Research on Self-Propulsion Simulation and Applications on Hull Form Optimization

Lin Lin, Shengren Wei, and Guisheng Peng
Dalian Shipbuilding Industry Design & Research Institute
Dalian, Liaoning, China

ABSTRACT

In this paper, we investigated the accuracy of self-propulsion simulation based on SHIPFLOW. Through grid dependency study, an appropriate grid size which can well balance accuracy and efficiency has been found. Based on this grid size, validations of self-propulsions of different ship types have been made to verify the feasibility of numerical method. Then we apply this numerical method of self-propulsion to three engineering projects: hull form optimization of a VLCC, hull form optimization of a VLOC at three different LCB positions and determination of propeller disk position of a VLGC. Results show this numerical method for self-propulsion simulation is practical for hull form optimization.

KEY WORDS: Self-propulsion simulation; hull form optimization; SHIPFLOW; accuracy; efficiency.

INTRODUCTION

Predicting the self–propulsion point of the ship is one of the main practical problems in marine hydrodynamics. Because of involving induced velocity filed by rotating propeller and viscous velocity field in boundary layer, ship self-propulsion is a very complex problem. It not only needs to consider interaction between hull and propeller, but also viscous effect, free surface effect and propeller unsteady rotation effect. There are two methods to solve hull-propeller interaction problem: one is body force method and the other is discretized propeller method. Body force method(Hino,2006; Choi,2009) couples fluid field computation program and propeller open water prediction program through body force. Discretized propeller method(Lubke,2005) incorporate propeller into RANS equation, i.e. actual propeller geometry is needed when grid generation and viscous no-slip boundary condition should be satisfied on propeller surface. In this method the propeller rotation is enabled by either a sliding interface approach(Quétey,2012) or dynamic overset grids(Carrica,2010). Since discretized propeller approach requires significant computational time, researchers have come up with different ways to speed up their computations without significantly affecting the results. For example, Ponkratov (Ponkratov,2015) first ran sliding interface CFD simulations with the Multiple Reference Frame (MRF) approach without rotating the propeller until the free surface stabilized, and then turned to full propeller rotation. Also, Carrica (Carrica,2015) presented a partial rotating frame approach, which allowed it to increase the time step with fully discretized propeller by one order of magnitude, while still being able to model a part of the propeller rotation. The application of discretized propeller method is restricted due to its complexity, especially for hull form optimization problem which need huge computations and analysis. Therefore, body force method is preferred to research hull-propeller interaction problem.

In the past few years, significant progress has been made in numerical simulation of self-propulsion problem, but simulation accuracy and efficiency still need to be improved. Therefore, developing faster and more reliable methods for CFD-based predictions of hull-propeller interaction becomes a hot topic, especially when used for hull form optimization.

In this paper, we propose a self-propulsion simulation method which can well balance accuracy and efficiency based on SHIPFLOW software. The effect of propeller is introduced in the RANS method as a body force for numerical modeling of propeller. The speed of propeller is automatically adjusted during the self-propulsion simulation such that the propeller thrust balances the resistance on the hull corrected for the towing force. A grid dependency study was carried out based on an Aframax tanker to find the best grid size which can well balance accuracy and efficiency. Validations of a VLCC and a chemical tanker were carried out based on this grid size to verify this method is faster and reliable. Then we apply this method to optimization for a VLCC(Very Large Crude Oil Carrier), a VLOC(Very Large Ore Carrier) and a VLGC(Very Large Gas Carrier). The optimization is carried out in the SHIPFLOW-CAESES DESIGN environment. Delivered power is taken as the optimization objective while the design variables are form local parameters of the hull form. Results show this numerical method for self-propulsion simulation is practical for hull form optimization.

NUMERICAL METHOD

Flow solvers

The basic theory of SHIPFLOW can be referred to many literatures (Broberg, 2012). For potential flow, it is a non-linear Rankine source panel method. It uses higher order panels and singularity distributions and a non-linear free surface boundary conditions. For viscous flow, SHIPFLOW solves steady incompressible RANS equation by finite