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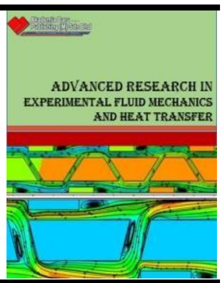

Hull Water Resistance Calculation of a Seaplane Twin Float with Clearance Ratio Variation Configurations

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ABSTRACT

Amphibians are a special aircraft that can operate on waters. Different from ordinary airplanes, these planes do not need airport facilities and can take off and land on water. A pontoon or float is an airtight hollow structure that floats on water. There are one or more floating pontoons attached to seaplanes. The purpose of this study is to calculate the hull shape resistance of a catamaran seaplane float. A numerical simulation was performed to predict its total fluid resistance of the twin float, as well as an investigation into interference phenomenon. The results are validated by using available experimental data investigated before. CFDSOF is used to predict the hull resistance. It was chosen because of its online training, and its open source. A numerical simulation of catamaran seaplane float model with symmetric demi-hull with three variations of hull separation was conducted with Operating Empty Weight (OEW) of Indonesian Aerospace (IAe) N219 airplane. Simulations were conducted with the model with Froude number ranging from 0.40 to 0.75. A mesh with four hundred thousand of cells has been chosen, with an 8% error of mesh convergence.

Keywords:
Ship; drag reduction; fluid resistance; clearance; pontoon

1. Introduction

Converting conventional type aircraft into amphibious aircraft have been done in many aircraft manufacturers and types such as Cessna 208 Grand Caravan and de Havilland Canada DHC-3 Otters. Meekins and Husa [1] and Rhea and Lim [2] stated that such aircraft utilize a float shape that stabilize and generates buoyancy to the aircraft on water but does not significantly impede the aircraft's performance in the air. Float designs rely on volume, displacement, and high-speed planning in order achieve minimum speed for aircraft to takeoff. However, seaplane floats designs were already developed since the Second World War and many aspects such as the volume, rake, chine, and step effects has been optimized since then as stated by Tetlow [3]. Float also features same characteristics as boat hull have, with the only difference is the longitudinal stability according to Canamar [4]. Most seaplane have twin hull configuration float, which according to Broglia *et al.,* [5] and Yanuar *et al.,* [6] a multihull vessel hull separation and speed impact its resistance. Therefore, the purpose of this research is to analyze the multihull separation configuration at specific Froude Number range of a twin float pontoon which can be applied to IAe's Nurtanio N219 Aircraft. The water resistance investigation is held to investigate the optimal twin floats configuration designed to get as little water

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resistance as possible to get a minimum take-off distance on the water. Floats with twin hull is no difference as a catamaran ship hull which according to Diana *et al.,* [7] have an additional component besides frictional and residual resistance component, such as interference effects between the hulls. Therefore, model testing and numerical simulations were investigated.

2. Methodology

2.1 Experimental Setup

A Catamaran float model with symmetrical hull was configured in this investigation, where each hull having a step with slight amount of trim angle on its afterbody. The model is scaled into 1:10 dimension as depicted in Figure 1. The geometric characteristic of the float model also shown in Table 1.

Table 1
Main dimension of the floats model

Parameter	Symbol	Main Hull	Demi Hull
Length (m)	*LoA*	1.23	1.23
Beam (m)	*B*	0.13	0.13
Draft (m)	*T*	0.042	0.042
Block coefficient	*Cb*	0.35	0.35
Waterplane-area coefficient	*Cw*	0.0016	0.0016
Prismatic coefficient	*Cp*	0.45	0.45
Displacement (kg)	*A*	2.6	2.6
Wetted surface area (m^2)	*Sa*	0.00321	0.00321

Three variations of hull separations were tested within Froude number ranged from 0.4 to 0.75, the experiment was held in calm water condition with a towing tank that has 50 m long, 25 m wide, and 2 m depth following the ITTC Procedure [9]. The experimental setup consisted of a load cell device attached to the model to measure the total resistance of the model. The load cell then transmits the data into a processing software via Bluetooth. Therefore, various data including time, Froude number, and total resistance were obtained. In order to achieve accurate data, each test was held 3times. A 2 kg of ballast were placed in the model, simulating the Operating Empty Weight (OEW) of the IAe's N219 Nurtanio Aircraft.

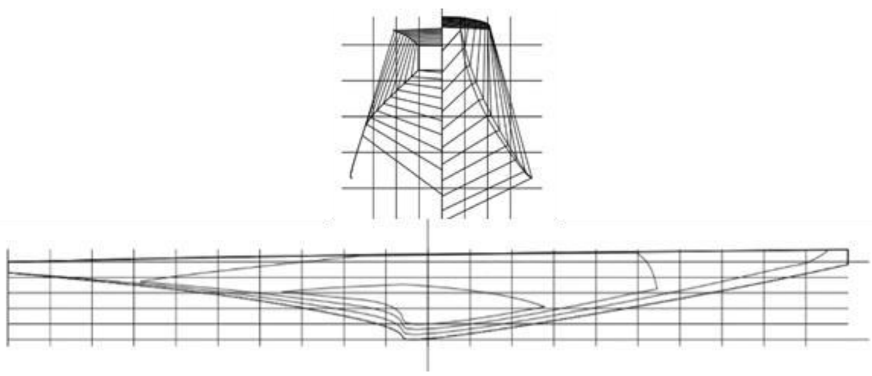

Fig. 1. Linesplan of the floats model

The separation variations configuration ranged between S/L 0.15 to 0.25, the separation was determined based on data that has been applied to aircraft with similar weight and size, the separation variations configuration can be seen on Table 2 and Figure 3.

Yanuar *et al.,* [10] stated that both wave resistance and viscous resistance affect the ship total resistance, with viscous resistance being dominated by frictional influenced by the form factor of the hull on the low-speed range, especially on floats with step configuration. The step allows the hull to significantly reduce the wetted surface area when it reached planning condition, therefore the total water resistance gradually decreased along with increasing speed of the hull as stated by Canamar [4]. Otherwise, on high-speed range the wave resistance has more influence on the total resistance calculation. The total resistance coefficient calculated with the formula below:

$$C_T = \frac{RT}{0.5\rho v_s{}^2\, S} \tag{1}$$

The effects of viscous and wave interference occur due to interference between the two catamaran hulls, calculations and experiments are carried out to investigate the interference phenomenon on twin hull floats, according to Zaghi *et al.,* [12] the interference factor can be determined by comparing the resistance components of the multihull with single hull of the multihull combined. The interference factor can be formulated with equations below:

$$IF = \frac{C_T{}^{(C)} - C_T{}^{(M)}}{C_T(M)} \tag{2}$$

with $C_T{}^{(C)}$ as a total resistance coefficient from a catamaran and $C_T{}^{(M)}$ as a total resistance from a single hull of the catamaran. Interference value is affected by hull separations variations and better when its value was lower according to Souto-iglesias *et al.,* [11].

2.2 Numerical Setup

Domains was built as a box around the hull as shown in Figure 3 with the boundary standard recommended by ITTC [12] with the Inlet being 1-L in front of the model ship with input in the form of fixed velocity in the form of the speed of the ship, outflow is 2-L behind the model ship with constant pressure. With boundary being 1-L of the ship and symmetry being half the length of the separations between the hulls. L is the Lwl of the float model as figured in Figure 4. A refinement box was made around the hull's draft with refinement value of 2 to make sure the smoothness of the mesh around the volume of air and water will be bordered. Demihull is placed at half of hull separations from the symmetry plane. A mesh convergence was set with 743302 number of cells with grid analysis resulting 7.6% of errors. As free surface simulations to be conducted, volume of fluid (VOF) was method was used, VOF method is based on the volume fraction of the fluid (α) as stated by Farkas *et al.,* [13].

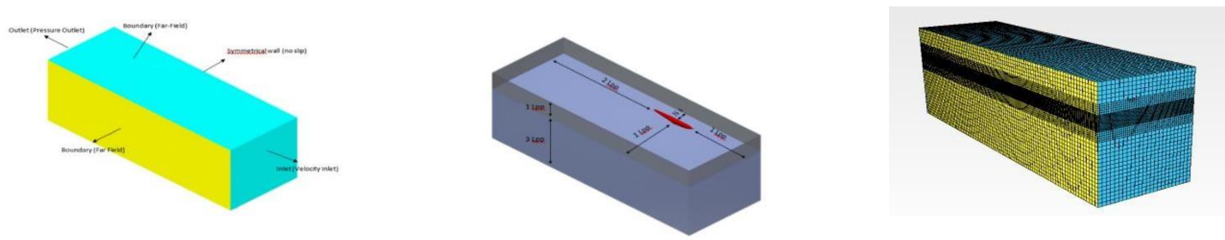

Fig. 2. Applied boundary conditions, mesh condition and size domain of the simulations

