The Influence of Different Factors on the Dynamic Anti-sinking Capacity of Submarines

Rui Luo, Xianzhou Wang*, Chang Meng, Zhiguo Zhang, Dakui Feng
School of Naval Architecture and Ocean Engineering, Huazhong University of Science and Technology
Wuhan, Hubei, China

ABSTRACT

In this paper, a complete mathematic model of submarines’ emergency surfacing is built based on the non-linear motion equations of six degrees of freedom, which includes the damage flooding, high-pressure blowing-venting of ballast tank, surfacing with a large angle of attack, PID auto-steering. Using the mathematic model, a submarine emergency surfacing simulation code is programmed. Furthermore, a certain submarine’s surfacing motions under different locations and magnitudes of damage, initial speed, and blowing-venting conditions are calculated. Through analysis of the simulation results: The pattern of depth and attitude changing during the emergency surfacing is obtained, and the effectiveness on anti-sinking of high-pressure blowing-venting, accelerating, and steering is also validated. The changing pattern of the critical diameter for retrieval is analyzed as an indicator of the dynamic anti-sinking capacity of submarines.

KEY WORDS: Damage; flooding; dynamic anti-sinking; blowing-venting; critical diameter; factors.

INTRODUCTION

Submarines may encounter battle damage and maritime accidents, which will threaten their capacity of sailing and fighting, or even lead to sinking.

The anti-sinking capacity is a vital constituent of submarine’s vitality, as well as the foundation of fighting against accidents. Therefore, it is of great importance to research on it.

The theory of submarine’s anti-sinking capacity above water-static anti-sinking is mature, and applied to the design and use of submarines. However, modern submarines mainly sail under water. So the anti-sinking capacity under water becomes a popular topic about submarine’s vitality.

To evaluate the effectiveness of the dynamic anti-sinking measures, the motion of damaged submarines should be simulated and analyzed. CHEN, Zhi-yong and MA, Yun-yi (1982) simulated the process of dynamic anti-sinking with a mathematic model, and used the area of the damage as an indicator of submarine’s dynamic anti-sinking capacity. LIU, Chang-bo (2013) calculated the motion of a submarine under different damage conditions focusing on high-pressure blowing-venting. In his model, the temperature of the gas in high-pressure bottle is assumed to be constant. LIU, Hui (2009) etc. adopted a simplified model of blowing-venting, in which the flow rate of water blew out from the ballast tank is assumed to be proportional to the pressure of the gas remained in the high-pressure gas bottle.

The three different kinds of measures, i.e. accelerating, auto-steering, and high-pressure blowing-venting are not comprehensively taken into account in the previous research. Meanwhile, the mathematic models built for the high-pressure blowing-venting do not correspond well to the experiment results. Also, the impact of changing damage conditions and anti-sinking measures on the dynamic anti-sinking capacity of submarines need to be analyzed more detailedly.

The damage flooding underwater, high-pressure blowing-venting and PID auto-steering are comprehensively considered in the motion equations of six degrees of freedom. The simulation of the dynamic anti-sinking of a submarine is carried out.

THE MATHMATIC MODEL OF SUBMARINE’S UNDERWATER MOTION

Based on the “standard equations used for submarine motion simulation” presented by Gertler (1967), the remaining static loading $P_1, P_2$ are introduced, to reflect the influence of inflowing water from the damage and outflowing ballast water. The mathematic model of submarine’s underwater motion is as Eq.1~Eq.7.

Axial Force Equation:

$$m(\ddot{u} - \dot{v}r + \dot{w}q + Z_1 pr) = \frac{1}{2} \rho L X_{1\dot{q}} + \frac{1}{2} \rho L X_{1\dot{u}} + \frac{1}{2} \rho L \left( X_{1\dot{v}2} + X_{1\dot{v}2} + X_{1\dot{w}2} \right) + \frac{1}{2} \rho L \left( X_{1\dot{r}2} + X_{1\dot{r}2} + X_{1\dot{p}r} \right) + \frac{1}{2} \rho L \left( X_{1\dot{w}q} + X_{1\dot{v}r} \right) + \frac{1}{2} \rho L u^2 \left( X_{1\dot{w}2} + X_{1\dot{v}2} + X_{1\dot{w}2} \right) + X_r + \frac{1}{2} \rho L X_{1\dot{w}2} \dot{\theta}\theta (1)$$

Lateral Force Equation: