Hull Resistance Analysis of Hydrofoil Mode-crocodile Ship Prototype

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Abstract: This study presents resistance simulation of hydrofoil mode crocodile ship prototype 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's hull. Different turbulent models are used for comparing the results in ship resistance calculations, in order to select the most appropriate methods. This study on the creation of geometrical model considered exact pressure and velocity around hydrofoil mode vessel submerged in calm seawater conditions, grid generation, setting mathematical model in Fluent and evaluation of the simulations results. Comparison with experimental results also carried out.

1 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 using 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) used in this research, requires 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. The approach for assessing ships resistance by using experimental and CFD simulations are also a part of this study. This 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. This will be applied in crocodile ship prototype in calm seawater, which represents seawater condition in archipelagic countries such as Indonesia.

This paper presents a numerical study in different speed conditions. This study has predicted resistances characteristics of special hull using numerical simulation and comparing the results with the experimental results in the towing tank.

2 METHODOLOGY

This study is intended to conduct calculation as a technique to predict resistance for ships. This method starts with full scale dimension of ship model ran in CFD analysis. The CAD ship model have previously been conducted at various speed condition in calm seawater: length (L) of 11m, breadth (B) of 3m, depth (H) of 2m, maximum draft (T) of 1.8m and maximum speed of carriage is at 4.0 m/s. Model resistance was measured with dynamometer. The model was attached to the measuring head of the resistance dynamometer by a connector which can transmit and measure only a horizontal tow force, even though the model should be 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

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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 through gravity (g) multiplication.

2.1 Experimental Setup

3D model of the crocodile hull was created according to the dimensions (as shown in Tab.1) and shapes defined seen in Figure 1 below which showed the strout and nacelle positions under three modes of operation. The vessel itself is currently 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.

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

The equation for the Froude number is

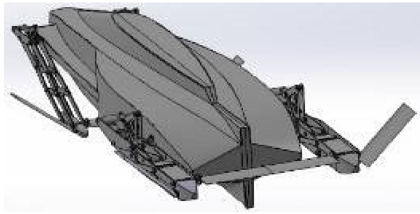
$$Fr = V.gL \quad (2)$$

Where:

Ct	:	total resistance coefficient
RT	:	total hull resistance
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)

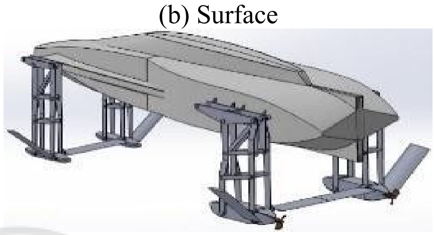
Table 1: Principal dimension crocodile ship

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



(a) Submarine

(b) Surface



(c) Hydrofoils

Figure 1: 3D Model Crocodile hull condition.

Figure 2: Crocodile hull prototype under construction.

2.2 Numerical Setup

The simulation is made for various speed at 10, 20, 30, and 40 knots velocity of the crocodile prototype. The Realizable k- epsilon, viscous models were also 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 standard 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 in symmetrical boundary condition. Simple algorithm was used for pressure- velocity coupling, which is widely used and considered the most suitable 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):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho v_i) \quad (3)$$

In this study, the flow is 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 Equation (3) may also be eliminated depending on the type of solution FVM will return.

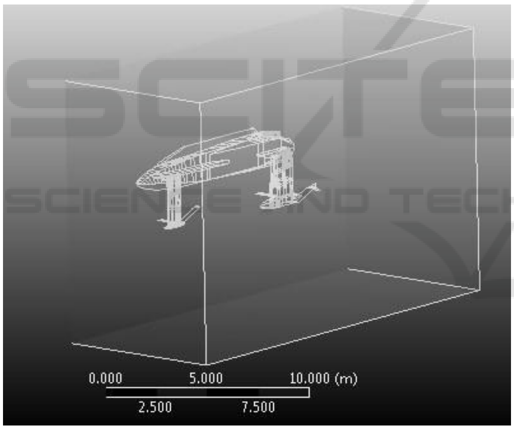
Table 2 : K-epsilon realizable model scale resul tnumerical simulation.

