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Prediction of Resistance of a Passenger Catamaran Operating in the Bay of Vlora

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ABSTRCAT: This study presents a comprehensive methodology for predicting the hydrodynamic resistance of a passenger catamaran intended for daily operations in the Bay of Vlora. Catamarans offer notable advantages for coastal transportation due to their high stability, shallow draft, and large deck area. Accurate estimation of their resistance presents a complex challenge due to the hydrodynamic interactions between the hulls, which significantly influence both wave-making and viscous resistance components. A 3D model of the catamaran was developed using *Maxsurf* software, based on the vessel's lines plan. Resistance predictions were performed using Slender Body Theory. The analysis covered speeds ranging from 0 to 15 knots and also included simulations of wave pattern formation. The results show a gradual increase in resistance at lower speeds, followed by a more pronounced rise within the wave-dominated regime, with local peaks and troughs associated with hull-wave interactions. The findings demonstrate that CAD environments such as *Maxsurf* provide an effective framework for rapid resistance estimation and power requirement assessment of passenger catamarans, particularly in the absence of empirical data or towing tank tests.

KEYWORDS: Resistance, Catamaran, 3D Modelling. Maxsurf, Slender Body Theory.

1 INTRODUCTION

Catamarans are twin-hull vessels widely employed in various maritime sectors, including passenger transportation, recreational activities, and specialised operations. Over recent decades, catamarans have gained significant popularity in the global maritime industry, particularly within the passenger ferry market [1], encompassing both coastal transportation and day-cruise services. These vessels present advantageous characteristics such as high transverse stability, low draft, and increased deck area [2]–[4]. These favourable characteristics make them ideal for shallow waters and short-distance passenger services. Reference [5] highlights an increasing preference for catamarans in short-distance passenger transportation, particularly within public transport systems and the tourism sector. The tourism sector, in particular, is expected to exhibit an even stronger shift toward the use of catamaran hulls in the near future, including the Mediterranean region.

Albania, with its long coastline and rapidly growing tourism sector, is experiencing increased interest in developing maritime transportation infrastructure. Coastal tourism, especially day cruises and short-distance maritime trips, has become an important part of the Albanian maritime tourism sector. The Bay of Vlorë, located in the southern region of the country, stands out as a strategic center for these activities due to its favorable geographic position, natural beauty, and proximity to key destinations such as Sazan Island and the Karaburun Peninsula. In recent years, growing demand for safe, reliable, and comfortable vessels for tourist transport within the bay has opened opportunities to introduce innovative vessels like catamarans, which are particularly well suited for these conditions.

The prediction of resistance for catamaran hulls presents a complex challenge. This complexity arises because, beyond the resistance of the individual demi-hulls, the interference effects between the two demi-hulls must also be taken into account. These interference effects are classified into two main categories: viscous interference and wave interference [1]. The hydrodynamic resistance of a catamaran differs substantially from that of monohulls due to the complex interference effects between the two hulls. Such interactions tend to increase wave resistance, necessitating careful consideration during the design process to ensure optimal fuel efficiency and overall performance. Consequently, accurate resistance prediction becomes a critical task in the preliminary design stages of catamaran hull forms.

Various methods exist for predicting resistance, including empirical, analytical, numerical, systematic series data, and experimental approaches. Several studies have been performed to address the problem of resistance of catamaran hull forms. Insel, M (1992) [2] in his doctoral thesis, provided a comprehensive investigation combining both theoretical and experimental analyses of the resistance components of catamarans with symmetric demi-hulls. Millaward (1992) [6] investigated the effect of hull separation on the resistance of catamarans hull forms. Insel and Molland (1992) [1], and Molland et al. (1994) [7] presented experimental results on

NPL catamaran series. Resistance experiments on a high-speed displacement catamaran of the Series 64 form are detailed in reference [8]. An extensive series of model tests on catamarans in calm water has been described by Molland et al. (1994) [7], [9]. Sahoo et al. (2007) [10] have presented practical methods for the evaluation of the resistance of high-speed catamarans. Pacuraru and Mandru (2019) [11] have used CFD simulation to improve the hydrodynamic performance of a passenger catamaran. Iatan & Obreja (2019) [12] have performed experimental investigation to find the optimum distance between the hulls of a catamaran passenger vessel. Mandru and Pacuraru (2020) [13] carried out experimental tests on central bulb catamarans to study resistance characteristics. Sahoo et al. (2006) [14], and Sahoo et al. (2004) [15] performed CFD studies to evaluate the wave resistance of catamaran hull forms. Samuel et al. [16] performed CFD and Slender Body Theory approaches to investigate the resistance components of converting a traditional fishing vessel into catamaran form.

