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Analysis of Viscosity on the Rolling Motion of Ship Transverse Section

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ABSTRACT

Ship rolling is a significant factor of ship design with regards to the ship motions. The majority of current studies are mainly focused on validating the calculations by combining damping coefficients within variable parameters. The analysis of ship motions in viscous fluid is extremely complex, which requires a large amount of computations. At present, most analyses are based on solving RANS equations, while in this paper, the comparisons between different frequencies, amplitudes, shapes of transverse sections are conducted by the solver naoe-FOAM-SJTU, which is developed based on the open source CFD toolbox OpenFOAM. The paper is aiming at figuring out relations between the damping coefficients and distinct parameters. It is demonstrates that the frequency and the amplitude of a roll motion have considerable impacts on the viscous flow field, and circle bilges are conducive to mitigate vortex shedding. In addition, the influences of these parameters on different components of damping coefficient are different.

KEY WORDS: roll motion, viscous fluid, RANS, damping coefficient, naoe-FOAM-SJTU.

INTRODUCTION

Accurate predictions of roll motions are extremely important since roll motions extraordinarily affect the sea-keeping, the stability and the maneuverability of a ship. However, it is rather hard to achieve a desirably accurate prediction in viscous flow since the viscosity cause nonlinear effects, which is the main factor resulting in roll motions.

In the past, the roll motion is predicted roughly by diffraction/radiation theory, semi-empirical formulas and physical tank tests. In general the roll-damping coefficients consist of five components: 1)skin friction of the hull, 2)eddy shedding from the hull, 3)free surface waves, 4)lift effect damping, 5)bilge keel damping. The five components mentioned above are separately caused by the skin friction stress, the eddy formed near the bilge, the free surface waves, the sway motions of a ship with forward speed and the bilge keel. It's convenient to calculate and analyze different components individually while ignoring the interaction among these components (Subrata, 2001). For these components, Ikeda (1977; 1978) presented corresponding empirical formulas through a series of model experiments with regards to the bilge keel, the waves and the speed of a ship. However, the accuracy of empirical formulas is limited. With the development of computer technologies, CFD (Computational Fluid Dynamics) has been developed (Alessandrini and Delhommeau, 1999) and RANS (Reynolds Averaged Navier-Stokes) method has been widely applied in solving the governing equations. Till now, 2D roll motions can be well predicted by means of RANS method while it has not matured in 3D roll motions yet. Researchers are still making attempts in 3D roll motions, for instance, Miller (2002) simulated roll motion for 3D cylinder (include bilge keels and forward speed) by RANS method; Wilson and Stern (2002) accurately predicted the natural rolling frequency and roll decay rates at multiple ship speeds on the SFDSHIP-IOWA solver. Yang Chun-lei et al. (2013) simulated free decay motions and forced roll motions for Series 60 ship models, in addition, they compared damping coefficients among the results of CFD, tests and empirical formulas respectively.

The flow field in this paper is performed by the solver--naoe-FOAM-SJTU, developed based on the open source CFD toolbox—OpenFOAM (Hrvoje, Aleksandar and Zeljko, 2007),