Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Computing the Hydrodynamic Coefficients of Underwater Vehicles Based on Added Momentum Sources

Zhiqiang Hu[1,2] *and Yang Lin*[1]

[1]State Key Laboratory of Robotics
Shenyang Institute of Automation, Chinese Academy of Sciences
Shenyang, Liaoning, China
[2]Graduate School of the Chinese Academy of Sciences
Beiing, China

ABSTRACT

An added momentum sources-based method is proposed in this paper to compute hydrodynamic coefficients of an underwater vehicle. It is assumed that the vehicle is at rest. Added momentum sources are introduced to account for the effects of the Coriolis acceleration and the acceleration of entrainment because the frame of reference is attached on the underwater vehicle. Compared with a moving boundary method, the method presented need not to reconstruct meshes, and can simulate wind/water tunnel tests and rotating arm tank tests at less efforts. The computational results for a flat type of autonomous underwater vehicle, named SMAL01, prove the validity of the method, and show that the hydrodynamic coefficients from numerical calculations agree well with those from scale model tests.

KEY WORDS: Underwater vehicles; hydrodynamics; computational fluid dynamics; momentum sources.

INTRODUCTION

Underwater vehicles are widely used in ocean exploration. Different types of new-form and low-cost vehicles are increasingly developed in recent years. Under the new situation, it is more urgent to get hydrodynamic coefficients quickly, accurately and cheaply during design of an underwater vehicle. Several methods can produce hydrodynamic parameters for a given geometry. These methods involve analytical, semi-empirical, experimental, system identification-based and computational approaches.

Analytical methods include strip theories and solving the simplified Navier-Stokes (NS) equation set. They are used mostly to determine hydrodynamic parameters for simple shapes, such as spheres, ellipsoids and slender bodies. Semi-empirical approaches, like DATCOM method and ROSKAM method, derive approximate formulas from a series of experimental data. The accuracy of estimated parameters is dependent on similarities of shapes of the designed vehicle and the mother model. And these methods can only give stability derivatives directly. Doing experimental studies is a conventional means to attain hydrodynamic predictions for marine vehicles, including underwater vehicles and ships. However, experimental methods are costly and time-consuming due to constructing scale models and operating the experimental facility. The method of system identification gives estimated model parameters via analyzing trial data. This method can be used to correct hydrodynamic coefficients, while does not suit guiding the design of an underwater vehicle.

Computational Fluid Dynamics (CFD) is considered as the most competent means to calculate hydrodynamic forces of a marine vehicle. It solves the NS equation set numerically to simulate scale model tests. Comparatively, a CFD method is less costly and less time-consuming than an experimental method. However, CFD has not readily become an effective tool that can attain a full set of hydrodynamic coefficients for marine vehicles.

Most researches focus on the simulation of wind/water tunnels, including a computation of positional derivatives (Kim, Sutoh, Ura, and Obara, 2001), an extraction of control derivatives (Arabshahi and Gibeling, 2000), a study of propeller-hull-rudder interaction (Simonsen and Stern, 2005), and so on.

Only a few methods developed can be used to acquire rotating-related coefficients numerically. Gregory, Joubert and Chong (2004) put a deformed body in rectilinear flow to investigate the flow separation over a body of revolution in steady turn. This is a novel approach. But, for a vehicle with many appendages or a complex geometry, this method may have difficulties on model construction and grid generation. Racine and Paterson (2005) successfully computed all stability derivatives and eleven significant maneuvering coefficients of a marine vehicle using an overset grid method. Unfortunately, the computation cost is prodigious. About 10,000 hours of CPU time was used on a machine with 1.53 TeraFLOPS for 13 bare-hull simulations, and 50,000 hours for 16 appended-vehicle simulations on a machine with 13.9 TeraFLOPS. Also using overlapping grid system, Orihara and Miyata (2003) evaluated the added resistance of ships in regular incident waves, and Suzuki et al (2007) simulated the motion of an underwater vehicle with mechanical pectoral fins. To avoid the great demand of computational resources, Hu, Lin and Gu (2007) completed calculations of the hydrodynamic forces and moments for an autonomous underwater vehicle (AUV) in a rotating frame of reference.

The objective of this work is to develop a more general and less-efforts method for computating hydrodynamic coefficients of an underwater vehicle. On the basis of the previous work (Hu et al, 2007), this paper locates the frame of reference on the body of a vehicle and introduces added momentum sources to realize the change of frame.