Analyze of Crocodile Ship Prototype Hull Resistance in Hydrofoil Mode

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Abstract – *This study presents resistance simulation of Crocodile ship prototype in hydrofoil mode in calm seawater conditions using CFD in hydrofoil mode. The RANSE (Reynolds Averaged Navier-Stokes Equation) methods are used for the viscosity solution of turbulent flow around the ship hull. Different turbulent models are used for the comparison of their results in ship resistance calculations, for selecting the appropriate methods. This study on the creation of geometrical model which considers exact pressure and velocity around vessel submerged in hydrofoil mode in calm seawater conditions, grid generation, setting mathematical model in Fluent and evaluation of the simulations results. Comparison with experimental results also carried out.*

Keywords: *Crocodile ship prototype, CFD resistance simulation, RANSE methods*

I. Introduction

The prototype of Crocodile Ship has been designed and fabricated to combine operational modes of hydrofoil vessels, surface ships and submarines in its mission. The vessel is designed with front and rear wings of hydrofoil that can be controlled in all modes of ship operation. The current paper investigates the ship resistance in hydrofoil operation mode with numerical simulation based on RANS Equations. Assessment of ship resistance started to gain importance with the advent of machine-propelled ships in the early nineteenth century. The dependence of ship resistance on velocity was necessary for calculating the required power of the propulsion system. Computational Fluid Dynamics (CFD) was necessary cooperation of several disciplines such as mathematics, physics and information technology for the development of this method. CFD simulation gained larger scale acceptance in the 90's and has sometimes replaced experiments in many fields today. The CFD simulations have commonly been integrated into project of every new vessel, especially in the design of seagoing ships. This approach for assessing the ships resistance by using experimental and CFD simulations are also a content of this study. The study aims at developing the process and selection of appropriate methods for creating the geometrical model, setting-up the mathematical model and creating the preliminary CFD simulation. It will be applied in the case of crocodile ship prototype in calm seawater, which is more interesting for archipelago countries such as Indonesia.

This paper presents a numerical study on for different speed conditions. This study have carried out for the prediction of resistances characteristics of special hull using numerical simulation and compare the results with the experimental results in the towing tank.

II. METHODOLOGY

This study is intended to conduct for calculation of the techniques for resistance prediction ships. This method starts with full scale dimension of ship model run in CFD analysis. The CAD ship model have been conducted at that varies speed condition in calm water: length (L) of 11m, Breadth (B) of 3m, depth (H) of 2m, maximum draft (T) of 1.8m and maximum speed of carriage is 4.0 m/s in figure.3. Resistance measurement of model were made with dynamometer. The model attached to the measuring head of the resistance dynamometer by a connection which can transmit and measure only a horizontal tow force, even though raked the model should be run at the correct calculated displacement. The resistance dynamometers were attached at the LCB of the model as close to the shaft line as possible. The electrical signal from dynamometer are transmitted through overhead cables on trolley wires to the signal conditioning equipment and ultimately to the computer. Data were sampled for resistance and speed in the longitudinal direction Fx. The forces are measured in mass (kg) and converted to N by multiplication by g.

II.1. Experimental Setup

3D model of the crocodile hull was created according to the dimensions (as shown in Tab.1) and shapes defined seen in Fig. 1 below which shows the strut and nacelle positions under three modes of operation. The Crocodile ship prototype is now under construction in

Institut Teknologi Sepuluh Nopember (ITS) Surabaya as shown in figure.2.

The calculation of the total resistance was achieved by using the procedure as outlined in the ITTC recommended procedures [ITTC, 2011]. The total resistance was calculated where the total hull resistance is a function of hull form, ship speed, and water properties, the coefficient of total hull resistance is also a function of hull form, ship speed, and water properties. The coefficient of total hull resistance is found from the following equation

$$R_T = 0.5.\rho.Ct.S.V^2 \qquad (1)$$

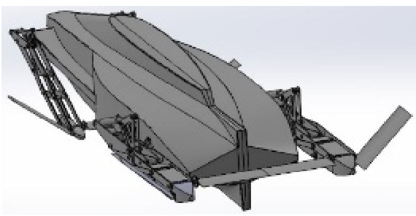
The equation for the Froude number is

$$Fr = V\sqrt{gL} \qquad (2)$$

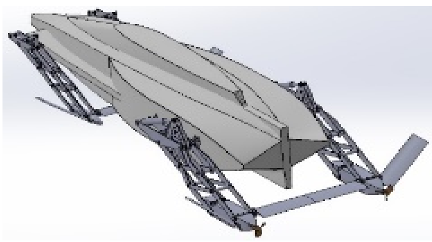
Where:
Ct = total resistance coefficient
RT = total hull resistance (N)
ρ = water density (kg/m^3)
V = velocity (m/s)
S = wetted surface area of the underwater hull (m^2)
L = ship length (m)
g = gravity (m/s^2)

