International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 8 (2018) pp. 6211-6215

Numerical Modelling for Traditional Fishing Vessel Prediction of Resistance by CFD Approach

Aldias Bahatmaka[1,*], Dong Joon Kim[2]

[1] Interdisciplinary Program of Marine Convergence Design, Pukyong National University, South Korea.
[2] Department of Naval Architecture and Marine Systems Engineering, Pukyong National University, South Korea.

*(*Corresponding author)*

Orcid: 0000-0002-1933-7020, Scopus ID 57200256525

Abstract

This paper presents the numerical investigation of ship resistance of Indonesian traditional fishing vessel. The Open-source computational fluid dynamics (CFD) library, OpenFOAM, was used to predict three dimensional, incompressible, unsteady RANS equations for the ship resistance. The volume of fluid (VOF) method is used to predict the resistance. InterFoam solver is adopted to solve the computational problem. The KCS model was calculated and compared to the experimental result for validating the solver and relatively good agreement is achieved, then can be used to simulate the present model. The present model was using Indonesian traditional fishing vessel from the north and south coastal of Java island. The water condition in this study is in calm water condition and the same Froude number (*Fn*) for both models. As a result, the presented model for preliminary total resistance prediction in advance of the evaluation of the traditional fishing vessel performances.

Keywords: Traditional fishing vessel, resistance, CFD, OpenFOAM, InterFoam solver, VOF

INTRODUCTION

Determining ship resistance is important for ship designer. The use of numerical simulation is needed for predicting the ship resistance. CFD method were based on the potential flow theory, which is use the Navier-Stokes equations was difficult to solve, then the problem can be solved by Reynold-Average Navier-Stokes (RANS) equations to compute the simulation for ship resistance. Traditional fishing vessel is one of transportation and livelihood support in Indonesia. The vessel was made based on generation to generation. Thus, the traditional fishing vessel design in each island is different.

Many studies on the ship resistances have been conducted, especially for the numerical analysis [1–4]. Another approach is to reduce the frictional component of the resistance with active methods as injection of the air under the hull [5]. Some studies investigate the free surface flow around at different Froude number by CFD [6].

The common of numerical models for predicting the ship resistance performance in preliminary step is using CFD method. CFD is computational fluid dynamics. The recent development in computing technology has still problems to solve because of the license of the software. The Open-source of CFD is one of the solution in engineering problems, especially in CFD problems. OpenFOAM provides solver which can be used to predict the CFD approach and can be compared with the experimental result and other commercial software.

In this present study, the open-source CFD libraries were used to predict the ship resistance. CFD software with the use of Finite Volume methods, in this type is useful tools are open-source program to reduce the costs. This study open-source software is used to predict the free-surface flow. InterFoam is one of the basic application solvers of OpenFOAM was used [7]. For proofing numerical analysis in comparing the experiments results has been discussed for the planning hull[8] and using KCS model for validating the simulation was conducted [9].

MODEL DESCRIPTION AND NUMERICAL METHODS

The present study was used 3600 TEU KRISO Container Ship (KCS) in the Fig.1 is designed by the Korea Research Institute of Ship and Ocean Engineering (KRISO). The KCS used in model experiment. Table 1 lists the principal particulars of the KCS. As listed in Table 2, the case set up of the simulation conditions include calm water and used interFoam to solve the resistance simulation. This solver is multiphase flow which used the volume of fluid (VOF) method to solve the free surface for the incompressible flow.

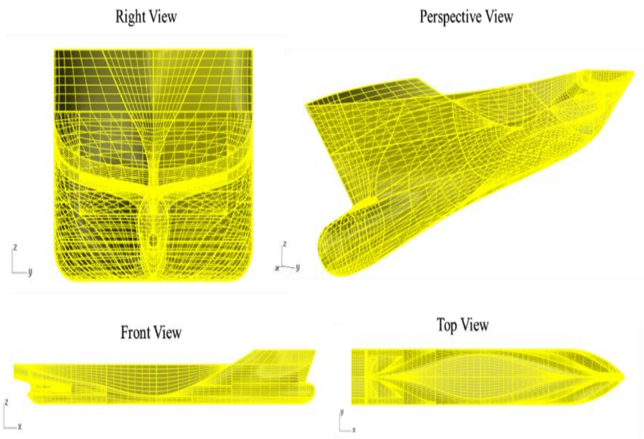


Figure 1. KCS hull model

Table 1. Principal particulars of model scale KCS.

