Numerical Analysis on Added Resistance of Ships

Kyong-Hwan Kim, Min-Guk Seo and Yonghwan Kim*
Department of Naval Architecture and Ocean Engineering, Seoul National University, Seoul, Korea

This paper presents a comparison of the computational results of added resistance on ships in waves by 2 different numerical methods, namely the direct pressure integration method (near-field method) and the momentum conservation method (far-field method). These methods are combined with the Neumann-Kelvin and double-body linearization schemes, which are used to calculate 1st-order velocity potentials and their derivatives. In this study, the time-domain formulation is considered, and the corresponding equations of added resistance are derived. As a method of solution, a higher-order Rankine panel method is used, and the added resistance is evaluated using 1st-order velocity potentials and their derivatives. The computational results are validated by comparing them with experimental data on Wigley hull models, the Series 60 hull and S175 containership; reasonable agreements are observed for all the models. The study is extended to the analysis of added resistance in irregular waves, and the proper criteria for a time window and number of wave frequencies are observed for an irregular sea.

INTRODUCTION

As the accurate prediction of added resistance is important in the design of a ship with propulsion power, the added resistance problem has been widely studied for a long time. Experimentally, added resistances on the Series 60 hull have been measured by Gerritsma and Beukelman (1972) and Storm-Tejsen et al. (1973); for the Wigley hull, they have been measured by Journee (1992). The added resistance on the S175 containership was measured by Fujii and Takahashi (1975) and Nakamura and Naito (1977). There are 2 major analytical approaches which can be used to analyze the added resistance problem. One is a far-field method based on the momentum conservation theory proposed by Maruo (1960). This approach is simple and powerful: Because there is no need to solve a complete boundary value problem to obtain the body pressure, the far-field method has been widely used to estimate added resistances in real applications. Recently, Kashiwagi et al. (2009) calculated the added resistance by using the far-field method and applied the unified theory to solve the ship motion problem. Liu et al. (2011) applied the Rankine source-Green function method to the far-field method and considered some asymptotic and empirical methods to improve the calculation results of a short wave range. The other approach to calculating the added resistance is a near-field method which integrates hydrodynamic pressure on the body surface. Due to the significant development of computer power, the near-field method, as well as the far-field method, have been acclaimed recently. An advantage of the near-field method is the easy-to-understand physical phenomena and its extendability to the multi-body problems and nonlinear problems. Many research studies have been carried out using the direct pressure integration method to estimate the added resistance. Faltinsen et al. (1980) used potential theory—a direct pressure integration approach—with good validation results. They also addressed the deficiency of the approach in short waves and introduced a simplified asymptotic method. Grue and Biberg (1993), Ye and Hsiung (1997), Choi et al. (2000) and Fang and Chen (2006) applied the wave Green function method to the added resistance problem. These efforts are mainly based on a 3D analysis and a frequency-domain approach. Recently, Joncquez et al. (2008) analyzed the added resistance problem by extending a ship motion program (AEGIR), based on a higher-order Rankine panel method, and they compared the computational results with those of the momentum conservation theory. A comparison between the computational results based on the Neumann-Kelvin and double-body linearization schemes was also carried out by Joncquez (2009). Kim and Kim (2011) also applied the time-domain higher-order Rankine panel method to calculate the added resistance problem. They used the near-field method and presented the differences between the free-surface linearization schemes of Neumann-Kelvin and double-body linearization.

In spite of the success of previous studies on the added resistance problem, very limited research can be found that is based on the Rankine panel method, with the exception of Joncuez et al. (2008) and Kim and Kim (2011), while the Rankine panel method is widely applied today to the ship motion problem including linear and nonlinear problems. In this study, a formulation of added resistance based on a time-domain B-spline Rankine panel method is derived. Both the near-field and far-field methods are applied to calculate the added resistances of a ship. In addition, 2 different free-surface linearization schemes, Neumann-Kelvin (NK) and double-body (DB) linearization, are considered for the forward speed problem. Computational results of the added resistance are validated for several models—including the Wigley hull, Series 60 ($C_R = 0.7$) and S175 containerships—by comparing them with experimental data. The differences between the computational results of these methods are observed by comparing experimental data. Further, the added resistance of the S175 containership is analyzed in irregular waves, and appropriate criteria to estimate the added resistance in irregular waves are presented throughout the numerical experiments.