Numerical Simulations on Ship Added Resistance in Waves

Mingyu Kim [1]*, Osman Turan [1] and Atilla Incecik [1]

[1] *Department of Naval Architecture, Ocean and Marine Engineering,*

University of Strathclyde, Glasgow, UK

*(*mingyu.kim@strath.ac.uk)*

Abstract and Introduction

Now more than ever, reduction of ship pollution and emissions, maximization of energy efficiency, enhancement of safety requirements and minimization of operational expenditure have been required. Traditionally, ship resistance and propulsion performance in calm water has been concentrated in the ship design stage even though there have been some changes for hull form design and optimization from design draught and speed to specific range of draught and speed considering operating profile (Kim and Park, 2015). But, when a ship advances through a seaway, she requires additional power in comparison with the power required in calm water due to weather effects, hull fouling and ship operating conditions. This degradation of the ship performance in a seaway is generally called "Sea Margin" and is reported to be about 15-30% of the power required in calm water. The added resistance due to waves is one of the major components affecting ship performance in a seaway. Therefore, accurate prediction of the added resistance in waves is essential to evaluate the additional power, to assess environmental impact and to design ships with high fuel efficiency in actual operating conditions with other operation measures, such as voyage planning and weather routing. Also correct estimation and understanding of the ship motions is crucial to ensure safe navigation. Regarding the international regulations, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) issued new regulations to meet the requirements in order to improve the energy efficiency level and to reduce carbon emissions. These regulations include Energy Efficiency Design Index (EEDI) as a mandatory technical measure for new ships and Energy Efficiency Operational Indicator (EEOI) which is related to ship voyage and operational efficiency as a voluntary technical measure for ships in service. Recently, the ship speed reduction coefficient (fw) is under discussion for the calculation of EEDI in the representative sea states (IMO MEPC, 2012 and 27th ITTC seakeeping committee, 2014). Moreover, guidelines for determining minimum propulsion power to maintain the manoeuvrability of ship in adverse weather conditions (IMO MEPC, 2013) have been developing in concern with the safety regulations.

The added resistance and the ship motion problems in waves have been widely studied by conducting experiment and numerical simulations by the potential flow theory and CFD approaches. For potential flow approaches, there are two major analytical approaches as potential flow methods for the calculation of the added resistance using the velocity potentials; the far-field method and the near-field method. The far-field method is based on the added resistance computed from the wave energy and the momentum flux generated from a ship and is evaluated across a vertical control surface of infinite radius surrounding the ship. The first study was introduced by Maruo (1960) and later on the far-field method based on radiated energy approach was proposed by Gerritsma and Beukelman (1972) for added resistance in head seas and has become popular in strip theory programs due to its easy implementation. Recently, Liu et al. (2011) solved the added resistance problem using quasi-second-order approach using in-house developed hybrid Rankine Source-Green function method considering the asymptotic and empirical methods to improve the results in short waves.

On the other hand, the near-field method estimates the added resistance by the integration of hydrodynamic pressure on the body surface, which was first introduced by Havelock (1937) where the Froude-Krylov approach was used to calculate hull pressures. The near-field method was improved by Faltinsen et al. (1980) based on the direct pressure integration approach and the 2-D linear strip theory by Salvesen et al. (1970) with the introduction of a simplified asymptotic method to overcome the deficiency of this approach in short waves. Kim et al. (2007) and Joncquez (2009) solved the added resistance based on Rankine panel method using time-domain approach with B-spline functions.

Recently as computational facilities have become more powerful and more accessible, CFD method is commonly used to predict the added resistance and ship motions. It has advantages to deal directly with large amplitude ship motions and the nonlinear flow phenomenon such as breaking waves and green water without explicit approximations and empirical values. Sadat-Hosseini et al. (2013) predicted the added resistance and motions for KVLCC2 using URANS code. In addition to researches on the prediction of the added resistance and ship motions in waves, there have been studies on reduction of the added resistance by developing hull form. Park et al. (2014) and Kim et al. (2015) modified the forebody of KVLCC2 to improve the performance of the added resistance in waves. Also there have been researches on the increase of the required power and the ship speed loss due to waves (Kwon, 2008; Prpić-Oršić and Faltinsen, 2012; Kim et al, 2015).

In this study, the numerical simulations for the prediction of the added resistance and the ship motions for KVLCC2 in regular head waves are performed using URANS and the 3-D potential flow methods. Obtained results are validated with the available experimental data including grid convergence tests. The added resistance and the vertical ship motions are analysed at various wave conditions at design and operating speeds and at stationary condition taking into account operational and harbour conditions of the vessel. Unsteady wave patterns and time history results of the resistance and vertical ship motions in waves simulated by CFD are analysed at each ship speed. The relationship between the added resistance and the ship motions for various ship speeds and wave steepness are investigated including viscous effects and non-linear phenomena.

Keywords*: Added resistance, Ship motions, Potential flow, CFD, KVLCC2.*