Wave Added Resistance Analysis for Full-Scale Ship Based on Onboard Measuring Data and Machine Learning Approach

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ABSTRACT

Recently, with the implementation of the IMO guidelines about EEDI, added resistance simulation methods with higher precision are needed for the optimization of energy efficiency. With the enlargement tendency of ships in recent years, the encountering waves in real sea states has become shorter compared with the scale of ships. However, both the experimental and the numerical simulations of added resistance still remains great uncertainty because of the instability of wave-making in water basins and the limitations of numerical schemes. In order to solve the problems in real sea states, data from full-scale ships may benefit in general. In this research, the data originating from the onboard measuring system of a 210,000 DWT bulk carrier are adopted. After several operations, including data cleaning and data filtering, on the initial data of main engine power recording have been conducted, the influence of other environmental loads such as wind and current are corrected according to several widely-used empirical formulas. Then the wave added resistance can be resolved from the whole resistance at service. At the same time, the quadratic transfer function (QTF) of added resistance is applied in long waves, i.e. wave-ship length ratio above 0.7, is provided by a program using 3-D time-domain Rankine panel method, because the power spectrum density is relatively low in long waves at the actual sea. With the numerical results in long waves and the data of the bulk carrier at service, a supervised machine learning method based on the gradient descent method is used to fit the QTF in short waves. The results of this approach are checked through the testing data, which is a set of 20% data chosen from the whole dataset randomly. And the applicability of this new method has been confirmed through the checking results.

KEY WORDS: wave added resistance, Rankine panel method, seakeeping, onboard data, full-scale analysis

INTRODUCTION

Since the requirement of energy efficiency is increasing through the past years, more attention has been paid to estimate fuel consumptions at real sea precisely. The current Energy Efficiency Design Index (EEDI) requirements demand a 30%-50% reduction of ship emissions by this year (2022). According to the calculation method of EEDI, the coefficient $f_w$ for decrease in ship speed in a representative sea condition needs to be calculated. Wave added resistance is one of the most significant factors which affect $f_w$. Thus, to analyze wave added resistance accurately is essential to the estimation of EEDI.

Many numerical approaches have been raised in order to simulate wave added resistance in the past century. Havelock (1942) firstly raised a simplified equation to estimate the average steady drifting force on ships among regular waves. Maruo (1960, 1963) simulated hydrodynamic features through strip method and obtained wave added resistance with far field method based on the conservation of momentum. Gerritsma and Beukelman (1972) advanced the far field method to a well-known equation based on the law of energy conservation. Opposite to the far field method, several researchers (Boese, 1970; Pinkster, 1979; Faltinsen, 1980) applied pressure integration directly on the mean wetted surface of ship hull to estimate the added resistance, which is also referred to the near field methods. With the development of computer science and technology, the 3D potential flow method and computational fluid dynamics (CFD) method are applied to the problem since the last decades of the 20th century. Sclavounos and Nakos (1993) and Kim et al. (2011) adopted the 3D Rankine panel method to calculate the wave added resistance, and the numerical results fit well with the experimental results generally. Chen et al. (2018) and Sigmund et al. (2018) simulated the phenomenon of wave added resistance based on the Reynolds-Average Navier-Stokes (RANS) equations. Meanwhile, a great quantity of experiments on wave added resistance have been conducted in towing tanks, circulating water channels and seakeeping tanks all over the world. In the early years, the study mainly focused on the added resistance in regular waves. Several models have been tested, such as Series 60 (Strøm -Tejsen, 1973), S175 container ship (Nakamura, 1977), Wigley I-IV (Journee, 1992), etc.

The majority of the researches above mainly focus on the wave added