Flow-induced Noise Characteristic Analysis of Submarine Flow Cavity
Based on Large Eddy Simulation

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ABSTRACT

Because of the working environment and movement mode of the submarine, it is necessary to set up a certain number of flow cavities on the submarine's non-pressure and non-water-tight shell to assist the submarine's submersible tank's water intake and drainage, and then realize the submarine's floating and submerge. However, when submarines navigate underwater, the fluctuating pressure on the surface of flow cavity structure will have a greater impact on the noise performance of submarines. Therefore, the prediction of the fluctuating pressure generated by the turbulent boundary layer and the flow-induced noise generated by the fluctuating pressure is of great significance for improving the acoustic concealment of submarines.

In this paper, two types of flow cavities structures on submarine according to the principle of consistent drainage performance are studied. The large eddy simulation combined with the generalized FW-H equation in Lighthill's acoustic analogy theory is used to predict the fluctuating pressure, far-field radiated noise and directivity of submarine flow cavity, and the characteristics of noise characteristics of the two types of flow cavities are analyzed from different angles. The calculation has the advantages of high stability and fast calculation speed, and the research contents and numerical methods in this paper provide theoretical support for the optimal design of submarine flow cavities. The calculation results show that the flow-induced noise performance of the continuous flow cavity is better than the intermittent flow cavity on the premise of ensuring the same drainage performance.

KEY WORDS: Flow cavity, Drainage Performance, Large eddy simulation, Acoustic analog theory, Flow-induced noise

INTRODUCTION

Submarine is one of the most important ships in the navy, and it is known as the big black fish in the sea. It has played an irreplaceable role in the protection of the coastline, sea assault operations and underwater investigation. Submarine is an important combat tool for naval combat troops and has been widely used since the First World War. Compared with surface combat vessels such as aircraft carriers, destroyers and frigates, submarines have the advantages of good concealment, strong endurance, excellent assault capability and flexibility. At present, the combat missions are more complicated and diversified, and the research on submarines has always been a hot topic for science and technology worker.

Because of the working environment and movement mode of the submarine, it is necessary to set up a certain number of flow cavities on the submarine's non-pressure and non-water-tight shell to assist the submarine's submersible tank's water intake and drainage, and then realize the submarine's floating and submerge. Therefore, the flow cavities play an irreplaceable role in realizing the floating and diving of the submarine.

Flow cavities are generally arranged in the parallel mid-body position of the submarine, and there are also a few flow cavities at the head and tail of the submarine. In order to meet the requirements of water inflow and drainage rate, the flow cavities are generally large in size and very eye-catching. However, the flow cavities have a great influence on the noise performance of submarine when sailing underwater. Fluctuating caused by vortex and stagnation flow at various scales in the flow field leads to pressure pulsation on the outer surface of the submarine, which will seriously affect the safety performance of the submarine. In order to ensure the rapidity and concealment of the submarine, designers should try their best to reduce the area of flow under the premise of ensuring safety.

In the research of submarine noise, the noise generated by the pulsating pressure on the surface of flow cavities is a component that cannot be ignored in the flow noise. How to determine the open form and arrange the open position, and how to accurately predict the pulsating pressure generated by the stagnant boundary layer and the flow noise generated by the pulsating pressure not only have theoretical significance, but also have important practical application value.

In recent years, with the development of Computational Fluid Dynamics(CFD) technology and the improvement of computer performance, Large Eddy Simulation(LES) method has gradually matured, making the numerical calculation of flow-induced noise possible. Germano(1991) and Lilly(1992) adopted the Dynamic Smagorinsky Model to improve the stability and reliability of Large Eddy Simulation, which is of great importance. Seror(2000,2001) and He(2002,2004) verified the stability and reliability of the Dynamic Smagorinsky Model in predicting flow-induced noise through a series of