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ANALYSIS OF INTERCEPTOR POSITION VARIATIONS TO OPTIMIZE THE EFFECT OF RESISTANCE ON A CATAMARAN

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Abstract

Catamarans are multihull vessels that offer superior stability and lower resistance potential compared to monohull ships. For high-speed vessels, one method commonly used to reduce hydrodynamic resistance is the installation of an interceptor at the stern. This study aims to analyze the effect of interceptor position variations on the total resistance of a catamaran using the Computational Fluid Dynamics (CFD) method. The interceptor configurations investigated include no interceptor, full interceptor, partial near keel, and partial near side. Simulations were conducted using ANSYS Fluent with variations of Froude numbers 0,6; 0,8; 1,0; 1,2. The results indicate that total resistance increases with increasing Froude number. Among the configurations studied, The use of a full interceptor provides the lowest total resistance value with a resistance value of 13.9 N compared to other variations, although the difference is relatively small with a decrease in the resistance value of around 1,03%.. Therefore, it can be concluded that the full interceptor is the most optimal configuration for reducing the total resistance of a catamaran under the conditions examined in this study.

Keywords: Catamaran; interceptor; Total Resistance; CFD; Froude Number

1. Introduction

The development of the maritime industry demands increasingly efficient ship designs in terms of hydrodynamic performance, particularly in efforts to reduce total resistance and improve the operational efficiency of high-speed vessels. One hull configuration that has been widely developed is the catamaran, which offers advantages such as high stability and the potential for lower resistance compared to monohull vessels due to more favorable wave distribution and wetted surface area (Faltinsen, 2005). However, the performance of catamarans is strongly influenced by wave interactions between the hulls as well as flow conditions at the stern, making additional solutions necessary to control resistance at high speeds.

One device that has proven effective for high-speed vessels is the interceptor, a thin plate installed at the transom to increase local pressure, reduce trim angle, and suppress wave formation at the stern (Lee et al., 2011). Previous studies have shown that the effectiveness of interceptors is highly dependent on their position and installation configuration, where variations in placement can result in different resistance responses depending on hull characteristics and operating conditions (Sulistyawati et al., 2020; Putra & Suzuki, 2024). Therefore, this study aims to analyze the effect of variations in interceptor position on the total resistance of a catamaran using a Computational Fluid Dynamics (CFD) approach, in order to determine the most optimal interceptor configuration for reducing resistance and improving the hydrodynamic performance of catamaran vessels.

2. Literatur Review

A catamaran is a multihull vessel configuration consisting of two parallel hulls and is well known for its superior transverse stability and potential for lower hydrodynamic resistance compared to monohull vessels, particularly at high operating speeds. This advantage arises from a more favorable wave distribution and a more efficient wetted surface area (Faltinsen, 2005; Molland et al., 2017).

Ship resistance is defined as the hydrodynamic force acting opposite to the direction of vessel motion due to the interaction between the hull and the surrounding fluid. In general, total resistance consists of frictional resistance and

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wave-making resistance, the relative contributions of which are strongly influenced by the vessel's speed. A key nondimensional parameter used to represent the effect of speed on wave formation is the Froude number (Fr), which is expressed as follows :

$$Fr = V\sqrt{gL} \qquad (1)$$

where V denotes the ship forward speed (m/s), g represents the gravitational acceleration (m/s²), and L is the characteristic length of the vessel (m), which in this study is defined as the length between perpendiculars (LPP).

In resistance analysis, the total resistance RTis commonly expressed in terms of the total resistance coefficient CT, which is defined as follows:

$$C_T = \frac{C_T}{\frac{1}{2}\rho V^2 S} \qquad (2)$$

where RT is the total resistance of the vessel (N), ρis the water density (kg/m³), V is the ship speed (m/s), and S is the wetted surface area of the vessel (m²).

In catamaran vessels, the total resistance may increase due to wave interference between the two hulls; therefore, the inter-hull spacing (clearance) becomes an important parameter, commonly expressed as the ratio S/L. A non-optimal clearance configuration can significantly increase wave-making resistance (Insel & Molland, 1992; Yanuar et al., 2019). One of the devices widely used to control resistance and trim in high-speed vessels is the interceptor, which is a thin plate installed at the stern of the hull to increase local pressure, generate hydrodynamic lift, and reduce the vessel's trim angle, thereby decreasing wave-making and pressure resistance (Lee et al., 2011).