Froude Number Fr	Velocity model Vs (m/s)	Velocity model Vs (knots)	Force in x-axis (kN)	Model Scale Resistance (kN)
0.55.14		10	28.4	32.5
0.9910.29		20	113.01	122.67
1.4915.43		30	253.41	257.83
1.9820.58		40	468.12	472.17

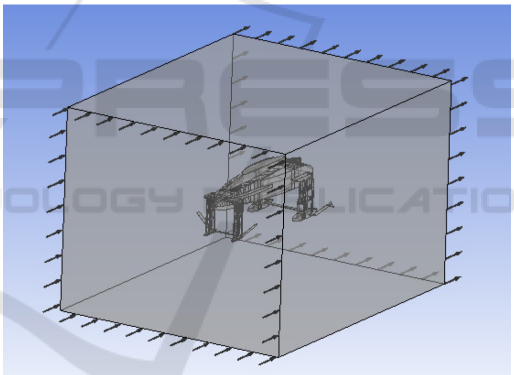
3 RESULT AND DISCUSSION

Results from Numerical Simulation using K-EPSILON Realizable Model Scale Results are shown 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.

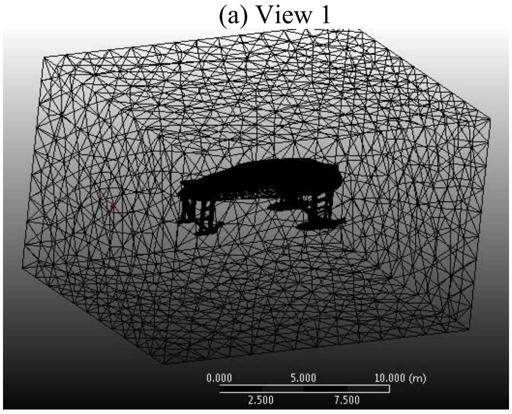
Numerical Simulation using K-EPSILON Realizable Model Scale graph grows exponentially as Froude Number increased.



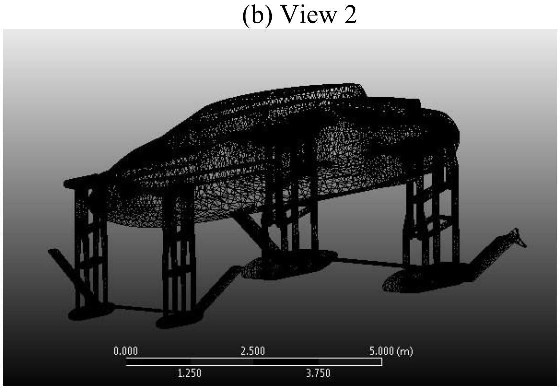
(a) View 1



(b) View 2



(c) View 3



(d) View 4

Figure 3: 3D crocodile ship meshed model.

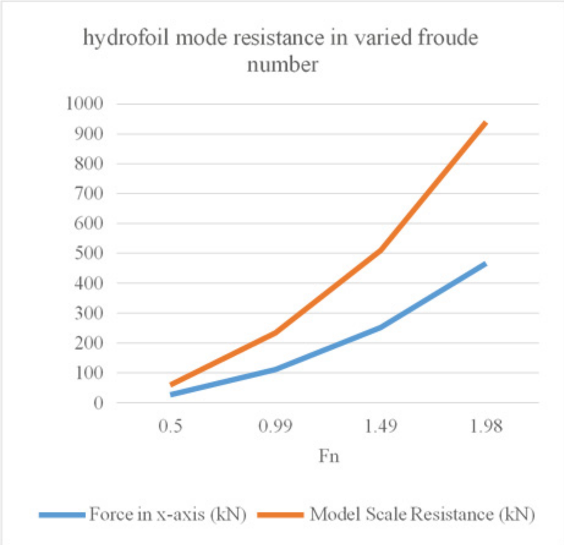


Figure 4: Resistance of each froude number in full scale CFD experiment.

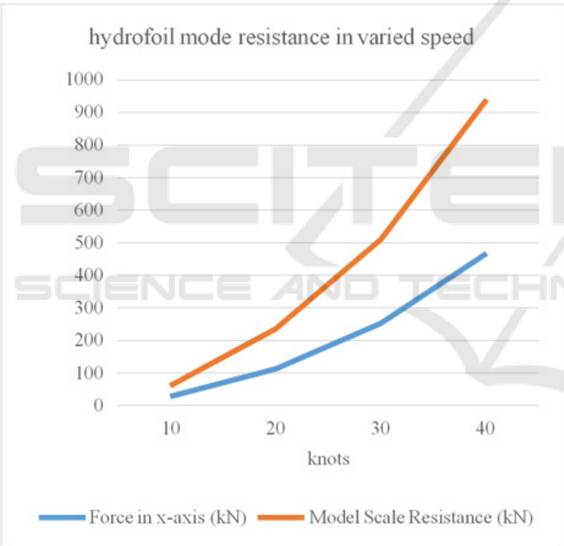


Figure 5: Resistance in each speed of full scale CFD experiment.

