A simple body-force distribution model by quasi-steady blade element theory is coupled with the Reynolds averaged Navier-Stokes (RANS) code CFDSHIP-IOWA to study the propeller-hull interaction around Series 60 CB = 0.6 hull. The hull form is modified with the stern tube and the hub; and the propeller is a right-handed 5 blade fixed pitch. Modified-AU methodical series type which is treated as infinite bladed model. In this paper as an extended research of Win et.al (2013), the detailed flow field in the wake region is observed and the effect of the existence of the rotating hub in the computation of the propeller is analyzed.

KEY WORDS: Body-force; blade element theory; Series S60; CFDSHIP-IOWA; propeller-hull interaction.

INTRODUCTION

A simple new propeller model has been recently developed by authors group with a body-force distribution concept by quasi-steady blade element theory (Tokgoz et.al (2014) and Win et.al (2013)). Within this theory, the inflow velocity components, including induced velocity effect by time-averaged infinite bladed vortex system shed by propeller blade, to the propeller are determined by CFD code and thrust and torque distributions are calculated by blade element theory. By using this model, the propeller-hull interaction behavior has already been studied by the authors with Series S60 hull in original offset without stern tube and hub by coupling the propeller model with Reynolds averaged Navier-Stokes (RANS). In that study, the lack of stern tube and propeller hub in the computation made weaker vortex patterns near the shaft center position in propeller wake than Experimental Fluid Dynamics (EFD) data where the hull was modified to attach the stern tube and the propeller with the propeller hub.

In order to recover the weak point of previous research and to understand the interaction behavior in the inclusive of stern tube and hub, the original S60 hull is modified by attaching the stern tube to the hull and the propeller dummy hub is added similar as the model in experiment. The computations are performed for the ship sailing straight ahead with- and without propeller. In the without propeller case, the bare-hull results are made sure for confirmation with the experimental data to prove the magnitude of the flow field quantities with fair agreement. With the propeller model working, the computation is performed at the model point and the results of the flow fields in the wake regions are compared with the EFD data as well as between the results of with- and without hub.

COMPUTATIONAL BACKGROUND

Computational Fluid Dynamics Method

The computations are performed with the RANS solver CFDSHIP-IOWA version 4 which is an unsteady single-phase level-set solver with dynamic overset grids. It solves the continuity and unsteady incompressible RANS equation (Eq. (1) and Eq. (2)) using a blended \( k-\varepsilon \) model for turbulence without wall-function. Captive, semi-captive and full 6DOF capabilities for multi-objects with parent/child hierarchy are available but 6DOF function is deleted out in the present work and the computation is performed for the ship-fixed case parallelization with MPI-based domain decomposition.

\[
\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial X_j} = - \frac{\partial p}{\partial X_i} + \frac{1}{Re} \frac{\partial^2 U_i}{\partial X_j^2} - \frac{\partial}{\partial X_j} \left( \frac{\partial U_i}{\partial X_j} + f_{hi} \right)
\]  

(2)

\( X_i = (X, Y, Z) \) are the Cartesian coordinate non-dimensionalized by ship length \( L_{pp} \), where \( X \) is in axial (ship length) direction, \( Y \) is in starboard side direction and \( Z \) is in upper direction, respectively. The origin is in center plane at FP and at still water surface. \( U_j = (U, V, W) \) are mean velocity components in \( X, Y \) and \( Z \) directions, respectively and \( U_i \) is fluctuation velocity which are non-dimensionalized by the ship speed \( U_0 \). Non-dimensional piezometric pressure \( \hat{p} \) is defined as \( \hat{p} = (p - p_a)/(\rho U_0^2) + Z/\text{Fr}^2 \), where \( p \) is pressure, \( p_a \) is air pressure, \( \text{Fr} = U_0 \sqrt{g/\rho} \) and \( g \) is gravity acceleration. \( f_{hi} \) is the body-force term representing the propeller model effect non-dimensionalized by \( \rho U_0^2 / L_{pp} \) which is calculated as in Eqs. (18–19),