TABLE I
PRINCIPAL DIMENSION CROCODILE SHIP

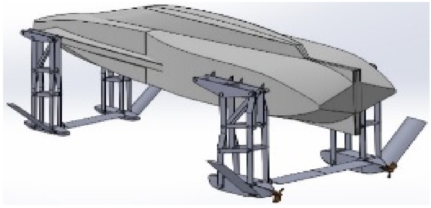
Principal Dimension	Full Scale	Model Scale
LOA (m)	11	1.1
B (Breadth) (m)	3.0	0.3
T Draft (m)	0.75	0.075
Full/Model Scale ratio (λ)	1	1/10



Submarine



Surface



Hydrofoils

Fig.1. 3D Model Crocodile hull condition

Fig.2. Crocodile hull prototype under construction

II.2. Numerical Setup

The simulation is made for a 10, 20, 30, 40 knots velocity of the crocodile prototype. The Realizable k-epsilon, viscous models were used. For a detailed explanation of the discretization of FVM, please refer to the book published by Versteeg and Malalasekera (2007). The calculations involved in this study are all for steady cases. Since there are two types of flows solved with FVM (inviscid and viscous), conditions of the viscous solver is divided into two. For the viscous solver, the realizable and standart k –ε turbulence model is used. The inlet of the fluid domain is selected as velocity inlet and the outlet as pressure outlet. The top and bottom walls are symmetry boundary condition attached. SIMPLE algorithm is used for pressure-velocity coupling which is the mostly used and the most straightforward method. Pressure, momentum, turbulent kinetic energy and dissipation rate are all selected as second order.

This approach is called Reynolds Averaged Navier Stokes Equation (RANSE):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}\left(\rho v_i\right) = 0 \qquad (3)$$

In this study, the flow is accepted to be steady and incompressible and the effects of free surface and cavitation are ignored. Due to incompressible flow, energy equation is automatically eliminated from the conservation equations and only the continuity and momentum equations are left. The viscosity term in Eq. (4) may also be eliminated depending on the type of solution FVM will return.

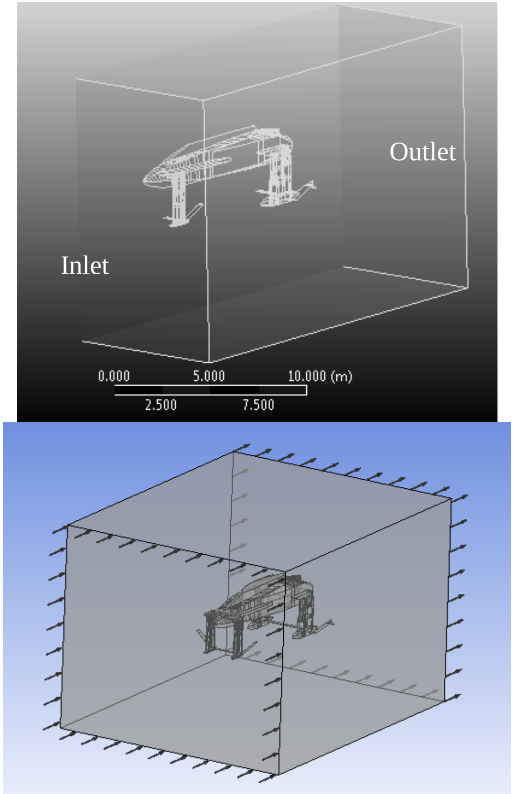


Fig. 4. 3D Computational domain around crocodile ship and boundary conditions.

