Proceedings of the Twenty-fifth (2015) International Ocean and Polar Engineering Conference
Kona, Big Island, Hawaii, USA, June 21-26, 2015

ISBN 978-1-880653-89-0; ISSN 1098-6189

www.isope.org

Comparison of Two Methods for Forecasting the Drag, Sinkage and Trim Experienced by a Moving Ship

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ABSTRACT

This research applied CFD solver naoe-FOAM-SJTU and NMShip-SJTU solver which based on the Neumann-Michell theory to forecast the drags, sinkage and trim experienced by several ship hulls that steadily advance along a straight path at constant speeds in infinite calm water. We explore the advantages and disadvantages of two methods by comparing efficiency and accuracy of the predictions based on the two methods respectively. The comparisons of these hydrodynamic characters between the two method show that CFD method can yield more accurate results, and is well suited for detail design and evaluation, while the NM method is more efficient, so it is a practical tool for preliminary design and hull optimization which involve a very large number of alternatives.

KEY WORDS: naoe-FOAM-SJTU solver; NMShip-SJTU solver; drag; trim; sinkage.

INTRODUCTION

The drag, sinkage and trim of a ship hull that advances at constant speed along a straight path in still water of effectively infinite depth and lateral extent, are naturally important and dominant hydrodynamic factors for ship design (especially in preliminary stage) and hull form optimization. Accordingly, how to predict these hydrodynamic elements has been a classical problem that many researchers have investigated it, and a number of related methods have been developed to compute the flow around a ship hull in huge body of literature. These prediction method include Michell's classical thin-ship theory (1898) related slender ship approximations, panel methods based on Green function, and computational fluid dynamics (CFD) method.

In the past decades, computational fluid dynamics (CFD) becomes one of the most popular research tools to solve the classical problem. Especially, the efficiency and reliability of the CFD have been greatly improved with the development of computation performance and numerical methods. CFD method computes drags and motions of ships by solving the Reynolds Averaged Navier Stokes (RANS) flow equations that takes the water viscosity into consideration, consequently CFD method can yield more accurate prediction of steady flow around a ship hull in calm water. Besides, the use of various turbulent models to describe complex flow also contributes to the accuracy of prediction results. In this paper, the computations related to CFD method are performed with the solver named naoe-FOAM-SJTU, which is developed based on the open source CFD tool OpenFOAM to solve hydrodynamic problems of ships and ocean engineering. The reliability of the naoe-FOAM-SJTU solver has been validated in previous work. Shen *et al.* (2011) simulated the flow around the hulls based on naoe-FOAM-SJTU solver for three benchmark ships. Ye *et al.* (2012) studied the added resistance and vertical ship motions of S-175 in regular head waves and validated the ability of naoe-FOAM-SJTU solver to solve the strong nonlinear problems. Zha *et al.* (2014) predicted viscous wave-making resistances of six ships moving in still water using naoe-FOAM-SJTU solver.

A modified theory named Neumann-Michell theory, which is based on the classical Neumann-Kelvin theory, has been developed by Francis Noblesse *et al.* (2013). The most important improvement is that the waterline integral in NK theory is eliminated in NM theory by using a consistent linear flow model and a mathematical transformation. Hence, we can predict the velocity potential of the flow around a ship which is advancing at a constant speed along a straight line in calm water of infinite depth and lateral extent by computing surface integration by parts on the mean wetted ship hull. In this paper, the computations related to NM theory are performed with NMShip-SJTU, a solver developed for hydrodynamics of ship based upon the NM theory.

We utilize NMShip-SJTU solver to predict the wave drags of three benchmark ships, and use 1957-ITTC formula to estimate the friction drags. The sum of the two components is present as the total drag of a ship. Furthermore, we present the drags of these benchmark ships at several speeds by using naoe-FOAM-SJTU. Besides, we also calculate the ship motions for DTMB-5415 hull by the two methods respectively. Through comparing these results with corresponding experimental measurements, we come to a conclusion that both of the two methods can yield realistic results, while the NM theory is more efficient, and the CFD method is more accurate. Accordingly, they are suitable for different needs from different ship design stages.

CFD NUMERICAL METHODS