Research on Aerodynamic Noise Simulation of Rearview Mirror Based on Reverse Engineering

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Abstract

With the speed of the automobile moving up, the aerodynamic noise behind the rearview mirror becomes an important part of the aerodynamic noise of the passenger vehicle, and the shape of the rearview mirror is the important influence factor of the aerodynamic noise behind the rearview mirror. In this paper, a SUV rearview mirror is used as the research object, which entity model is reconstructed by reverse modeling technology, the flow field and noise field in the rear of rearview mirror are analyzed by ANSYS Fluent, then the flow field characteristics and aerodynamic noise characteristics at the rear of the rear view mirror are obtained, which is helpful for the aerodynamic modeling of the rearview mirror.

Keywords

rearview mirror; aerodynamic noise; reverse modeling technology; Fluent

1. Introduction

With the increase of the automobile driving speed, the aerodynamic noise of the automobile increase gradually, When the automobile speed reach 100km/h, which has a direct impact on the automobile driving performance[1]. As the automobile has a very complex surface profile, which surface each part will produce vortex and noise when the air flow through the automobile surface. As the rearview mirror protrudes from the outside of the automobile, a strong turbulent structure is generated in the wake region of the rearview mirror by the flow around a blunt body, and the aerodynamic noise is generated by turbulent structure moves regularly and beat the front window. Due to the rearview mirrors with different external shapes have different aerodynamic noises characteristics, analyzing the influence of external shape of rearview mirror on aerodynamic noise have a great significance to study the aerodynamic noise of automobiles.

Wang Yi-Ping et al has used the modeling software to increase the bottom arc transition of the rearview mirror, making it more streamlined, and then the Large Eddy Simulation is used to simulate and analyze the aerodynamic noise characteristics, their results showed that the aerodynamic noise after the modification of the rearview mirror has declined[2]. Li Qi-Liang et al studied the flow field of automobile rearview mirror by using LES based on the separation eddy simulation and reynolds averaged simulation was used to study the unsteady automobile outflow field[3]. Yang Bo et al obtained the unsteady characteristics and the sound pressure level in the wake region of the rearview mirror by using the separation vortex simulation method[4]. Chen Ji-Fu et al have studied the influence of shape and structure of rearview mirror on aerodynamic noise in detail and founded that the rearview mirror after modification have a great significance to noise[5]. Bahram Khalighi Simulated the flow field in the rearview mirror and the wind induced noise[6]. Christoph Reichl studied the effects of different grid types on the aerodynamic noise in the rearview mirror region by using the simplified rearview mirror, which was divided into tetrahedron or hexahedron grid[7].

The researchers have made a more comprehensive study of aerodynamic noise in the rearview mirror region, however, in the study of the influence of different shapes of rearview mirrors on aerodynamic noise, the shape of the rearview mirror is modified all through manually, the amount of time consumed in the establishment of the model and the division of the grid.

In this work, a specific SUV rearview mirror as the object of research, which entity model is reconstructed by reverse modeling technology, the ANSYS Fluent is used to analyze the flow field of the rearview mirror and obtained the aerodynamic noise characteristics, as the rearview mirror is based on the real rearview mirror, the analysis results can provide a reference for the aerodynamic modeling of the rearview mirror.

2. Reconstruction of rearview mirror geometric model

The rearview mirror entity model is shown in figure 1, which contour is scanned by the OptimScan-5M 3D optical scanner, scanning scene is shown in figure 2, the scanned contour point cloud of the rearview mirror is imported into the reverse modeling software Geomagic Studio and the slice model is formed by removing spots, filtering, and encapsulating in it[8], figure 3 shows the slice model, finally, the slice model is imported into UG and the geometric models is generated by stitching and thickening in it, figure 4 shows the reconstructed geometry model of the rearview mirror.

