Analysis of Hydrodynamic Performance of Tip Loaded Propellers

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ABSTRACT

In the current study, the hydrodynamic characteristics of two tip loaded propellers, a Contracted and Loaded Tip (CLT) propeller and a KAPPEL propeller, are numerically calculated by using the RANS method, comparing with the hydrodynamic characteristics of a conventional propeller. The numerical calculated hydrodynamic characteristics of a CLT propeller (P1727 Propeller) are firstly validated by comparing with the experimental results from the 28th ITTC report. The pressure and velocity field of the three propellers, especially those around the propeller tip, are then analyzed to examine the influence of the end plate on the hydrodynamic performance of the tip loaded propellers.

KEY WORDS: hydrodynamic performance; tip loaded propeller; CLT propeller; RANSE; wake field.

INTRODUCTION

Energy issues, energy conservation has become one of the important concerns around the world due to global energy issues. The tip loaded propellers, normally meaning unconventional propellers with end-plate effect, have then attracted the attention of designers for the possibilities of improving the efficiency of the propeller. The idea of end-plate has been used by aircraft designers for the design of winglets, inspired by the wings tip of birds which can be controlled to save their strength. This idea of winglets has then been introduced into marine propellers as unconventional propellers with end-plate effect, namely tip loaded propellers (Cheng HJ, 2010).

The tip loaded propeller maintains a certain chord length at the tip of the conventional propeller blade, and a small end plate is mounted on the blade surface to prevent the lateral flow around the blade tip. It would produce pressure difference between the blade face side and blade back side, allowing the propeller to generate more thrust and increased efficiency (Yan L, 2018). However, wide blade tips and end plates also increase viscous resistance and consume energy.

The geometry of the tip loaded propeller differs from the conventional propeller in the rake of the blade tip. A Contracted and Loaded Tip (CLT) propeller is dedicated to a propeller with an end plate that is bent toward the pressure side, which has been firstly proposed by Gomez (Gomez G.P, 1983). While a KAPPEL propeller is dedicated to a propeller with an end plate that is bent toward the suction side.

Hu ZA (1996) proposed that end plate propellers have the ability to prevent or eliminate tip vortices, and the load at the blade tip, can make the radial load distribution of the blade more uniform, resulting in the reduce of energy loss, and thus increase of propeller efficiency. Kappel et al (2005) applied the nonplanar principle to marine propellers, led to the KAPPEL propeller with blades curved toward the suction side integrating the fin or winglet into the propeller blade. The combined theoretical, experimental, and practical approach to develop and design marine propellers with nonplanar lifting surfaces has resulted in propellers with higher efficiency and lower levels of noise and vibration excitation. Sanchez et al. (2006) used the RANS method to simulate the incompressible viscous flow around an end plate propeller. The numerical results of hydrodynamic performance are in good agreement with the experimental results. The results of the computations show that RANS solvers are a valuable tool for assisting the propeller designer. Haimov (2011) used the RANS solver to calculate the open-water performance of ducted propellers and CLT propellers, with good agreement with the experiments. Gonzales et al. (2014) used the RANS solver and the surface element method to simulate the unconventional propeller in scale and full scale, confirming the reliability and accuracy of the RANS solver in the simulation of the tip loaded propellers.

Gaggero et al. (2015, 2016) based on a parametric description of the propeller blade proposed and implemented a design by optimization of contracted and tip-loaded (CLT) propellers. Based on this design, Boundary Element Method and RANSE results compared with the available experimental measurements in order to validate the adopted design approach. Confirming the plausibility of using RANSE calculations as reference and verification of the propeller performance when measurements are not available.

The current study focuses on the influence of the end-plate at the blade tip on the hydrodynamic performance of the tip loaded propellers by comparing the hydrodynamic characteristics and the wake field of a CLT propeller, a KAPPEL propeller and a conventional propeller with the same main dimensions and properties, despite of different rake at the blade tip.