of the new design are presented in Table 3. The change ship's speed is a variable control with a minimum speed of 8 knots and a maximum speed of 14 knots. Based on the ITTC 1975, the configuration must be as follows: kinematic viscosity 0.0000011 m^2/s, sea water density = 1025.9 kg/m^3, gravity = 9.8 m/s^2, saltwater (3.5% salinity) and water temperature on 15°C.

Table 3
Data design and characteristics of the new design

No.	Parameters	Value	Unit	Savitsky	Holtrop
1	LWL	70.03	m	70.03	70.03
2	Beam	13.50	m	13.50	13.50
3	Draft	6.70	m	-	6.70
4	Displacement volume	4024.16	m^3	4024.16	4024.16
5	Wetted area	1351.58	m^2	-	1351.58
6	½ angle of entrance	24.60	deg.	-	24.60
7	Deadrise angle at 50% LWL	0.90	deg.	0.90	-
8	Kinematic Viscosity	0.0000011	m^2/s	0.0000011	0.0000011
9	Water density	1025.90	kg/m^3	1025.90	1025.90

Based on a benchmark study of the characteristics (see Figure 5), the new designs were produced in the same trend line and well in agreement with the Savitsky and Holtrop method as shown in Table 4. It means the data can be used for the analysis to produce the resistance profile and wave pattern.

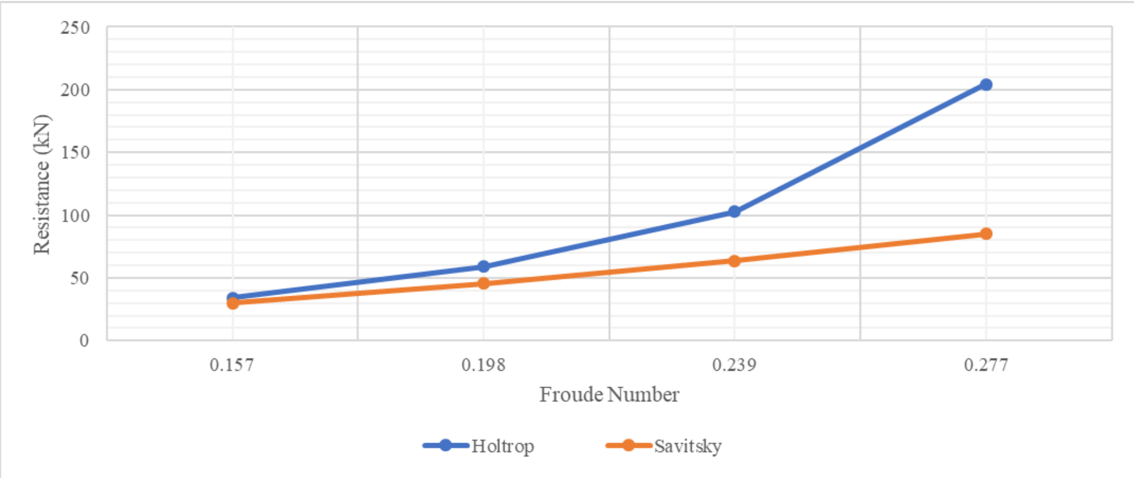


Fig. 5. Comparison method of the total resistance

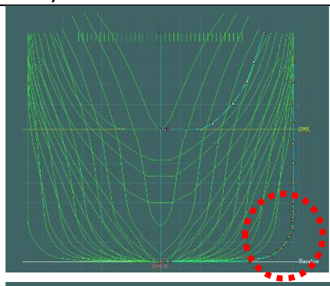
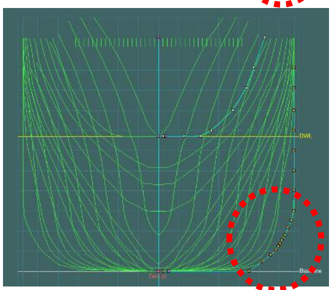
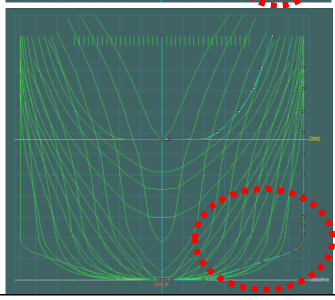
Table 4
Data comparison method of the total resistance

Fn (-)	Rn (-)	V (knot)	Savitsky (Analytical Solution) (kN)	Holtrop (Numerical Calculation) (kN)
0.157	2.62E+08	8	29.91	34.30
0.198	3.27E+08	10	45.36	58.80
0.239	3.93E+08	12	63.76	102.60
0.277	4.58E+08	14	85.05	204.10

3.3 Design Variations

The design variations are to change the deadrise angle for the coastal and north designs. The change in deadrise angle will produce the contour of the waterline turn higher. The variation was investigated on the deadrise angle 0.9, 1.3, and 8.6 degrees to measure the effect of change that occurs. The variations of the deadrise angle can be seen in the Table 5.

