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NOISE CONTROL FOR A BETTER ENVIRONMENT

Research on Numerical Simulation of Aerodynamic Noise in Split Air-Conditioning Evaporation unit of Rail Vehicle

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ABSTRACT

A computational fluid dynamics model of split air-conditioning evaporation unit is established. The transient flow field of air flow is calculated by large eddy simulation, the frequency domain data of air flow field are obtained by FFT of transient flow field data.Basing on the frequency domain data of flow field, the aerodynamic noise of evaporation unit is calculated through the boundary element method, the calculated results are compared with the test results，the calculated result is only 1.46 dB different from the test result .The result of research shows that the noise value at the outlet of evaporation unit is the highest,and the loudest pressure level is higher than 56 dB; loudest power level occur in the 125Hz to 400Hz low frequency band. Although the sound power level gradually decreases with the increase of frequency, the high frequency band at 5000Hz still radiates

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more than 55 dB sound power level. This indicates that the aerodynamic noise of the air-conditioning evaporation unit belongs to broadband noise.

Keywords: Air-conditioning, Aerodynamic Noise, Sound power
I-INCE Classification of Subject Number: 70

1.INTRODUCTION

Due to space constraints, the EMU driver's room uses split air-conditioning.The evaporators, centrifugal fans and other electrical control components are installed in indoor units, but the axial fans, compressors and condensers are installed under the carbody[1]. When the EMU is running,the main noise sources are wheel-rail noise, aerodynamic noise and equipment noise. The air-conditioning evaporator is installed in the driver's room, and its noise still has a great influence on the room[2].The test data show that the indoor noise of EMU driver can be up to 75dB (A), the noise of air-conditioning outlet position is obviously higher than that of other parts, and the sound level can reach 68dB (A)[3]. One part of the air-conditioning noise is the vibration of compressor, and the other is aerodynamic noise[4-6].

The noise research methods include experiment and simulation[7].The sound power levels and sound energy levels of noise source can be measured through anechoicrooms or hemi-anechoic rooms, and the aerodynamic noise also can be calculated by Large Eddy Simulation method (LES), Boundary Element Method (BEM)[8-10].

In this paper, the computational fluid dynamics model of split air-conditioning evaporation unit is established. The steady flow field is calculated when the air flows through the evaporator,the transient flow field is calculated by LES method. Then the aerodynamic noise is calculated by BEM.

In the end, the sound power levels of evaporators test data and simulation results are compared, the feasibility of the research results is verified effectively.

2.MODELINGANALYSIS

2.1 Geometric Models

The geometric model is shown in Figure1. The evaporation unit is composed of a fan, a radiator, a heater, an air duct, and so on. The evaporation unit can be divided into A, B, C three parts. A have two fans, and the air is mixed here. There is a radiator and a heater in part B. Part C is an air duct. The others can be seen in Fig.1.

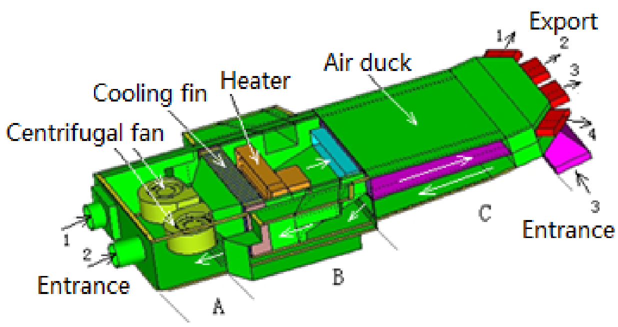

Fig.1 Models of evaporator unit

2.2 Computational Fluid Dynamics Model

The evaporation unit mesh is shown in Fig.2. Fig.2 is the overall model, Fig.3 is the internal fluid grid, and Fig.4 is the fan model. The surface mesh scale of the body is the largest, the maximum value is 20mm, the fan Leaf fan surface scale is the smallest, the minimum scale is 1.5mm, a total of 5649455 fluid units are divided.