Principal particulars	Symbol	Unit	Real Ship	Model
Length between perpendiculars	L_{pp}	m	230.00	7.28
Length of waterline	L_{wl}	m	232.50	7.36
Breadth	B	m	32.20	1.02
Depth	D	m	19.00	0.57
Draft	T	m	10.80	0.34
Scale Ratio	λ		31.59	31.59
C_b			0.6508	0.6508
C_p			0.6608	0.6608

Table 2. Case set up of simulation condition.

Item	Symbol	Unit	Set up
Solver			interFoam
Velocity	U	m/s	2.196
Start time	T_1	s	0
End time	T_2	s	5000
DeltaT	Δt	s	0.455
Froude number	Fn		0.26

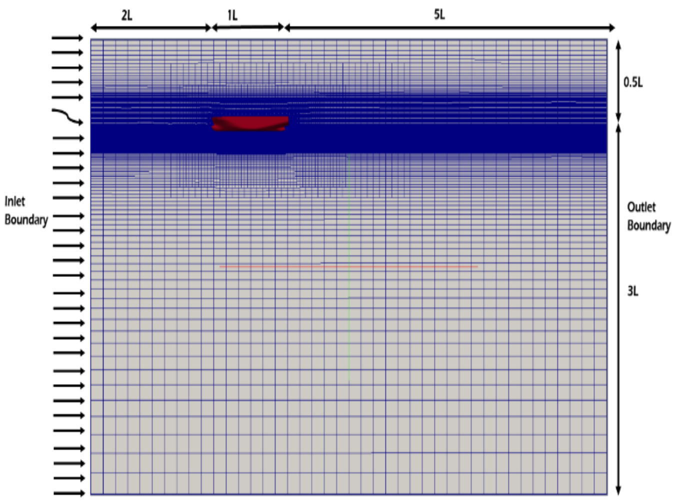


Figure 2. Domain grid and boundary condition in OpenFoam

The KCS model was scaled to 31.59 from the real size. The simulation conditions in calm water. This model calculated in OpenFOAM and used interFoam solver to predict the resistance. The computational domain was built as rectangular block around the hull in the deep water with the space coordinate range is determined as $-2L < x < 5L$, $0 < y < 2.5L$, $-0.5L < z < 3L$. The domain grid and boundary conditions were created in OpenFoam [10] can be seen in the Fig.2, and the mesh is generated by snappyHexMesh, the mesh generation utility of OpenFoam.

Governing equations

In the simulations of unsteady incompressible viscous flow field, the Reynolds-average Navier-Sokes (RANS) equations are adopted in this present study as governing equations. The equation of continuity and momentum equation can be written as

$$\nabla . U = 0 \qquad (1)$$

$$\frac{\partial \rho U}{\partial t} + \nabla . \left[\rho\left(U - U_g\right)U\right] = -\nabla p_d - g.x\nabla\rho = \nabla . \left(\mu_{eff}\nabla U\right) + (\nabla U).\nabla\mu_{eff} + f_{\partial +} f_s \qquad (2)$$

where U stands for the velocity field while U_g means velocity of mesh points, p_d is dynamic pressure, whose value is equal to total pressure subtracting hydrostatic component, ρ is mixed density of the two phases, g is gravitational acceleration, μ_{eff} is the effective dynamic viscosity computed by $\rho(V - V_t)$, V is kinematic viscosity coefficient and V_t is eddy viscosity, f_∂ is surface tension term, which impacts the free surface. To protect the flow field from the interface of echo waves, the source term f_s is added generate a sponge layer to absorb the generate wave [11].

The VOF method is used to solve the simulation with artificial bounded compression technique and simulate the free surface. The VOF transport equation is formulated as follows:

$$\frac{\partial \rho U}{\partial t} + \nabla . \left[\rho\left(U - U_g\right)\alpha\right] + \nabla . \left[U_r(1-\alpha)\alpha\right] = 0 (3)$$

where α represents the volume of fraction, the relative proportion of the two phase fluid, α is used to distinguish the fluid of two phases [12].

