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RANS Computations of Added Resistance of Advancing Modified Wigley Ships in Head Waves

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ABSTRACT

In this paper, RANS simulations on added resistances and vertical motions of modified Wigley ship advancing in head waves with a Froude number of 0.2 are presented. The numerical computations are fulfilled by our in-house solver naoe-FOAM-SJTU based on open source package OpenFOAM. Regular wave conditions with a wide range of wave length ($0.4<\lambda/L<1.6$) are considered besides the steady calm-water cases. The simulations are compared very well with those using unsteady wave analysis methods. Good agreement with experimental measurement is also observed. It shows that the solver naoe-FOAM-SJTU has good potential to study more complex added resistance issues.

KEY WORDS: added resistance; motion response; OpenFOAM; naoe-FOAM-SJTU solver; RANS simulations.

INTRODUCTION

Ship hydrodynamic performances under wave conditions are essentially associated with the added resistance in waves and ship motions. After the Energy Efficiency Design Index (EEDI) and Energy Efficiency Operational Indicator (EEOI) were put forward, how to predict the added resistances and motion responses is of great importance for ship design, construction and operation. Currently the investigations are aim to develop a valid computation method for calculating added resistance and predicting the motion responses of a ship advancing in waves with enough accuracy and high efficiency and low cost.

Many researches based on potential flow theory and experimental fluid dynamics (EFD) have been applied to predict the added resistances and wave-induced motions. Different approaches for prediction are developed: The strip method including near-field and far-field method; the Rankine panel method; the Cartesian grid method and the enhanced unified theory. Kashiwagi (1995) studied the enhanced unified theory (EUT) and a modified Maruo's formula was used to calculate the added resistance in waves. Kashiwagi (2011) adopted the unsteady wave analysis method to predict the added resistance and wave-induced forces. The effects of forward speed on added resistance of a ship and characteristics of added resistance in the range of short incident waves were also studied. Tsugukiyo (1993) put forward a simple estimation method to obtain the added resistance coefficients in single transient water wave experiment and the irregular water waves were considered.

Recently with the developments of efficient numerical methods and high performance computers, many progresses are made by computational fluid dynamics (CFD) methods. Especially the Reynolds-Averaged Navier-Stokes (RANS) method has been widely applied in ship hydrodynamic computations. When handling the large-amplitude ship motions, slamming, green water, and other strong nonlinear problems, CFD has more advantages over conventional methods. The fluid viscosity effect is directly taken into account, therefore the flow flied is simulated more realistically and accurately. Hamid (2013) carried on the CFD verification and validation by simulating the added resistance and ship motions of the model KVLCC2 sailing in short and long head waves using CFDShip-Iowa. Guo (2012) also studied the prediction of added resistances and ship motions of KVLCC2 in head waves. The comparison with strip theory showed that RANS results are better in all wave length of this study. Castiglione (2011) used an overset grid method to predict the seakeeping characteristics of a high-speed catamaran in large-amplitude waves. In a word, RANS simulation has been extensively adopted to simulate the hydrodynamic performances of advancing ship in waves.

In this study, added resistances and ship motions in waves are computed by our multi-function hydrodynamic RANS solver named naoe-FOAM-SJTU, which is developed based on open source package OpenFOAM. A wave generation and damping module is developed to generate regular and irregular waves. The coupled equations of pressure and velocity fields are solved by PISO algorithm. Volume of Fluid (VOF) method is used to capture the free interface and Finite Volume Method (FVM) is adopted as the discretization scheme. The wave-induced ship motions are simulated by solving the six-degree-of-freedom (6DoF) motion equations and a dynamic deforming mesh method is used. Cao et al (2011, 2013) validated the ability of wave generation of naoe-FOAM-SJTU by simulating the wave run-up around a vertical cylinder . Shen et al (2013, 2012, 2011) provided the numerical computational results of added resistances and ship motions of a DTMB ship 5512 in a wide range of wave steepness by using naoe-FOAM-SJTU. Ye et al (2012) computed the added resistance and vertical ship motions in regular head waves, and validated the ability of