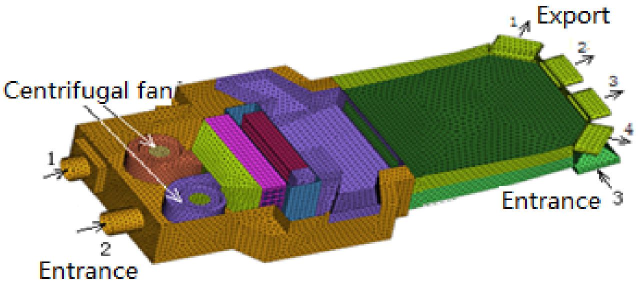

Fig.2 The global mesh

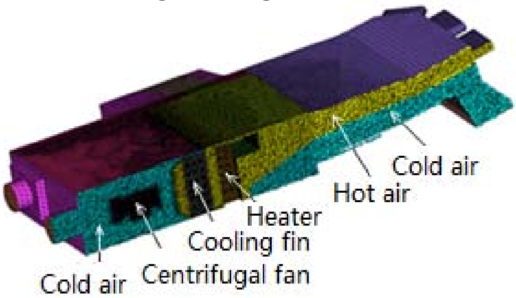

Fig.3 The internal fluid grid

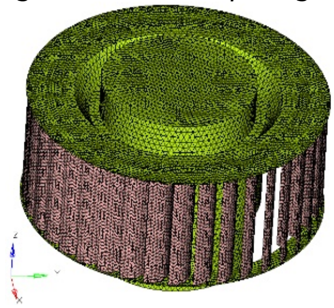

Fig.4 The fan model

2.3 Boundary Unit Model

The boundary element of the evaporator unit is composed of a triangle and a quadrilateral mesh, and a total of 93512 boundary element meshes are divided.

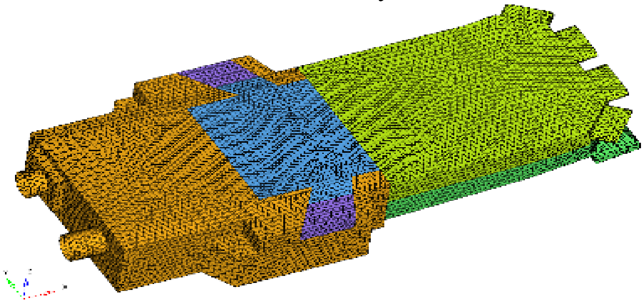

Fig.5 Global model of BEM

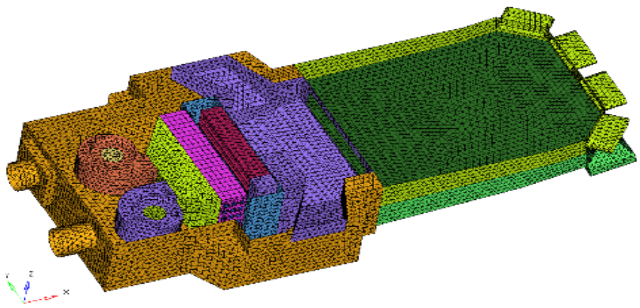

Fig.6 Internal of BEM model

3. STEDY CALCULATION AND INITIAL RESULTS

Based on fluent software, a common standard k-εturbulence model is used to calculate the steady flow field of the condensing unit, and the constant solution of the flow field is obtained, and the initial condition is calculated as the transient flow field.

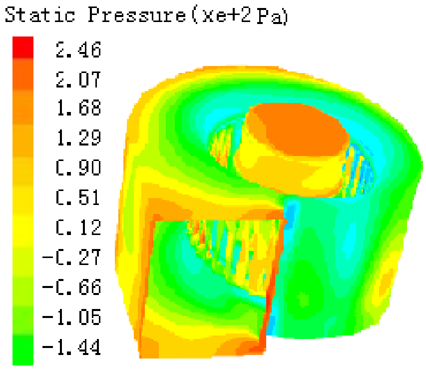

Fig.7 Static pressure of shell

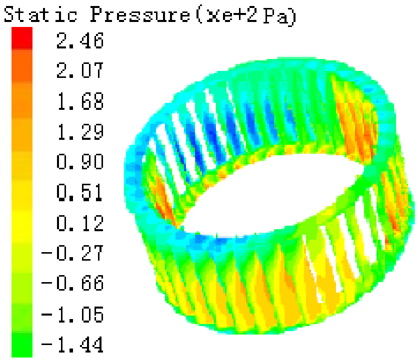

Fig.8 Static pressure of fan

The static pressure cloud diagram of the centrifugal fan shell and the fan is shown in Fig.7 and Fig8, it shows that the outlet area of the shell is more pressing, the pressure on the windward side of the fan is larger, and the pressure of the leaf fan near the axis is smaller.Therefore, the steady-state solution of the split air conditioning evaporator is used as the initial condition for the transient calculation of the LES.

