Studies on the Snap Roll Modelling for a Submarine

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ABSTRACT

Snap roll during the hard turn is the hot issues of the submarine operation. Hydrodynamics modeling in high incidence flow angle is required to predict the roll behavior during the hard turn maneuver. In this research, submarine dynamics modeling is suggest to investigate the snap roll. Captive model tests are conduct to obtain the hydrodynamic coefficients in the dynamics model. The test results are analyzed by using least square and golden section research. Hard turning simulations for the various initial ship speeds and $\bar{B}G$ conditions. Roll behavior and other phenomenon during the turning maneuver are analyzed based on the simulation results.

KEY WORDS: Snap roll; Towing tank test; Wind tunnel test; Planar Motion Mechanism; Golden section research; Fourier series;

INTRODUCTION

Snap roll is the maximum roll amplitude that results from a turning maneuver (Liberatory, 1977). When the submarine turned, there is a drift angle. The drift angle induces the lift to the sail. The center of pressure of the sail located at the upper side of a submarine, so roll moments is induced. Sharp turning maneuver refer as “hard turn” makes the high drift angle rapidly, so the roll moment induced by sail lift can makes the excessive snap roll. The roll angle, pitch moment induce by the drift angle and yaw rate makes the depth change which referred “squat”. The depth change may cause a deviation from the safe operation area. So the analysis method of this phenomenon is necessary for the safety of the crew and submarine equipment.

Motion characteristics during this maneuver can be predict by used of the three different approaches such as free running test, CFD (Computational Fluid Dynamics) and coefficient-based simulation. Free running test is the precise method, but it is the time consuming process and it demands high costs. CFD base maneuvering simulations such as emergency rising maneuver is conducted by Bettle et al. (2009), but the results are sensitive to the numerical scheme, number of grid and intensity of the turbulence. So it can be the optimal way to predict the by using coefficient-based simulation.

Coefficient-based simulations are generally performed by using Gertler (1967) model. The model is appropriate to describe standard mild maneuvering, but it is not suitable for the high incidence angle maneuver such as hard turning and emergency rising maneuver. The model is revised by Feldman (1979), and it consider the nonlinear effect such as cross flow drag and sail vortex. Watt (2007) proposed the submarine dynamics model suitable for the emergency rising maneuver. To obtain the hydrodynamic coefficients, captive model test and analysis method is needed. Many research aimed to obtain the hydrodynamic coefficients by using captive model test (Feldman, 1987; Feldman 1995; Mackay, 2003; Nguyen, 1995). Static drift test ($\bar{b}$ test), static angle of attack test ($\bar{a}$ test), Planar Motion Mechanism (PMM) and Rotating Arm (RA) test are generally used for the captive model test. But it is hard to find experimental research related with combined $\bar{a}/\bar{b}$ test.

This paper proposes the submarine dynamics model which is suitable to high incidence angle maneuver. To obtain coefficients in the model, maneuvering experiments are conducted in towing tank and wind tunnel. Resistance test and PMM test are conducted in towing tank. Combined $\bar{a}/\bar{b}$ test with $\pm 30^\circ$ angle of attack range and $\pm 24^\circ$ drift angle range and control surface test are performed in wind tunnel. Hard turning simulation based on the obtained coefficients are performed and the simulation results is analyzed.

MATHEMATICAL MODEL

Coordinate systems

The coordinate systems used in this research is shown in Fig. 1.