飞行器表面声场环境预计

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Highlight

The vibration noise sources of the aircraft in cruise state are sorted out, including the boundary layer noise and engine noise on the surface of the body. The external dynamic load of typical mission profile of aircraft is calculated by CFD (Computational Fluid Dynamics) simulation and empirical formula. Firstly, NLAS (nonlinear noise solution) method is used to simulate the surface noise and jet noise of the aircraft; Then, the sound pressure levels of engine combustion noise, turbine noise and fan noise are calculated respectively based on empirical formula. Considering the acoustic radiation of engine noise on the fuselage surface, the acoustic radiation calculated by empirical formula is added to the surface of the aircraft body, and the total noise and sound pressure level of the aircraft surface is obtained.

Methods

Nonlinear acoustic equation and its numerical solution

In the three-dimensional Cartesian coordinate system, it is assumed that a disturbance is added to the N-S equation, and each original variable is decomposed into statistical average variable and random disturbance variable, i.e $\varphi=\varphi+\varphi'$, The nonlinear acoustic equation can be obtained by substituting it into the N-S equation and reorganizing the N-S equation:

$$\frac{\partial Q'}{\partial t}+\frac{\partial F_i'}{\partial x_i}-\frac{\partial\left(F_i^{v}\right)'}{\partial x_i}=-\frac{\partial \bar{Q}}{\partial t}-\frac{\partial \overline{F_i}}{\partial x_i}+\frac{\partial \overline{F_i}^{v}}{\partial x_i}$$

Where, Q' is the disturbance; Q is the transient average; is linear inviscid momentum; F_i is the average amount of inviscid; $\left(F_i^{v}\right)'$ is the viscous disturbance; F_i^{v} is the average viscosity.

Omit the density pulsation and time average it:

$$\overline{LHS}=\overline{RHS}=\frac{\partial R_i}{\partial x_i}$$

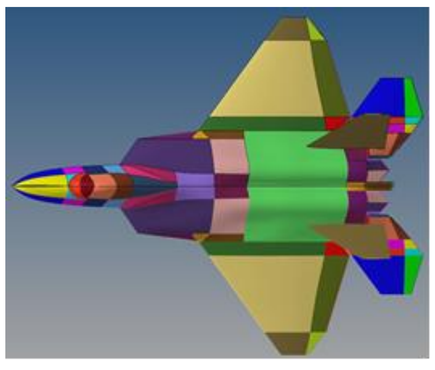
$$R_i=\begin{bmatrix}0\\ \bar{\rho}\overline{u_i'u_j'}\\ c_p\overline{\rho T'u_i'}+\bar{\rho}\overline{u_i'u_k'}\,\overline{u_k}+\frac{1}{2}\bar{\rho}\overline{u_k'u_k'u_i'}+\overline{u_k'\tau_{ki}}\end{bmatrix}$$

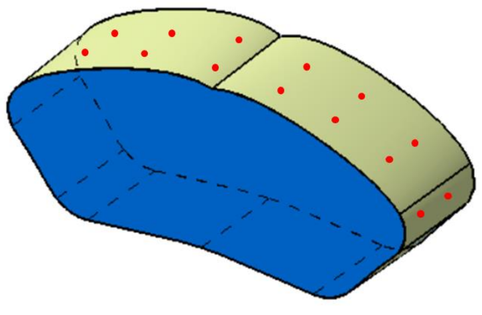
To solve the nonlinear acoustic equation, we need to obtain the values of these unknowns first. It can usually be obtained by solving the RANS equation, such as cubic K above- ε The equation is a closed N-S equation, and the small quantities that cannot be solved can be obtained by the artificial reconstruction method of turbulence. After calculating the statistical average variable, the nonlinear acoustic equation can be time advanced.