Figure 1. Entity model of rearview mirror

Figure 2. Scanning scene of rearview mirror

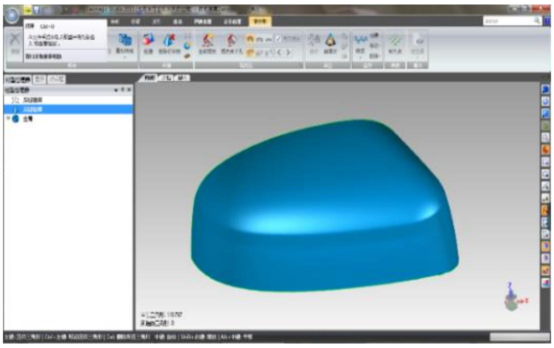


Figure 3. Geometric slice model of rearview mirror

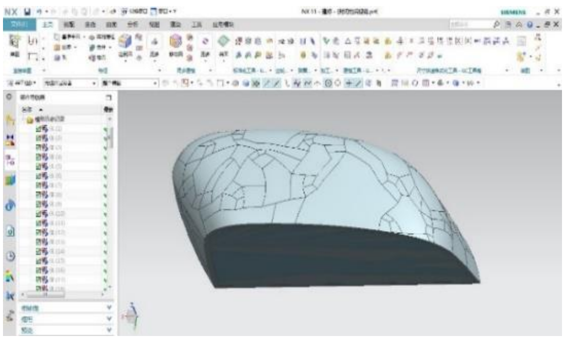


Figure 4. Geometry model of rearview mirror

3. Analysis process of aerodynamic noise

3.1 Analysis theory of aerodynamic noise

According to the previously mentioned, the main reason for the aerodynamic noise of the automobile is that the rearview mirror protrudes from the outside of the automobile, in the process of automobile running, around the rearview mirror will produce airflow instability and pressure pulsation[9]. Therefore the computational fluid dynamics (CFD) theory[10] is applied to solve the fluctuating pressure around the flow field of the rearview mirror in time domain, the aerodynamic acoustics (CAA) theory[11] is applied to solve the noise spectrum and the sound pressure level around the rearview mirror in the frequency domain.

3.2 Analysis procedure of aerodynamic noise

3.2.1. Computational domain model selection and mesh generation

Before the fluid analysis is performed, it is necessary to determine the computing domain of the rearview mirror in the flow field, in order to ensure that the airflow in the computing domain is fully developed, the length of the computational domain model, the width of the computational domain model and the height of the computational domain model are 10L * 5L * 5L (L is the length of the rearview mirror), respectively, figure 5 shows the computational domain model. The ICEM is used to mesh the rearview mirror, structure grid and unstructured grid are adopted in the process of mesh generation, that is the core computing domain is divided into non-structural grids by using tetrahedral element; the non-core computing domain is divided into the structure grid by using hexahedron element[12]; the grid model of computing domain is shown in figure 6.

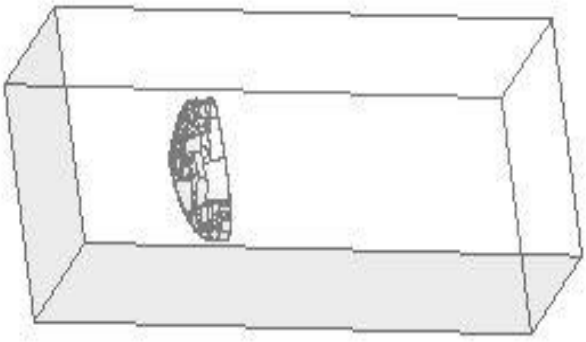


Figure 5. Geometry model of computational domain

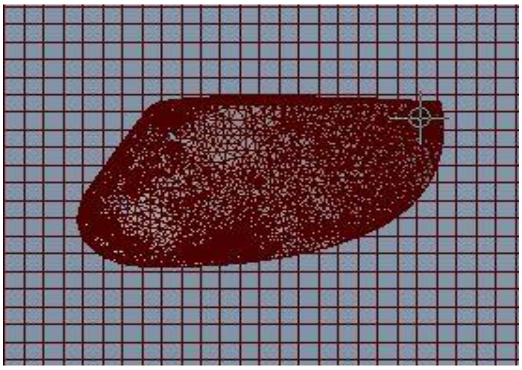


Figure 6. Grid model of computational domain

3.2.2. The scheme of numerical simulation

The rearview mirror is directly installed in the cuboid computing domain, the Reynolds-Averaged Navier Stokes (RANS) method is used to solve the steady flow field, the LES method is used to solve the transient based on the steady-state flow field, after the transient flow field is calculated, the Ffowcs-Williams and Hawkings acoustic model is transferred into the simulation, in which the noise source and the receiving point is defined, the noise source is disposed on the surface of the rearview mirror, the position of the receiving point is evenly distributed near the back of the rearview mirror, figure 7 shows the schematic diagram of the receiving points, finally, the noise spectrum and the sound pressure level is obtained by Fast Fourier Transform (FFT).

