CFD Prediction of Slamming Loads on KCS in Oblique Waves

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ABSTRACT

The slamming loads of the KCS model were studied in different wave directions. Angles between wave and ship heading are 0 deg, 30 deg and 60 deg when Fr = 0.26. Numerical simulations were studied by in-house CFD solver naoe-FOAM-SJTU, where dynamic overset grid technology was used to deal with the large vertical movement of the hull. Ship motions and the characteristics of slamming loads were investigated in different wave directions. Both temporal and spatial characteristics of pressure in bow region were illustrated. Flow visualizations, such as pressure distribution on hull surface, wave pattern, etc. were presented and analyzed. The results showed that the slamming loads in small heading angle were higher than that in head wave while it is opposite for large heading angle.

KEY WORDS: Slamming loads, CFD method, Overset grid, Oblique waves

INTRODUCTION

Ships sailing in waves often encounter slamming phenomena. The transient and huge impact force threatens the safety of ship structure, passenger, device, etc. Therefore, it is necessary to predict the slamming load. There are two types of ship slamming: symmetric slamming and asymmetric slamming. The former often occurs in head wave while the latter occurs in oblique wave. Compared with symmetric slamming, the prediction of asymmetric slamming load is more challenging due to the influence of ship roll and wave direction.

Some studies on the asymmetric slamming problem have been done. Iafrati (2000) directly solved the velocity potential and its derivative in the water entry problem of asymmetric wedges through the boundary element method, and discussed the free surface form and pressure distribution under different heel angles. Judge et al. (2004) studied the water entry problem of wedge with both horizontal and vertical velocities through the vortex distribution model. The comparison between the experiment showed that the theoretical method cannot completely explain some fluid characteristics in the experiment. Aarsne (1996) carried out a falling body experiment on an asymmetric ship section. In the experiment, the slamming loads and slamming force were measured, but the latter had severe oscillation. Russo et al. (2018) conducted an oblique water entry experiment on a wedge with 37° deadrise angle, and measured the displacement, velocity and acceleration of the falling body. The results showed that with the heel angle increasing, the wedge decelerated faster and the side of lower deadrise angle was submerged faster. However, the water entry speed had little effect on the slamming pressure, free surface pile-up, etc.

In recent years, CFD methods have been used for the research of ship slamming loads. Krastev et al. (2018) comprehensively considered motion and geometric asymmetry of a two-dimensional wedge and achieved the water entry of asymmetric wedges based on the coupled VOF (Volume of Fluid) algorithm and dynamic mesh solver. There were two main fluid forms emerged in the simulation process: flow separation and flow ventilation. Xie et al. (2018) studied the asymmetric water entry problem of a full-size bow-flared section from Ultra Large Container Ship (ULCS) using FLUENT. Both geometrical asymmetry and kinematic asymmetry were studied, and results showed that kinematic asymmetry can significantly influence pile-up water form and pressure if flow separation occurred. Xie et al. (2020) applied a hybrid two-step method to predict the bow flare slamming loads in oblique waves, and the results showed that the slamming loads in oblique wave had obvious asymmetry and were even higher than that in head wave. Li et al. (2022) further considered the wave-body interface on the basis of Xie et al. (2020) and proposed a more reasonable method to predict bow flare slamming loads in oblique long waves.

Although asymmetric slamming has been extensively studied, most of them are still limited to partial structures. Considering the actual ship slamming condition, asymmetric slamming studies of three-dimensional hulls still need to be expanded. Kim et al. (2019) studied the slamming loads of 10000TUE container ship in oblique waves through experiment. The results showed that the slamming loads in oblique wave can be higher than that in head wave as a result of the