

Numerical Simulations of Ship Motions in Confined Water by Overset Grids Method

Qingjie Meng, Decheng Wan

State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering,
Shanghai Jiao Tong University, Shanghai, China

ABSTRACT

Numerical simulations of ship navigation in confined water channel of varying channel width by using overset grid technique are presented. Three ship speed ($Fr=0.267$ and $Fr=0.316$ and $Fr=0.40$) and four canal width ($B=1.0L_{pp}$, $B=1.5L_{pp}$, $B=2.0L_{pp}$, $B=3.0L_{pp}$) were taken into account to analyze the channel bank effects and ship motions of heave and pitch. Finally a ship motion in a varying width channel is also carried out to validate the numerical results of ship heave, pitch and resistance in confined channel water by using the presented numerical method.

KEY WORDS: Confined water; overset grids; bank effects.

INTRODUCTION

There has been a growing tendency in the last a few years to maneuver vessels in confined waters while the number of port does not increase at the same rate. Therefore ship maneuvers in limit water continue to be of great importance. The hydrodynamic phenomena induced by the bank are important, since the ship's movements are strongly influenced by those phenomena which are very different from open water.

Maimun A. et al. (2009) studied ship maneuvering of a LNG ship in shallow water with ship-bank interaction effects using a Planar Motion Mechanism (PMM). The simulations show that the ship-bank interaction effects and rudder size have significant effect on the maneuvering capability of the ship. Wang H M. et al. (2009) studied the viscous flow around a ship undergoing unsteady berthing in shallow water with its focus on the lateral hydrodynamic force on a ship undergoing unsteady berthing in shallow water. The comparison with experiments showed very good agreement. Vantorre, M. et al. (2012) studied the behavior of ships approaching and leaving locks, A selection of model test results studying ship behavior approaching and leaving locks has been made available by the Knowledge Centre Maneuvering in Shallow and Confined Water. Katrien Eloit et al. (2011) used EFD technology to study ship behavior in shallow and confined water, and the parametric investigation of hydrodynamic effects through experimental fluid dynamics is illustrated for ship maneuverability in shallow water, ship-bank interaction, ship-to-ship

interaction and the concept of nautical bottom. Rigo P et al. (2013) studied ship behavior in the situation which may occur in case of rapid river stream condition, when ships lost its power in current. It is demonstrated how a ship behaves in the current and relatively large drift angle may happen, if the current is comparative to ship speed.

In order to study the difference of the resistance when a ship moving in limited water and open area, in this paper, we present computations of heave and pitch of wigley ship using a single-phase level set method to compute the free surface flow. Ship motions are handled by using overset grids, with interpolation coefficients obtained at each time step.

Predicted results for heave and pitch and resistance at three ship speed ($Fr=0.267$ and $Fr=0.316$ and $Fr=0.40$) in open area were designed for verification and validation analysis. Additional, Froude number ($Fr=0.316$) case was subject to grid convergence study by running three grids with refinement ratio $\sqrt{2}$. Heave and pitch computations were performed for three ship speed ($Fr=0.267$ and $Fr=0.316$ and $Fr=0.40$) and for four canal width ($B=1.0L_{pp}$, $B=1.5L_{pp}$, $B=2.0L_{pp}$, $B=3.0L_{pp}$). The computation of ship behavior free to heave and pitch in inclined channel at three different speed was also demonstrated.

MATHEMATICAL AND NUMERICAL MODEL

Governing equations

In this paper, we use an inertial coordinate system to compute the flow field and ship motions. And the viscous flow around the hulls is assumed incompressible and the numerical problem is described by RANS equations coupled with the time-averaged continuity equation. For Cartesian coordinates, the unsteady incompressible RANS and continuity equations in non-dimensional tensor form can be written as:

$$\frac{\partial U_i}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_j} = -\frac{\partial \bar{p}}{\partial x_i} + \frac{1}{Re} \frac{\partial^2 U_i}{\partial x_j \partial x_j} - \frac{\partial}{\partial x_j} \overline{u_i u_j} \quad (2)$$

where $U_i=(u, v, w)$ are the Reynolds-average velocity components,