The effectiveness of an interceptor is strongly influenced by its installation position, where variations such as full interceptor, partial near-keel, and partial near-side configurations may produce different hydrodynamic responses, particularly in catamaran arrangements characterized by complex inter-hull flow interactions (Putra & Suzuki, 2024). To analyze these phenomena in detail, a Computational Fluid Dynamics (CFD) approach using ANSYS Fluent is widely employed, as it is capable of numerically modeling fluid flow, pressure distribution, and free-surface characteristics with high accuracy. Therefore, this approach is well suited to evaluate the effect of interceptor position variations on the total resistance of a catamaran in the present study.

3. Research Methodology

The research methodology and its sequential workflow are illustrated in the flowchart presented in Figure 1.

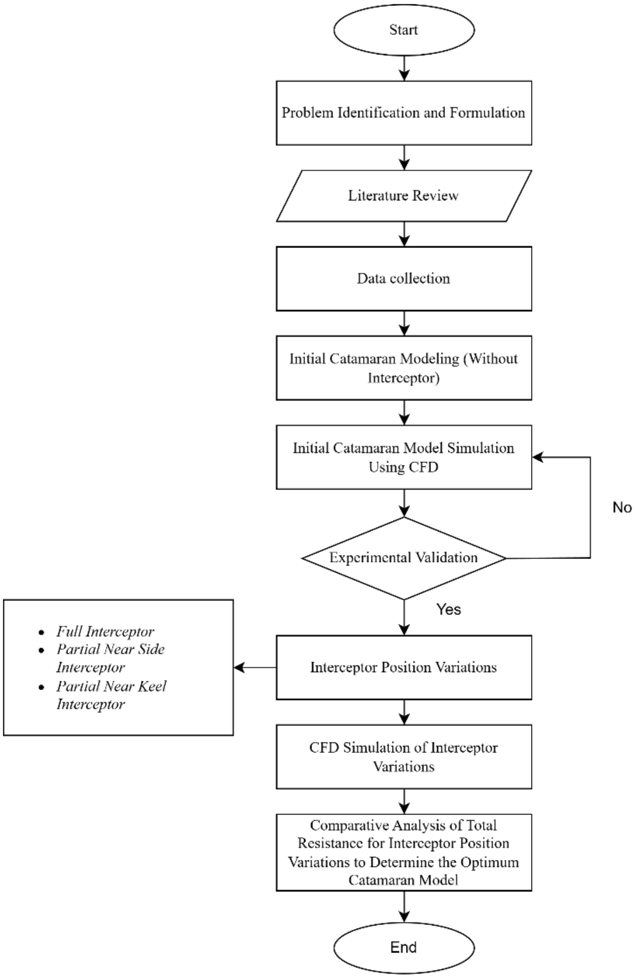

Figure 1. Flow Chart

This study employs a numerical approach based on Computational Fluid Dynamics (CFD) to analyze the effect of interceptor position variations on the total resistance of a catamaran. The research procedure begins with a comprehensive literature review to determine the design parameters and reference previous studies, particularly experimentally validated catamaran models. The catamaran geometry is modeled using Maxsurf Modeler Advance based on the principal dimensions listed in Table 1, with a symmetric hull configuration and an inter-hull clearance ratio of 0.2L.

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Table 1. Main Vessel Dimensions

Parameter	Main Dimensions
LPP (m)	2,393
B (m)	1,5
H (m)	0,15
T (m)	0,04
Wetted surface area ($m2$)	0,3697
Displacement (t)	0,0194
Volume Displacement ($m3$)	0,019
Cp	0,784
Cb	0,206

The model is then evaluated under four different conditions as illustreted in figure 2 (a-d), namely (a) without an interceptor, (b) with a full interceptor, (c) with a partial near-keel interceptor, (d) and with a partial near-side interceptor.

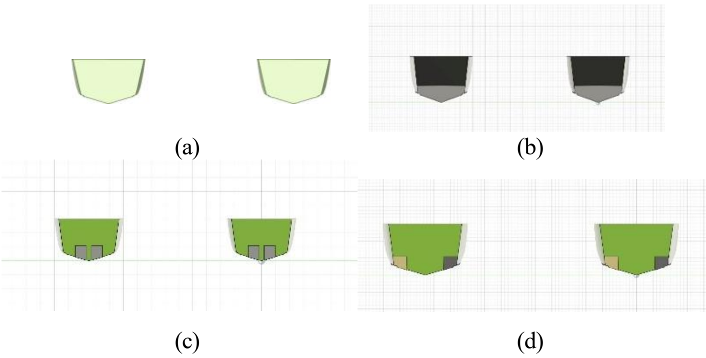

Figure 2. (a) without an interceptor, (b) with a full interceptor, (c) with a partial near-keel interceptor, (d) and with a partial near-side interceptor

Subsequently, the numerical simulations are performed using ANSYS Fluent with a two-phase fluid domain (water and air). The boundary conditions are specified to represent free-stream flow around the vessel, with the hull surface defined as a no- slip wall, while the remaining domain boundaries are treated as free-slip walls. The meshing process is conducted using local sizing, curvature and proximity controls, along with the application of boundary layer refinement to enhance the accuracy of hydrodynamic force predictions.

As described in Figure 3 and Table 2, the simulations are conducted at several Froude number variations within the range of Fr = 0.3to evaluate the effect of speed on resistance. The numerical model is validated by comparing the simulation results of the catamaran without an interceptor against experimental data (Experimental Fluid Dynamics). The resulting error levels are within acceptable tolerance limits, indicating that the numerical model is valid. The final stage of the study involves a comparative analysis of the total resistance values for all interceptor position variations in order to determine the most optimal configuration for reducing catamaran resistance.

Table 2. Validation of CFD Result by Comparison With Experimental Data

Parameter	Main Dimensions	CFD	Eror (%)
0,4	0,00561	0,00544	2,88
0,5	0,00540	0,00505	6,62
0,6	0,00504	0,00510	1,16

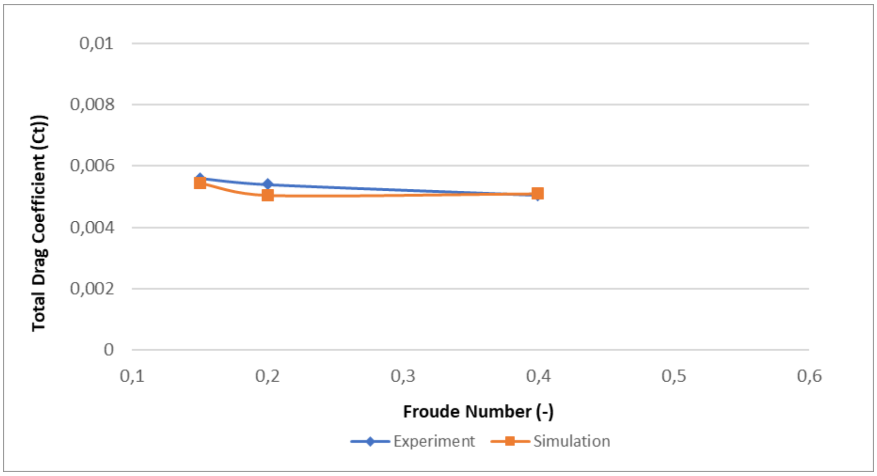

Figure 3. Validation Chart of CFD Results by Comparison With Experimental Data

4. Results and Discussion

Of the four interceptor position variations examined—namely without interceptor, full interceptor, partial near- side, and partial near-keel—the simulation results indicate that the differences in total resistance among these configurations are relatively small at each Froude number. At Fr = 0.6, the full interceptor configuration exhibits the lowest total resistance value (RT = 13.93) compared to the configuration without interceptor (RT = 14.50), partial near-keel (RT = 14.28), and partial near-side (RT = 14.20).

