Technical Note

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MODELLING THE INTERIOR SOUND FIELD OF A RAILWAY VEHICLE USING FINITE ELEMENT METHOD

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The interior sound field of a railway vehicle was modelled using Finite Element method. The Finite Element model was composed of air cavity and seats. The boundary of the compartment was modelled as rigid surface and no fluid-structural coupling was considered. The simulated sound pressure level spectrum is in overall good agreement with the measurement result.

INTRODUCTION

At present, the statistical energy analysis and ray-tracing method are commonly used to predict the interior sound field of a railway vehicle [1-3]. These two methods could provide reasonably accurate predictions in middle and high frequencies, but will bring fairly great error in low frequency because of the diffraction effects. According to previous studies, low frequency noise is particularly dominant in modern high-speed trains [4]. In order to study the low frequency sound field with high accuracy, Finite Element (FE) method was used in this paper to model the compartment. The FE model was validated by experimental results.

FINITE ELEMENT MODELS

In this paper, two major elements were taken into consideration during the modelling process - the enclosed cavity of the compartment and the seats inside the compartment. In fact, coupling effect was created between the fluid and structure domain. However, accurately modelling the train's structure was almost unachievable with the existing processing power considering its complexity. In this case, greater error would have been produced if the effect of the structure was taken into account. According to V. Jayachandran's research [5], there is little difference between sound pressure distribution in rigid surface enclosure and in vibrating surface enclosure, though the difference is significant at the boundary. In this paper, rigid surface was used to model the boundary, and this simplification has proved to be reasonable according to the simulation results as shown in RESULTS AND DISCUSSIONS.

The geometrical model of the compartment was set up within CATIA, and its size and layout were determined based on the fifth compartment of CRH380AL, a Chinese electric high-speed train. The FE meshes were obtained using HyperMesh. The cavity and seats were meshed with tetrahedron elements using an average size of 0.17 m. The FE mesh of the compartment was shown in Figure 1. The software Actran was used for the FE simulation.

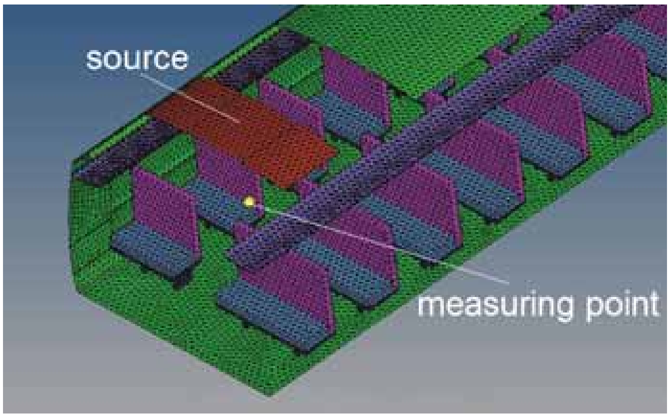

Figure 1. FE mesh of the compartment.

The most important source of interior noise of high-speed trains is aerodynamic noise generated by pantograph [4], and thus an area source was placed at the location of the pantograph. The simulation frequency is from 100 to 250 Hz, in which region the sound energy can be a source of human fatigue [4]. The interval of the simulation frequency is 1 Hz. The computing work was completed on a laptop with a 1.6 GHz dual-core processor and 4 GB memory, and the computing time was around 3 hours.

EXPERIMENT

To verify the FE model, a measurement was performed inside the CRH380AL's compartment. During the measurement, the train was stationary. A loudspeaker driven by white noise was set at the location of pantograph and it was 0.5 m above the roof. Data acquisition and processing were carried out by B&K PULSE platform with recording time of 15 s.

RESULTS AND DISCUSSIONS

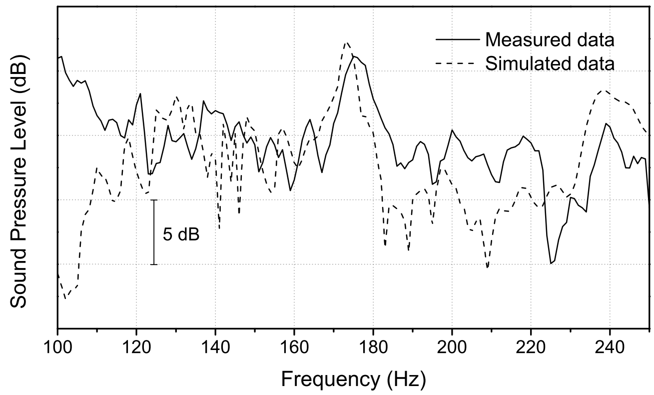

Figure 2. Comparison of SPL spectra obtained from measured (—) and FE simulated (- - -) data.

A measuring point was set inside the compartment, right below the pantograph and 1.2 m above the ground. As shown in Figure 2, the simulated spectrum basically agrees well with the measurement result. Compared to the measured curve, the simulated curve shifts about 2 Hz to lower frequencies. The reason is that the boundary is actually not rigid, using rigid surfaces in the model slightly affects the peak positions of the simulated result. Additionally, the error is relatively large at 100 Hz, the reason for which requires further analysis. The error is less than 5 dB in the frequency region from 110 to 250 Hz.

CONCLUSIONS

The FE method could predict low-frequency interior sound field of railway vehicle with high accuracy. The time cost of the computing work is acceptable.

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