Numerical Study of Viscous Hydrodynamic Forces on a Ship Navigating near Bank in Shallow Water

Huaming Wang1,2, Zaojian Zou3, Yonghe Xie1 and Wanlun Kong3
1. School of Naval Architecture and Civil Engineering, Zhejiang Ocean University, Zhoushan, Zhejiang, China
2. School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China
3. Zhejiang Marine Research Development Institute, Zhoushan, Zhejiang, China

ABSTRACT

Hydrodynamic forces acting on a ship navigating near bank in shallow water are quite different from those in wide and deep water. In this paper, a CFD method based on Reynolds-Averaged Navier-Stokes (RANS) equations solution is applied to investigate the viscous flow field and the hydrodynamic forces on a ship navigating near bank in shallow water. SST k-ω turbulence model is adopted to enclose the governing equations in the numerical simulations. Viscous hydrodynamic forces and some detailed information of the flow field at different distances to the bank and different water depths are obtained. The validity of the proposed method is demonstrated by comparing the numerical results with experimental ones published in literatures. Some useful conclusions are drawn by analyzing the variation of the lateral force and yaw moment with the distance to bank and water depth, which can provide some practical guidance for manoeuvring and control of a ship navigating near bank.

KEY WORDS: viscous flow; lateral hydrodynamic force; yaw moment; bank effect; shallow water; numerical simulation.

INTRODUCTION

Most ships may undergo the process of departing from and entering harbors in their operations, and during the process the ships might pass through the water, of which the width and depth are confined. During the last decades, with the ship size becoming larger, waters such as gulls, estuary regions and inland channels are becoming shallower and narrower relatively. A ship navigating in these waters is often in the shallow water and near bank condition. In this condition, the hydrodynamic forces acting on the hull are more complicated than those in unrestricted waters, and it will become difficult to steer the ship because of the effects of the bank and shallow water. Therefore, it is of great significance for us to study the hydrodynamic forces on a ship navigating near bank in shallow water to ensure a safe navigation.

When a ship navigates in the waters near a bank, the flow around the hull is asymmetrical on the port and starboard sides of the hull due to the influence of the bank, which causes the asymmetry of the pressure distribution on the hull surface. Thus the ship may suffer a lateral force which attracts the ship to the bank and a yaw moment which pushes the bow away from the bank. Especially in shallow water, the hydrodynamic forces acting on the hull are much larger than those in deep water, and the possibility of ship collision with the bank increases greatly. Both bank and shallow water effects are dangerous factors for a ship navigating near the bank and in shallow water. A great deal of researches on the hydrodynamic performance of the ship navigating near the bank has been carried out during the past decades. Norrbom (1974) studied the bank effect through a large amount of captive model tests performed with a tanker model moving along long and short side wall banks and platform shallows, and off-set from the centre-line of a dredged channel. Renilson and Munro (1989) investigated the effect of the slope and angle on bank interaction by experiments. A series of model tests were conducted by Ch’ng, Doctors and Renilson (1993) to investigate the influence of a bank on the manoeuvring of a ship in restricted water. Li, Otooson and Trägårdh (2003) developed a mathematical model for prediction of bank effects based on experimental results, which is in general suitable for vertical and sloping banks, but not for flooded banks. Vantorre et al (1998–2003) conducted many tests to investigate the ship-bank interaction and developed a regression formulation for the lateral force and yaw moment. Moreover, some numerical methods were developed to predict the manoeuvring hydrodynamic forces acting on the hull navigating in restricted waters. Miao, Xia and Chwang (2003) developed a modified numerical approach based on Dawson’s method to study the lateral force and yaw moment on a ship traveling off the centerline of a rectangular channel. Recently, an international conference, the International Conference on Ship Manoeuvring in Shallow and Confined Water: Bank Effects was held in Antwerp, Belgium. However, most of the reports in this conference are about experimental and empirical methods. The CFD methods based on viscous flow theory have seldom been applied to the study of bank effects.

In this paper, an approach based on Reynolds-Averaged Navier-Stokes (RANS) equations solution by using a general purpose CFD code FLUENT is applied to investigate the viscous flow field and the hydrodynamic forces acting on a ship navigating near bank in shallow water. SST k-ω turbulence model is employed to enclose the governing...