Investigation on the performance of the traditional Indonesian fishing vessel

Aldias Bahatmaka[1,*], *Dong-Joon* Kim[2], *Samuel*[2], *Aditya Rio* Prabowo[1], *May-Thu* Zaw[2]

[1]Marine Design Convergence Department, Pukyong National University, Republic of Korea
[2]Naval Architecture and Marine Systems Engineering Department, Pukyong National University, Republic of Korea

Abstract. In this study, numerical investigation of ship resistance and ship motions at the traditional Indonesian fishing vessel is presented. The Computational Fluid Dynamic (CFD) code is used to calculate three dimensional, incompressible, and RANS equations. Different types of the fishing vessel hull form were performed. In this research, the data were collected chosen in north and south coast of Java island. The models were drawing in three dimensional, required for performing the analysis, were developed using Rhinoceros. The present study, the open-source computational fluid dynamics library, OpenFOAM was used to predict the resistance with the interFOAM solver. For the motion analysis, using strip theory in the Maxsurf motions. The probability of deck wetness analysis and ship motion were performed for comparing the models. Both analyses of ship Response Amplitude Operators (RAOs) are performed at three types of sea state (slight, moderate, and rough water). The comparisons of the hull form design will be evaluated to get the best performance based on the sea state condition of the java island.

1 Introduction

The traditional fishing vessel is one of transportation and livelihood support in Indonesia. The vessel was made based on the knowledge gained from generation to generation. Due to the experience in the field and instinct adapt to the environment. Thus, the traditional fishing vessel of region or island is one of the developed means product based on the ability to adapt to the natural environment in the region. The process of adaptation and culture of each island will determine the various forms of the traditional fishing vessel in terms of various size and style of the hull form.

Based on the territory, Indonesia has 17.508 islands, which is 70% of the sea with an area 5.8 million km^2. Indonesian sea is consists of 2.3 million km^2 marine territory and million km^2 Exclusive Economic Zone Area (EEZ)[1].

The common of numerical models for predicting the ship resistance performance in preliminary step is using CFD method. CFD is the computational fluid dynamics which based on potential flow theory, the Navier-Stokes equation to solve. The recent developments in computing technology have big problems to solve in shipbuilding industry

* Corresponding author: aldias@pukyong.ac.kr

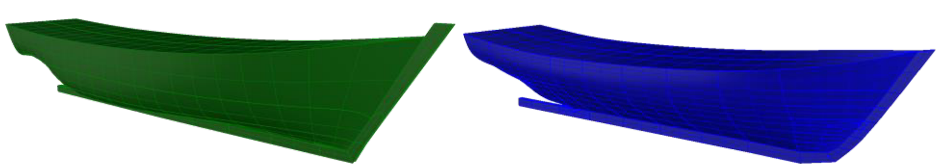
because of the license of the software. The open-source of CFD is one of the solutions to engineering problems, especially in CFD problems. OpenFOAM provides solver that can be used to predict the CFD approach and can be compared with others. Many studies on the hydrodynamics ship performance have been investigated by numerical models [2–4]. The analysis of flow around mono-hull form has been conducted with the traditional snake boats of Kerala [5] by CFD, while the prediction of ship resistance also performed based on empirical approach has been investigated [6]. The proof numerical analysis in comparing the experiments result has been discussed for the planning hull [7]. In addition, the numerical approach with strip theory in ship motion to determine optimal short-range routing of vessels in a seaway has been analyzed [8].

2 Model description and simulation conditions

The traditional fishing vessel of the present study was a mono-hull designed by Indonesian Shipyard in North and South Coastal of Java island. The South coastal design has the character of hull shape with a larger deadrise angle than the North coastal. Table 1 shows the principal dimensions of the models.

Table 1. Principal dimensions of the traditional Indonesian fishing vessel.

Principal Dimensions	Unit	Designs	
		North Coastal	South Coastal
Length overall (LOA)	***m***	17.65	20.00
Length waterline (LWL)	***m***	15.75	18.09
Breadth (B)	***m***	4.00	4.80
Depth (H)	***m***	2.50	1.80
Draft (T)	***m***	1.75	1.20
Gross Tonnage (GT)	***Ton***	30.00	30.00
Speed (Vs)	***Knot***	10.00	10.00



(a) North coastal design (b) South coastal design

Fig. 1. Model in Rhinoceros: (a) North coastal design; (b) South coastal design

The models in Fig.1 should be scaled in the same dimension and can be compared to the resistance simulations. The North coastal is scaled 1:5 and South coastal design scaled 1:5.74 then, both the designs will be at same Wetted Surface Area (WSA) and the Froude Number (FN).

