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RANS Computations of Added Resistance and Motions of Ship in Head Waves

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ABSTRACT

The RANS computations of a ship with sink and trim motion in head waves are presented. The added resistance, heave and pitch motions are investigated numerically. The computations are based on volume of fluid (VOF) and dynamic deformation mesh methods, discretized by finite volume method (FVM). A six-degrees-of-freedom (6DoF) module is implemented to predict the motions of ship. Four wave conditions with a wide range of wave steepness ($0.025 \le ak \le 0.100$) are considered. The wave length of all conditions is one ship length and the results show strong non-linear features, especially for ak = 0.100, where the phenomenon of green water on deck is observed. The comparison of added resistance between the presented computational results and measurements shows good agreements. All computations are performed by our solver naoe-Foam-SJTU developed under the framework of the open source code, OpenFOAM.

KEY WORDS: VOF, dynamic mesh, ship motion, 6DOF, added resistance, naoe-Foam-SJTU.

INTRODUCTION

The accurate prediction of wave loads, ship motions and added resistance in sea waves is of great importance for ship hydrodynamics. These problems are closely related to the safety and powering characteristics of ship in the sea. An accurate prediction of added resistance and ship motions can provide valuable information for the design of ship hull to achieve higher safety and better performance in a seaway. Therefore, it’s essential to develop an efficient tool to evaluate the added resistance and motions of ship in a seaway.

Many previous studies of seakeeping are mainly focused on the potential flow methods. However, the conventional methods still have limitations when handling large-amplitude motions, high-speed vessels and other strong nonlinear problems. With the development of computational techniques and numerical methods, computational fluid dynamics (CFD) has experienced unprecedented developments in the past decades. Since it is based on more realistic model and takes viscous effects into account, CFD can handle more nonlinear problems and obtain more accurate results than conventional methods did.

In recent years, many efforts have been made for the Reynolds-Averaged Navier-Stokes (RANS) method to simulate the ship advancing in waves with large-amplitude motions and fully nonlinear flow features. Sato, Miyata *et al.* (1999) computed heave and pitch motions of Wigley hull and Series 60 in regular waves by using density function method to model the free-surface and treating the motions of ship as body force in N-S equations. Chen, Liu *et al.* (2002) used Chimera domain decomposition approach to simulate the large-amplitude ship roll motions. Orihara and Miyata (2003) evaluated the added resistance and transfer functions of a container ship in head waves based on overlapping grid system. Wilson, Carrica *et al.* (2006) simulated the roll damping motions of a surface combat ship, DTMB model 5512, with bilge keels and applied surface tracking technique to compute the surface. Carrica, Wilson *et al.* (2007) implemented overset grid method to compute large-amplitude motions of DTMB model 5512 in both medium and high speeds. Castiglione, Stern *et al.* (2011) use the same methods to predict the seakeeping characteristics of a high-speed catamaran in large-amplitude waves.

In this paper, an incompressible RANS method with two-phase interface is applied to simulate the viscous flow around ship in regular head waves. A surface combat ship, DTMB model 5512, is simulated in four wave conditions with a wide range of wave steepness ($0.025 \le ak \le 0.100$). Predictions of heave and pitch motions and added resistance are concerned in this case. The predicated added resistances are compared with the experimental data. The RANS equations are discretized by finite volume method (FVM). The coupled pressure and velocity fields are solved by PISO algorithm. The water-air interface is captured by a VOF method with a compression technique. The shear stress transport (SST) model is used to compute the turbulent viscosity. A six-degrees-of-freedom (6DOF) module is implemented to predict the motion of ship, which is be handled by a dynamic deforming mesh method solved by a Laplace equation. All the simulations in this study are performed by our solver naoe-Foam-SJTU(Shen, Cao and Wan, 2012) developed based on the open source CFD toolbox, OpenFOAM.

This paper is organized as follows: The first section gives a brief introduction of the numerical methods. The second section presents the geometry and setup of the computational cases. The computational