Full scale simulations of the external and internal flow fields for a waterjet-propelled ship

***Jie Gong[1,2], †Chunyu Guo[1], Chao Wang[1], Nhan Phan-Thien[2], Boo Cheong Khoo[2], and Di Wang[2]**

[1]College of Shipbuilding Engineering, Harbin Engineering University, China
[2]Department of Mechanical Engineering, National University of Singapore, Singapore

*Presenting author: gongjie13@hrbeu.edu.cn
†Corresponding author: gcy_heu@163.com

Abstract

Waterjets are widely used in high-speed marine vehicles due to the high propulsive efficiency and better cavitation margins. With the development of the upgrading design, waterjets have been gradually applied to large–scale ships. Model tests are the most common and reliable method to predict the hydrodynamic performance of the waterjet ships, however, it has to admit that extrapolating results of full-scale ships are unsatisfactory due to the scale effect of the flow fields in experiments. Differs from the wake fields of ships with conventional screw propellers, the flow fields of the waterjet-propelled ships consist of the external and internal flow fields as part of the flow enters the waterjet from the hull bottom. By virtue of Computational Fluid Dynamics (CFD) tool, a direct full-scale simulation of the waterjet-propelled ships is an alternative way to predict the hydrodynamic performance of the actual ship. Also, it could provide some reference for the scale effect study of the flow fields.

In present study, a four-waterjet-propelled ship is studied with considering the free surface effect, and the viscous flow fields in model and full scales are solved numerically by RANS methods. The SST $k-\omega$ turbulence model is selected for all model and full scale simulations as suggested by International Towing Tank Conference (ITTC). The Volume of Fluid (VOF) model is utilised to capture the free surface, and two virtual disk (VD) models are employed to simulate the effect of the pump with the body force method. The Reynolds numbers (*Re*) are $1.9*10^7$ for the model-scale cases and $1.2*10^9$ for the full scale cases.

Model-scale simulations were used to verify the grid generation and calculation method, and the verification and validation (V&V) of numerical results is accomplished. It is noted that $|E| < U_V$ (comparison error < validation uncertainty) was satisfied in five stations for the averaged values based on the L2 norm. Solutions of the resistance coefficients are validated at the level of 5%, while the uncertainty $\|U_{SN}\|_2$ is within 20% of the flow field analysis. With respect to the external flow fields, it is found that the total ingested boundary layer thickness in the capture area is relatively thinner in full scale simulation than that in model scale, and thus led to the large values of the momentum/energy velocity coefficients, which means the model scale simulation overpredicted the negative effect of the hull on the waterjet inflow. For the internal flow fields, the axial velocity distribution and uniformity of the pump inflow plane are compared. A symmetric velocity distribution is observed for inner waterjet (IW), while an asymmetric law is observed for outer watetjet (OW) which is related to the inflow characteristics. Major difference of the turbulence kinetic energy (TKE) between model and full scale simulations concentrates on the wall boundary of the channel, and the turbulence intensity is apparently different for high turbulence flow under different Reynolds numbers.

Keywords: Hydrodynamic; Waterjet ship; Full-scale; Scale effect