This paper presents a complete procedure for the assessment of the resistance of a passenger catamaran designed for daily cruise operations in the Bay of Vlorë. A 3D model was developed using *Maxsurf Modeller* software, and resistance was evaluated using the Slender Body Theory approach with *Maxsurf Resistance* software. The study aims to demonstrate that the CAD environment can serve as a rapid evaluation tool for predicting the resistance and power requirements of a catamaran hull in the absence of experimental resistance data and when resistance testing in a towing tank is not possible.

2 METHODOLOGY

2.1 Vessel Description

The vessel analysed in this study is a small twin-hull passenger catamaran intended for daily tourist transportation in the Bay of Vlorë, Albania. The principal dimensions of the catamaran under consideration are: length overall L_{OA} = 24 meters, waterline length L_{WL} = 20.85 m, beam overall B = 9 meters, overall breadth of each demi-hull B_{OADH} = 1.75 meters, centreline spacing between hulls s = 7.25 meters, and design draft T = 0.938 meters. The hulls are slender and symmetrical. The vessel is designed to operate at a service speed corresponding to Froude numbers ranging from 0.3 to 0.6.

2.2 Resistance calculation for catamarans

The prediction of the resistance of catamaran hulls presents a complex challenge. This complexity arises from the fact that, in addition to the resistance of the individual demi-hulls, the interference effects between the hulls must also be taken into account. These interference effects manifest in two primary forms: viscous interference and wave interference [1].

According to Insel and Molland [1], [17], the total resistance of a catamaran, expressed in terms of resistance coefficients, can be described by the following formula:

$$C_T = (1 + \varphi k)\, \sigma C_F + \tau C_W \quad (1)$$

where:

- C_F is the frictional resistance coefficient calculated using the ITTC-1957 correlation line,
- $(1 + k)$ is the form factor for a demi-hull in isolation,
- φ is introduced to take account of the pressure field change around the hull,
- σ takes account of the velocity augmentation between the two hulls and would be calculated from an integration of local frictional resistance over the wetted surface,
- C_W is the wave resistance coefficient for a demi-hull in isolation,
- τ is the wave resistance interference factor.

For practical purposes, φ and σ can be combined into a viscous interference factor β, where $(1 + \varphi k)\sigma C_F$ is replaced by $(1 + \beta k)C_F$
whence

$$C_T = (1 + \beta k)\, C_F + \tau C_W$$

for the demi-hull (mono-hull) in isolation, β = 1 and τ = 1.

2.3 Methodology for the reconstruction of the 3D model of the hull

In order to perform the analysis in the *Maxsurf Resistance* software, the first step is to model the 3D geometry of the hull. Since a lines plan of the hull is available, the 3D model must be created in the *Maxsurf Modeller* software based on measurements extracted from the lines plan. The flowchart presented in figure 1 illustrates the overall methodology for the generation of the 3D CAD model of the catamaran.

The measurements from the lines plan of the demi-hull catamaran can be carried out using *AutoCAD* software. Measurements should be taken in the main transverse sections of the demi-hulls, as well as at the bow and stern profiles. These measurements are very important for creating the cloud of points and to generate the 3D model of the hull. Some other hydrostatic characteristics, such as displacement and form coefficients, must be used in order to verify the accuracy of the 3D model. These particular characteristics for the vessel under investigation were obtained from the book of stability of the boat.

For each section, 6 to 10 measurements were taken in the AutoCAD software. Measurements were also taken at the bow and stern profiles. The surface of the demi-hull was initially generated based on the cloud of points generated from the measurements in the *AUTOCAD* software, and was subsequently refined to obtain the final surface form. The resulting 3D hull surface of the model must be verified for accuracy against the known main hydrostatic characteristics of the actual model. This model was subsequently used in the

Maxsurf Resistance for hydrodynamic resistance prediction analysis. After the modeling and validation of one demi-hull, the hull surface has to be transformed and mirrored laterally at the appropriate centreline to centerline distance in order to obtain the outer and the inner surface to form the complete 3D model of the hull of the catamaran. This model must be subsequently used in the *Maxsurf Resistance* software for hydrodynamic resistance prediction analysis.