In resistance simulation for the KCS model, the main dimensional parameters in the flow around the hulls are Froude number (F_n) and the Reynold number (R_n) [13] expressed as:

$$F_n = \frac{V}{\sqrt{gL}} \qquad (4)$$

$$R_n = \frac{VL}{v} \qquad (5)$$

where F_n is the Froude number V is the ship speed, g is the gravity, L is the longitudinal of perpendicular from the ship, which has relation with R_n is the Reynold number, v is the kinematic viscosity.

Validation of solver with experimental result

This study compared the result from numerical calculation to the experimental result. For the numerical calculation used interFoam solver to solve the problem of resistance for measuring the parameters and continuing the research. For the simulation of KCS resistance model, the wave pattern shows in the Fig.3 and for the force convergence can be seen in the Fig.4. As the listed in the Table 3, the calculated hull resistance of the

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 8 (2018) pp. 6211-6215

KCS model is slightly different from the experimental result. Compared with experimental value of the total resistance coefficient of 3.55, the numerical calculated value of 3.41 is less than 4% and that means the validation reach is in good achievement.

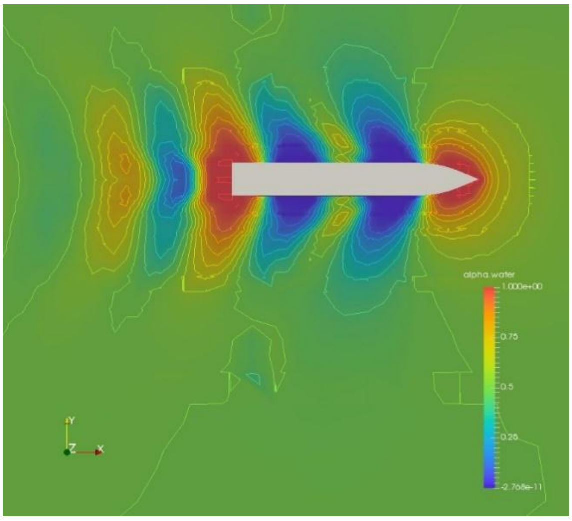


Figure 3. The flow around KCS model in OpenFoam

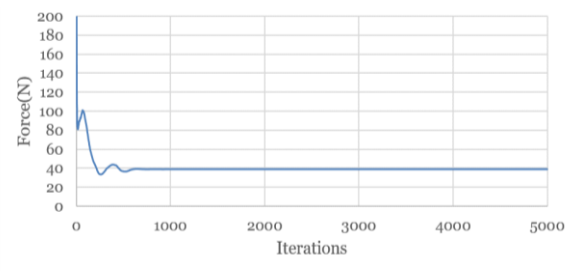


Figure 4. The KCS convergence history (interFoam solver)

Table 3. Comparison the result of resistance.

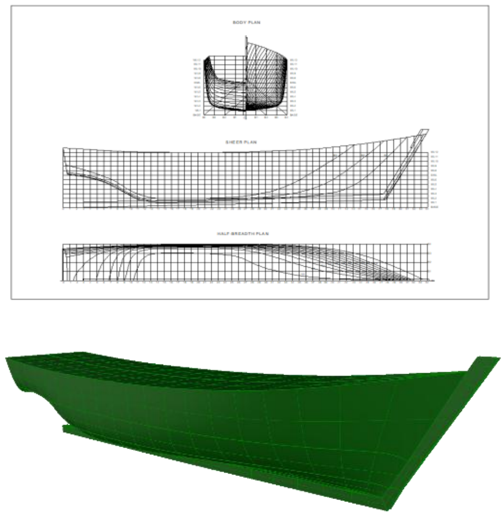
F_x (*N*)	Total drag (*N*)	C_t CFD X10^{-3}	C_t EFD X10^{-3}	Error %
39.20	78.40	3.41	3.55	3.99

