INVESTIGATING PERFORMANCES OF PROPELLERS WITH DIFFERENT LOADING DISTRIBUTIONS BY ENERGY COEFFICIENT CONCEPT

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Long Abstract

Introduction

The objective of this paper is to investigate performances of propellers with different loading distributions by "Energy Coefficient" concept. We will try to understand the relationship between the propeller loading distributions and the energy loss in this paper. "Efficiency" usually cannot reveal the components of energy loss; however, the energy coefficients based on the momentum theory can decompose the efficiency into components, and they are axial loss coefficient, rotational loss coefficient, and axial gain coefficient. The coefficients are first defined and derived in this paper; two different methods, analytical method by Hough & Ordway, and Boundary Element Method, are first used for induced velocity computation. To investigate different loading distributions, a conventional container ship propeller, the end-plate propeller, Kappel propeller, along with a series of hub unloading propellers are analyzed by the present energy coefficient method. The analysis results will then be compared to the computational results from RANS method by transferring the pressure distributions to the circulation distributions. The variations of energy loss for propellers operating in the ship wake will also be analyzed in the paper.

Analysis Methods

The common index for evaluating propeller performance is "efficiency", which gives a proportion in energy delivery and transferring. In some sense, "efficiency" only provides the sum of energy loss. Since Glauert [1], many scholars have tried to characterize the physics of energy loss, and they have attempted to divide the efficiency into several parts by different theories. The present work is based on concept of energy coefficients raised by Swedish scholar Dyne [2][3]. He expressed efficiency as the sum of several components as in Equation (1).

$$\eta = (1 - w)(AXG - AXL - ROTL - FRL - FBNL) \tag{1}$$

In Equation (1), the terms on the right hand side are axial gain, axial loss, rotational loss, frictional loss and finite blade loss. Equation (1) has clearly described the components of loss, and has demonstrated the physics behind "efficiency". By some derivatives, the efficiency would be an expression of velocities, which can be computed from an analytical method developed by Hough and Ordway [4][5] and Boundary Element Method [6]. The terms AXL and ROTL related to the square of axial and tangential induced velocities hence regarded as axial and rotational energy losses. The term AXG related to the multiplier of axial induced velocity and velocity far downstream is recognized as axial gain energy. The axial gain energy is an idea that velocity recovering from the wake, and in the case of uniform inflow, AXG will be zero. FBNL introduces an error generate by the number of blades between momentum theory and the boundary element method. FRL is the loss due to frictional loss.

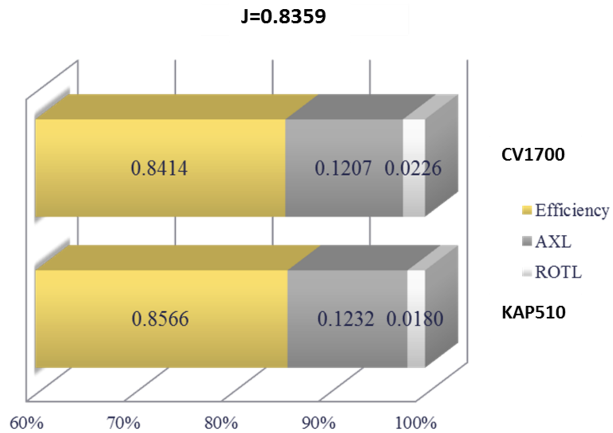

Figure 1: The energy coefficient analysis of a conventional propeller CV1700 (upper) and a Kappel propeller KAP510 (lower) at J=0.8359

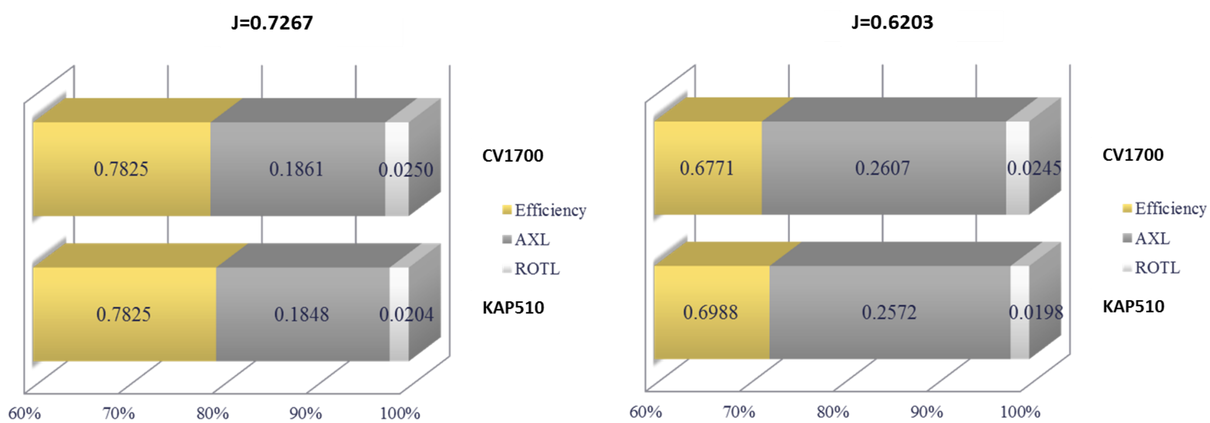

Figure 2: The energy coefficient analysis for a conventional propeller CV1700 (upper) and a Kappel propeller KAP510 (lower) at J=0.7267 (Left) and J=0.6203 (Right)

Preliminary Results

Some preliminary results are shown here. This case is the comparison between the Kappel propeller (KAP510) and a conventional container ship propeller (CV1700). Two propellers at three advanced coefficients, J=0.8359, 0.7267 and 0.6203 are evaluated, and the efficiencies of two propellers are the same at design J=0.7267. For J=0.8359, the efficiency of KAP510 is slightly higher than CV1700 as in Figure 1, and the analysis of energy coefficient method shows that KAP510 has more axial loss than CV1700, and this is due to higher thrust. On the other hand, the KAP510 has a lower rotational loss than CV1700. While in conditions J=0.7267 and J=0.6203, we obtain the same trend shown in Figure 2, and the Kappel propeller KAP510 has higher axial loss but lower rotational loss. This analysis shows that the end-plate effect propellers can indeed obtain a higher efficiency by recovering the tangential loss in steady inflow. More analysis will be carried out for these propellers in unsteady inflows.

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