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RANS-based Manoeuvring Performance Prediction for Under-actuated Marine Vehicle, Underwater Glider

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ABSTRACT

Underwater gliders play a crucial role in monitoring and surveying the Earth's oceans. They gather data on subsurface elements such as ocean currents, salinity, density, and temperature variations. This information enhances our understanding of marine ecosystems, improves weather predictions, aids in assessing global climate change, and helps address the issue of man-made pollution in the marine environment. Gliders are particularly well-suited for these tasks due to their remarkable endurance. They operate by creating a difference between gravity and buoyancy forces, with the attitude controlled by a movable mass in the system, primarily the battery. This design allows them to glide over long distances for months to years in the ocean. However, also because of this, underwater gliders are mostly under-actuated vehicles with very limited manoeuvrability. Currently, most research has been devoted to improving glider endurance, speed, and control strategies, aiming to challenge deeper water and stronger current. Limited research has been focused on addressing the manoeuvrability of gliders.

The 6-DoF models developed by Fosson and Feldman are the commonly used manoeuvring models to predict the dynamics of gliders and other underwater vehicles. Other simplified prediction methods for gliders utilize linearized damping derivatives by constraining the attack angle. Furthermore, since the glider's main saw-tooth motion occurs in a vertical plane, the horizontal plane motion is often considered less significant. Although several non-linear hydrodynamic models exist for underwater vehicles, the accuracy of methods in predicting the trajectories remains uncertain in both acceleration and steady phases. As an alternative, RANS-based methods can accurately simulate a glider's manoeuvring characteristics while incurring lower numerical costs.

The current work aims to analyse the manoeuvring performance of the Petrel-II glider with high accuracy and affordable computational cost. The commercial CFD software STAR-CCM+ is employed to establish this study. Reynold Average Navier Stokes (RANS) method is used to predict the hydrodynamic forces around the underwater glider, eliminating the assumptions in quasi-static hydrodynamic coefficients. Glider motion with buoyancy control and movable mass are enabled by using Dynamic Fluid Body Interaction in 6 Degrees of Freedom. Body-fitted mesh with a moving reference frame largely enhances the computational efficiency, making the simulation efficient and affordable. Initially, the glider's speed and attitude in saw-tooth trajectory are calculated for various battery positions at maximum engine capacity to validate the methodology. Subsequently, the vehicle's manoeuvrability is explored through spiral manoeuvres by adjusting the battery position during ascending and descending. The results of this study show the glider behaviour in manoeuvring and explore the potential manoeuvring strategy. Additionally, the findings will assist in designing intelligent mission strategies to navigate through the ocean and overcome obstacles during operations.

Keywords: Underwater glider; Manoeuvring analysis; CFD study.