Study on load transfer law and dynamic response of double shell structure under underwater explosion

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ABSTRACT
Considering the complex processes of blast shock wave propagation, interaction between shock wave and double shell structure and dynamic response of the structure, a finite element numerical simulation model of underwater explosion of double shell was established, and the effects of the contained water, the connection structure and the shell plate on shock wave load transfer law and impact response of the structure were studied. The results show that the greater the stiffness of the connection structure, the greater the contribution of the connection structure to the impact load transmission. When the pressure shell stiffness is larger or smaller, the shock wave load is mainly transmitted through the contained water, and when the pressure-resistant shell spring stiffness is moderate, the connection structure has a certain impact on the transmission of the shock wave load, but the contribution to the shock wave load transfer is still lower than the contained water.

KEY WORDS: Blast shock wave; double shell; load transfer; dynamic response.

INTRODUCTION
Taylor (1963) studied the interaction between fluid and solid assuming the same incident pressure and reflected pressure, and found that the impulse transferred to the rigid plate could be reduced by reducing the mass of the plate, which summarized to obtain the Taylor formula. Yan and Zhang (1993) derived the theoretical formula for the specific impulse of underwater explosion shock wave based on the empirical formula of Cole (1948), combined with the energy similarity principle. Kistiakowsky (1950) and others obtained the pressure and velocity of underwater explosion shock wave from the perspective of hydrodynamics by theoretically deriving the basic equations of one-dimensional hydrodynamics. Luo, Zhou, Mao, Liu (2017) established a transient fluid-solid coupling model of a one-dimensional underwater blast shock wave and a flat plate structure, and derived an analytical formula for the impulse transfer ratio of the underwater blast shock wave interacting with the flat plate. As for the experimental aspects, many scholars at home and abroad have also carried out a lot of research work. Qian, Zhang and Xu (1983) studied the effect of near free surface on underwater blast shock wave through experiments, modified Cole's empirical formula of underwater blast shock wave, and obtained the computational expression of nonlinear reflection area of underwater blast shock wave. Liu, Luo, Gu (1999) and Yan (2003) measured the shock wave related parameters, analyzed the underwater explosion shock wave pressure variation and distribution law, and fitted the time course curve of the underwater explosion shock wave pressure. Temperley and Craig (1950) combined thermodynamic and hydrodynamic methods to obtain the time course curve of the underwater explosion shock wave generated by spherical explosives. Liddiard (1983) explored the variation of underwater explosive shock wave propagation distance and shock wave propagation velocity with time through spherical explosive blast experiment, and gave the interrelationship between the three. Hollyer (1959) studied the effect of different charge forms on the variation of underwater explosive shock wave pressure with time based on experimental data, and summarized the relevant empirical equation of shock wave. In terms of numerical simulation, Yu, Liu, Zhang (2006), Jia, Hu, Dong (2008) and Hu, Jia, Rao (2009) studied the accuracy and efficiency of numerical simulation of underwater explosion by various different finite element software, and analyzed the effect of different explosion-related parameters on the accuracy of numerical simulation of shock waves. Zhang and Xie (2023) apply the mesh-insensitive finite element method to study the stability of floating bodies. Shi, Zong and Jia (2009) combined the Level-Set method to numerically simulate the variation characteristics of underwater explosion shock wave pressure and specific impulse by solving the one-dimensional hydrodynamic equations and fitted the approximate regression equations. Zhang, Wang, Shi (2014) studied the far-field underwater explosion problem based on Taylor plate theory and DAA method, and explored the influence of the size of the water grid division on the accuracy of numerical simulation of shock wave propagation characteristics. However, less research has been done on the force transmission characteristics of the contained water and the connection structure of double-hulled submarines. In this paper, the transfer law of underwater explosion shock load in multi-layer medium is investigated; the contribution of the contained water and connection structure to the shock load transfer is compared; parametric analysis is carried out to study the influence of changes in mechanical properties of contained water, connection structure and...