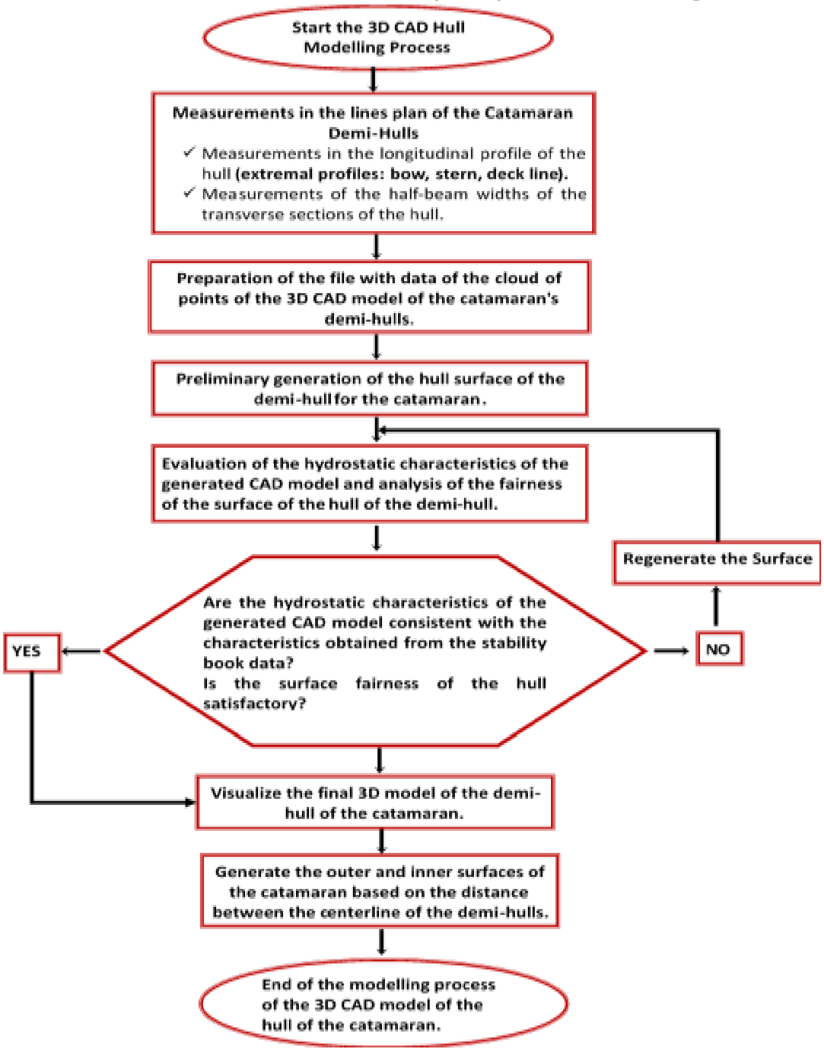


Figure 1: Overall flowchart illustrating the 3D CAD modelling process of the catamaran hull.

2.4 Methodological Justification for Resistance Prediction Approach

Accurate prediction of the hydrodynamic resistance of catamarans requires the selection of an appropriate method, due to the presence of the twin-hull geometry and the interference effects between the hulls. Within the *Maxsurf Resistance* software, two primary approaches are available: parametric regression-based methods and the theoretical model based on the slender body theory (SBT).

Parametric regression-based methods are derived from mono hulls and do not take in consideration the effects of interference (viscous and wave interference), which significantly influence the total resistance. On the other, hand the Slender Body Theory (SBT), provides a more physics-based framework that is particularly suitable for slender hulls characterised by a high length-to-beam ratio of the hull, such as those of catamarans. As highlighted in the *Maxsurf Resistance User Manual* [18], this method is based on the work of Couser et al. (1998), [19] and uses the Michell (1898) [20] approach to compute the wave resistance of many slender hull forms including the multihulls forms. The total resistance is calculated by adding the viscous resistance component, using the ITTC'57 frictional resistance coefficient, and a form factor that also accounts for the viscous interference effect. For catamarans, the form factor is determined using the algorithm proposed by Molland algorithm [17], [21]. For these reasons the slender body method was used to calculate the resistance of the catamaran.

3 RESULTS AND DISCUSSION

The methodology outlined in the previous section was applied to evaluate the hydrodynamic resistance of the catamaran. Initially, a 3D CAD model of the catamaran hull was developed based on the measurements extracted from the lines plan of the demi-hull. The resulting cloud of points comprised the coordinates of 113 measurement points, corresponding to transverse sections as well as to critical profiles, such as the bow and stern. Following the validation of the generated 3D CAD surface model, the model was imported into the *MAXSURF Resistance* for analysis. Within the *MAXSURF Resistance* environment, the model was prepared and configured for simulation. The Slender Body Theory (SBT) method was applied for the analysis, incorporating the form factor (1+k), specifically adapted for catamarans, in accordance with the approach developed by Molland [1], [21].