A RANS (Reynold Average Navier-Stokes) is modelled in this simulation and transport properties are needed for linear eddy viscosity models to represent the turbulence properties of the flows. The turbulence k-Omega Shear Stress Transport (SST) model is chosen to represent the turbulence properties. The k-Omega SST method, according to Diana *et al.,* [7] has a two-equation linear eddy-viscosity model A steady state with three-dimensional flow was implemented in numerical process with constant air and sea water properties. A series of time steps can be determined in steady state solutions to adjust the mesh convergence in steady state. It allows fixed time step size to be used in the entire domain stream, as stated by Jeong *et al.,* [14], time steps can be formulated with governing equation below:

$$\Delta t = \frac{L}{2U} \tag{3}$$

The numerical process was solved with 5 seconds time control, with time steps (Δt) value of 0.0001 and 0.1 second of run time. The process was run using numerical applicable equations, with form of mass, momentum, total pressure, and flow velocity as its components. Results is visualized in the post-processing software. Validation was done by comparing the value of total resistance coefficient and interference effect of the floats with such results from the experimental investigation held before.

3. Results

CFDSOF calculate the total resistance component forces of pressure, normal, viscous forces in and around the mode as stated by Song *et al.,* [15]. Figure 5 and Figure 6 shows the wave pattern of the floats in low and high froude numbers. Froud number and hull separations of the twin hull was configurated the same as the experimental investigated before. Figure 7 shows the total resistance and the coefficient total resistance and Figure 8 shows the interference factor of the experiment and numerical data being compared as a validation process.

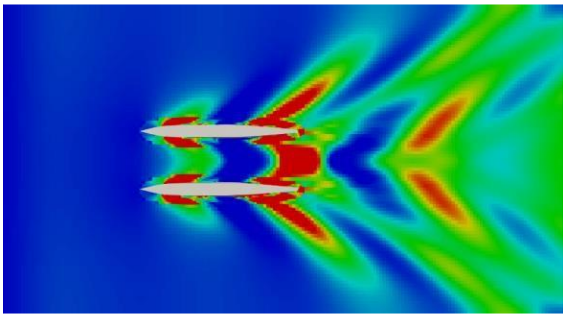

Fig. 3. Wave Pattern of the floats at Fn = 0.4

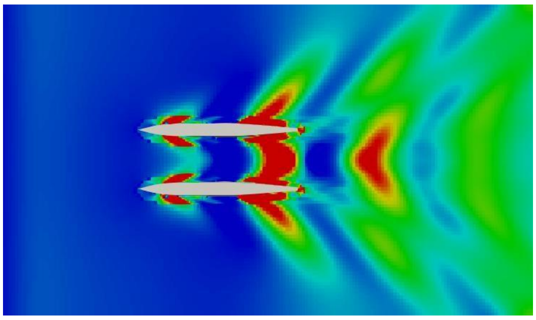

Fig. 4. Wave Pattern of the floats at Fn = 0.5

Total resistance coefficent on the y axis compared with range of froude number on the x axis .We can see the total resistance coefficient which numerically as with the experimental investigation the trend also shows that the hull with least value of the hull variations separations (S/L = 0.15) had a highest resistance coefficient trendline, while the hull varation separations with the highest value (S/L = 0.25) had a lowest resistance coefficient trendline. An interference factor numerical analysis was also held on this investigation, which according to Yanuar *et al.,* [11] and Zaghi *et al.,* [12] it has effects on drag reduction where the negative value of interference factor could lead to resistance decrease, while positive value could lead to resistance increase.

