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Simulation of Air-Gap Noise of New Energy Automobile Motor

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Abstract. The simulation of Air-Gap Noise of the motor includes two aspects: near-field noise and far-field noise. Firstly, a three-dimensional solid model of the motor is built in CATIA, and then imported into HyperMesh to generate the grids of the motor Air-Gap. Then the meshing model in HyperMesh is introduced into Fluent CFD software in the form of .cas to calculate the near-field noise of the motor Air-Gap; Finally the meshing model is imported into the CFX CFD software in .cas format for transient calculation to obtain the boundary conditions of the acoustic boundary element, and the far-field noise of the motor Air-Gap is calculated with Lms Virtual Lab.

1. Introduction

Under normal operating conditions, new energy motor has complex noise sources. The main noises are mechanical structure noise, electromagnetic noise, coupled noise (that is, noise generated by the interaction of gas and solid elastic systems) and Air-Gap Noise. Among them, Air-Gap Noise is the most difficult to control in the high-speed section (above 6 000 r/min) as electromagnetic excitation noise. The source of Air-Gap Noise is the periodic pulsation of the surface pressure of the rotor and the shedding, generation and rupture of the vortex. The size of Air-Gap Noise is closely related to the rotor structure, the rotational speed, and the internal air duct structure. Air-Gap Noise appears as a superposition of discrete noise and broadband noise. Discrete noise, also known as rotational noise, is generated by the periodic pulsation of the air caused by the rotor. Broadband noise, also known as eddy current noise, is a broadband noise radiated by the stator cogging and gas coupling during the rotation of the rotor. It includes turbulent noise, turbulent boundary layer noise, trailing edge eddy current shedding noise and tip, etc.

At present, for Air-Gap Noise problem, many scholars have done a lot of research as on the aerodynamic noise characteristics, noise sources, propagation paths and noise reduction of the motor through theory, simulation and experimental research methods. Huibin Li et al. [1] proposed an effective turbocharger flow field calculation method and aerodynamic noise calculation method, and



verified the effectiveness of the simulation through experiments. Yadong Zhang et al. [2,3,4] studied the contribution of the main orders of the alternator to the total noise, and obtained the sixth, eighth, tenth, twelfth, and eighteenth order as the main aerodynamic noise components of the alternator. Guilan Chen et al. [5] studied the noise damper device for reducing the noise of asynchronous motor, and proposed an effective method to add noise damping for the motor hole to control the aerodynamic noise. Qiang Su et al. [6] studied the aerodynamic noise of the motor by two methods: the surface drilling of the blade and the opening of the blade edge. It is proposed that the combination of the surface drilling of the blade and the opening of the blade edge is the best. Qi Liu et al. [7] obtained numerical simulation analysis that the radiated sound field of AC generator aerodynamic noise has a certain dipole directionality, and the distribution has certain symmetry. In terms of numerical simulation studies, Lighthill. [8,9] shown that acoustic analog theory has been applied to the aerodynamic noise prediction of alternators. Nises. [10] pointed out that a dipole point source can be used to describe the aerodynamic noise caused by the high-speed rotation of the centrifugal cooling fan. Kim et al. [11] studied the aerodynamic noise of the alternator using the standard k- ϵ turbulence model. The results show that the numerical simulation results at high speed are about 12 dBA, which is higher than the experimental measurements. In summary, the mechanism of aerodynamic noise of new energy motor needs further research.

2、Three-dimensional model of the motor Air-Gap

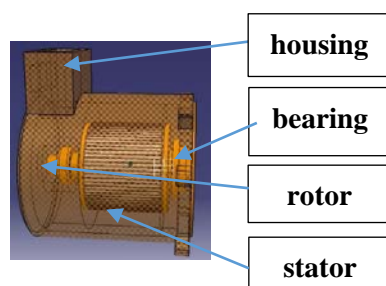


Figure 1. Motor model.

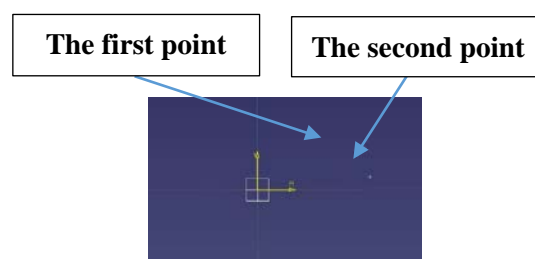


Figure 2. Motor rotor eccentric position.

A three-dimensional model of the motor in CATIA, was shown in Fig. 1. The motor consists of a stator, a rotor, bearings, and a housing. The stator is fixed to the outer casing. The rotor is connected to the outer casing through the bearing, and the space enclosed by the stator, the rotor and the outer casing and the bearing is the motor Air-Gap. However, the eccentricity of the rotor will occur during the actual operating conditions.

The Air-Gap Noises of the motor at two positions of the rotor eccentricity are calculated. As show in Fig. 2, the coordinates of the first point are (0. 1715 mm, 0. 0651 mm), and the coordinates of the second point are (0. 1807 mm, 0. 02 mm). In the subsequent simulation, the motor Air-Gap Noises at these two points are selected for calculation.

