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Numerical Study on the Motion and Added Resistance of a Trimaran in Stern Waves Using a Hybrid Method

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This paper presents a one-way coupling method based on the open-source computational fluid dynamics tool OpenFOAM. This hybrid method that couples the fully nonlinear potential theory (FNPT)-based quasi-arbitrary Lagrangian–Eulerian finite element method (QALE-FEM) with the viscous flow method is applied to simulate the forward movement and motion of a trimaran in stern waves. With this hybrid method and the corresponding solver qaleFOAM, the linear and nonlinear incident waves are generated by the external domain of FNPT-based QALE-FEM. The waves propagate to the internal domain by a transition zone. The interaction between the wave and trimaran model in the internal domain is simulated by the viscous flow method. The validation of the wave generation is carried out first. Then, the motion of the trimaran model in stern waves is simulated. Finally, by changing the forward speed and the wave parameters, the amplitude and time history are obtained to analyze the trimaran's motion characteristics in stern waves.

INTRODUCTION

The motion and added resistance in waves play an important role in the design and performance optimization of a ship, a role that has been widely investigated in recent years (Yu et al., 2017; Chen et al., 2018; Diao et al., 2019; Begovic et al., 2020; Tang et al., 2021). Furthermore, the hydrodynamics of a trimaran, as a kind of high-performance ship, has been studied by both numerical methods and tank tests (Tang et al., 2017; Chen et al., 2018; Zong et al., 2019a). Therefore, the characteristics of a trimaran's motion and added resistance in waves have attracted more and more attention in past decades. Furthermore, the trimaran has the advantages of low resistance in calm water, a large deck area, and good transversal stability. Hence, the study of the seakeeping performance of a trimaran in waves plays an essential role in the further application of a trimaran.

The study of the trimaran's hull form began at the end of the 20th century (Pattison and Zhang, 1994), and the trimaran's motion in waves of different headings was preliminarily studied (Kurultay, 2003). With the development of numerical methods and tank tests, the study of the seakeeping performance of trimarans has been widely carried out in recent years. Tang et al. (2016) carried out a tank test to study the wave loads, slamming, and the corresponding effect on the vibration of the trimaran. Zong et al. (2019a, 2019b) carried out a tank test to study the scheme of T-foil control of trimarans, with an aim to reduce the longitudinal motion of a trimaran in the head wave. Deng et al. (2019) used the computational fluid dynamics (CFD) method to simulate the motion of a trimaran in head waves. By analyzing the computed result, the effect of the wave amplitude on the added resistance in waves can be studied. Ghadimi et al. (2019) investigated the seakeeping performance of the trimaran in both head waves and bow quartering waves via the commercial computational fluid dynamics code Flow-3D, and the numerical method was validated by comparison with the experimental result. Duan et al. (2019) applied the high-speed slender body potential flow theory (2.5D method) to predict the seakeeping performance of trimarans in waves. The computed results were compared with the experimental results for validation. Li et al. (2020) carried out a numerical study on the effect of wave steepness on the hydrodynamic coefficients and motion of trimarans in the head waves. Sun et al. (2020) studied the flow interaction between the center hull and side hull by the PIV method. Tang et al. (2020) studied the trimaran's motion and wave load using the time-domain Rankine-Green matching method. Liu et al. (2020) carried out a tank test to study the effect of the fixed appendage and the actively controlled appendage on reducing the trimaran's vertical motion. Nowruzi et al. (2020) studied the impact of different geometrical parameters on the seakeeping performance of a trimaran in regular oblique waves by tank test. It was found that the position of outriggers and the hull shape have significant impacts on the dynamic performance of the model. By combining a multiobjective shape optimization approach with the CFD method, Nazemian and Ghadimi (2021) improved the bow region of a trimaran ship hull to reduce the total resistance in calm water and wavy conditions.

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KEY WORDS: Trimaran, stern wave, motion, added resistance, hybrid method.