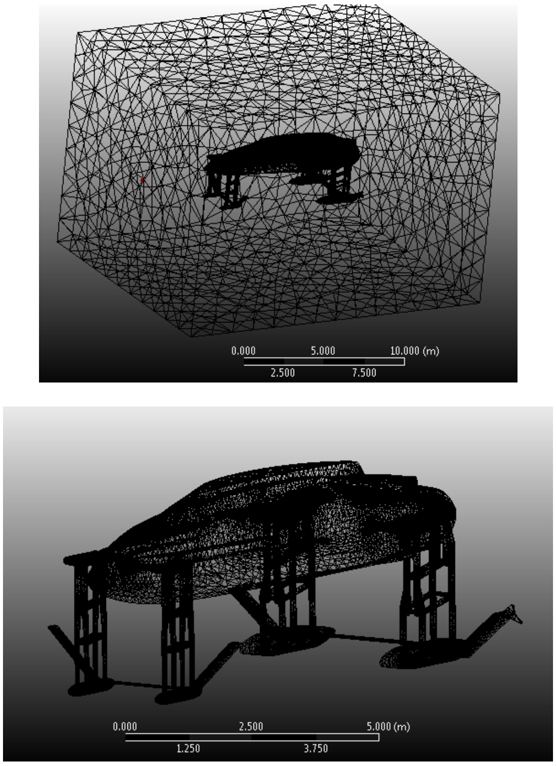


Fig.5. 3D crocodile ship meshed model.

III. Result and Discussion

Results from Numerical Simulation using K-EPSILON Realizable Model Scale Results shows in table below that fr = 0.5, 0.99, 1.49 and 1.98 resistance obtained by results data of Force in x-axis for each Froude Number are 28.4, 113.01, 253.41, and 468.12 kN.

TABLE III
K-EPSILON REALIZABLE MODEL SCALE RESULT
NUMERICAL SIMULATION

Froude Number Fr	Velocity model Vs (m/s)	Velocity model Vs (knots)	Force in x-axis (kN)	Model Scale Resistance (kN)
0.5	5.14	10	28.4	32.5
0.99	10.29	20	113.01	122.67
1.49	15.43	30	253.41	257.83
1.98	20.58	40	468.12	472.17

Numerical Simulation using K-EPSILON Realizable Model Scale graph grows exponentially as Froude Number increased.

