Effects of Section Geometry on the Energy-saving Rate of PBCF and Model/full-scale Correlation - A CFD Study

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Abstract

Propeller Boss Cap Fins (PBCFs) have been widely used in vessels as an energy-saving device that is cheap but effective. For the convenience and cost-saving of manufacture, most PBCFs take the shape of flat plates. As the Computerized Numerical Control technology is widely adopted in propeller manufacture nowadays, machining the PBCFs with a complex geometry becomes relatively easy and inexpensive, which makes it possible to further improve the design of the PBCFs. This paper shows a CFD investigation into the energy-saving rate of the PBCFs with systematically varied section profiles, focusing mainly on the camber-line geometry.

The steady flows and hydrodynamic performances of a propeller without and with the PBCFs were simulated by solving the Reynolds-averaged Navier-Stokes (RANS) equations using the software package STAR-CCM^{+}. The computational domain was divided into a number of sub-domains and discretized with hybrid unstructured grids. To determine a suitable grid setting, a grid convergence study was carried out first by changing the grid sizes separately in the sub-domains enclosing the propeller blades and the PBCFs. Then the RANS simulations were conducted at model scale and the hydrodynamic forces were evaluated for different thickness ratios and camber-line geometries of the PBCF sections. It was found that an S-shaped camber line with an appropriate camber ratio could further improve the energy-saving rate. The flows downstream of the boss cap were also investigated, including fin-surface pressures, circumferentially averaged velocity profiles, and so on, to explain the effects of section geometry on the energy-saving rate of the PBCFs.

Full-scale simulations were carried out using typical PBCF geometries investigated at model scale, and the results were compared with model-scale ones to evaluate the Reynolds scale effects on the energy-saving rate. The hydrodynamic forces acting on the propeller blades, the PBCFs, and the boss cap were compared to explore the mechanism behind the scale effects on the PBCFs.

Keywords: PBCF; Section geometry; Scale effect; RANS; CFD

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