Proceedings of the Twenty-fifth (2015) International Ocean and Polar Engineering Conference **www.isope.org**
Kona, Big Island, Hawaii, USA, June 21-26, 2015

ISBN 978-1-880653-89-0; ISSN 1098-6189

Numerical Simulations of Viscous Flows around a Ship While Entering a Lock With Overset Grid Technique

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ABSTRACT

By solving the unsteady RANS (Reynolds Averaged Navier–Stokes) equations in combination with the *k-ω* SST turbulence model, the unsteady viscous flow around a 12000TEU ship model while entering a lock at different speeds is simulated and the hydrodynamic forces and vertical displacement are predicted and analyzed. Overset grid technology is used to maintain grid orthogonality. The effects of the free surface are taken into account. A benchmark test case is designed first to validate the capability of the present methods in the prediction of the viscous flow around the ship when maneuvering into the lock. Accumulation of water in front of the ship during entry into a lock is noticed, which causes the increase of the velocity of the return flow. A set of systematic computations with different ship speed are then carried out to examine the effects of ship speed on the ship-lock hydrodynamic interaction while entering a lock. At higher ship speeds, more water is pushed into the lock and higher velocity of the return flow is shown. Moreover, there will be higher risk for the bottom of the ship to hit the bed.

KEY WORDS: lock; 12000TEU; overset grid; ship-lock interaction.

INTRODUCTION

A number of locks have been under consideration or construction in recent years. The growing number of large vessels can only be used if sufficient infrastructure, like locks, is available. Especially for large vessels that are most critical, the hydrodynamic phenomena induced by a lock entry are important, since the ship's movements are strongly influenced by those phenomena. A ship will experience a particular hydrodynamic force caused by the hydrodynamic interaction with the lock, during the entering manoeuvre into a lock. The hydrodynamic interaction has a significant influence on the ship navigation safety, and the study on this influence is of crucial importance for safe operation and effective control of ships passing through a lock.

The lock approach will always be accompanied with an effect of shallow water on the hydrodynamic forces, since ships are allowed with a very small under keel clearance to exploit the lock maximally. Ships can also have very small side margins in the lock and thus typically a high blockage. The high blockage influences the flow along the ship hull, increasing the relative speed between ship and return flow. Furthermore, the high blockage also causes a so called piston effect, which provokes an accumulation of water during entry into the lock. The frictional resistance increases and water piles up inside the lock resulting in higher resistance.

Several methods are used in order to examine the feasibility to use locks for large vessels. Particularly the entrance of large ships has proven to be crucial. Real scale and model scale tests can be carried out, but reliable simulations are necessary to examine infrastructure in an affordable and efficient manner.

Vrijburcht (1988) used six-waves-model to calculate the translation waves generated by the lock entry. Vergote (2012) improved the six-waves-model model. Chen (2010) developed viscous frictional model to calculate dynamical ship-lock interaction problem. Delefortrie et al. (2008, 2009) analyzed the navigation behavior of different ship models in the Third Set of Panama Locks and the influences of approach wall configurations, eccentricities, propeller rates, approaching scenarios and under keel clearances were discussed. Verwilligen and Richter (2012) investigated the entering manoeuvre of full form ships into the Terneuzen West Lock by means of model testing, full scale trials and real-time simulations. Wang et al. (2014) studied the viscous flow around a ship when entering the Pierre Vandamme Lock based on CFD package Fluent, but the free surface was neglected.

The objective of this study is to predict and analyze the viscous flow and hydrodynamic forces of a 12000TEU ship model during maneuverer into the Third Set of Panama Locks. At the first stage, the capability of the present method for the prediction of the viscous flow around the ship model is confirmed by the good agreement of the predicted results with the corresponding experimental data. Then a series of systematic computations with different ship speed are carried out and the predicted forces and moment and vertical displacement, are analyzed to investigate the viscous flow around the ship and the influence of the ship speed on the ship-lock hydrodynamic interaction during entry into a lock.

The computation is carried out by an in-house research code based on