4. AERODYNAMIC NOISE ANALYSIS

4.1 Noise Measurement Point

According to the geometric dimensions of the air conditioning unit and the main sound source, a reference body is set, just as Figure 9. The reference body is the minimum hexahedron of the envelope sound source. The length, width and height of the reference body are L1=1.9m, L2=1.1m, L3=1.6m respectively.A total of 21 monitoring points were arranged on the monitoring surface.

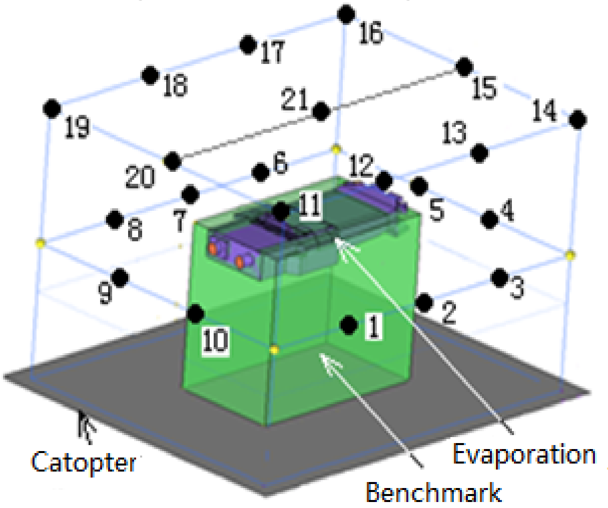

Fig.9 Noise monitoring points

4.2Aerodynamic Noise Cloud Picture

The hexahedron of each measuring point in Figure 9 is the noise response surface, and the sound pressure level of 100Hz and 1250Hz on the response surface is shown in Figure 10 and Figure 11.It shows that the inlet and outlet aerodynamic noise is lager at 100Hz, but the outlet noise is greater at 1250Hz.

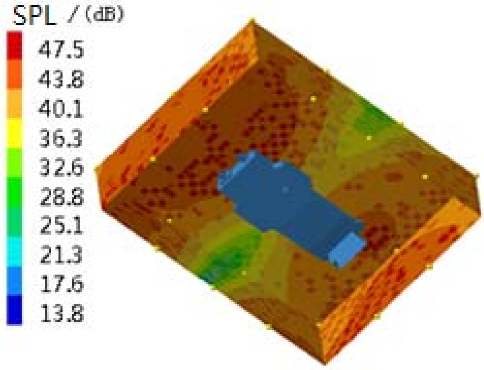

Fig.10 Sound pressure level at 100Hz

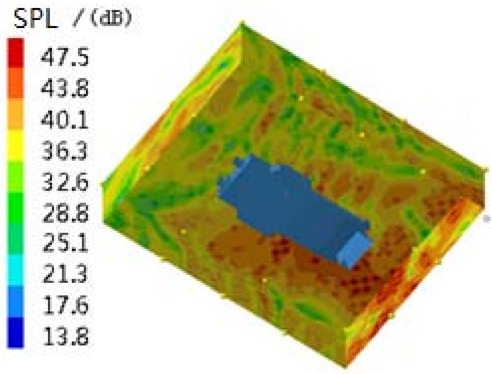

Fig.11 Sound pressure level at 1250Hz

4.3Sound Pressure Level and Average Sound Pressure Level

The sound pressure level of some monitoring points is listed in table 1. At the outlet position and inlet position of the upper part of the evaporator, the noise is greater,the maximum value appears at the monitoring point 15 which is shown in the Figure 9.The frequency is 125Hz, and the value is 56dB.The maximum average sound pressure level appears in 160Hz, and overall the sound pressure level increases with the frequency firstly, and then decreases gradually.

