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The Reconstruction of Noise Acoustic Fields of Interior of the Car Based on LMS Virtual.Lab

Zhang Wenping[1], Qi Hongzhong[2]
[1]*(College Of Automotive Engineering, Shanghai University Of Engineering Science, China)*
[2] *(College Of Automotive Engineering, Shanghai University Of Engineering Science, China)*

Abstract: The concept of the acoustic transfer function of acoustic cavity is expounded.This paper proposes a method through solving the acoustic transfer function to reconstruct the interior noise sound fieldbased on Virual.Lab acoustic finite element analysis.Some control points on surface of the wall of cavity are set up and the transfer functionsfrom control points of the key positions in the acoustic cavity are given.With the acoustic transfer function and the measured sound pressurefrom the test, system of linear equations can be solved and the excitation signals of control points are gained.Take a caras an example, the feasibility of the sound field reconstruction method is proved.

Key words： transfer function;Virual.Lab; system of linear equations;sound field reconstruction

I. Introduction

Due to the requirement of energy saving and environmental protection, the vehicle body design of modern cars continues to develop in the direction of lightweight, which makes the low frequency noise problem caused by the engine and car body vibration become more prominent.The too powerful low-frequency noise is easy to make the person fatigue and reducepassenger acoustic comfort and enjoyment. Generally,decorative materiallying on the body inner panecan hardly absorb the low-frequency noise, but active noise active control can reduce low frequency noise.For complex cavity acoustic field, the complexity of geometric shape makes the theory of modeling difficult to reflect the real situation, for the reasons of cavity inner pane's surface vibration and acoustic field coupling and the dynamic response of the interior is also difficultlynumerically simulated, the prediction errorof sound field theory is large[1].The meaning of solving the acoustic transfer functionis that for the actual car body, no matter how complex the internal cavity structure is and the dynamic response of the interior, the sound pressure of key positionsin the cavity of car,such as the positions near the occupants'heads, can be measured with the aid of experiment. By the Virtual.Lab acoustic finite element analysis, the sound fieldcan be reconstructed with the transfer function and the pressure of the simulation is more close to the actual measurement of sound pressure and can be used for acoustic optimization.Active noise control can reduce the noise in this method and the speakers in the carcan be used to reconstruct the interior acoustic field under a certain condition.

II. The Transfer Function

For vibration of elastic paneof the car, the elastic plate is divided into several small vibrant areas [2][3]. If the size of each area relative to the acoustic wavelength is very small, the sound radiation of vibration area with the same intensity can be used to approximate point source. The ratio ofacoustic pressure value of the key location generated by the point source in the cavity and the intensity of the point source itselfis called the transfer function between the two.Therefore, sound transfer function actually reflects the relationship between the volume velocity of the pane vibration area and the sound pressures of its key location in the sound field.The numbersof monitoring points used for monitoring targetpressure $Po(f)_i$ ($i \le N$),which distributedinside acoustic cavity is 'N'.The numbers of monopole sound source points, which distributedon the top of the car cavityand used to control the sound field is 'M'. The excitation signals of control points are $Gd(f)_j$ ($j \le M$).If the responsefrequency is f, the transfer function of every control point to the monitoring point is $H(f)_{i,j}$. The following expressions are given:

$$\boldsymbol{H}(f)\bullet\boldsymbol{Gd}(f)=\boldsymbol{Po}(f) \quad (1)$$

$$\boldsymbol{H}(f)=\boldsymbol{Po}(f)\bullet\boldsymbol{Gd}(f)^{-1} \quad (2)$$

Where $\boldsymbol{Po(f)}=[Po(f)_i]^{\mathrm{T}}_{M*N}$ is a matrix expressing sound pressures of monitoring points,

$\boldsymbol{Gd(f)}=[Gd(f)_i]^{\mathrm{T}}_{N*N}$ is a matrix expressing excitation signals of control points, $\boldsymbol{H(f)}=[H(f)_{i,j}]^{\mathrm{T}}_{M*N}$ isa matrix expressing transfer function of control points to monitoring points[4].The acoustic pressures of monitoring pointsarecomposed of direct sound and reverberation sound.

Assuming that the actual measured sound pressures of monitoringare $\boldsymbol{Po'(f)}$, excitation signalsof control point source are $Gd'(f)$ and the expression is inferred as

$$Gd'(f) = H(f)^{-1} \bullet Po'(f) \quad (3)$$

III. The Reconstruction Of Noise Acoustic Fields

1.1 The solution of transfer function

In Virtual.Lab, the locationsof monitoring points are neardriver'sears and the passenger's ears.Using the finite element method to compute acoustic modes, the control points are set on the front and rearof the upper cavity with the two monopole sound sources are arranged on, as shown in figure 2.