The traditional fishing vessel

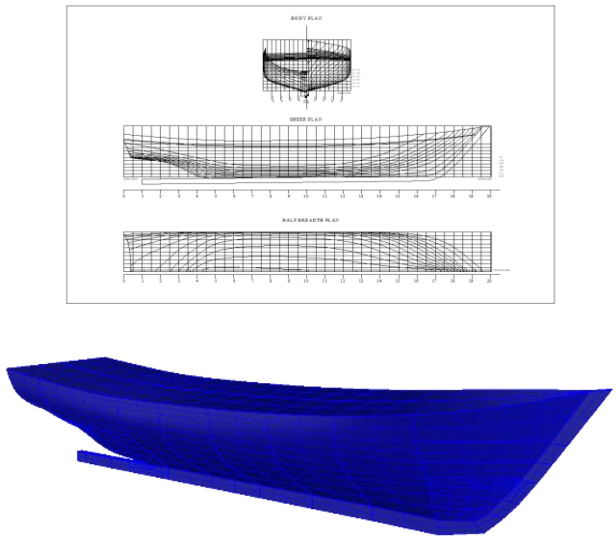
The traditional fishing vessel of the present study was mono-hull designed by Indonesian Shipyard for the north and south coastal of Java Island. The south design has the character of hull shape with larger deadrise angle than the north coastal and can be seen in the Fig.5. Table 4 shows the principal dimension of the models.

Table 4. Principal dimensions of the traditional Indonesian fishing vessel.

Principal Dimensions	Unit	Designs	
		North Coastal	South Coastal
Length over all (*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*)	kts	10.00	10.00



(a)



(b)

Figure 5. Model in Rhinoceros:

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

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 8 (2018) pp. 6211-6215

NUMERICAL RESULTS

The traditional Indonesian fishing vessel for the north and south coastal design was performed in this research. The hydrodynamic analysis of the traditional fishing vessel was conducted in OpenFOAM with interFoam solver. The results of the ship resistance for scale model can be compared between the north and the south coastal design as shown in Table 5.

In the Fig.6 the resistance result shows the north coastal design has greater than the south coastal design and from the Fig.7 and Fig.8 we compare both of the figures, the computed result from OpenFOAM produce the difference wave pattern both the designs. From the wave pattern and results, the north coastal design has stronger pattern and greater resistance than the south coastal design. This result corresponds to the theory that resistance/weight is almost independent from *L/B* [14]. The *L/B* of the north coastal design is greater than the south coastal design.

