ABSTRACT

Hydrodynamic impacts of the propeller on a rudder are studied in this paper. Incompressible viscous flow around a NACA 0018 spade rudder is analyzed in open-water conditions and in the slipstream of the propeller based on a Reynolds-Averaged Navier-Stokes (RANS) method. The numerical method is validated in open-water conditions for the propeller and the rudder. For the rudder steered behind a propeller, hydrodynamic performance is compared with that in open-water conditions. The impacts of the propeller loading and the distance between the rudder and propeller on rudder hydrodynamics are studied, aiming to present a clearer description of the propeller-rudder interaction phenomenon.

KEY WORDS: Propeller-rudder interactions; hydrodynamic performance analysis; RANS simulations.

INTRODUCTION

Rudders are widely used in the great majority of ships as steering devices, whose performance connects directly with ship maneuverings. A significant amount of effort has been made on hydrodynamics of isolated rudders in open-water conditions experimentally and numerically. However, for rudders steered behind propellers during maneuverings, the inflow into the rudder is accelerated and distorted due to the propeller slipstream. The acceleration leads to enhancement of rudder forces, while swirled inflow changes the effective rudder angles of different profiles (Molland, 2011). Such flow straightening effects cause the rudder to experience increased incoming turbulence, which brings great challenges for accurate predictions of ship maneuverability. Therefore, the investigation on how the propeller impacts rudder hydrodynamics is quite significant for ship maneuverability assessments.

Some model experiments are conducted to study hydrodynamic performance of rudders influenced by propeller impacts. Molland (1991) investigated interactions of a series of all-movable rudders and a propeller. According to experimental results, increment ratios of lift and drag coefficients have raised with an increase in propeller loading, and the stall occurs later when the propeller exists. Molland (1992) tested systematic experiments on various control parameters in propeller-rudder interactions, demonstrating that the lift force of the rudder is controlled by thrust loading only. Lubke (2009) conducted PIV measurements for the velocity field of a semi-balanced rudder after the hull and the propeller, velocity fluctuations and separation regions on rudder faces can be observed.

Theoretical predictions for hydrodynamic coefficients of the propeller-rudder system based on potential flow methods are also applied. Turnock (1993) developed a theoretical method for propeller-rudder interaction on the basis of the lifting surface panel method, and the flow of both components are coupled through modified respective velocity fields. Kinnas (2007) coupled body forces terms in a three-dimension Euler solver to calculate velocities distributed on rudder surfaces, and the sheet cavitation of the rudder is predicted with a boundary element method. Extended from the methodology of wake/hydrofoil interactions, He (2010) applied a panel method and a vortex lattice method to solve the flow around the rudder and the propeller respectively, while the interaction is evaluated by calculating induced velocities of each component iteratively. A time-averaged scheme predicts lower lift coefficients than that by unsteady scheme due to interactive effects.

Stimulated by the improvement of calculation power, Computational