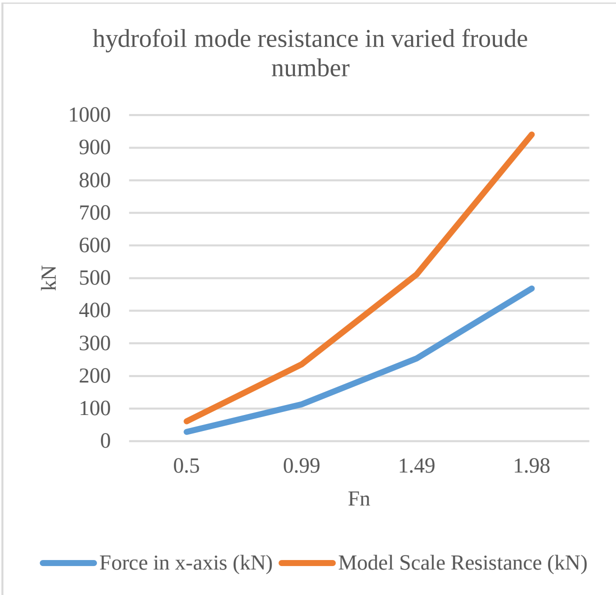


Fig. 6. Resistance of Each Froude Number in Full Scale CFD Experiment

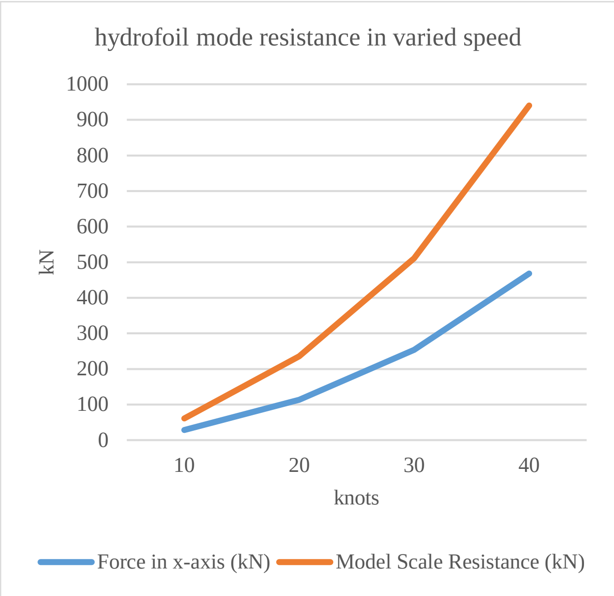


Fig. 7. Resistance in Each Speed of Full Scale CFD Experiment

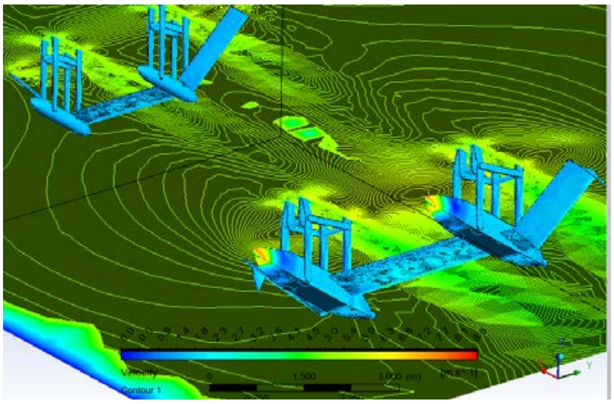


Fig. 8. Force in x-axis Contour at 10 knots speed of Hydrofoil Mode.

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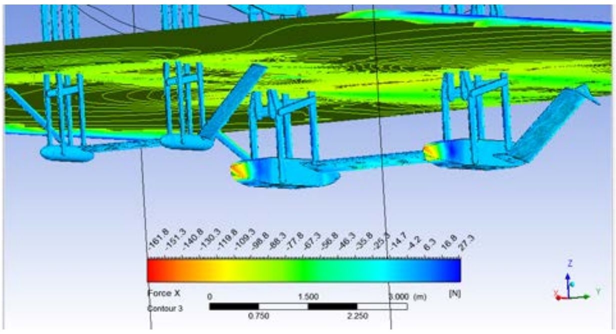

Fig. 9. Force in x-axis 20 knots speed of Hydrofoil Mode.

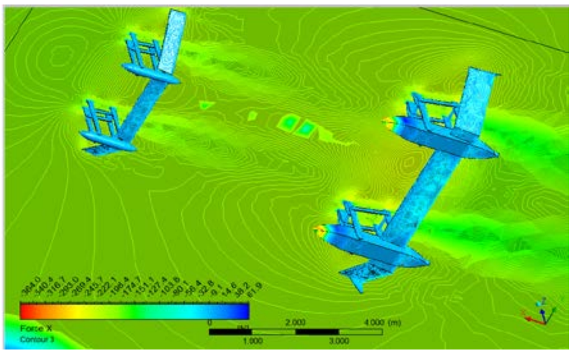

Fig. 10. Force in x-axis 30 knots speed of Hydrofoil Mode

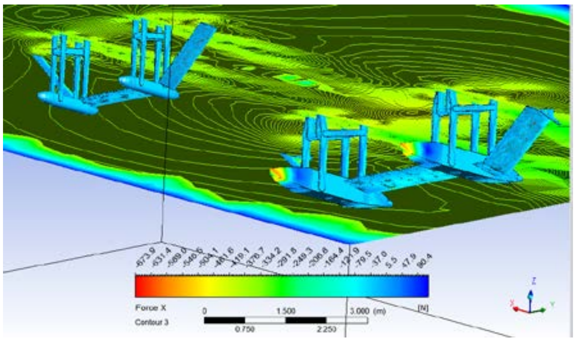

Fig. 11. Force in x-axis 40 knots speed of Hydrofoil Mode

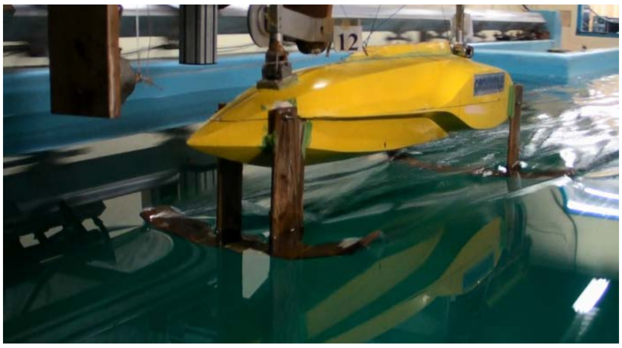

Fig. 12. Towing tank test at 12knots speed

IV. Conclusion

This paper investigated the resistance and hydrodynamic crocodile ship hydrofoil condition. A finite volume based RANS solver has been used to evaluate the performance of these systems. .

Appendix

Appendixes, if needed, appear before the acknowledgment.

