Experimental and URANS, LES-based numerical comparative study on the maneuvering coefficients of BB2 submarine

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ABSTRACT

This study conducted a comparative analysis between the captive model test results of BB2 submarine model with a scale ratio of 1/15 and the relevant computational fluid dynamics (CFD) results based on an Unsteady Reynolds-averaged Navier-Stokes (URANS) and large eddy simulation (LES) analyses. The URANS results for static drift without propeller condition were validated using the previous numerical results. The static drift, angle of attack, pure yaw, and pure sway test results, as well as the relevant URANS results were compared. In the cases of pure yaw and pure sway, the effects of time step and repeatability were examined. For the static drift condition, an LES analysis was attempted, and the results showed a trend similar to that of the experimental results at a large drift angle.

KEY WORDS: BB2 submarine; Maneuvering; VPMM; URANS; LES.

INTRODUCTION

Maneuvering coefficients are required to simulate the various submarine maneuvering performances at the design stage. Many studies have been conducted on the hydrodynamic characteristics related to the maneuvering motion of submarines based on experimental fluid dynamics (EFD), particularly captive model tests. Captive model test techniques to implement the maneuvering motion of a submarine include the planar motion mechanism (PMM) (Goodman, 1979; Rhee et al., 2000; Kim et al., 2012), rotating arm (Feldman, 1987), and conning motion (Lewandowski, 1991; Rhee et al., 2000; Park et al., 2015).

The recent development and growth of high-performance computing has allowed numerical studies using virtual captive tests and virtual free-running tests based on computational fluid dynamics (CFD) to be performed. Toxopeus (2008) calculated the forces and moments of the DARPA SUBOFF model under straight and oblique conditions using a Reynolds-averaged Navier-Stokes (RANS) solver, and the results were compared with the experimental results. Some differences were observed in the study between the CFD and experimental results for the sway force and yaw moment in the oblique condition. Takahashi and Sahoo (2019) conducted a RANS CFD study for the hydrodynamic performance of the SUBOFF models, and benchmark test data were used for validation. According to their study, there were some discrepancies between the CFD and experimental results for the sway force and yaw moment under drift and turning conditions. Detached eddy simulation (DES) and large eddy simulation (LES) methods are capable of a more precise analysis of small-scale turbulent flow than the RANS method but require considerable computational resources. Suh and Park (2021) performed DES analyses of the SUBOFF model in a straight-ahead condition. They investigated complex vortical flows that developed from the hull boundary layer and appendages.

The Korea Research Institute of Ships and Ocean Engineering (KRISO) has conducted captive model tests on various submarine projects. Since 2020, researches on the integrated performance analysis of submarines has been performed using not only captive model tests but also free-running tests and CFD analysis. In this study, the captive model test results for the Joubert BB2 submarine model with a scale ratio of 1/15 and relevant Unsteady Reynolds-averaged Navier-Stokes (URANS) analysis results were compared. The URANS results for the static drift condition of the BB2 model without a propeller were validated using the previous numerical results. Subsequently, URANS analyses for static drift, angle of attack, pure yaw, and pure sway tests were performed, and the results were compared with those of the experiments. In the cases of pure yaw and sway simulations, the effects of time step and repeatability were examined. In addition, the motion time series for various period and amplitude conditions were integrated using a ramp function to improve computational and post-processing efficiency. LES calculations were attempted for the static drift condition, and the results were compared with those of URANS and the experiments.

CAPTIVE MODEL TEST

A captive model test for a BB2 submarine model with a scale ratio of 1/15 was conducted by Kim et al. (2021) using vertical planar motion mechanism (VPMM) equipment in a towing tank at KRISO, as shown in Fig. 1. An X-plane rudder configuration was applied to the submarine. Fig. 2 and Table 1 present the shape and principal