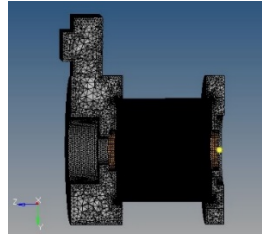
3、Three-dimensional model meshing of the motor Air-Gap

Air-Gap meshing of the motor is generated by Hypermesh software. The grid size is about 5 mm, the stator cogging grids size is 1 mm, and the body meshing is generated by Tetramesh modules. All the elements of the motor are selected to generate the volume meshing. The quality of the volume meshing is shown in Table 1.

Table 1. Grid Quality of the motor Air-Gap.

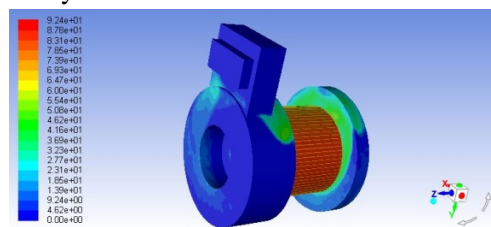
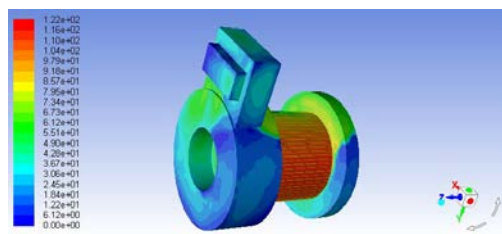
Project of Grids	Value
Aspect ratio	14. 17
Twist index	86. 11°
Jacobian ratio	1

As show in Table 1, Aspect ratio of the motor Air-Gap grids and Jacobian ratio are both ideal, but Twist index is slightly worse. The main reason is that the groove of the stator and the gap between the stator and the rotor are too small. Air-Gap meshing of the motor is generated as show in Fig. 3.

**Figure 3. Internal Meshing of the motor.**

4、Near-field noise calculation of the motor Air-Gap

The near-field noise calculation of the Air-Gap steady flow is carried out with Fluent software, the solver adopts Pressure-Based, the Energy model uses Energy-Equation, the Viscous model uses k-epsilon, and the Acoustics model uses Broadband Noise Sources. Material uses Air, Scheme uses Simple in Scheme, Gradient selects Least Squares Cell Based, Pressure selects Second Order, Momentum selects Second Order Upwind, Turbulent Kinetic Energy selects First Order Upwind, Turbulent Dissipation Rate selects First Order Upwind, Energy selects Second Order Upwind. The motor rotor speed is set to 8000 rpm. The Air-Gap flow field of the motor is calculated to obtain the near-field noise till it reaches steady state.

**Figure 4. Air-Gap sound power level diagram of the motor rotor in eccentricity 1 position.****Figure 5. Air-Gap sound power level diagram of the motor rotor in eccentricity 2 position.**

As show in Fig. 4 and Fig. 5, the simulation with Fluent software shows that the acoustic power distribution of the motor Air-Gap at the eccentricity 1 and eccentricity 2 is basically the same. Compared with eccentricity 2, the motor sound power level at eccentricity1 is lower, and its maximum

sound power level of the near-field noise reaches 92.4 dB, and the maximum sound power level of the near-field noise at the eccentric 2 reaches 122 dB.

5、Far-field noise calculation of the motor Air-Gap

Far-field noise of the motor Air-Gap is jointly calculated by CFX and Lms Virtual Lab software. The first step is to calculate the unsteady flow of the motor Air-Gap with the CFX software. The time step is taken as 0.00005 s, and the Acoustic Dipole is derived. In the second step, in the Lms Virtual Lab software, the Acoustic Dipole is used as the boundary condition of far-field noise calculation, and the Acoustics Response Case is used to calculate far-field noise of the motor. Far-field noise calculation model of the motor Air-Gap is shown in Fig. 6.

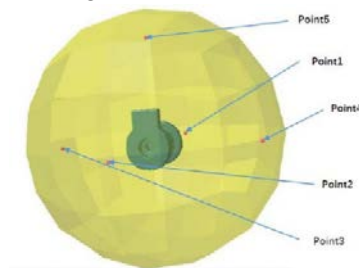


Figure 6. Far-field calculation model of the motor (5 measuring points are distributed in the figure).

Table 2. Total sound pressure level of each point in the far-field of the motor.