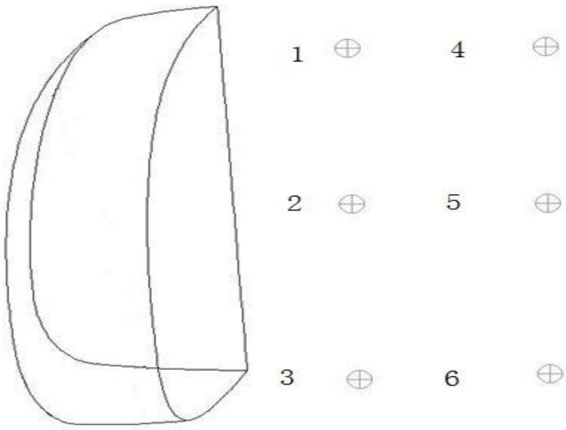


Figure 7. Schematic diagram of the receiving point in space position

4. Analysis of simulation result

4.1 Analysis of outflow field

Figure 8 shows the nephogram of pressure distribution on the surface of the rearview mirror when the automobile speed is 100 km/h, as can be seen from the nephogram, the positive pressure on the surface of rearview mirror is larger, while the negative pressure value of the tail is larger, positive and negative pressure difference is an important factor that causes running resistance of automobile and main source of automobile aerodynamic noise.

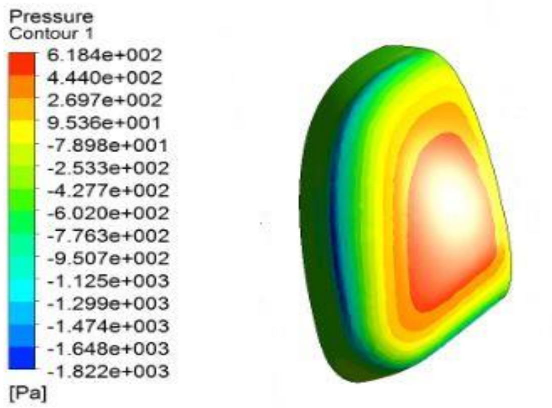
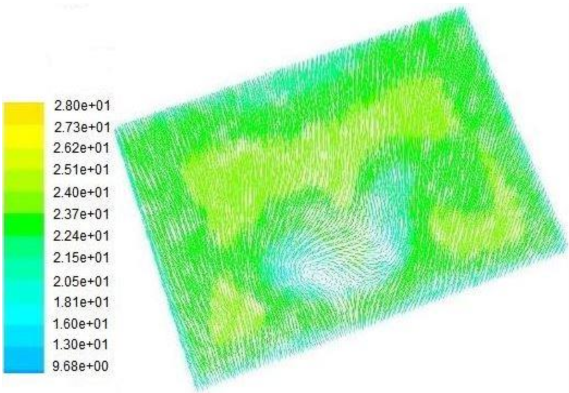


Figure 8. Nephogram of pressure distribution on the surface of rearview mirror

A section of the rearview mirror is selected as the distribution plane of the velocity vector diagram, the section diagram is shown in figure 9, and the velocity vector diagram is shown in figure 10. As can be seen from the graph, as the pressure difference between the front and the back of the rearview mirror is large, airflow produces two swirling vortices when it flows through the back of the rearview mirror, one of which is larger and the other smaller, the two vortices form two negative pressure centers and generate the reflux region, which move constantly behind the rearview mirror and generate aerodynamic noise.



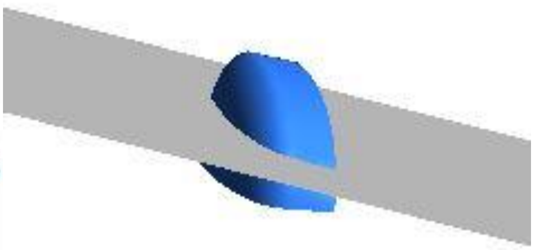


Figure 9. Schematic diagram of section Figure 10. Diagram of velocity vector

Figure 11 shows the streamline diagram at the back of rearview mirror, as can be seen from the graph, the streamline produce disorder when it through the back of the rearview mirror, in which the above of the streamline is less disorder, but the below of the streamline is more, so the vortex that is generated in below is larger than the vortex that is generated in above, which is consistent with its velocity vector diagram.

