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Hydrodynamic Simulation of Pure Sway Tests with Ship Speed and Water Depth Effects

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ABSTRACT

With the development of high performance computers, at present, many scholars make great efforts to research PMM (Planar Motion Mechanism) tests by CFD method for ship maneuvering. In this article, pure sway tests are simulated based on naoe-FOAM-SJTU solver, where the forces and moments are obtained by the RANS equations, and sinkage and trim are solved by the prescribed motion equation and free motion equations. Some simulations of the tests are carried out at zero and design speeds, and others are executed in the deep and shallow water, the ratio of water depth and draft is 4 for deep water cases, and 2 for shallow water cases. From the simulation results, at design speed, the yaw moment is a big difference from that at zero speed, and ship speed has a large impact on the center of force, which is 1.3 m over the gravity center, besides, the ship squats deeper at design speed and rises at zero speed. In shallow water, the force obviously increases and is 29.1% bigger than that in deep water, and the ship squats as well as at design speed.

KEY WORDS: naoe-FOAM-SJTU solver, pure sway tests, ship speed, water depth

INTRODUCTION

Ship maneuverability is one of the important performances, and can be predicted by running model test in indoor basins and sheltered outdoor lakes. Another possibility is to use a PMM in a towing tank to determine the hydrodynamic coefficients in a mathematical model for the ship maneuvering motion. With the development of high performance computers, at present, many scholars make great efforts to simulate PMM tests by CFD method for ship maneuvering, and PMM tests include pure sway test, pure yaw test and other coupled tests. In this article, pure sway tests simulation is studied based on naoe-FOAM-SJTU solver (Shen and Wan, 2011, 2012, 2013).

Up to now, much work has been done on PMM tests simulation in the world. Especially, simman2008 and simman2014 workshops have been hold up to improve the simulation level. Sakamoto, N., et al(2012) presented the analysis and validation results of local flow characteristics for a surface combatant Model 5415 bare hull under static and dynamic PMM simulations, URANS computations are carried out by URANS/DES simulation search code CFD-Ship-Iowa. Some examples for pure drift motions can be found in Stern et al. (2009), Toxopeus and Vaz (2009) and Lungu and Pacuraru (2009), among others. In Wang et al. (2009) pure yaw motions for different water depths are investigated and a validation for the deep water case is made. Some studies mentioned above took free surface effect into account, others focused on effect of water depths. Therefore, the coupled effect of free surface, water depth and ship speed should be further investigated.

This study is intended to simulate pure sway tests at zero and design speeds and in deep and shallow water. In this study, the two-phase incompressible RANS equations are used and the surface interface is captured by a VOF method with bounded compression technique, moreover, the forces and moments are obtained by the RANS equations, and the ship sinkage and trim are solved by the prescribed motion equation and free freedom motion equations in.

This paper was organized as follows. Firstly, the mathematical model including governing equations, VOF method, discretization schemes and six degrees of freedom (6DOF) module was introduced. Secondly, model and grid was described, and ship geometry, some parameters and hull grid were given. Finally, numerical calculation like comparison at zero and design speed, comparison in deep and shallow water was shown.

MATHEMATICAL MODEL

Governing equations

The incompressible Reynolds-Averaged Navier-Stokes equations are used as governing equations, which can be written as:

$$\nabla \cdot U = 0 \tag{1}$$

$$\frac{\partial \rho U}{\partial t} + \nabla \cdot \left(\rho\left(U - U_g\right)U\right) = -\nabla p_d - g \cdot x\nabla\rho + \nabla \cdot \left(\mu_{eff}\nabla U\right) + \left(\nabla U\right) \cdot \nabla\mu_{eff} + f_\sigma + f_s \tag{2}$$

Where, U is velocity field; Ug is velocity of mesh points; $pd = p$-ρg.x is dynamic pressure, substracting hydrostatic component from total pressure. ρ is the mixture density with two phases; g is the gravity acceleration vector; $\mu_{\text{eff}} = \rho(\nu+\nu t)$ is effective dynamic viscosity, in which ν and νt are kinematic viscosity and eddy viscosity, respectively; the latter is obtained by k-ω turbulence model; f_σ is the