A numerical study of wave drift force on an oblique moving ship in regular waves

Tianlong Mei1, Zaojian Zou1,2
1 School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China
2 State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, Shanghai, China

ABSTRACT.

A time domain higher-order Rankine panel method is developed and applied for predicting the wave-induced motions of a ship navigating with a small drift angle in waves. As for the numerical procedure of solutions, the double-body flow accounting for the trailing vortices effect is first evaluated and then applied in the free surface and body surface boundary conditions of unsteady velocity potentials. The pressure equality Kutta condition is imposed at the trailing edge of the ship hull to generate the required circulation. Subsequently, the higher-order Rankine panel method, in which the physical variables are described by the quadratic B-spline basis function, is used for the evaluation of wave-induced motions and added resistance. By comparing the present numerical results with the experimental data, an acceptable agreement is achieved, and it is shown that even in head waves the small drift angle has a considerable effect on the lateral motions, but the effect on the added resistance is relatively small.

KEY WORDS: Time domain Rankine panel method; drift angle; motion response; added resistance.

INTRODUCTION

For a ship navigating at sea, it may subject to winds, waves and currents, which not only affect the ship motions, but also lead to power loss and speed reduction. Moreover, the Marine Environment Protection Committee (MEPC) of International Maritime Organization (IMO) has now established the new regulations to constrain the arising greenhouse gas emissions from the perspective of an Energy Efficiency Design Index (EEDI). Therefore, an accurate prediction of added resistance of a ship sailing in waves is highly important and practical.

Existing approaches for studying added resistance can be classified into experimental method and numerical method. The former mainly relies on the model tests which proved to be most reliable, but costly and time consuming as well; the latter usually can be divided into two categories: the potential flow method which includes near field method using pressure integration and the far field method using momentum conservation; and the Computational Fluid Dynamics (CFD) method for viscos flow.

Many experimental studies on added resistance can be found in literature (Nakamura and Naito, 1977, Takahashi, 1988, Guo and Steen, 2011, Kashiwagi, 2013, Park et al., 2015, Sprenger et al., 2017, Park et al., 2019). As for the potential flow method, the pioneering researches using the momentum conservation and pressure integration were carried out by Maruo (1957) and Falinlslen et al. (1980) respectively. By following their works, many researchers further modified and extended these two approaches to investigate the added resistance problems. Joncquez et al. (2008) and Joncquez (2009) employed a B-spline function based time domain Rankine panel method to predict the added resistance. Similar approach was also applied in Kim and Kim (2011), Seo et al. (2013), Seo et al. (2014), Zhang and el Moctar (2019). Liu et al. (2011) formulated the added resistance by using a hybrid time domain Rankine-Transient free surface Green function solver. Söding et al. (2014) utilized a frequency domain Rankine panel method accounting for the nonlinear free surface conditions and dynamic squat of steady flow to investigate the wave added resistance. Riesner and el Moctar (2018) introduced a time domain Rankine panel method which can account for full nonlinear steady flow and weakly-nonlinear factors, i.e., nonlinear Froude-Krylov and hydrostatic forces; moreover, the viscous effects were also incorporated by introducing an empirical approach. Mei et al. (2019) evaluated the added resistance of a Duisburg Test Case (DTC) container ship moving at different water depths via the pressure integration method proposed by Joncquez (2009). Xiao et al. (2019) applied the hybrid Taylor expansion boundary element method (TEBEM), which is originally developed by Duan (2012), for evaluating the added resistance in waves at a low speed. Owing to the great contributions of the powerful computers, the CFD method solving the Reynolds-averaged Navier-Stokes (RANS) equations, which can capture the strong nonlinear factors, such as breaking waves and viscous effects, has been commonly used for computing the added resistance. Typical literatures addressing this problem are accessible in Simonsen et al. (2013), Park et al. (2014), el Moctar et al. (2017), Kim et al. (2017), Kim et al. (2017), Sigmund and el Moctar (2018).