Prediction of Ship Motions in Head Waves Using RANS Method

Ming Wu, Bo Yang and Zuochao Wang
Department of Postgraduate, Dalian Naval Academy
Dalian, Liaoning, China

Aiguo Shi and Xiao Wang
Department of Navigation, Dalian Naval Academy
Dalian, Liaoning, China

ABSTRACT

A computational fluid dynamics simulation method is developed to predict the heave and pitch motions of ship in head waves. A numerical approach of wave-generation method by defining inflow boundary conditions is employed to generate the regular and irregular waves, and the outgoing waves are numerically dissipated inside the artificial damping zones. To predict the motions of ship in waves, the kinematics equations of rigid body and the Reynolds Averaged Navier–Stokes (RANS) equations describing the flow around the ship are solved simultaneously. The method is applied to simulate the motions of WigleyIII in regular and irregular waves, and the pitch and heave transfer functions are obtained. The simulation results are examined by the comparisons with the results of modified strip theory method and experimental data from Delft University of Technology, and in general agree well, which demonstrate the ability of the present method to assess seakeeping characteristics.

KEY WORDS: RANS equations; viscous numerical wave tank; free surface; wave spectrum; ship motions; transfer functions.

INTRODUCTION

An accurate prediction of ship responds in waves are important for seakeeping design, the usual methods to predict the seakeeping characteristics are experimental test and theoretical calculation. The full-scale experimental test is always limited by the test conditions and the obtained data from an existing vessel may not always be available for other ship. The model test requires experimental facilities, and often be expensive and time consuming. The potential methods have the ability to provide accurate enough seakeeping results to be useful in the design process, however, the assumption of which ignore the viscosity of flow, and they are short for treating with the strong nonlinear motion, and the shortcomings mentioned above limited theirs application. Generally speaking, there are two important problems for seakeeping research, generating wave environment accurately, and simulating the large amplitude motion. In recent years, the tendency of the research of ship response in wave develop from frequency domain to time domain, linear to nonlinear and potential method to viscous method, with the development of viscous flow theory and computer technology, the Computational Fluid Dynamics (CFD) method has been applied to investigate ship characteristic more and more widely. With the advantage of low consume, time saving and modifying convenient, it tends to be the primarily method together with towing tank tests in the field of ship characteristic research.

The recent research has been pay attention to the predictions that are based on the solution of the viscous flow field. The simulations to predict pitch and heave motions of ships with forward speed in regular head seas are performed with CFDSHIP-IOWA by Weymouth et al (2005). A parallel unstructured incompressible free surface RANS solver developed by Wilson et al (2008) is applied to the solution of large amplitude ship motions for the ITTC S175 container ship in incident waves. Y. Sato et al (2008) developed the codes WISDAM to cope with the arbitrary ship motions in arbitrary wave conditions. Hosseini et al (2007) predicted the extreme motions of Tumblehome in regular waves. Luquet et al (2005) developed the SWENSE approach and used to validate for head regular waves acting on a fixed DTMB5415 ship. Very recently, on the Gothenburg 2010 CFD Workshop, Many groups carried out the numerical simulation cases including seakeeping tests and reported the results to the organizers. Most of the simulations mentioned above are preformed in regular wave, and more complex wave condition should be considered and deeply studied.

In this paper, a computational fluid dynamics simulation method is developed to establish a 3D viscous numerical wave tank (NWT), and the heave and pitch motions of ship in regular and white noise irregular head waves are predicted. A numerical approach of wave-generation method by defining inflow boundary conditions is employed to generate waves, and the outgoing waves are numerically dissipated inside an artificial damping zones located at the outflow boundary. To predict the motions of ship in waves, the kinematics equations of a rigid body and the Reynolds Averaged Navier–Stokes (RANS) equations describing the flow around ship are solved simultaneously. The flow solver uses second order upwind discrimination, SIMPLE algorithm method for pressure-velocity coupling, and RNG $k–\varepsilon$ two equations turbulence model with wall functions. The free surface is captured by the volume of fluid (VOF) method. The method is applied to simulate...