International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 26, No. 1, March 2016, pp. 72–80; http://dx.doi.org/10.17736/ijope.2016.sh11
http://www.isope.org/publications/publications.htm

Application of Quasi-Continuous Method to Open-Water Characteristics Predictions of Propellers with Energy-Saving Ducts

Akira Hanaoka
Structural Strength Evaluation Department, National Maritime Research Institute
Mitaka, Tokyo, Japan

Yasutaka Kawanami
Fluids Engineering and Hull Design Department, National Maritime Research Institute
Mitaka, Tokyo, Japan

Munehiko Hinatsu
Imabari Shipbuilding Joint Research Chair, Graduate School of Engineering, Osaka University
Suita, Osaka, Japan

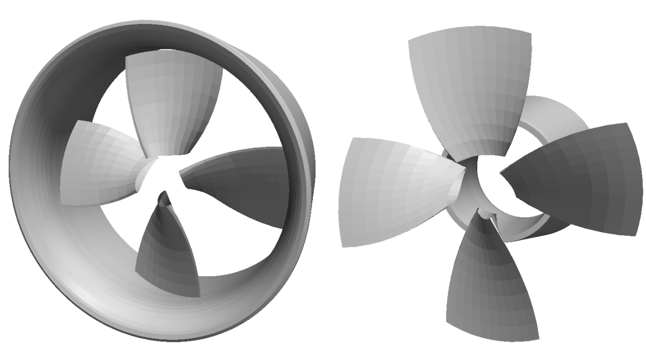
The quasi-continous method (QCM) was applied to open-water thrust and torque predictions of ducted propellers with different positions of the propeller and duct. Two methods to calculate the resultant velocity were discussed. The QCM results are in good agreement with the experimental data of the propellers positioned inside a duct. The results of propellers in the downstream part of the duct show no significant dependence on the length of the straight trailing vortex of the duct. Comparison with the results calculated without any duct indicates no improvement of the open-water characteristics calculated by positioning the present duct in front of the present propeller.

INTRODUCTION

As indicated by its name, a ducted propeller consists of two devices for propulsion, i.e., the propeller and the duct. There are two kinds of ducted propellers with regard to positions of the propeller and duct, as shown in Fig. 1. One kind of ducted propeller has the propeller inside the duct (Fig. 1a). The propellers rotating inside accelerating ducts show high propulsive efficiency at low speeds of advance. Because of this feature, the accelerating duct has been frequently applied in specific kinds of ships such as tugs and trawlers. The other kind of ducted propeller positions the duct in front of the propeller (Fig. 1b). This type of duct has been frequently used to enhance the propulsive efficiency of merchant ships and is known as a typical energy-saving device (ESD). The Sumitomo Integrated Lammeren Duct (SILD) and Mewis Duct are examples of ducts as ESDs in practice (Sasaki and Aono, 1997; Mewis and Guiard, 2011).

Several studies have been conducted concerning inviscid flow methods for performance predictions of ducted propellers. Yuasa (1980) applied a lifting surface theory to the analysis of steady performances of several ducted propeller configurations and showed good agreement between calculated results and experimental data. Kerwin et al. (1987) developed a panel method suitable for the analysis of ducted propellers and applied it to a two-dimensional hydrofoil, a propeller, two ducts, and a ducted propeller. Baltazar et al. (2012) discussed several modeling aspects that are important for performance predictions by a panel method. The aspects discussed are the alignment of the wake geometry, the influence of the duct boundary layer on the wake pitch, and the influence of a transpiration velocity through the tip clearance between the propeller blade tip and the inner side of the duct surface. Yu et al. (2013) calculated the open-water characteristics of Ka-series propellers (Lewis, 1988) at various pitch ratios and expanded area ratios inside the 19A duct (Lewis, 1988) by using a panel method and compared the calculations with the experimental data. They also analyzed the influence of the tip clearance on the calculated thrust and torque coefficients of the ducted Ka-series propeller.

The present study has applied the quasi-continuous method (QCM) to open-water thrust and torque predictions of ducted propellers with different positions of the propellers and ducts. The QCM is a numerical method for the lifting surface theory, which was developed by Lan (1974) originally to solve planar wing problems. Since its development, the QCM has been successfully applied to the estimation of the thrust and torque of various marine propellers in a uniform inflow (Nakamura, 1985; Nakamura, 1986) and in a nonuniform inflow (Hoshino, 1985). The objective of



(a) (b)

Fig. 1 Types of ducts for ducted propellers: (a) accelerating duct, (b) ESD. The hubs and shafts of the propellers are omitted.

Received September 1, 2014; updated and further revised manuscript received by the editors October 23, 2015. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-fourth International Ocean and Polar Engineering Conference (ISOPE-2014), Busan, Korea, June 15-20, 2014.
KEY WORDS: QCM, propeller, duct, resultant velocity, trailing vortex.