Numerical Investigations of Seakeeping Performances of KCS in Head Waves Using Viscous/Hybrid Models

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ABSTRACT

This paper describes URANS and SWENSE simulations to determine the seakeeping performances of a container ship KCS in head waves. SWENSE is a hybrid approach of potential and viscous flows based on the functional decomposition model, where the total field is composed of the incident field and complementary field. Four wavelengths of regular head waves are considered according to the benchmark cases. Seakeeping performances of KCS in head waves using different wave-generation methods are evaluated. Numerical accuracy of CFD results is investigated against EFD data. The comparison of the simulation results, computational requirements and efficiency of the URANS and hybrid methods is carried out. It is found that the SWENSE model has the almost same computational accuracy as the boundary wave-generation approach, which is more time-saving and cost-saving for ship seakeeping prediction.

KEY WORDS: SWENSE; Hybrid approach of potential and viscous flows; Functional decomposition model; Boundary wave-generation approach; Seakeeping

INTRODUCTION

During the actual voyage, the complex environmental factors, such as wind, waves and currents, will bring out the significant ship motions and then affect the resistance and speed of the ship. Thus, it is very important for ship safety and economy to be able to predict the seakeeping behaviors of ships in waves during the design stage. In general, there are three main methods for ship seakeeping performance prediction: model tests, potential theory and viscous CFD simulations (Computational Fluid Dynamics). Model tests can provide lots of robust data for CFD validation, which is expensive and time-consuming but irreplaceable currently. Due to ignoring the viscous effect, potential flow theory can obtain the results of wave-induced ship motions and forces for the ships sailing in waves quickly. Qiu and Peng (2013) developed a time-domain panel-free method, in which the linear free surface boundary and the body boundary condition imposed on the instantaneous wetted surface were used. Then this method was verified by the comparison of the hydrodynamic forces for the submerged sphere and the motions for a flared body and a Wigley hull between the present model, analytical solutions and other numerical methods. Hong et al. (2016) derived the semi-analytical expressions of 3D translating-pulsating (3DTP) frequency-domain Green's function in Havelock form as well as the partial derivatives, which were integrated along a horizontal line segment. Then simulations for Wigley III and S175 ship models are carried out and the simulated results of the wave excited forces and motions are compared with experiment data to validate the accuracy and efficiency of this method. Oh (2019) investigated motions of 3D floating structures advancing in waves by the Rankine source panel method with the hybrid radiation technique, in which the Sommerfeld radiation condition was combined with the damping method. Chen et al. (2021) combined the Rankine source in the inner domain and 3D transient Green function in the outer domain to develop a domain-decomposition method, in which the boundary integral equation was constructed by the impulse response function method and solved by Taylor expansion boundary element method. The 6DOF ship motions calculated by the hybrid method were in good agreement with the experiment measurements. However, detail flow and nonlinear ship motions can't be included in the potential theory.

Taking the viscous term into account, viscous CFD methods are able to obtain the detailed flow around structures and the strongly nonlinear phenomena accurately. Tezdogan et al. (2015) conducted URANS (unsteady Reynolds-averaged Navier-Stokes) simulations of the full-scale KCS ship model in head waves based on the Commercial software STARCCM+. Compared with the experimental data, the simulated results were in good agreement. Ship motions and added