Prediction of Unsteady Pressure Distribution in Irregular Waves Using Locally Measured Pressure Data and Convolution Integral

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ABSTRACT
In recent years, on-board monitoring data analysis is getting more important because of the restriction of carbon dioxide emission according to international rules. The ship performance is usually evaluated through the shaft power or ship motions, and so on. Besides these physical quantities, the pressure distribution on the actual ship hull would be useful for addressing the restrictions. In towing tank test, the dominant area of drag forces is visualized by obtaining pressure distribution (Kashiwagi, et al., 2019). However, the technique for measuring pressure distribution on the ship hull in the actual sea has not been established. Therefore, we propose a method to measure pressure distribution, which can be installed on the actual ships. From a practical viewpoint, the prediction of pressure distribution by using locally measured pressure data is reasonable. Hence, the pressure distribution is estimated through the convolution integral by using pressure measured at only one point in this paper. The estimated pressure distribution is validated by comparison with measured experimental values. The estimated pressure is discussed in the diffraction test and the motion-free test. In the diffraction test, the forces by integrating estimated pressure are checked through the comparison with measured forces by dynamometers.

KEY WORDS: Unsteady pressure distribution estimation; FBG pressure sensor; convolution integral; seakeeping; Rankine panel method.

INTRODUCTION
From the viewpoint of the international rules about carbon dioxide emission, such as EEDI, EEXI, and CII, the analysis by using on-board monitoring data and the evaluation of ship performances in actual ships is getting important. In these studies, the shaft power, ship speed, and so on are usually focused on (for example, Orihara & Tsujimoto, 2018, Minoura, et al., 2019). In addition to these physical quantities, the pressure distribution on the actual ship would be meaningful on-board monitoring data to know where is the dominant hull area regarding drag forces. This information could help to attach the additional products to reduce drag force or build new ship with high propulsion efficiency. However, the measurement method for pressure distribution on actual ships has not been established yet. On the other hand, Knowledge of towing tests to obtain the pressure distribution on the whole ship hull surface has been accumulated (Iwashita & Kashiwagi, 2018) with numerous Fiber Bragg Gratings (FBG) pressure sensors (Wakahara, et al., 2008). These obtained data are already used for the validation data for simulation schemes (Yang, et al., 2021, Suzuki, et al., 2021) as well as the visualization of the dominant drag forces on the surface (Kashiwagi, et al., 2019).

Recently, the FBG pressure sensor which is assumed as used for ships in actual seas has been developing (Hirota, et al., 2021). Therefore, the environment for measuring pressure on the actual ship hull is being prepared. However, the measurement for pressure distribution on the actual ship by using a large number of pressure sensors is unrealistic because of the cost and management. Hence, an effective measurement method of pressure distribution on an actual ship is necessary, which considers these concerns. As a practical measurement method, the prediction system of pressure distribution on the ship hull by using pressure measured at a few points, such as 3 points instead of hundreds of points, should be proposed.

Therefore, the authors have developed a method to estimate pressure distribution on the ship hull by using the data measured at one position as a first step (Suzuki, et al., 2022). In that paper, the diffraction pressure distribution in regular waves in some wavelength conditions was estimated by using the convolution integral. In this paper, the unsteady pressure distributions in the diffraction test and motion-free test in irregular waves are estimated through the convolution integral by using measured data at only one point based on the obtained knowledge in the previous study. Then, the pressure distribution is compared with directly measured pressure distribution. In addition, the unsteady pressure distribution in the diffraction test is validated by integrating it on the ship hull surface. The estimated forces are compared with the measured ones by dynamometers. Through these investigations, the validity of predicted pressure distribution is discussed.

THEORY
The theory for predicting pressure distribution and evaluating it is written below. The symbols for expressing equations in the theory written below