Numerical simulation of trimaran's motion in wave by a hybrid method based on QALE-FEM and OpenFOAM

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ABSTRACT

In this paper, based on open-source CFD tool OpenFOAM, a hybrid method coupling the FNPT-based (fully nonlinear potential theory) QALE-FEM (quasi arbitrary Lagrangian Euler finite element method) and the viscous flow method is applied to simulate the motion of trimaran in the stern waves. With the hybrid method and the corresponding solver QaleFoam, the linear and nonlinear incident waves are generated by the external wave tank of FNPT-based QALE-FEM and propagate to the internal domain by a transition zone. In the internal domain, the interaction between the wave and trimaran model in simulated by the viscous flow method. The wave generation is carried out first. Then, the motion of trimaran at different sailing speeds in the stern waves of different wave steepness is simulated, and the effect of the stern wave on the motion and moving forward of trimaran are analyzed.

KEY WORDS: trimaran; head wave; stern wave; motion; encounter frequency;

INTRODUCTION

The study of ship's motion in waves is the key factor affecting the comfortability and safety of the navigation, which 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). As a kind of high-performance ships, the hydrodynamics of trimaran has been studied by both numerical method and tank test (Chen et al., 2019; Zong et al., 2019a; Tang et al., 2021). As a kind of high-performance ships, the hydrodynamics of trimaran has been studied by both numerical method and tank test (Chen et al., 2019; Zong et al., 2019a; Tang et al., 2021), and the characteristics of trimaran's motion and added resistance in waves has attracted more and more attention in the past decades. Because the trimaran has the advantage of low resistance in calm water, large deck area, good transversal stability, et al. Hence, the study about the seakeeping performance of trimaran in longitudinal waves plays an important role in the further application of trimaran, especially the motion response in the head wave and the stern wave included.

The study about trimaran hull form begins at the end of the 20th century (Pattison et al., 1994), and the motion of trimaran in waves of different headings is preliminarily studied (Kurultay, 2003). With the technological development of numerical simulation and tank tests, in recent years, the study about the seakeeping performance of trimaran has been widely carried out by researchers. Tang et al. (2019) carried out the tank test to study the wave loads, slamming, and the corresponding effect on the vibration of the trimaran. Zong et al. (2019a; 2019b) studied the scheme of T-foil control of trimaran by experiment method, aims to reduce the longitudinal motion of trimaran in the head wave. Deng et al. (2019) predicted the resistance of trimaran in calm water and the motion of trimaran in the head wave, by the analysis of the computed result, both the effect of hull attitude on the resistance in calm water and the effect of wave amplitude on the added resistance in waves. Ghadimi et al. (2019) investigated the seakeeping performance of trimaran in the head wave and bow quartering wave by the commercial computational fluid dynamics code Flow-3D, and the numerical method is validated by comparison with the experimental result. Duan et al. (2019) validated the prediction of motion and added resistance of trimaran by 2.5D method of potential flow method. Li et al. (2020) carried out a numerical study on the effect of wave steepness on the hydrodynamic coefficients and motion 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) carried out a numerical study of trimaran motion and wave load prediction based on the time-domain Rankine-Green matching method. Liu et al. (2020) carried out the tank test to study the effect of the fixed appendage and the actively controlled appendage on the reduction of the trimaran's vertical motion.

It could be seen that the investigation about the hydrodynamics of trimaran has been widely carried out. However, most of the study is still mainly about the validation of the numerical method and the motion of trimaran in the head waves. The study about the seakeeping performance of trimaran in different states of the sea is limited, especially for the moving of ship in the stern wave, some dangerous conditions will usually occur, such as the emergence of propeller and surf-riding (Rinauro et al., 2019; Rinauro et al., 2020).

In this paper, the longitudinal motion and added resistance of trimaran in