Table 5
Variations in mono-hull and deadrise angle

Deadrise Angle (°)	Body Plan View
0.9°	
1.3°	
8.6°	

4. Results and Discussion

4.1 Resistance Characteristics

Analysis of resistance from this research is to compare the characteristic that occurs from the effect of the designs. Small resistance can be predicted for estimation of the power needed by the ship design. From the result, a several parameter and scenario has been conducted and tested using a variation of the Froude number, Reynold number and ship speed. As a comparison results, the deadrise angle affect to the total resistance. The detail comparisons of resistance are summarized in the Table 6.

Table 6
Results of the total resistance from variations of Deadrise Angle

Fn (-)	Total Resistance from variations of Deadrise angle (kN)		
	0.9 deg.	1.3 deg.	8.6 deg.
0.157	34.3	34.4	34.7
0.198	58.8	57.8	58.6
0.239	102.6	103.9	106.4
0.277	204.1	198.5	202.4

Based on a comparison of the total resistance (see Figure 6), increasing the deadrise angle reduced the total resistance on the high-speed condition of the ship.

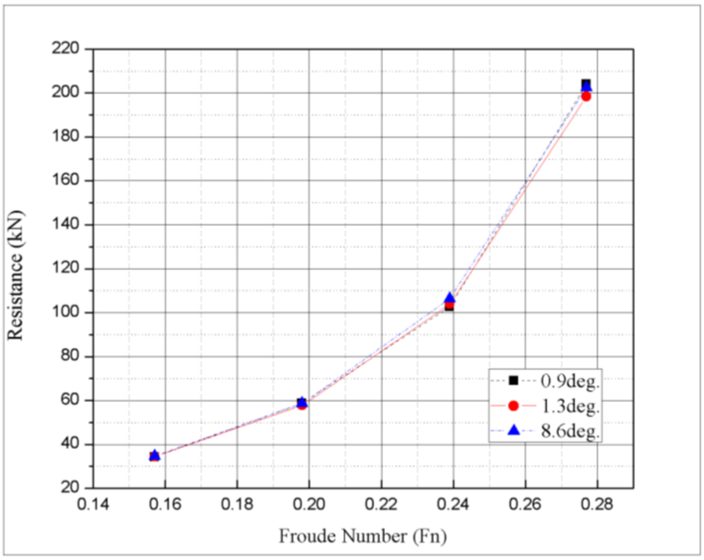
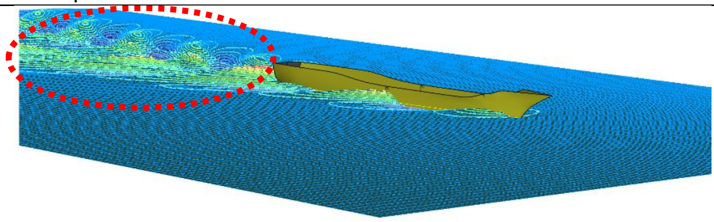
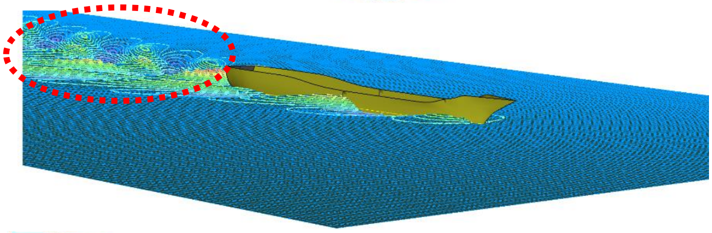
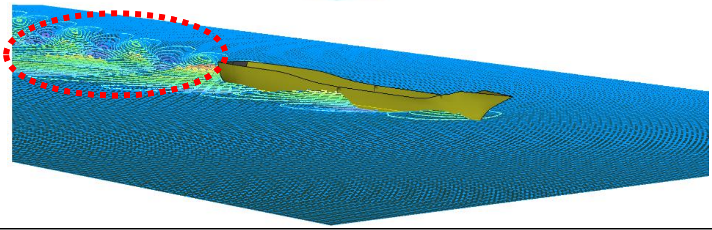


Fig. 6. Comparison method of the total resistance

4.2 Contours of the Wave Pattern

In this process, the Froude number of the ship entered the planning with a value, and the change wave pattern occurred even though not significant. Table 7 presents the configuration of the deadrise angle. When the Froude number was small or the ship entered the planning phase and the waves occurred around the ship smoother.

Table 7
Wave pattern of deadrise angle effect

Deadrise Angle (°)	Wave pattern on the Froude number 0.277
0.9°	
1.3°	
8.6°	

5. Conclusions

The numerical approach presents that the resistance characteristics were successfully approved compared to the analytical solution by Savitsky's mathematical method. The trend line is also in the same conditions and all proposed dimensions are presented in good agreement. In the mono-hull fishing vessel designs were proposed several deadrise angles to measure the resistance profile and wave pattern. From the result performed the deadrise angle affects the total resistance by improving the Froude number. Change in the angle affects the wave pattern around the hull even though a smooth pattern around the hull. This research can be improved by comparing another computational method to measure the interaction of the water around the hull.

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