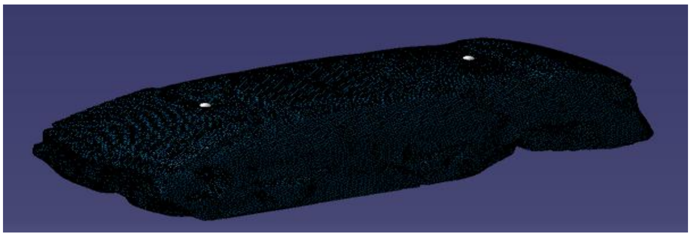


Fig. 1. The finite element model of a car

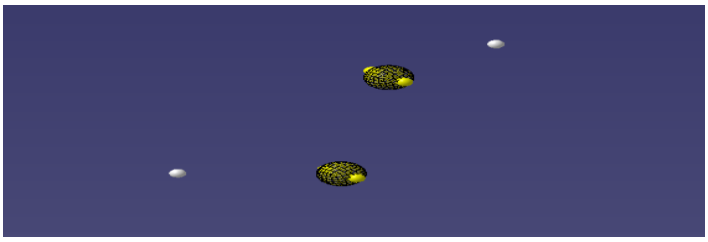
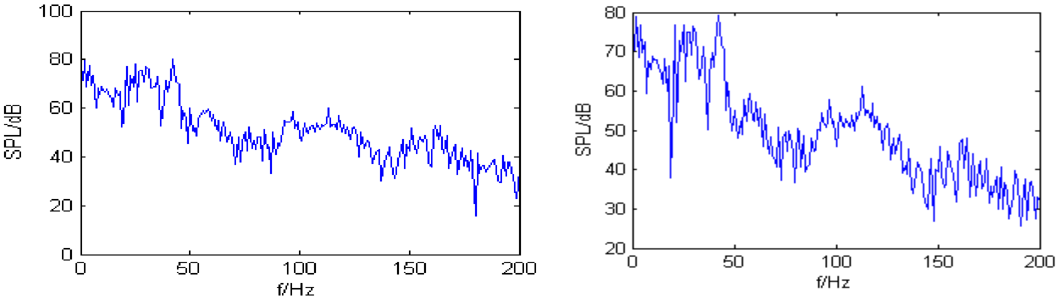
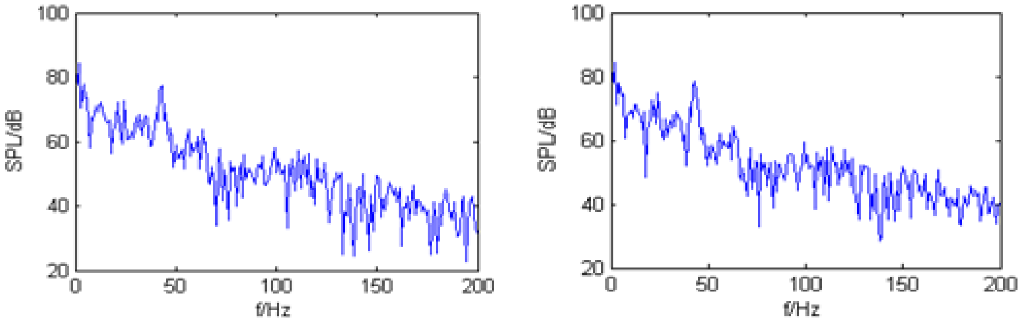


Fig. 2. Control monopole sound sources and monitoring points near the heads

In real vehicle tests under a certain conditions, frequency responsesof the locations of driver's ears and the passenger's ears are measured. The range of the frequency is from 1 Hz to 200 Hz and the step length is 1 Hz. Actual sound pressuresmeasured are shown in figure 3.



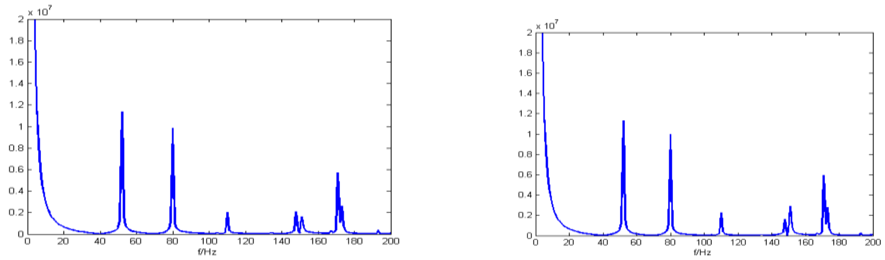
(a) Theleftear of the driver (b) The right ear of the driver