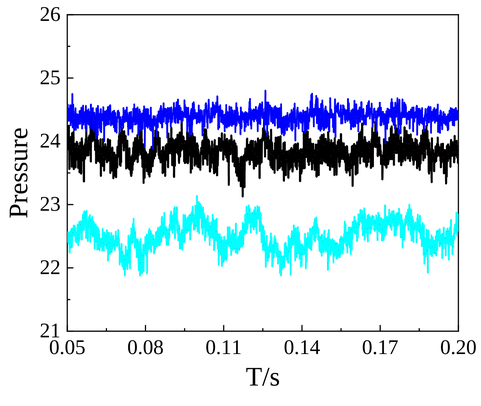
Results

Taking an aircraft as the object, this paper applies the nonlinear acoustic calculation method and empirical formula introduced earlier to calculate the aerodynamic noise on the aircraft surface.

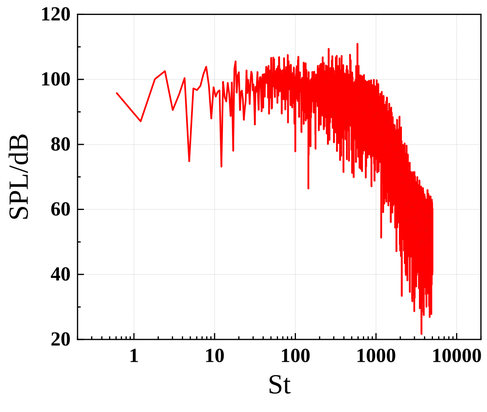
In this paper, the surface pressure of aircraft at Mach number Ma = 2.5 is calculated. The aircraft wall adopts the non slip wall condition. The noise calculation needs to start the unsteady calculation, and the time step is 1 × 10-5s, the flow solution time is 1.0s, the maximum number of iterations in each time step is 10, and the new boundary is set as the absorption layer boundary. Calculate the monitoring points on the aircraft surface as shown in Figure 2 to measure the pressure change at the monitoring points. Add the calculation results to the radiation pressure of engine noise to obtain the pressure time history curve of some monitoring points as shown in Figure 3 (the curve in the figure is dimensionless).

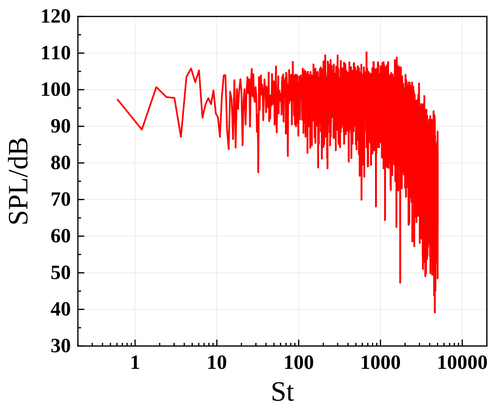


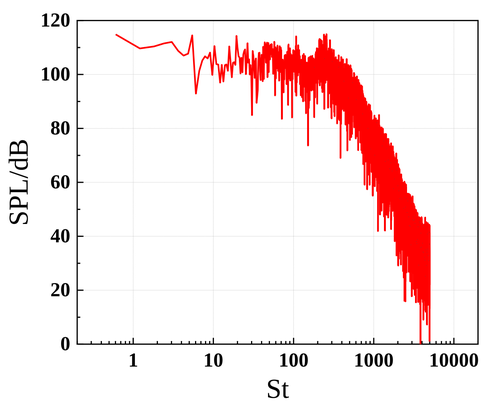




Fourier transform the pressure time curve at the monitoring points to obtain the spectral sound pressure level curve, and superimpose the spectral curve of aircraft engine noise to obtain the total sound pressure level curve of aircraft surface monitoring points, as shown in Figure 4.







Conclusions

1) The aircraft surface noise mainly includes flight aerodynamic noise and engine noise. The engine noise has little effect on the aircraft surface sound radiation under the condition of Mach number.
2) The nonlinear acoustic equation can effectively solve the aerodynamic noise of aircraft surface.
3) In this paper, the aircraft surface sound pressure level is about 110dB.