The numerical simulation for ship motion in Maxsurf motions was carried out in the 4 types of speed (2.50; 5.00; 7.50; 10.00 knots), with the heading parameters are stern on 0deg, stern quartering on 45deg, beam on 90deg, bow quartering on 135deg, and head on 180deg. The spectra parameters are JONSWAP spectra in three sea conditions that are significant wave height (H1/3) are 1.25 m; 2.5 m and 4 m, peak period 7.5, 8.8, 9.7 s. for slight water, moderate water, and rough water.

In the present study, the open-source CFD libraries were used to predict the ship resistance. To predict free-surface flow around the hull form, interFOAM is one of the simplest ways to solve the problem. This solver is a multiphase flow that uses the VOF method to solve the free surface for incompressible flow [9].

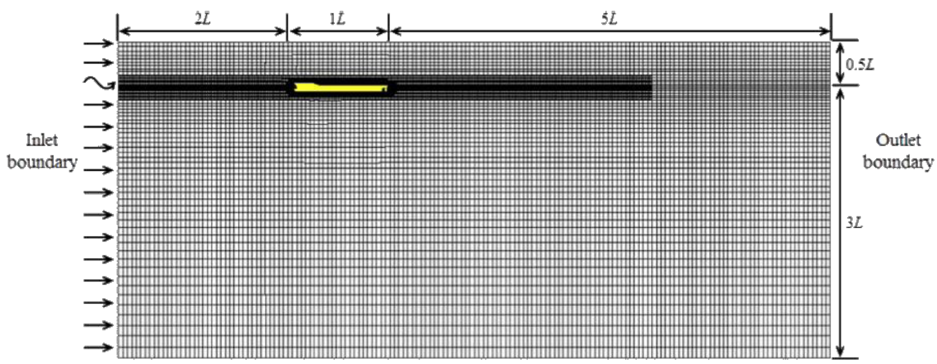


Fig. 2. Domain grid and boundary condition in OpenFOAM [6]

In the Fig.2 is the domain grid and boundary conditions that should be created in OpenFOAM [6]. The boundary conditions for this research are:

Inlet $$U = U, \frac{\partial p}{\partial n} = 0, \alpha = \int_0^1 \text{, if z < 0 otherwise} \quad (1)$$

Outlet $$\frac{\partial p}{\partial n} = 0, p = 0, \frac{\partial \alpha}{\partial n} = 0 \quad (2)$$

Wall $$U = 0, \frac{\partial p}{\partial n} = 0, \frac{\partial \alpha}{\partial n} = 0 \quad (3)$$

Top $$\frac{\partial U}{\partial n} = 0, p = 0, \alpha = 0 \quad (4)$$

Where n is the outer normal vector [2].

In resistance test, the main non-dimensional parameters in the flow around the hull are Froude number (Fn) which can be expressed as:

$$Fn = \frac{V}{\sqrt{gL}} \quad (5)$$

The probability of deck wetness is often important to be able to predict in a particular cycle of motion, and it was explained [10]. The probability is defined as:

$$P = \exp\left(\frac{-F^2}{2m_{0z}}\right) \quad (6)$$

Where F is the freeboard and m_{0z} is the mean square relative vertical motion. The roll motion of the vessel was analyzed using the software Maxsurf motions to obtain the RMS roll value. This program also uses the linear ship-motion strip theory to calculate the motion in the frequency domain.

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3 Numerical results

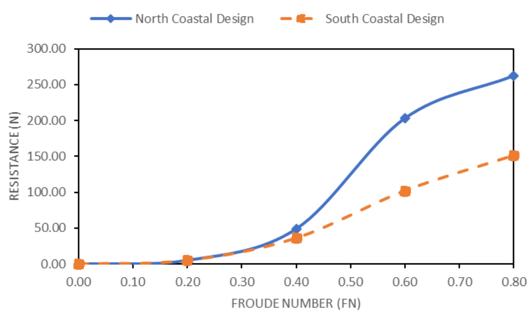
The traditional Indonesian fishing vessel for the north and south coastal design was performed in this research.

3.1 Ship resistance results

The results of the ship resistance for scale model can be compared as shown in Table 2.