Table 1 The sound pressure level

Points / Frequency	2	5	9	12	15	20	21
100	36	49	50	44	46	47	45
125	45	50	49	50	56	50	51
160	52	53	49	47	52	55	56
200	45	50	42	38	48	43	47
250	45	52	48	37	52	50	51
315	42	47	38	32	39	39	37
400	51	52	53	47	55	35	53
500	43	47	36	37	36	46	40
630	45	51	41	43	46	45	42
800	47	49	30	39	47	38	52
1000	41	50	32	40	40	43	40
1250	45	51	42	40	43	42	34
1600	48	42	44	44	45	47	46
2000	42	41	33	43	36	42	39
2500	37	45	48	35	36	39	36
3150	32	41	45	40	43	42	42
4000	39	42	29	41	39	42	39
5000	45	37	33	40	36	40	35

Table 2 The average sound pressure level

Frequency （Hz）	Average Sound Pressure Level	Frequency （Hz）	Average Sound Pressure Level
100	45.95	800	47.06
125	51.32	1000	42.28
160	51.81	1250	43.23
200	44.32	1600	46.52
250	47.61	2000	43.13
315	40.36	2500	43.41
400	49.27	3150	42.57
500	41.46	4000	42.11
630	45.06	5000	38.26

4.4Sound Power Level

The sound power level of evaporator unit is shown in table 3. The sound power level distribution characteristics of frequency are similar to the sound pressure level, and the maximum value appears in 160 Hz.The total sound power level is 75.71dB.

Table 3 The sound power level

Frequency（Hz）	Sound Power Level（dB）	Frequency（Hz）	Sound Power Level（dB）
100	62.80	800	63.91
125	68.17	1000	59.13
160	68.66	1250	60.08
200	61.17	1600	63.37
250	64.46	2000	59.98
315	57.21	2500	60.26
400	66.12	3150	59.42
500	58.31	4000	58.96
630	61.91	5000	55.11

4.5Experimental Test and Analysis

In order to verify the calculation results, the sound pressure level and sound power level were tested in the acoustic laboratory. The experiment is shown in Fig.12.

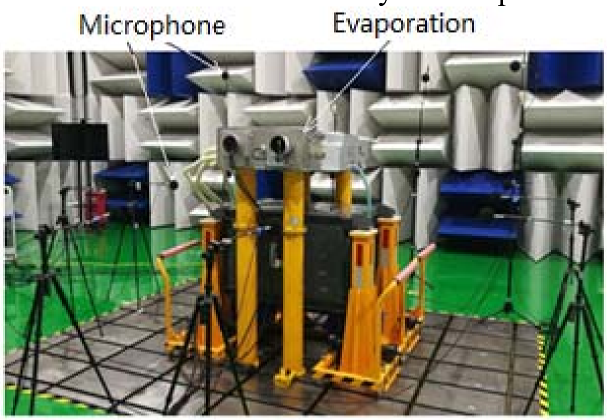

Fig.12The experimental model

The sound power level curvesobtained by experimental test and simulation are shown in Figure 13, and the result of simulation is the same tendency with the test curve. The sound energy of the low frequency band form 125Hz to 400Hz is larger, and it decrease gradually with the frequency increase. The test curve is relatively flat, but the simulation result appears more peaks and troughs. The error between simulation and test is larger over 2000Hz. The total sound power level of test is 74.25dB, and the simulation is 75.71dB, the error only is 1.46dB.

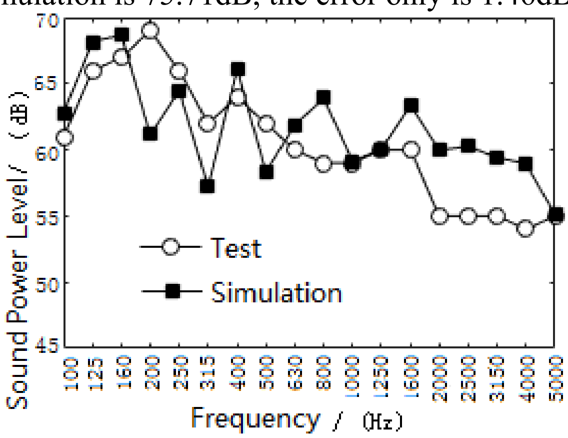

Fig.13Sound power levels simulation and test

5. CONCLUSION

(1) The split air-conditioning evaporation unit has a relatively large noise at the outlet and inlet position.

(2) The sound power level curves obtained by experimental test and simulation are basically in agreement, and the largest sound energy appears in the low frequency band from 125Hz to 400Hz.

(3) The total sound power level error of simulation and test is 1.46dB, and the method used in this paper is feasible.

5. ACKNOWLEDGEMENTS

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