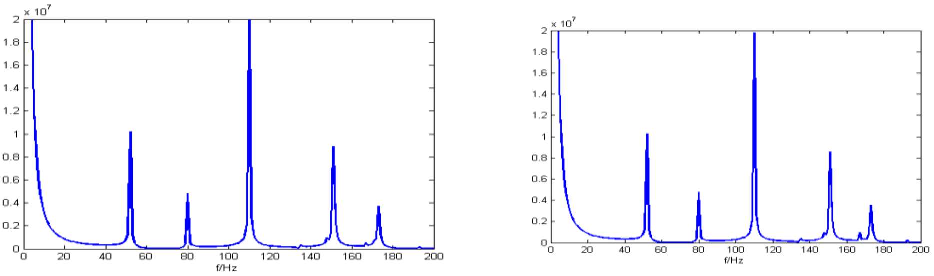
c) Theleftear of the passenger (d) The right ear of the passenger

Fig. 3. Real frequency response curve of the driver's ears and passenger's ears

ByVirtual.Lab, independent actionof the two monopoles at a particular frequency obtainsthe pressure from each monopole to every earto gain transfer function $H_{i,j}$, which is shown in figure 4, 5.

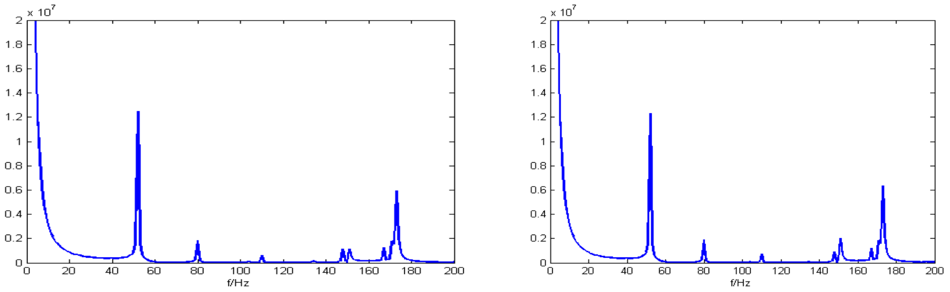


(a) Theleftear of the driver (b) The right ear of the driver

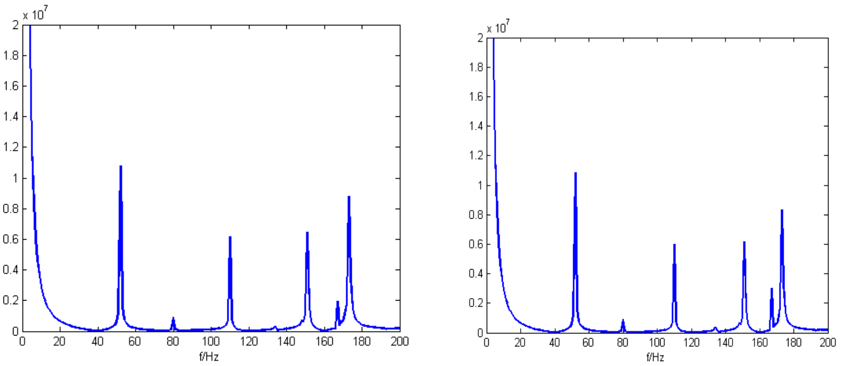


(c) Theleftear of the passenger (d) The right ear of the passenger

Fig .4. The transfer functionof the front monopole sound sourceaction



(a) Theleftear of the driver (b) The right ear of the driver

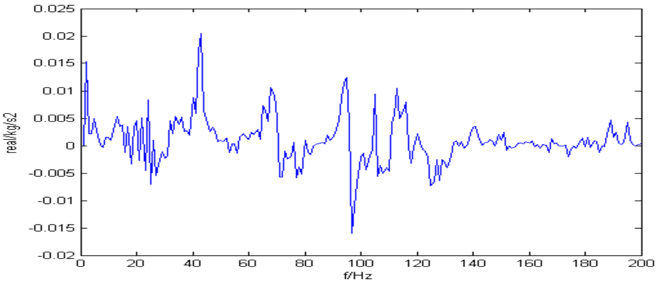


(c) Theleftear of the passenger (d) The right ear of the passenger

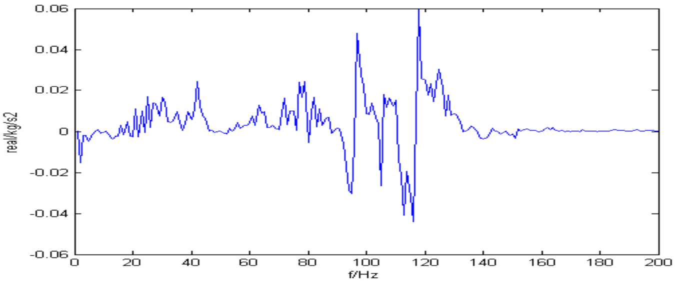
Fig .5. The transfer functionof the rear monopole sound sourceaction