Meanwhile, at Froude numbers ranging from Fr = 0.8 to Fr = 1.2, the partial near-side and partial near-keel configurations show a slight increase in resistance relative to the bare hull and full interceptor configurations. This trend is also observed in the graph presented in Figure 4, indicating that variations in interceptor position have a minimal effect on the resulting total resistance.

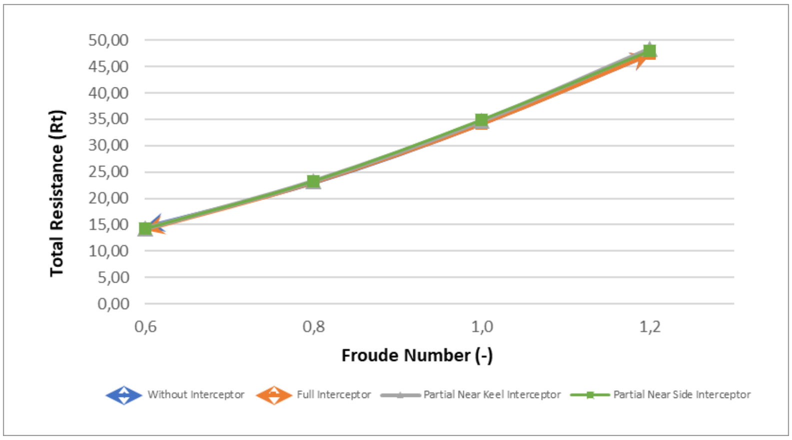

Figure 4. Comparison of Total Resistance Results

Based on the total resistance (R_T) simulation results for the various interceptor positions, it can be concluded that, among all configurations considered, the full interceptor demonstrates the most optimal performance, achieving an approximate total resistance reduction of 1.37%. This suggests that a fully installed interceptor is more effective in controlling the stern flow and minimizing the overall resistance of the catamaran. Although the differences in R_T among the configurations are relatively small, the full interceptor consistently yields lower total resistance values compared to the bare hull and partial interceptor configurations across all Froude numbers, particularly within the low to medium Froude number range.

This trend is consistent with previous studies indicating that the use of interceptors can reduce total ship resistance by modifying the pressure distribution in the stern region, thereby reducing wave-making and frictional resistance overall. A study by Song et al. (2023) reported that the application of a full interceptor on a ship model can lead to a noticeable reduction in resistance at sufficiently high Froude numbers, demonstrating the effectiveness of interceptors in significantly reducing total resistance under higher-speed operating conditions, although the magnitude of the effect depends on flow conditions and hull geometry.

5. Conclusion

Based on the numerical analysis conducted using the Computational Fluid Dynamics (CFD) method, it can be concluded that variations in interceptor position have a relatively small yet measurable effect on the total resistance of the catamaran within the investigated Froude number range (Fr = 0.6,0.8,1.0, and 1.2). In general, the total resistance increases with increasing Froude number due to the growing dominance of wave-making resistance, as indicated by enhanced free-surface deformation and intensified wave interference between the hulls.

Among all configurations analyzed, the full interceptor demonstrates the most optimal performance by consistently producing the lowest total resistance compared to the bare hull and partial interceptor configurations (partial near-side and partial near-keel), with an average resistance reduction of approximately 1.03–1.37%. In contrast, the partial near-side and partial near-keel interceptors provide resistance reductions only at low Froude numbers (Fr = 0.6), amounting to 2.07% and 1.52%, respectively. However, at medium to high Froude numbers, these partial configurations tend to increase the total resistance by up to 0.69%, likely due to local flow disturbances and increased wave interference effects.

These findings indicate that the effectiveness of interceptors on catamaran vessels is strongly influenced by both the installation position and operating conditions. The full interceptor is more effective in controlling the stern flow, stabilizing the wake pattern, and minimizing the overall total resistance. Therefore, within the scope and conditions of the present study, the full interceptor configuration can be recommended as the most optimal solution for reducing catamaran total resistance. Nevertheless, the observed improvements remain moderate, suggesting that further performance enhancement may be achieved through additional optimization of interceptor geometry and angle of attack.

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