Performance Analysis of Vessel Towing System in Shallow Water

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ABSTRACT

With the development of the shipbuilding industry, the scale of ships has increased, and towing operations have gradually expanded to shallow water. The hydrodynamic characteristics of a ship traveling in shallow water are very different from those in deep water. Methods derived from open water are no longer applicable in shallow water. Performance analysis of shallow water towing system is needed. The towing performance in shallow water is of great importance to the smooth operation of towing.

The calculation of cable tension based on potential flow method cannot reflect the influence of shallow water drag increase phenomenon on cable tension. Therefore, the frictional resistance line of the KCS boat in shallow water was corrected. Then the resistance extrapolation is performed to obtain the fluid load. Catenary model is introduced to simulate cable model, and six DOF motion of rigid body model for the motions of the ship. Numerical simulations of the forces on the towing system at different water depths were carried out. The effect of shallow water conditions on towline tension was studied and investigated. The results show that the increase in tension caused by shallow water can range from 10\% to 30\%. There is a certain guidance for the cable selection in shallow waters and the power selection for towing vessels.

KEY WORDS: towing system; shallow water; CFD; numerical simulation; resistance extrapolation.

INTRODUCTION

When the towing system sails from the deep water area to the shallow water area such as ports, inland rivers, and shallow seas, the distance between the bottom of the ship and the bottom of the water constitutes shallow water conditions, which in turn affects its hydrodynamic performance. The shallow water effect can be studied by experimental methods and CFD (Computational Fluid Dynamics) methods. Simonsen(2006) did a complete set of VLCC2 shallow-water experiments, and obtained the VLCC2 resistance curve under different water depth and drift angle. Mucha(2017) conducted a model test of inland river boats to calculate the shallow water resistance of inland river vessels.

With the development of CFD technology, methods for calculating ship resistance based on CFD numerical simulation became possible (K. Niklas, 2019). Ni(2011), combining the three-dimensional extrapolation with CFD numerical simulation methods, a new forecasting method for rapid prediction of real ship resistance based on CFD numerical simulation calculation is proposed. However, this method is only applicable to deep water conditions because he used the friction resistance line proposed in ITTC57(ITTC, 1957). The key point of shallow water resistance forecasting is to propose a new friction resistance line. Zeng et al. (2019) studied the shallow water effect by establishing water restriction conditions in 2D plates, and the results showed that for the same Re, when the two walls are close enough, the frictional resistance coefficient can be increased by 50\% at the lowest Re and 10\% at the highest Re. Subsequently, this research was extended to 3D conditions, the influence of water depth on the 3D hull and the influence of ship type on frictional resistance coefficient were analyzed, and ship friction lines in shallow water were proposed in the research of Zeng et al. (2020).

Most of the research on towing systems is carried out in deep water. Ismail(2019), studied the problem of controlling the transient planar dynamics of a two-ship tether connected by a massless cable. Fitriadihy(2013) studied the effects of an unstable towed ship and a stable towed ship were recorded using numerical analysis at various angles and velocities of wind. A 2D lumped mass method was applied to model towline motion incorporated with dynamic towline tension. The results showed that this towing instability could cause pulsed towing tension and could lead to serious towing accidents such as towing line breakage or collision. The shallow water effects will be noticeable when the ratio of water depth to ship draft is less than 4.0(1987, ITTC). Shallow water creates more uncertainty and it is necessary to take this into account during inland towing operations.

In this paper, the CFD software STAR-CCM+ is used to establish the shallow water effect calculation model. The empirical equation of shallow water frictional drag coefficient was fitted according to the numerical calculation results. The hydrodynamic parameters of the real