3.2 Excitation signals of monopole sourcesbased on the acoustic field transfer function.

Importthe data to Matlab and compile program aboutthe transfer function to get the frequency response function and excitation signals needed to be loaded into the two monopole sound source, as shown in figure 6.



(a) Thefrequency response function of front monopolesound source

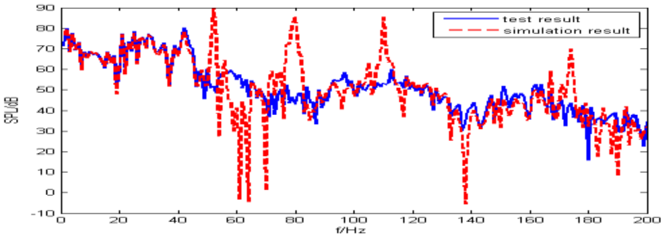


(b)Thefrequency response function of rear monopolesound source

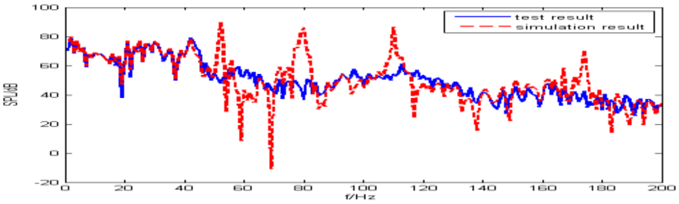
Fig6. Refactoring interior sound field, two monopole sound source frequency response curve

3.3 Simulation verification

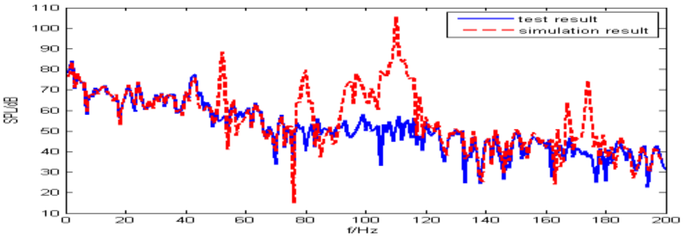
Import the frequency response function to Virtual lab and monopole sound sources work at the same time. Gainreconstructedsound pressuresof the monitoring points to compare with actual measured sound pressures, as shown in figure 7.



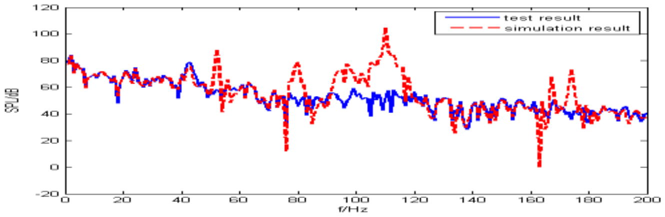
(a) Theleftear of the driver



(b) The right ear of the driver



(c)Theleft ear of thepassenger



(d)The right ear of thepassenger

Fig7. The simulation outputs compared with actual test results of monitoring points

From the figure,the curves of software simulation of noise signalsare close to the testresultsbetween 0 Hz and 200 Hz.However, for the reason that the systems of linear equations are morbid in some frequencies,there would be no solutions, which may loadto larger errors.Increasing the numbers of control points and monitoring points can be more realistic reconstructed the whole cavity sound field.

IV. Conclusion

Active noise active control is mainly aimed at the in-car noise below 1000 Hz frequency.Reconstructing interior sound field based on sound transfer function can establish the contact cavity sound field andthe specific location according to the acoustic transfer function in the casethat the frequency and the shape of the cavity structure and interior automotive materials under the condition were given,whichisbeneficial for acoustic optimization on key positions.On the basis of and the cavity acoustic pressure ofkey positions,the given sound sources and the frequency response function,the solving matrix equations are established and the transfer function of every sound source is also obtained.Excitation signals of the sound sources can be gainedwithreal test sound pressures.Finally,by the comparison between simulation resultsand actual measured, the factors affecting the simulating precisioncontain errorsof measurement,finite element modelsand morbid equations.

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