Analysis of a Tethered Underwater Vehicle Under the Influence of Sea Current with Adaptive Mesh

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ABSTRACT

The paper proposes a new modeling of the dynamic behavior of the underwater vehicle coupling the cable model with the finite segment approach. The hydrodynamic performance of underwater vehicle and the umbilical cable under different sea current velocity is analyzed. Numerical simulation is adopted to computational fluid dynamics (CFD) technique, including overset mesh, adaptive mesh. The experimental result verifies the validity of the numerical method. The numerical results show that the influence of the cable’s shape cannot be simplified, which produces some unstable forces in the y-direction when the tethered underwater vehicle is towed in the three-dimensional flow field.

KEY WORDS: finite segment approach; tethered underwater vehicle; hydrodynamic performance; overset mesh; adaptive mesh;

INTRODUCTION

The tethered underwater vehicle is widely used in exploring ocean resources and investigating the marine environment. It usually comprises hydrofoils, umbilical cable, and ducted propellers(Christ R. D. and Wernli R L, 2013). The tethered underwater vehicle is manipulated by the control equipment and influenced by multiple hydrodynamic factors. In order to investigate the maneuverability and hydrodynamic performance of the tethered underwater vehicle, considerable research about the control equipment and the shape of the tethered underwater vehicle carried out.

In investigating the influence of the ducted propeller on the underwater vehicle, Wu et al. (2015) investigated the thrust characteristics of the ducted propeller in the flow field of an underwater vehicle in turning motion. De Barros and Dantas (2012) discussed the effect of a propeller duct on the underwater vehicle's maneuverability by employing a numerical (CFD) simulation and semi-empirical, ASE approaches. Zhou and Zhao (2020) investigated the influence of four thruster interactions and layouts on the underwater vehicle.

In discussing the effect of the hydrofoil, Font (2011) et al. presented the design and implementation of a turtle hydrofoil for an underwater vehicle. Li et al. (2021) optimized the shape of the underwater vehicle and hydrofoils to decrease the average periodic resistance. Satoru and Yutaro (2021) investigated the lift and drag of the hydrofoils of the glider is studied and the characteristics of the blended wing body near a sea bottom based on CFD analysis. Wu et al. (2021) investigated the maneuverability and hydrodynamic performance of the underwater vehicle when the hydrofoils rotated in -30°~30°. Xu et al. (2022) discussed the underwater vehicle’s motion controlled by the hydrofoils under the influence of the cnoidal wave and quantitatively analyzed the wave influence on the hydrofoil.

The umbilical cable is also taken into account as a significant factor in influencing the underwater vehicle’s motion. Wu and Chwang (2000) utilized the finite difference method to establish a three-dimensional model of a tethered two-part underwater vehicle. Buckham et al. (2004) developed a finite element cable model to simulate the motion of slack marine cables. Vu et al. (2017) investigated the umbilical cable’s influence on the underwater vehicle’s surge, heave, sway and turning motion with a catenary method. Suzuki et al. (2018) investigated the mechanical properties of the cable and its influence on the underwater vehicle with the absolute nodal coordinate formulation’s method. Zhang et al. (2018) discussed the underwater vehicle’s trajectory without hydrofoil and analyzed the influences of the cable’s parameter on it when the underwater vehicle turned around. Norve Eidsvik and Schjolberg (2018) presented a novel three-dimensional cable model for an underwater vehicle using Euler-Bernoulli beam theory and analyzed the hydrodynamic parameters of the cable. Du (2019) numerically simulates the dynamic behavior of a sonar cable array towed by an underwater vehicle considering the influence of flow field disturbed by the underwater vehicle and its propeller. Htnu (2020) et al. proposed a dynamic model of ROV’s tether cable with a radially multilayered circular cross-section based on the absolute nodal coordinate formulation(ANCF). Guan (2021) analyzes and simulates the towing cable dynamics with the lumped mass method.

The above discussion shows that the researchers mainly discussed the hydrodynamic performance and motion of the underwater vehicle and its control equipment. It can be found that the multiple cable models are adopted to consider the effect of cable on the underwater vehicle, such as finite difference method, catenary equation, lumped mass method, absolute nodal coordinate formulation. However, the joint interaction