Numerical Analysis of Ship Hull Resistance Considered Trims

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ABSTRACT

In this paper, we firstly obtained the data of ship hull resistance of a very large crude carrier (VLCC) due to trims relying on ship model experiment. Then, we built up the full scale numerical model of the ship and calculated the ship hull resistance at various trims based on Reynolds Average Navier-Stokes (RANS) equation, mass conservation equation and continuity equation. Next, we compared and analyzed the results of numerical simulation and ship model experiment. Lastly, the characteristic value of the ship hull resistance was proposed for saving fuel consumption.

KEY WORDS: VLCC; ship hull resistance; CFD; trim.

INTRODUCTION

With the rapid development of world economy, the trend of large-scale ship is growing faster. Most oil tankers’ capacities are over 300000 tons, and the enormous consumption becomes a problem which is firstly considered by VLCC carrier. Besides, in recent years, there is a surplus of global shipping capacity, and market demand remains weak. How to compress fuel costs, expanding profit space, becomes a problem which is worth to study. The shape of a VLCC’s underwater part directly affects the hydrodynamic performance. As a result, VLCC’s navigation attitude has a direct effect on resistance. Adjusting trim properly can obviously reduce VLCC’s fuel consumption (Chen, 2010; Makino and Masuda, 2008).

Due to the complexity and irregularity of both the shape of VLCC’s underwater part and its sailing performance, it is difficult to use formula to calculate and forecast how the navigation attitude influences the resistance. In MMG ship motion mathematical model, the influence of trim is considered in resistance regression formula (Zhou-Sheng and Fen, 1983). But only a correction factor is added, and the formula comes from old types of ship. So the accuracy of this method cannot meet the requirements. At present, the influence of trim on ship’s resistance can be studied with the method of ship model experiment. However, it costs too much for common scholars, and the accuracy is affected by scale effect. Seeking for a fast and accurate method to study the influence of trim on ship’s resistance is of great significance.

In recent years, the increasing computational power particularly in terms of available parallel computing resources has made it possible to perform more detailed studies, but also to deal with more complex problems (Huang and Yamaguchi, 2010; Raven and Ploeg, 2008). As the experience on the use of CFD methods is increasing and as the simulation methods are becoming more mature and flexible the range of CFD applications is expanding further (Yang and Tao, 2013). There is a clear trend of using CFD increasingly to make full scale predictions which overcome the scale effect of ship model experiment. CFD provides a new method to solve the problem.

In this paper, we describe a numerical analysis of ship hull resistance considered trims. Unlike past research methods, we made a full-scale 3D model of a VLCC to avoid the scale effect, and defined the computational domains of flow field according to the ITTC formula (ITTC, 1999). Then, we meshed the domain with hexahedral meshes. Based on the mesh, we achieved the simulation by applying RANS (Yusuke-Robert-Wilson and Carrica, 2006) and Volume Of Fluid (VOF) method under two common loading condition and through the open channel flow (Chaudhry, 2008) to simplify the boundary condition and produce a uniform flow. At last, we analyzed the influence of trim on VLCC’s resistance, and find out the characteristic value of the ship hull resistance.

RESISTANCE CALCULATION METHOD

Numerical simulation method

In order to research the ship hull resistance considered trims, we chose a common simulation method in CFD, which is Reynolds Average Navier-Stokes (RANS). Under the assumption of viscous and incompressible fluid, the governing equations are two continuity equation and RANS equations as follows:

\[
\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_i)}{\partial x_i} = 0, \quad (i = 1, 2, 3) \tag{1}
\]

\[
\frac{\partial}{\partial t} (\rho u_i) + \frac{\partial (\rho u_i u_j)}{\partial x_j} = -\frac{\partial \rho u_i}{\partial x_i} + \frac{\partial}{\partial x_j} \left( \mu \frac{\partial u_i}{\partial x_j} - \rho u_i u_j \right) + S_i \quad (j = 1, 2, 3, i = 1, 2, 3) \tag{2}
\]

where \(\rho\) is the density of the fluid, \(t\) is the time variable, and \(u_i\) are the components of velocity.