The Study of Prediction Method on Propeller Broad-band Noise

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The propeller broad-band noise spectrum is contributed by the sound radiation of the trailing edge flow of propeller blade and interaction between tip vortex and blade. The turbulent with various scales eddies in these flows is directly related to generation of the noise. So how to obtain the detail structures of flow field around the propeller becomes one of the key points in propeller broad-band noise prediction by numerical method. Large Eddy Simulation (LES) method can get adequate flow details with relatively high accuracy, as well as satisfy the requirement of the sound source simulation calculation for noise prediction. Therefore, in this paper, the numerical prediction method of propeller noise in intermediate to high band is developed based on the combination of LES method and Fowcs-Willians & Hall (FW-H) equation. Time-series results of accurate eddy structure for turbulent flow around the propeller are obtained by the LES method, and then the acoustic analogy equations are deduced from the FW-H equations to predict the noise.

In order to verify the noise prediction method, numerical calculations are carried out for a three-dimension foil. The foil profile schematic diagram is shown in Figure 1. The chord length L, thickness H and span length D of the foil are 910mm, 50.6mm and 610mm respectively. In the first stage two-dimensional flow field around hydrofoil was calculated by LES method, the calculated area is 4L (streamwise, x) $\times$ 2L (normal, y), structured grid is adopted, the total grid number is about 120 thousand, the calculated time step is 5×10^{-5}s. After obtaining the two-dimensional flow field, the sound source term related to flow field is extracted and extend to the three-dimensional hydrofoil based on the sound source correlation. Then intermediate to high band noise of the three-dimensional foil is calculated by adopting the FW-H equations. The calculation results are compared with the noise experimental results obtained in the noise elimination wind tunnel of Notre Dame University, and the comparison results are shown in Fig. 2. The comparison shows good agreement both in the frequency spectrum characteristics and magnitude of the noise.

The propeller noise with intermediate to high band in uniform flow is calculated numerically by using the noise numerical prediction method mentioned above. In the calculations, three-dimensional model and unstructured grid are adopt to simulated the flow field by LES method, and calculated time step is 1×10^{-5}s. Comparison between calculations and model experiments shows that variation trends of propeller noise spectrum levels are consistent, and the difference in total sound pressure level can satisfy the requirements in engineering prediction. Based on the above studies, the effectiveness of the numerical prediction method developed in this paper is verified.

In order to provide a foundation for low noise design of rotating machine such as propellers, in this paper, low noise optimization for three-dimensional foil is studied with the noise prediction method.In the noise calculations NACA 66m hydrofoil with a=0.8 are selected as the basic scheme and the other foils with different thicknesses and camber distribution patterns based on the basic one. The results show that forwarding the position of maximum thickness and camber can decrease intermediate to high band noise compared with commonly used NACA 66m hydrofoil.

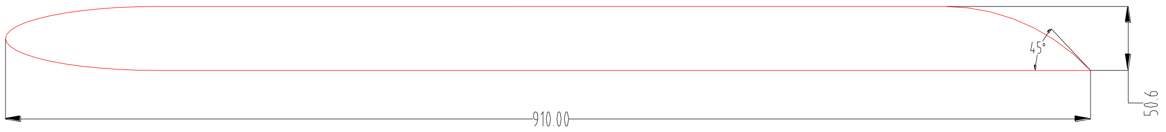

Fig.1 Schematic of foil profile geometry.

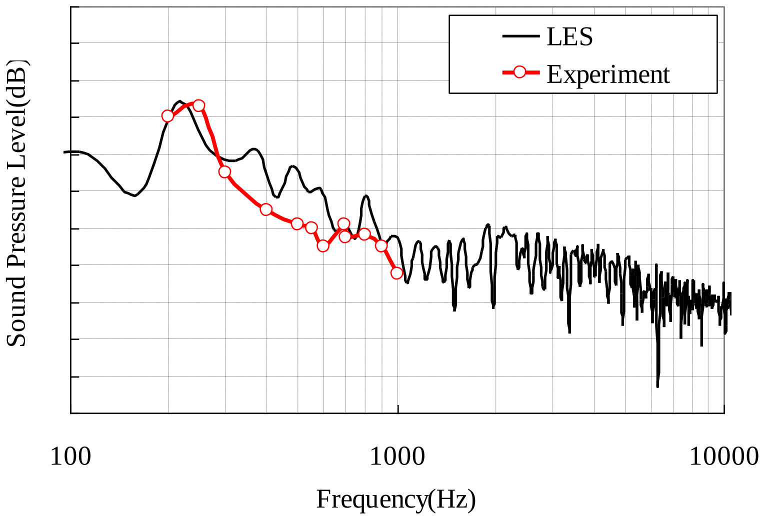

Figure 2 Comparison of computed and experimental sound pressure spectra