The Acoustic Analysis of Shallow Cavity based on Large Eddy Simulation

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Abstract: The influence of cavity geometrical parameters and air velocity on noise was discussed. The results shows that the self-oscillation was caused by the generation of the vortex periodically and the frequency of the self-oscillation coincide with the peak frequency of the noise. The distribution of the noise is directivity. The increase of air velocity leads to the increase of self-oscillation frequency, peak frequency of the noise and the SPL of the noise. The increase of length or decrease of depth of the cavity leads to the decrease of the self-oscillation frequency and the peak frequency of the noise.

Key-Words: *Shallow Cavity, Large Eddy Simulation, Acoustic Analogy Method, Noise, SPL*

1. Introduction

The shallow cavity structure is widely exist in various surfaces crack, assembling clearance, welding line and other position of the locomotive, aircraft and so on. The working environment of these equipment is often accompanied by high speed flow field [1-2]. And the high speed air flow through the shallow cavity will produce a strong aerodynamic noise around the shallow cavity when it meets a certain aerodynamic acoustic condition [3].

This phenomenon also occurs when a crack occurs in the bearing. And which influence the normal operation of the electronic components near the cavity even lead to some structural damage [4-5].

In this paper, the large eddy simulation method (LES) of fluid dynamic numerical simulation was used to solve the flow field when air went through the shallow cavity horizontally, which was called the background flow field. Then, aim at the numerical analysis results of the flow field, the pneumatic acoustic field characteristics under the action of the background flow field was analyzed by different sound spectrum characteristics and its transformation law under different shallow cavity structure parameters and inflow velocities can be obtained by this research.

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2. Method

2.1 Noise analysis

Figure 1 shows the simulation area of the shallow cavity. The finite element model of the simulation area was established and the grid near the cavity was refined, the total grid number was 203255. 33 receivers have been set around the cavity, as shown in Figure 1. The boundary conditions of the flow simulation are shown in Table 1.

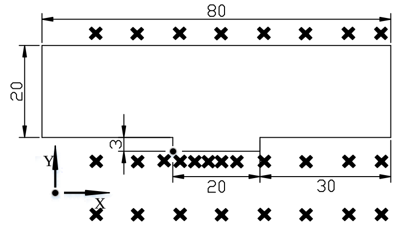

Figure 1 Simulation model and noise receivers of the shallow cavity

Table 1 Boundary conditions

Inlet velocity	50m/s	Time step	1e-4s
Outlet pressure	0.101MPa	number of steps	500
Temperature	300K		

2.2 Inlet Velocity and Cavity Structure

The influence of the inlet velocity on the frequency of the noise and the SPL of the noise was discussed.

The flow simulation and noise analysis were done with different cavity structure parameters, as showed in Figure 2. The parameters of the shallow cavity are: 2mm*20mm, 3mm*20mm, 5mm*20mm, 3mm*10mm, 3mm*15mm, 3mm*25mm, 3mm*30mm.

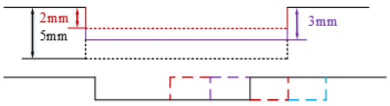

Figure 2 Different cavities

3. Result

The periodic time of the self-oscillation is about 0.0021s, the frequency is about 449Hz.

3.1 Noise

The sound pressure level-frequency curve of the receiver located at the right above of the cavity is as shown in Figure 3. It shows strong coupling relationship between the flow field and acoustic field. The peak SPL values of each receivers and the location of the receivers are shown in Figure 3 and 4. Gray area indicates the position of the shallow cavity.

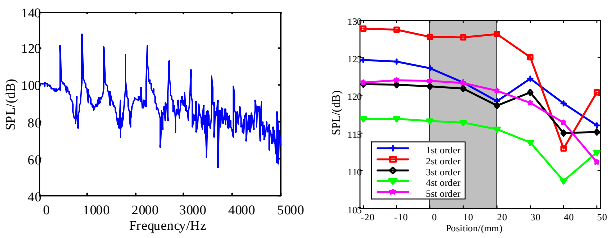

Figure 3 Sound pressure level-frequency curve and Peak SPL values above the cavity

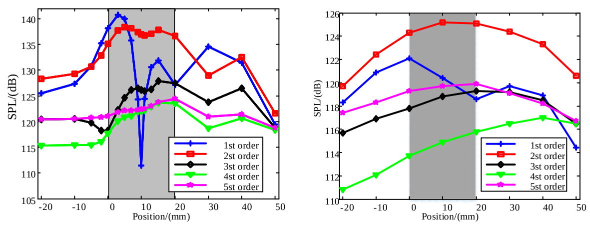

Figure 4 Peak SPL values bellow the cavity

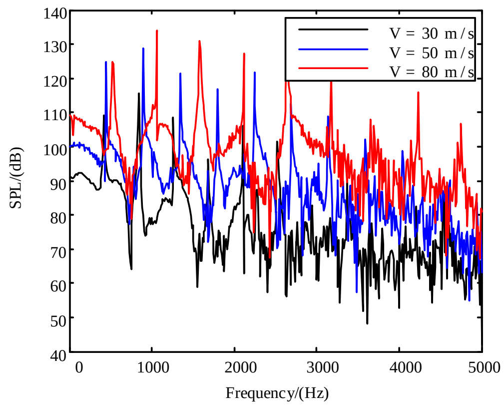

Figure 5 Influence of inlet velocity on SPL

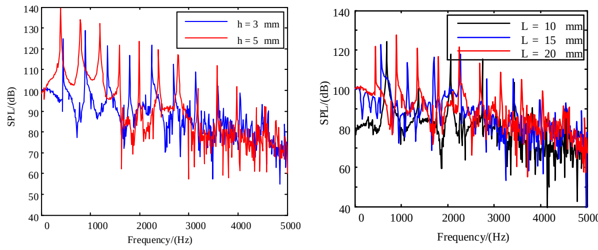

Figure 6 Influence of cavity on SPL

3.2 The Influence of Inlet Velocity and Cavity

The SPL of the noise located above the cavity in different inlet velocities and cavity structure parameters are shown in Figure 5 and 6.

The increase of inlet velocity can not only improve the intensity of the noise around the cavity, but also increase the frequency of the main components of the noise. When the size of the cavity is 2mm*20mm, 3mm*25mm and 3mm*30mm, the flow in the cavity is chaos and the noise is irregular.

The method used in this paper could apply to the bearing fault diagnosis in the situation that the lubricating oil or gas flow through the cracks in bearing.

4. Conclusion

The self-oscillation of flow and the sound field has a strong coupling. The frequency of self-oscillation in the flow field is the fundamental frequency of the noise caused by the cavity. The period of the self-oscillation of the cavity would decreases and the frequency and SPL of the noise would increase with the increase of the inlet velocity. The increase of the length of the cavity can increase the self-oscillation period of the flow field in the cavity and decrease the frequency of the noise. In addition, the decrease of the depth of the cavity have the same results.

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