The resistance analysis was conducted over the speed range of 0–15 knots, corresponding to a Froude number range of 0 to 0.540. An approximate total propulsion efficiency value of 60% was adopted for the purposes of the resistance evaluation. Figures 2, 3, and 4 graphically present the results of the total resistance, required power, and resistance coefficients (including the total resistance coefficient, wave-making resistance coefficient, and viscous resistance coefficient) as functions of vessel speed.

In addition to the resistance and power calculations, the wave patterns generated by the hull were also simulated. These simulations were conducted for speeds of 5 knots, 7.5 knots, 10 knots, 12.5 knots, and 15 knots. Figure 5 shows rendered visualizations of the simulated wave formations generated by the hull at the corresponding speeds.

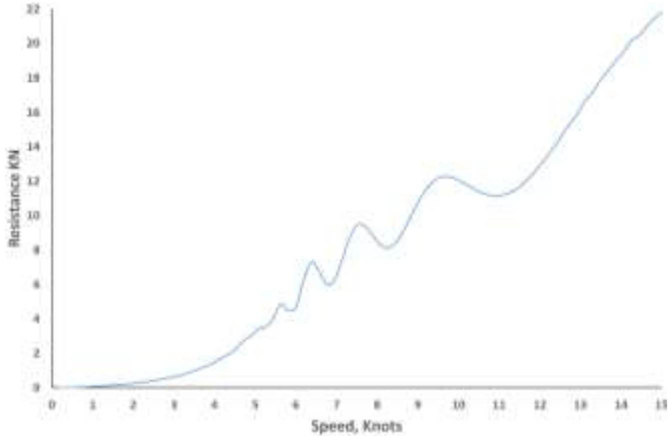


Figure 2 - Graphical representation of the total resistance as a function of vessel speed.

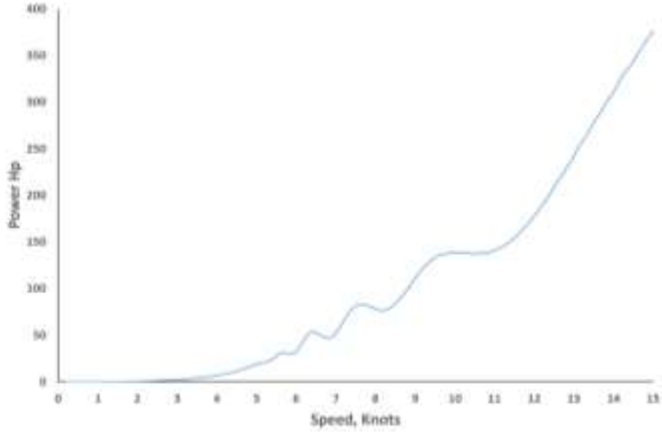


Figure 3 - Graphical representation of the estimated effective power as a function of vessel speed.

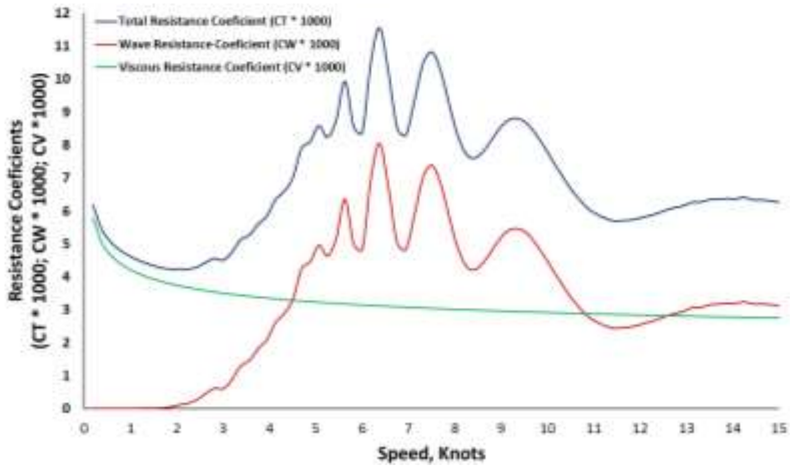
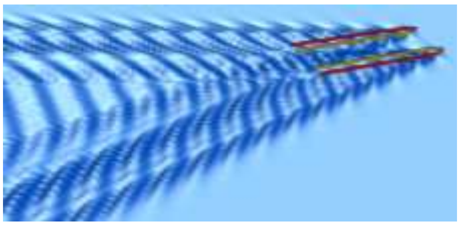
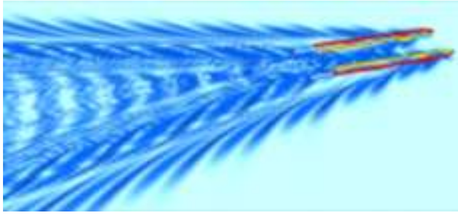
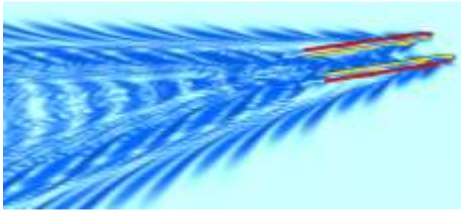
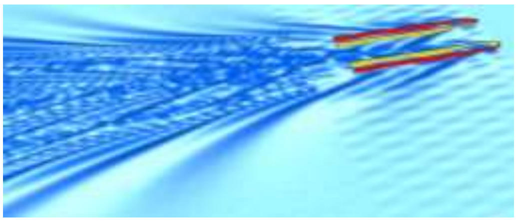