Acknowledgements

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Authors' information

Wisnu Wardhana was born in Surabaya in December 1958. He is now a senior lecturer at Department of Ocean Engineering, Institut Teknologi Sepuluh Nopember Surabaya (ITS), Indonesia, majoring in hydrodynamics and fluid-structure interactions. He graduated his BSc from Faculty of Naval Architecture and Ship Building ITS in 1985. He finished his MSc in 1990 and hi PhD in 1995 in Marine Technology Department, with dissertation: *Prediction of 2D Separated Flow about Cylinder in the Presence of Boundaries*, of the University of Newcastle upon Tyne, UK. He also graduated his BSc in economics from Department of Economics and Development Study of Indonesia Open University in 1998. Beside his formal studies, he also took few courses in engineering applications, such as, welding, non-destructive and pipeline inspectors.

During his carrier, he involved in several ship designs and engaged in some practical marine projects, such as, shipbuilding and heavy lifting transportation and engineering. He is also interested in doing researches in advanced marine vehicles, such as, hydrofoils crafts and submarines under Indonesian Government Research Funds.

Dr. Wardhana is a member of Indonesian Engineer Association and Indonesian Maritime Engineer since 1985. He is also an Associate Member of Royal Institution of Naval Architect.

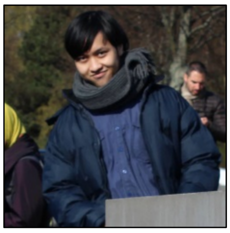
Meitha Soetardjo was born in Surabaya, in May 1959. She graduated with BEng degree in Naval Architecture and Shipbuilding Engineering from Institut Teknologi Sepuluh Nopember Surabaya (ITS). She is now senior researcher at Laboratory for Hydrodynamics Technology, BTH Surabaya, which is a work unit of the Agency for Assessment and Application Technology BPPT, Jakarta.

In 1989, She has trained for 1.5years, Design of Shipbuilding Course at Hamburg Institute fur Schiffbau, Germany.

In 1991 One year Training on Naval Architecture, Design Aspects; Hydrodynamics Laboratory Training, MARIN Wageningen Netherland, Marine Softwares for Hidrodynamics, MARIN Netherland, also in 1993 one year training at MARIN-LHI Surabaya., at Hydrodynamics Laboratory Equipment Training, ITS Surabaya, Mechanical and Wooden Workshop Trainings, and Several Training in Engineeing .

She has published technical articles in various scientific journals in the field of design and testing models marine technology.

Since 2006 her activities is as Auditor in the field of Internal Quality Assurance and Quality Control, has certificate of Quality Management & Risk Management system according to ISO / IEC 17025, RSNI 19-17025-2000, ISO / IEC 17025-2008, ISO / IEC 17025-2017 , and also KNAPPP guidelines 02: 2017. During few years involved work for research , PNBP (non-tax revenue) and for now is working as head of program in testing models for offshore infrastructure technology innovation.



Ede Mehta Wardhana was born in Surabaya, Indonesia, in 1992. Graduated Cum Laude From Department of Marine Engineering Institut Teknologi Sepuluh Nopember both in BEng and MEng. He had published various journal articles in conferences and scientific journals in the field of marine technology. His published articles contain topics about Marine Renewable Energy, Marine Piping, and Heating, Ventilating, and Air conditioning (HVAC) in Marine Technology. Now he is a lecturer in the department of marine engineering under the marine machinery systems (MMS) Laboratory. Currently, his primary research is about the usage of nanogenerator, triboelectric materials, piezoelectrics and self-generated devices in marine technology. His works could be seen on https://www.researchgate.net/profile/Ede_Wardhana. or https://scholar.google.co.id/citations?user=AQqPNgwAAAAJ&hl=id

Sujantoko was born in Bojonegoro, Indonesia, 1970. He graduated with BEng degree in Offshore Engineering from Institute of Technology Sepuluh Nopember (ITS), Indonesia, in 1995. He was further awarded with Magister Engineering degree in Department of Civil Engineering from Institute of Technology Bandung, Indonesia, 2003.

He had published some technical articles in various conferences and scientific journals in the field of marine technology. His articles contain the topics about coastal hydrodynamics, numerical model of wave-current interaction in shallow water, tide prediction with least square method, hydrodynamics effect to semi-submersible motion in irregular wave, and currently he is researching about the effect of hydrodynamics on porous floating breakwater.

He is a laboratory member at Department of Ocean Engineering ITS dan he is also a member of Indonesian coastal experts association (HAPI). Currently, Sujantoko is pursuing doctoral education at Department of Ocean Engineering ITS.