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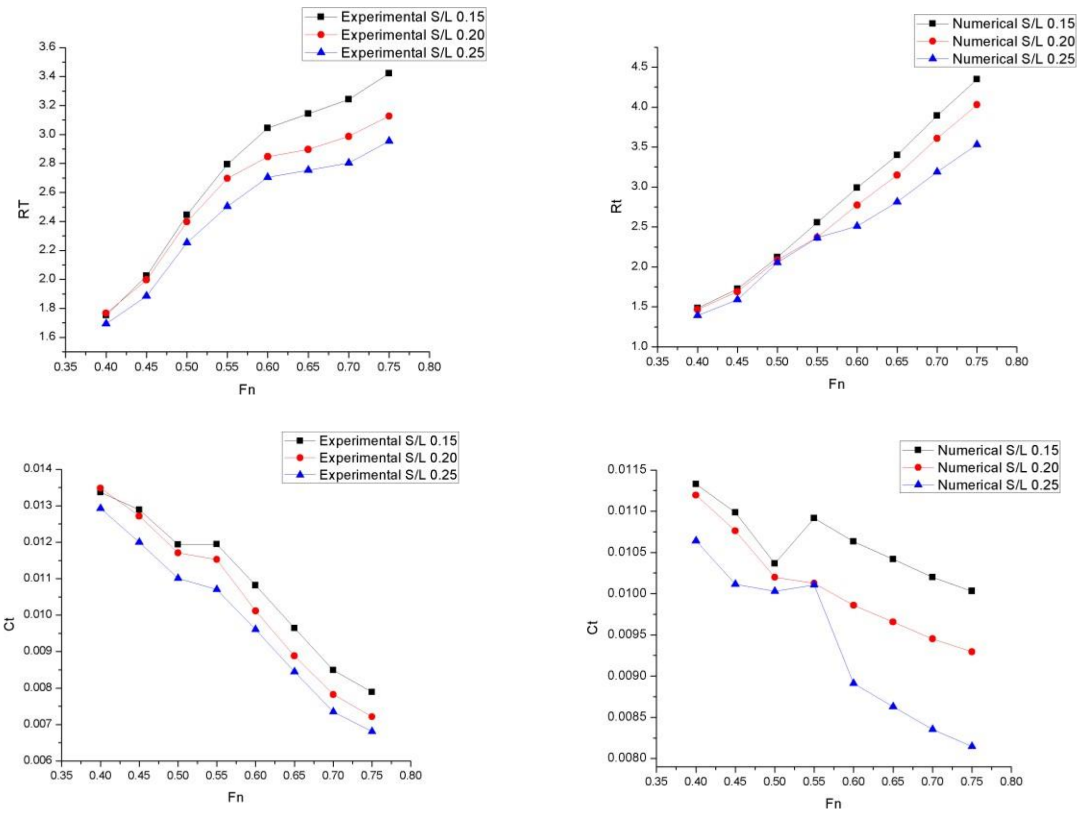

Fig. 5. The total resistance and total resistance coefficient of the model between experiment and numerical

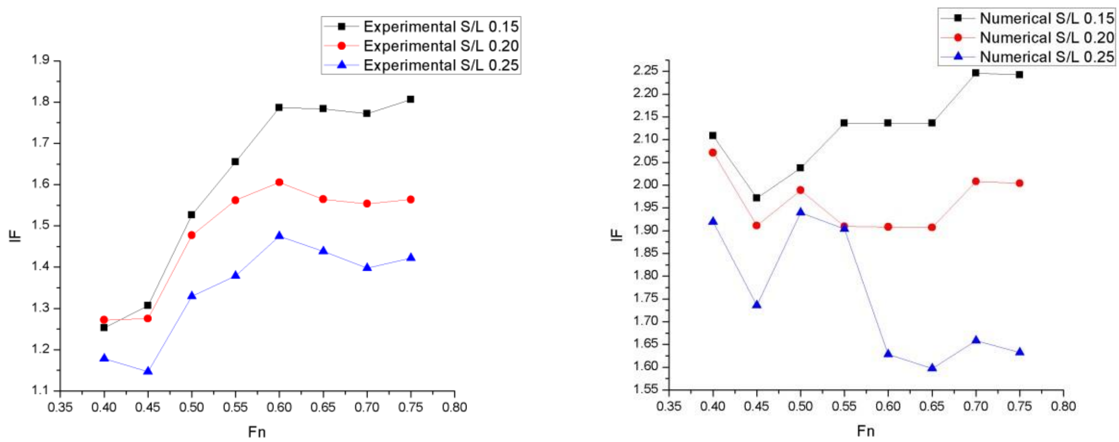

Fig. 6. The interference factor of the model between experiment and numerical compared

4. Conclusions

The interference factor have a slight difference trendline between the numerical investigation and the experimental data as shown in Figure 11 with the highest error data of interference factor shows 19.58% of error on the A configuration (S/L= 0.15) in Froude numbers of 0.60 while the least error of data occurs in configuration B (S/L=0.20) in Froude numbers of 0.60 with 10.41% number of error. The results of the investigation from all the configuration shows no negative value on the interference factor. Therefore, there is no drag reduction occurred between the range of hull separations held in this investigation. However, the drag reduction could be occurred on higher value of hull separations. We hope this examination can be helpful for further research.

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