Seakeeping Performance of Small Vessels Using CFD-Modified Potential (CMP) Simulation

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ABSTRACT

According to statistics from the Korea Maritime Transportation Safety Authority (KOMSA), over 30% of marine accidents nearshore in domestic coasts over the past 5 years involved small vessels such as fishing boats. This highlights the insufficient stability of small fishing vessels, which are often built based on empirical methods. Typically, the design of these vessels relies on empirical values for damping coefficients, which significantly influence motion analysis directly related to stability. Such analysis results are seldom verified properly. Therefore, improving the stability of small vessels requires a more realistic and reliable model for deriving damping coefficients and analyzing vessel motion and seakeeping performance.

In this study, a CFD-modified Potential (CMP) model, a hybrid simulation method that calibrates motion Response Amplitude Operator (RAO) through Computational Fluid Dynamics (CFD) simulation after performing motion analysis using a linear potential-based program, was proposed. Initially, a 6-DOF motion simulation for a barge was performed in various wave directions under sea states 3 and 4 conditions, using a linear potential-based simulation for the target sea site (Shinan, Jeollabuk-do, South Korea). Subsequently, CFD simulations were performed under regular wave conditions at resonant frequencies for roll and pitch, respectively, and the damping ratios were calculated. These coefficients were then used as input values in the potential simulation, adjusting the damping ratio to match the RAO of the potential simulation to that of the CFD.

The final motion RAO obtained through the CMP model was compared with results from a linear potential-based simulation using empirically-derived damping coefficients and a physical wave tank model test. The results indicated that, for roll motion, the CMP model provided results closer to the experimental data compared to the potential-based simulation with conventional damping coefficients. The relative error for roll was reduced to 1-15% using the CMP model, compared to 59-80% with the potential flow program. For pitch motion, while the CMP model results were generally smaller than the experimental data, they closely matched experimental results at 180 degrees wave direction (head seas), where pitch motion is most severe, with a relative error of 10-13%, compared to 22-37% with the potential flow program. This study confirms that the CMP model offers more accurate seakeeping performance analysis for small vessels compared to conventional potential-based simulations, enhancing the reliability of motion predictions and contributing to the safety and design improvements of small fishing vessels.

KEYWORDS

Seakeeping performance, Damping ratio, Response Amplitude Operator (RAO), Computational Fluid Dynamics (CFD), CFD-Modified Potential (CMP) model, Experiment