CFD Investigations of Ship Propulsion Performance at Different Trim Angles

Jianhua Wang¹, Decheng Wan¹*, Moustafa Abdel-Maksoud²

¹Computational Marine Hydrodynamics Lab (CMHL), State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China
²Institute for Fluid Dynamics and Ship Theory, Hamburg University of Technology, Hamburg, Germany
*Corresponding author

ABSTRACT

In the present work, ship propulsion performance at different trim angles are investigated. CFD method with dynamic overset grid technique is used to directly simulate the free running ship model. The self-propulsion with design ship speed $Fr=0.20$ is firstly conducted and the predicted results are compared with experimental data. Then ship with different trim angles varying from $-0.8^\circ$ to $1.6^\circ$ are simulated to investigate the propulsion behavior at different trim condition. All the numerical simulations are carried out by CFD solver naoe-FOAM-SJTU. Hydrodynamic forces including thrust and torque of twin propellers are analyzed. It is found that the thrust and torque have much different behavior at negative and positive trim angle. The corresponding wake flows at different trim angles are responsible for the above propulsion characteristics.

KEY WORDS: Ship propulsion; trim effect; overset grid method; computational fluid dynamics; ship hydrodynamics.

INTRODUCTION

Recently, the performance of ship propulsion, especially for the efficiency of propulsion, has become a very hot topic due to the strict terms proposed by International Maritime Organization for the newly built commercial ships to meet the increasing requirement of Energy Efficiency Design Index (EEDI) regulations. Thus, it is of great importance to find a suitable and reliable approach to evaluate the ship propulsion performance under various conditions. Generally, ship propulsion is closely related to resistance and the propeller performance. In order to evaluate a ship’s propulsion performance, firstly we need to have the ability to estimate the behavior of ship hull-propeller interaction, and another important aspect is the resistance prediction at different conditions. Both the above two aspects can contribute to improve the efficiency of ship propulsion. For the hull-propeller interaction, it is very essential to have an accurate prediction model of the hydrodynamic forces of self-propelled ship to see whether the reduction of power will affect the performance of ship propulsion. For the ship resistance, ship trim optimization will have a good influence on the hydrodynamic forces of ship hull and further finding a proper position to reduce the resistance. Therefore, trim angle effects on the ship propulsion should be drawn more attention.

Regarding to the prediction of ship propulsion with ship-propeller interaction, there are mainly two approaches, one is the experimental study and another one is the computational fluid dynamic (CFD) simulations. Experimental tests in a towing tank with free-running model is widely used to predict the performance of ship propulsion. The experiments can give reliable data, while the facility cost is very expensive and the test procedure are still very complex. The disadvantage can be more obvious when we want to get the detailed flow information for further analysis. So far, many researchers are using the CFD approach to predict the ship-propeller interactions and the previous studies can be classified into two categories based on the propeller description: body-force model and discretized propeller model. The body-force model is more efficient when compared with the simulations using fully discretized propeller model. Gaggero et al. (2017) carried out self-propulsion simulation using coupled BEM/RANS approach and the authors noted that the more work need to be done to improve the accuracy of the coupled model. Gokce et al. (2018) performed CFD simulations of self-propulsion based on RANSE approach, where a virtual disk propeller model are used to compare with empirical methods. It is concluded that the body force model has a better performance than empirical method with respect to empirical relations advised by IMO.

Apart from the body force propeller model, fully discretized propeller using dynamic overset grid method has been successfully applied to the CFD simulations of ship-propeller interaction. Carrica et al. (2010) computed the self-propulsion of KCS model free to trim and sinkage with using discretized propeller and the results show good agreement. Castro et al. (2011) also simulated the self-propulsion of KCS model...