Estimation of Marine Propeller Performance in Open Water

Case Study of SC/Tetra

Using SC/Tetra to estimate marine propeller performance for the boundary layer transition phenomenon

Estimation of Propeller Performance in Open Water

Most of a ship's propulsive power is provided by a propeller. Enhancing propeller efficiency, even by small percentage points, can lead to significant environmental and economic benefits. These potential benefits can include massive reductions in carbon dioxide emissions and major improvements in fuel efficiency.

Developing a highly efficient propeller requires conducting an accurate performance estimation during development. In this case study, the suitability of using a CFD simulation tool to evaluate propeller effectiveness was performed by comparing analysis results with experimental measurements[1].

[1] Fujiyama et al., Turbomachinery, 40th volume, pp.212-217, 2012 (in Japanese)

Analysis model

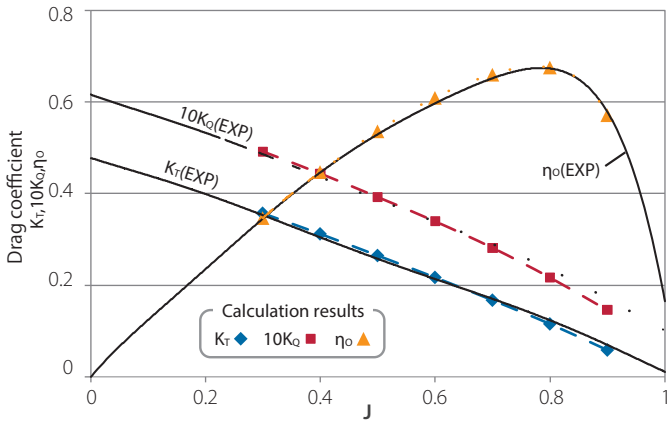
High skew propeller of Seiunmaru

Seiun-Maru high skew propeller
Model: HSP-II (MP No.220)
Number of blades: 5
Diameter: 220 [mm]
Rotation speed: 12 [rps]

Analysis Mesh

Number of mesh elements: 55 million
Boundary layer elements: First layer $5 \cdot 10^{-7}$ [m], 30 layers

Analysis results of propeller performance in open water



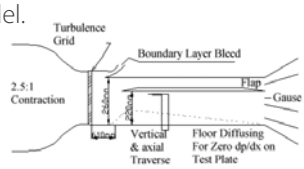
Advance ratio	$J = U/nD$
Thrust coefficient	$K_T = T/\rho n^2 D^4$
Torque coefficient	$K_Q = Q/\rho n^2 D^5$
Efficiency	$\eta_O = J \cdot K_T / 2\pi \cdot K_Q$

Analysis results agreed well with measurement[4]

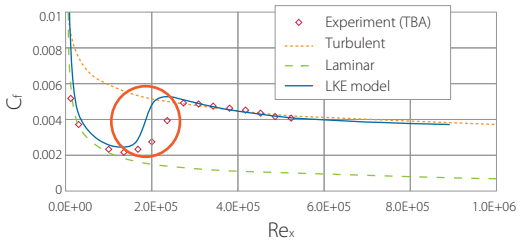
LKE k-k_L-ω model

LKE k-k_L-ω model[2], which accounts for laminar-turbulent transition, was used for the turbulence model.

Laminar-turbulent transition of the flat plate boundary layer[3]

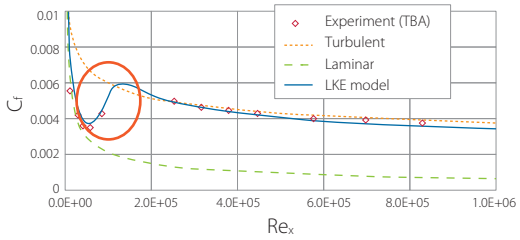


T3A



○ = Position of transition is accurately predicted

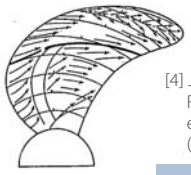
T3B



[2] Walters, D.K., et. al., ASME J. of Fluids Engineering, 130, 121401, 2008
[3] Coupland, J., ERCOFTAC Special Interest Group on Laminar to Turbulent Transition and Retransition, 1990

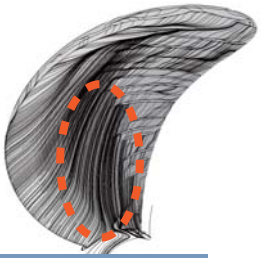
Flow on propeller blade surface

Experiment [4]



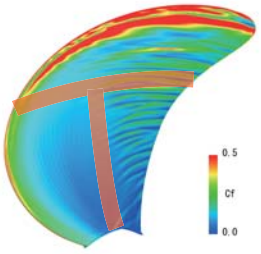
[4] Japan Ship Technology Research Association, Research on propulsion capability of propeller and estimation methods of noise characteristics. 1986 (in Japanese)

Analysis results



Changes in limiting streamlines on blade surface were captured

Distribution of wall friction coefficient



Changes in streamline positions and increasing wall friction coefficient along the blade surface, due to boundary layer turbulent transition, agreed with experiment

Notes

By using SC/Tetra and applying a turbulence model that accounted for boundary layer transition, an accurate simulation was achieved for a marine propeller operating in open water. This confirms that CFD can be used for both propeller conceptual and detailed design evaluations. Conducting these studies as part of the propeller design and development processes can lead to more efficient propellers.