Position	Acoustic pressure level of each measuring point in eccentric 1 position (dB)	Acoustic pressure level of each measuring point in eccentric 2 position (dB)
Point-1	77. 12	76. 24
Point-2	82. 04	76. 41
Point-3	91. 55	74. 93
Point-4	68. 49	61. 15
Point-5	67. 18	64. 18

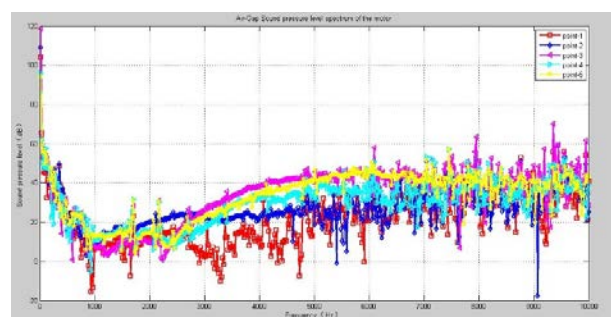


Figure 7. Sound pressure level spectrum of far-field of the motor rotor in eccentricity 1 position.

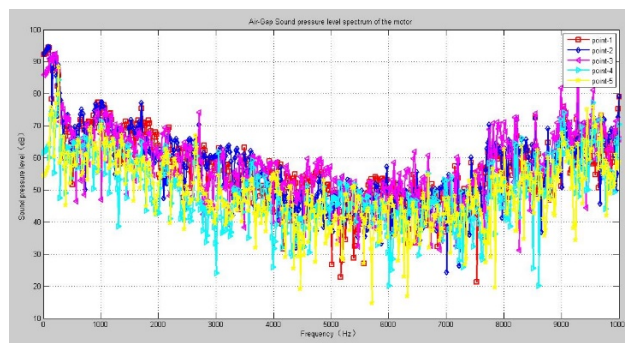


Figure 8. Sound pressure level spectrum of far-field of the motor rotor in eccentricity 2 position.

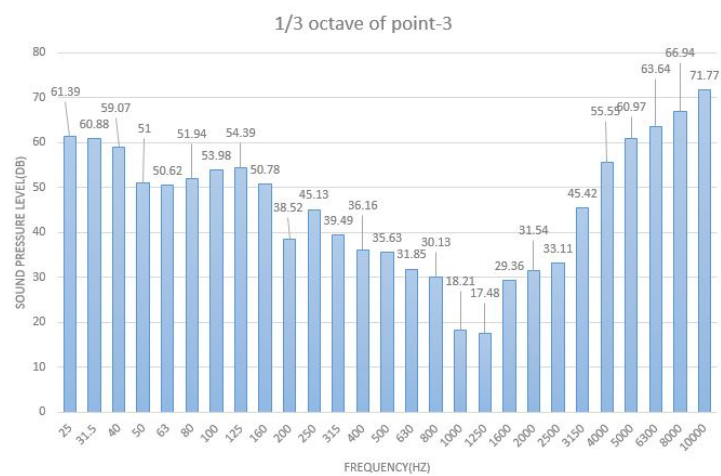


Figure 9. 1/3 octave diagram of point-3 of the far-field of the motor rotor in eccentricity 1 position.

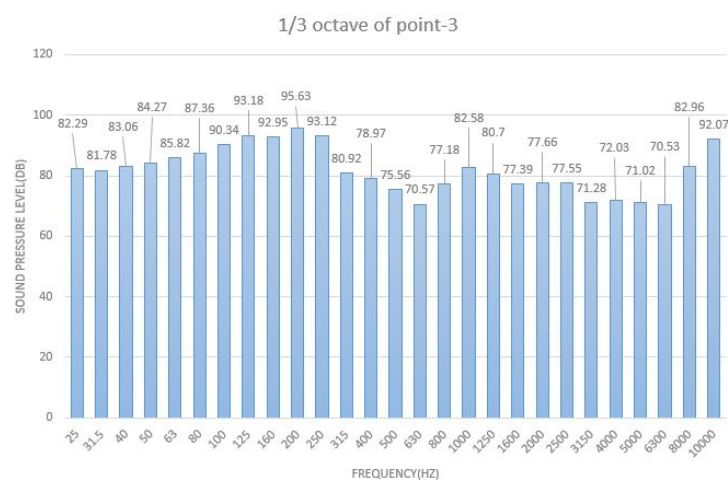


Figure 10. 1/3 octave diagram of point-3 of the far-field of the motor rotor in eccentricity 1 position.

6、 Conclusion

The motor rotor's near-field sound power level at eccentricity 1 is smaller than that at eccentricity 2.

For the five points of the far-field, total sound pressures level of the motor is the highest at point-3 and point-2 which correspond to the eccentricity 1 and the eccentricity 2. The far-field noise are different because of the eccentric position of the rotor, and at point-3 of the eccentricity 1 position the total sound pressure level reaches 91.55 dB.

The Air-Gap Noise spectrum of the motor rotor at eccentricity 1 position concentrates below 400Hz and 10000Hz, but it is relatively uniform at eccentricity 2 position.

The far-field noise simulation results of the motor Air-Gap show that the noise is mainly broadband, and the noise is prominent at point-3 in 25Hz, 100Hz, 250Hz and 10000Hz in eccentricity 1 position, but the distribution of noise spectrum is more uniform in eccentricity 2 position, and the noise at point-3 reaches the peak in 250Hz, 1000Hz and 10000Hz.

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