Table 5. Resistance results for scale model

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

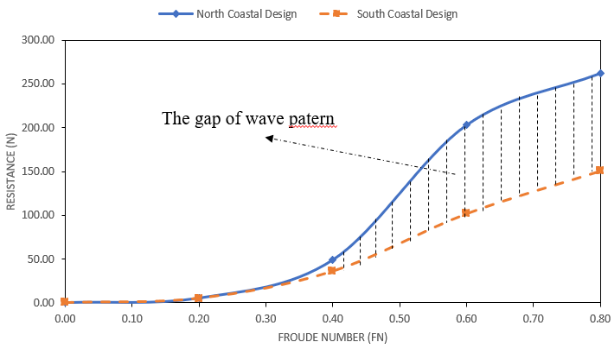


Figure 6. Resistance result

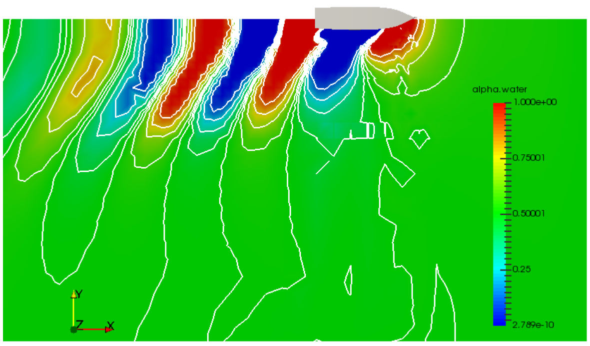


Figure 7. Post processing of north coastal resistance simulation in OpenFOAM

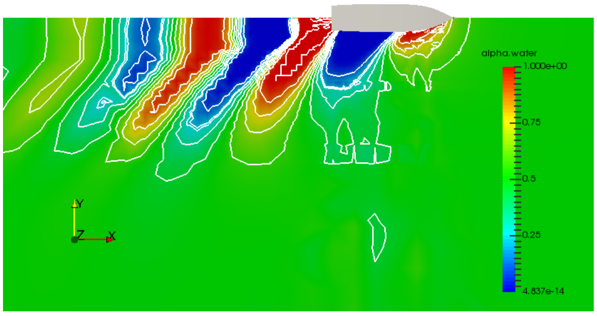


Figure 8. Post processing of south coastal resistance simulation in OpenFOAM

CONCLUSIONS

In this research, numerical analysis of the traditional Indonesian fishing vessel was performed using the open-source CFD software OpenFOAM. The simulation was performed by interFOAM solver from the hull form design which has an effect on the resistance performance. The validation of simulation was compared with the experimental result using the KCS model and the result is in good achievement, thus the boundary setting could be used in the traditional fishing vessel simulation. Due to the result, the north coastal design has greater resistance than the south coastal design for the calm water conditions. It happened caused by the hull-form of the south coastal design has larger deadrise angle than the north coastal design and it fits the theory.

ACKNOWLEDGEMENT

This paper was supported by the BK21 plus MADEC human resource development group, Pukyong National University, South Korea.

REFERENCES

[1] G. K. Saha and M. A. Miazee, "Numerical and Experimental Study of Resistance, Sinkage and Trim of a Container Ship," *Procedia Eng.*, vol. 194, pp. 67–73, 2017.

[2] Y. M. Ahmed, O. . Yaakob, M. F. A. Rashid, and A. H. Elbatran, "Determining Ship Resistance Using Computational Fluid Dynamics (CFD)," *J. Transp. Syst. Eng.*, vol. 1, pp. 20–25, 2015.

[3] S. Jeong, K. Choi, K. Kang, and J. Ha, "ScienceDirect Prediction of ship resistance in level ice based on empirical approach," *Int. J. Nav. Archit. Ocean Eng.*, no. 2006, 2017.

[4] B. V. Subbaiah, S. G. Thampi, and V. Mustafa, "Modelling and CFD Analysis of Traditional Snake Boats of Kerala," *Aquat. Procedia*, vol. 4, no. Icwrcoe, pp. 481–491, 2015.

[5] A. De Marco, S. Mancini, S. Miranda, R. Scognamiglio, and L. Vitiello, "Experimental and

numerical hydrodynamic analysis of a stepped planing hull," *Appl. Ocean Res.*, vol. 64, no. 1, pp. 135–154, 2017.

[6] Y. M. Ahmed, "Numerical simulation for the free surface flow around a complex ship hull form at different Froude numbers," *Alexandria Eng. J.*, vol. 50, no. 3, pp. 229–235, 2011.

[7] L. Axner, J. Gong, A. Chiarini, and L. Mascellaro, "Partnership for Advanced Computing in Europe SHAPE pilot Monotricat SRL : Hull resistance simulations for an innovative hull using OpenFOAM," *Pr. Partnersh. Adv. Comput. Eur.*, pp. 1–8, 2014.

[8] A. De Marco, S. Mancini, S. Miranda, R. Scognamiglio, and L. Vitiello, "Experimental and numerical hydrodynamic analysis of a stepped planing hull," *Phys. Procedia*, vol. 64, pp. 135–154, 2017.

[9] S. Sherbaz and W. Duan, "Ship trim optimization: Assessment of influence of trim on resistance of moeri container ship," *Sci. World J.*, vol. 2014, no. January, 2014.

[10] S. Seo, S. Park, and B. Koo, "E ff ect of wave periods on added resistance and motions of a ship in head sea simulations," *Ocean Eng.*, vol. 137, no. October 2016, pp. 309–327, 2017.

[11] R. S. Zha, H. X. Ye, Z. R. Shen, and D. C. Wan, "Numerical computations of resistance of high speed catamaran in calm water," *J. Hydrodyn.*, vol. 26, no. 6, pp. 930–938, 2015.

[12] C. Emmanuel, L. Mesina, "The Conceptual Design of a Ballast Free Ship by The Conceptual Design of a Ballast Free Ship Ballast Free," Pukyong National University, 2017.

[13] S. Eliasson and D. Olsson, "Barge Stern Optimization," *Anal. a straight shaped stern using CFD*, no. X, 2011.

[14] E. Begovic and C. Bertorello, "Resistance assessment of warped hullform," *Ocean Eng.*, vol. 56, pp. 28–42, 2012.