Numerical Simulation of Energy Saving Effects of Pre-swirl Stators and Mechanism Analysis

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ABSTRACT With a CFD method based on the general CFD code FLUENT 14.0, the viscous self-propulsion flow fields of a model-scaled 55k DWT Product Carrier fitted with rudder-bulb-fin and pre-swirl stator, were numerically simulated. The energy saving effect of stator was evaluated through the increase of propulsive efficiency, which was in good accordance with the EFD data. And the computed changing tendencies of almost all the self-propulsion factors with stator relative to without stator were the same as experiments, such as decreased revolution rate, increased thrust deduction and mean wake. And the wake energy analysis was also done to verify the energy-saving effect of stator and the mechanism analysis showed that the stator decreases the flow kinetic energy behind the propeller through the contra-propeller pre-swirl.

KEY WORDS: Pre-swirl stator; energy-saving; self-propulsion; CFD.

INTRODUCTION

The importance of marine energy conservation has been recognized by many countries all over the world, and the techniques of ship energy-saving have been widely focused on. Compared with new type of energy-saving ship or highly efficient propeller, hydrodynamic energy-saving appendages are undoubtedly of low cost, high efficiency and convenience, such as ducts, stators, rudder-bulb-fins, and twisted rudders (Celic, 2007; Hollenbach, 2011). Better energy-saving benefits can be got by combining two or more different kinds of hydrodynamic energy-saving appendages. Pre-swirl stator is a kind of energy-saving device that attached to stern boss in front of a propeller. As to pre-swirl stator, Daewoo Ship Building claimed that through the combination of twisted rudder, bulb, and PSS, 3%~6% of energy-saving effect could be derived (Guo, 2014; Park, 2015).

Yang et al. (2014) evaluated the energy saving effect of a pre-swirl stator with tail flaps equipped with a large bulk carrier. The numerical simulated energy-saving effect measured by the increase of received power of propeller was 3.1%, while that of model test was 6.0%. And the energy-saving mechanism analyzed through velocity vector diagram and energy analysis in wake showed that it's the tail flaps that result the pre-swirl effect.

Huang et al. (2013) evaluated the energy saving effect of a pre-swirl stator equipped with a bulk carrier. Herein, the energy-saving effect was measured by the decrease of received power of propeller. And the numerical simulated result was 1.05%, while that of model test was 3.40%. It's shown that the torque was increased and the rotational speed was decreased, in all the received power was decreased. Huang et al. (2014) tried a compounded energy-saving technique with a combination of pre-swirl stator with a duct. This time they derived good agreement of numerical simulated result with model test. Still through the received power, they get the CFD energy-saving effect was 2.48%, and the EFD was 2.86%.

Miao et al. (2013) analyzed the circumferential arrangement of stator blades in a pre-swirl duct without the hull. The effects of angles of attack for a single blade, and intersecting angles for two blades were researched. For a single blade case, the circumferential influenced ranges of one stator were determined and the effects of attack angles on tangential pre-swirl were discussed. Furthermore, the best intersection angle between two blades was suggested to be 45°. In addition, Miao et al. (2014) set out thorough post-process of the CFD results got by Huang et al. (2013) and the resistance characteristics and pre-swirl mechanism of stator were proposed through analyzing its pressure contour and its effect on ship wake.

In this paper validation of numerical simulation and evaluation method of energy saving effect based on the general CFD code FLUENT 14.0 was done according to the model test data from SSPA provided by FTC. The comparison between the prototype and two modified types of stator was also done. And the energy saving mechanism was analyzed.

GEOMETRY AND MESH

Geometry Modeling

The origin of the CFD coordinate system is located on the axis of rudder at the stern where it meets the hull bottom base line. The x-axis lies in the center plane and bottom plane, positive toward the bow. The