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Simulation and Validation of an AUV in Variable Accelerations

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This paper presents computational and experimental studies of an Autonomous Underwater Vehicle (AUV) undergoing prescribed lateral and angular acceleration manoeuvres (pure sway and pure yaw). The Computational Fluid Dynamics (CFD) modelling is based on the Unsteady Reynolds-averaged Navier-Stokes (URANS) equations with the use of a hybrid meshing scheme through systematic grid refinement. The obtained CFD predictions were validated through Experimental Fluid Dynamics (EFD) utilising a captive model fitted to a Horizontal Planar Motion Mechanism (HPMM). The present investigation will contribute to the identification of force and moment coefficients for the development of control system algorithms for underwater vehicles.

NOMENCLATURE

ρ	Fluid density (kg/m^3)
υ	Fluid kinematic viscosity (m^2/s)
U_0	Free stream velocity (m/s)
g	Gravitational acceleration (taken as 9.810 m/s^2)
σ	Normal stress (N/m^2)
L	Overall length (m)
p	Pressure (N/m^2)
t	Time (s)
τ	Viscous shear stress (N/m^2)

INTRODUCTION

Interest in the research and development of Autonomous Underwater Vehicles (AUVs) has grown substantially in recent decades due to the increasing need for such vehicles for underwater exploration (Farrell et al., 2005), hydrographical survey (Doble et al., 2009), and defense (U.S. Navy, 2004). Limited underwater acoustic communication has resulted in the need for the vehicles to operate independently for significant periods of time without user intervention. This requires pre-programmed control systems that are able to maintain the desired trajectory of the vehicle under varying conditions.

When an AUV is in motion, hydrodynamic forces on the vehicle and inertial reaction forces caused by the vehicle's acceleration can result in rapid changes to the vehicle's motion. This may lead to the vehicle failing to reach given waypoints or to collision when operating close to other vessels, the seabed, or hazards. A good understanding of the vehicle's manoeuvring characteristics is a prerequisite for designing a control system to maintain the required trajectory under different manoeuvres and for establishing the manoeuvring limitations and a safe operating envelope (Gregory et al., 2004). The manoeuvring characteristics of an underwater vehicle can be quantified by obtaining the forces and moments acting on the vehicle through numerical modelling, experimental testing, or a combination of both (Zhang et al., 2010). These characteristics are then represented in the form of the force and moment coefficients that are, in turn, fed into a control system simulation.

One method of numerically obtaining the coefficients is to conduct Computational Fluid Dynamics (CFD) simulations of the vehicle's manoeuvres. With the increasing capabilities of CFD software and computer resources, CFD has proven to be a powerful prediction tool (Godderidge et al., 2008). However, the level of accuracy is highly dependent on the mesh quality and model settings (Stern et al., 2013). The credibility of CFD predictions can be established by the verification of the CFD settings and validation through Experimental Fluid Dynamics (EFD) (ITTC, 2011b).

In recent years, researchers (Jagadeesh et al., 2009; Phillips, 2010) have successfully used CFD and EFD to predict the velocity-based coefficients under prescribed steady state motions (straight line, drift angle, uniform rotation, etc). With some exceptions (Malik and Guang, 2013; Tyagi and Sen, 2006; Zhang et al., 2010), the acceleration-based coefficients under prescribed unsteady motions (e.g., pure sway and pure yaw) have not been extensively investigated. This is mainly due to the modelling difficulties experienced in CFD for such motions, and in most cases, without the validation through EFD due to the lack of suitable test facilities.

This paper presents an investigation into the capabilities of CFD as a tool to predict the forces and moments acting on an axisymmetric AUV hull under prescribed horizontal acceleration manoeuvres (pure sway and pure yaw). This enables the determination of the acceleration-based coefficients, which include the added inertia due to the acceleration of the surrounding water. Complementary

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KEY WORDS: AUV, prescribed acceleration manoeuvres, CFD, EFD, URANS, HPMM.