Numerical Study on The Effect of Water Depth on Roll Natural Period and Damping Coefficient of DTC in Shallow Water Regions

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ABSTRACT

With the gradual large-scale of ships, some navigational areas can no longer be regarded as deep water but shallow water. The hydrodynamic performance of ships in shallow water is significantly different from that in deep water. Therefore, it is of great significance to study the roll motion of ships in shallow water and analyze the influence of water depth. In this study, the container ship model DTC (Duisburg Test Case) is selected as the computational model and the numerical simulations are conducted at different water depths. The simulation results of different water depth conditions are compared in detail to investigate the effect of water depth on roll natural period and damping coefficient and the cause of the change.

KEY WORDS: DTC; shallow water; overset grid; free roll decay; CFD.

INTRODUCTION

In recent years, the drought conditions due to global warming have led to a low water level in many rivers. With the gradual large-scale of ships, some navigational areas can no longer be regarded as deep water but shallow water. The navigation risk will be greatly increased because of the effect of the seabed, shore wall, etc. When ships sail in restricted waters, the hydrodynamic performance of ships in shallow water is significantly different from that in deep water. The roll motion of the ship will affect the stability of the ship and the comfort of the people on board, it is one of critical risks for the safety when the ship sails in the sea. Therefore, it is of great significance to study the roll motion of ships in shallow water and analyze the influence of water depth.

At present, there are two methods to study the hydrodynamic performance of ships in shallow water: Experimental Fluid Dynamics (EFD) and numerical calculations based on Computational Fluid Dynamics (CFD). For EFD, the model tests are carried out in towing tank, which is the most reliable method and is widely used for comparative validation of numerical calculation results, the manoeuvring characteristics of the Esso Osaka in shallow water were investigated in Manoeuvring Committee in 21st ITTC, performing a series of model tests and full-scale sea trials (ITTC, 2002). The Flanders Hydraulics Research (FHR) in Belgium and the University of Ghent jointly carried out a series of model test studies of KVLCC2, DTC and a large container ship type (ULCS) under the action of waves in shallow water, and published the relevant test results, including the hull motion response under different working conditions and the hydrodynamic force of the hull (Ruiz, 2015; Sprenger, 2017). The Knowledge Centre investigated the manoeuvring characteristics of the KVLCC2 and DTC in shallow water carrying out captive model tests in the framework of the European SHOPERA project (Papanikolaou et al., 2015), with particular attention to the presence of waves. Mehr (2022) focuses on investigating the effect of water depths on the roll natural period of a vessel in calm water condition such as operating on inland waterways. Roll decay tests were undertaken to obtain the roll period of two models (Container ship and Bulk carrier), with different CB, in calm water condition with zero forward speed. From the experiment, it was shown clearly that the roll period was affected by the change in water depth especially in the shallow water region due to the change of roll added mass moment of inertia.

CFD method has the advantages of high fidelity, high efficiency, and the ability to obtain detailed information of flow field, it has been widely used in ship hydrodynamic forecasting. Oortmerssen (1976) calculates the added mass coefficient, damping coefficient, wave force and motion response of a zero-speed tanker in shallow water by using free-surface Green function method. Carrica et al. (2016) carries out a 20/5 zigzag manoeuvre for the KCS in shallow water at the water depth to the draft ratio of 1.2 with the CFD method. Timo (2019) used the Rankine source element method in the high-order time domain to carry out numerical calculations on the 5th MASHCON benchmark research condition, and obtained the additional mass and damping coefficient of DTC ship models in different water depths, as well as the motion response and wave drag increase when sailing against the waves in regular waves. Kim et al. (2022) used the unsteady Reynolds-Averaged Navier-Stokes (URANS) computations coupled with the equations of rigid body motion with full six degrees of freedom (6DOF) to comprehensively analyze the manoeuvrability of the KRISO Container Ship (KCS) model in different shallow water conditions.