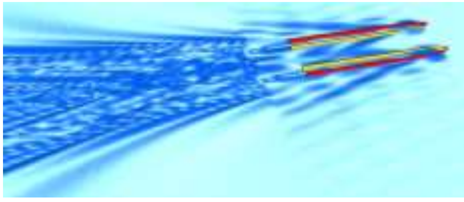
Figure 4 - Graphical representation of the calculated resistance coefficients.

a) – Wave pattern at 5 knots b) Wave pattern at 7.5 knot

c) Wave pattern at 10 knot d) Wave pattern at 12.5 Knot



d) Wave pattern at 15 knot

Figure 5 - Representation of wave patterns generated by the vessel at speeds of 5, 7.5, 10, 12.5, and 15 knots.

The graphical representation of the total resistance for the catamaran under study highlights several interesting aspects related to changes in resistance as a function of speed. At low speeds, there is a slow increase in resistance with increasing speed, which indicates the presence of viscous resistance. In the speed range of 6 to 10 knots, peaks and troughs appear in the resistance curve. In this zone, the graph also shows a rapid increase in resistance. This phenomenon can be explained by the increasing dominance of wave-making resistance. The presence of peaks and troughs in the resistance curve suggests interference effects between the wave systems generated by the individual hulls of the catamaran. In the speed range of 10 to 12 knots, a stabilization of the resistance curve is observed, followed by a more rapid increase in resistance beyond this speed.

The second graph, which presents the resistance coefficients, also reveals the presence of peaks in the resistance coefficient curves for speeds between 6 and 10 knots, corresponding to the interference zone caused by the wave systems generated by the two hulls of the catamaran. Both graphs highlight that the functional operating regime lies within the speed range of 10–12 knots and emphasize the importance of avoiding continuous operation in regions characterized by significant wave interference.

4 CONCLUSIONS

This paper presents a comprehensive procedure for evaluating the resistance performance of a catamaran vessel used for daily touristic purposes in the Bay of Vlora. The combination of AutoCAD-based measurements, 3D hull modeling in Maxsurf, and resistance evaluation using the Slender Body Theory approach enables a detailed assessment of hull resistance performance. The results obtained from the hydrodynamic resistance evaluation, as well as their graphical representations, serve as valuable tools for assessing the efficient operating regime from the hydrodynamic perspective of the vessel’s navigation.

The application of the Slender Body method within a CAD-based platform such as Maxsurf provides a practical and powerful tool for predicting the resistance of existing catamaran hulls that lack experimental resistance data, such as the vessel analysed in this study, as well as for newly developed vessel designs during the conceptual design phase. During the conceptual design phase, the method enables the efficient exploration of alternative hull forms and configurations aimed at improving hydrodynamic performance under specific sea conditions. The methodology presented in this study can also be applied to other Albanian catamaran vessels for which experimental hull resistance data are not available. However, it has certain limitations and is primarily suitable for slender-body hulls, including both monohull and multihull types. For fuller hull forms, more reliable and accurate approaches, such as experimental towing tank testing or CFD simulations, should be considered for hull resistance analysis. Furthermore, this study contributes to the consolidation of good design practices and provides a practical framework to support future experimental and CFD investigations.

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