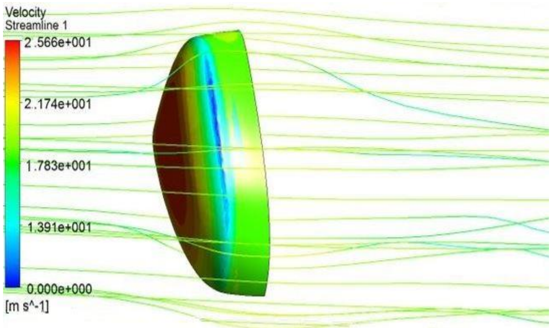


Figure 11. Streamline diagram at the back of rearview mirror

4.2 Analysis of aerodynamic noise

Figure 12 shows the noise spectrum curve behind the rearview mirror on the basis of the flow field, due to the receiving points are evenly distributed behind the rearview mirror and are not very close to each other, the noise spectrum curve of the six receiving points is the same basically, the noise spectrum curve of the receiving point 3 near the window side is selected for analysis, which frequency range is 0-50000Hz, as can be seen from the sound pressure spectrum curve, in low frequency region, the sound pressure level is higher and the energy is larger, in high frequency region, the sound pressure level is low and the energy is smaller. Human hearing is the most sensitive to noise of 2000-6400Hz, the result shows that the sound pressure level is larger in this region, therefore the noise around the rearview mirror is mainly concentrated in the low frequency region which can be heard by the human. As can also be seen from the sound pressure spectrum curve, the sound pressure level around the receiving point has periodic fluctuation, and the greater the fluctuation, the greater the noise, so it is important to optimize the shape of the rearview mirror for reducing the noise of the back of rearview mirror.

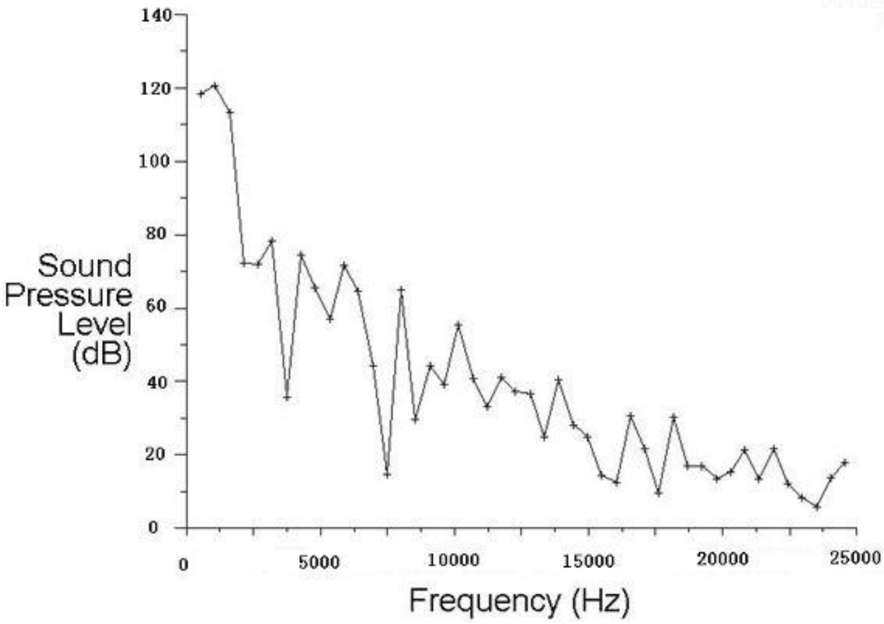


Figure 12. Noise spectrum of receiving point at the back of rearview mirror

5. Conclusion

In the present paper, a specific rearview mirror is taken as the object of research, the aerodynamic noise characteristics behind the rearview mirror are analyzed by using ANSYS Fluent based on the reverse modeling technology, the results of the analysis can not only provide reference for the aerodynamic noise behind the rearview mirror, but also provide reference for the pneumatic modeling of the rearview mirror.

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