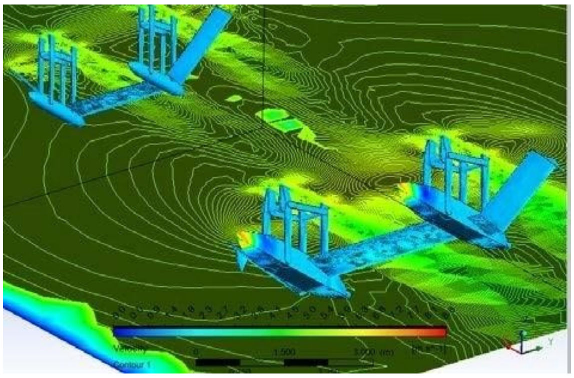


Figure 6: Force in x-axis contour at 10 knots speed of Hydrofoil Mode.

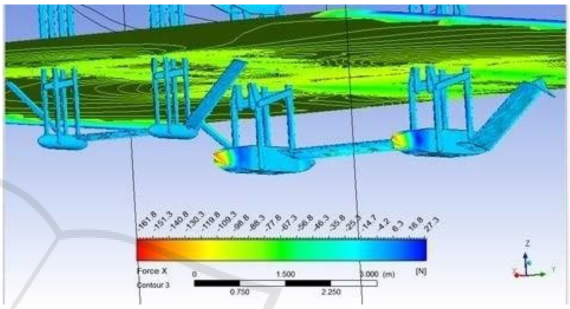


Figure 7: Force in x-axis 20 knots speed of Hydrofoil Mode.

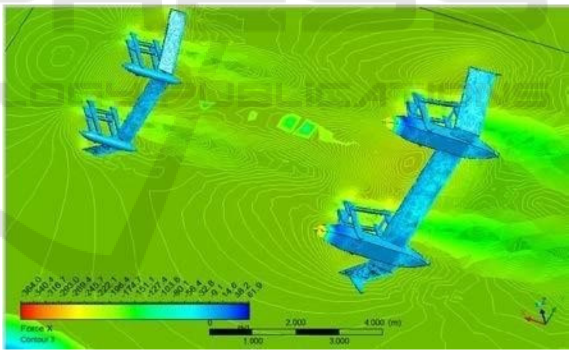


Figure 8: Force in x-axis 30 knots speed of Hydrofoil Mode.

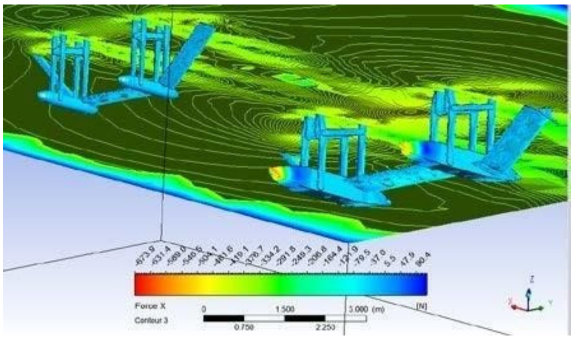


Figure 9: Force in x-axis 40 knots speed of Hydrofoil Mode.

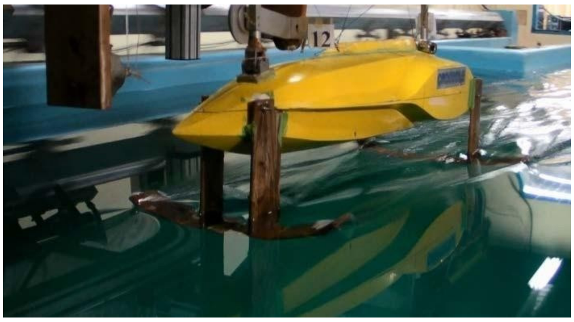


Figure 10: Towing tank test at 12knots speed.

4 CONCLUSION

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

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