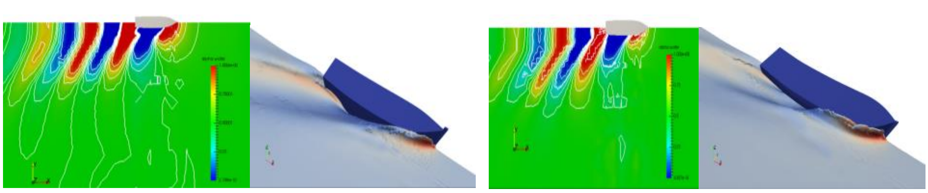
Table 2. Resistance results for scale model

	Froude number (*Fn*)	Velocity of models (*m/s*)	North coastal resistance (*N*)	South coastal resistance (*N*)
V1	0.20	1.11	5.23	5.23
V2	0.40	2.22	48.90	36.10
V3	0.60	3.33	203.00	102.00
V4	0.80	4.45	262.00	151.00



North Coastal Design South Coastal Design

(a) Resistance result



(b) Wave pattern in OpenFOAM

Fig. 3. Post-processing of resistance simulation in OpenFOAM

In the Fig.3 the computed results from OpenFOAM produce the difference wave pattern both the designs. From the wave pattern and results, the north coastal design has a stronger pattern and greater resistance than the south coastal design.

3.2 Ship motion results

In this study, both the designs will be compared for the added resistance and the probability of the deck wetness. From the simulation, the results of ship motions for full scale can be seen in Table 3.

Table 3. Ship motion results for full scale

VS (*Knots*)	Added Resistance (*N*)		Deck Wetness (%)	
	North	South	North	South
2.50	13358.18	14525.509	0.0141	0.0117
5.00	14613.09	15742.903	0.0143	0.0118
7.50	15158.42	16264.678	0.0146	0.0120
10.00	15436.10	16434.678	0.0149	0.0121

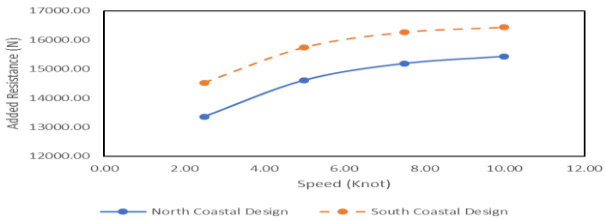


Fig. 4. Added resistance in ship motions

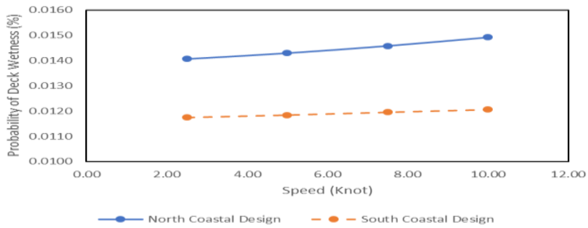


Fig. 5. Probability of deck wetness

The input of the simulation condition in this study was the same. From the Fig.4 and Fig.5 show the result the north coastal design has the added resistance smaller and the probability of deck wetness is greater than south coastal design. Thus, the north coastal design is better than the south coastal design.

The summary of ship motion analysis for both the designs can be seen in Table 4.

Table 4. Summary of ship motion performance

Vessel motion: 10kts; head seas	**North Coastal Design**	**South Coastal Design**
MSI at bridge	approx. 20% after 2hrs	approx. 20% after 2hrs
Propeller emergence	41.76% (0.156 per hr)	34.11% (0.008 per hr)
Deck Crew	36.75% (0.01 per hr)	31.61% (0.000 per hr)
Working Deck	40.19% (0.05 per hr)	35.03% (0.003 per hr)
Deck wetness	0.0149%	0.0121%
Calm water resistance	14.40 ***kN***	13.71 ***kN***
Added resistance (Slight, Moderate, Rough Sea)	(14.61; 15.18; 15.44 ***kN)***	(15.35; 16.22; 16.43 ***kN)***

4 Conclusions

In this work, hydrodynamic analysis of the traditional Indonesian fishing vessel was performed using the open-source CFD software OpenFOAM. The analysis was performed by interFOAM solver from the hull form design has an effect on resistance performance. Due to the results, the north coastal design has greater resistance than the south coastal design for the calm water conditions. In other work, the ship motion was analyzed using strip theory in Maxsurf motions. The result was performed that the north coastal design has smaller added resistance than the south coastal design. It means for the same condition is better to use the north coastal design. The probability of deck wetness for the north coastal design is greater than the south coastal design. It is caused by the south coast is more fierce than the north coast of Java, thus the south coastal design has characteristic to reduce the deck wetness by the hull form. The future research is the development of bow height calculation. The designs should be modified using several scenarios and point of deck wetness. The ship length and wave heights are parameters to get an optimum result and best performances of the ships.

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