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Exterior Noise Source Identification Test for Railway Box Car

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Abstract. Based on the beamforming technology, taking the typical railway box car (P_{70}) as the research object, a noise source identification test was carried out under the condition of loaded operation on the line. The noise source areas of the box car (P_{70}) were divided, the sound power contribution of noise sources in different areas was analyzed, and the spectral characteristics of specific areas were analyzed to determine the main noise frequency bands of the noise sources. The results show that: the significant frequency range of the box car (P_{70}) noise is 500~8000 Hz in terms of the 1/3 octave band center frequency, and the frequency range with large noise energy is 2000 Hz~5000 Hz; the bogie area is the region with the largest noise contribution ratio of the boxcar, and the frequency range with the maximum sound power in the bogie area is 2000~5000 Hz, which is mainly wheel-rail noise.

Keywords: noise source identification, railway box car, beamforming

1. Introduction

Right now, in the study of finding where noise comes from, people have done a lot of research on high-speed trains and urban rail trains. Wang Dewei and others [1] did tests to check how much each noise source outside high-speed trains contributes to the total noise. They found that the noise from the wheel and rail area is the biggest part of the total noise. Wang Chaoliang and others [2] used beamforming technology to do noise source tests on elevated urban rail trains. They analyzed the noise sources in different parts of the train body.

The noise from freight trains has also become a big part of railway noise pollution. It seriously affects people's work and life on both sides of the railway lines. But there are very few studies on finding where the noise from freight trains comes from. Wang Jian [3] did noise analysis on 30t axle load coal hopper cars exported to Australia. He analyzed the noise frequency outside the cars, but did not find where the noise sources of the hopper cars are. Liu Hongri and others [4] designed the coal hopper car structure to reduce noise according to the EU's noise requirements for freight cars, and did tests to prove the design works.

Most existing studies on freight train noise focus on the noise limits when freight trains pass by. There are very few reports on finding where the freight train noise sources are. This paper takes a typical freight box car (P_{70}) as the research object. Based on beamforming technology, we did tests to find the noise sources on the railway when the box car is loaded with goods. We divided the box

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car into different areas by their noise sources, and analyzed how much each noise source area contributes to the total noise power.

Right now, the common ways to find noise sources include beamforming, acoustic holography, and operational transfer path analysis. Among them, beamforming noise source identification technology is a signal processing technology that uses a microphone array to filter sound in space. It is also called microphone antenna, phased microphone array, acoustic telescope, acoustic camera, and acoustic focusing. This method uses a microphone array made of several microphones to receive sound signals. It uses the "delay and sum" method or other processing algorithms to focus on the useful sound signals from the real noise sources, forming a sound beam (main lobe). At the same time, it blocks the interfering sound signals from other directions (side lobes). In this way, we can find the noise sources and get detailed information about the measured noise sources [5,6].

The instrument used in the tests of this paper is the 9-arm, 54-channel, 2.5-meter diameter planar microphone array noise source identification system from B&K company, which is based on beamforming technology.

2. Noise test

2.1. Test overview

The microphone array of the noise source identification system is placed 7.5 meters from the track center line, with the array center 1.3 meters above the track surface. The sampling frequency is set to 25.6 kHz. A photo of the field test is shown in Figure 1.

The test site is next to the Longhai Railway Line.

The test object is the box car (P_{70}) running on the line. The test conditions are noise source identification tests at the loaded state with speeds of 90 km/h and 110 km/h.

2.2. Test conditions and data processing

he test speeds of the car in the loaded state are shown in Table 1.

Table 1. Test car type and speed in loaded state

Car Type	Speed Grade
Box Car(P_{70E})	90km/h,110km/h



Figure 1. Field test photo

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Data processing method for noise source identification test: The moving beamforming noise source identification algorithm is used to process the array sound pressure signals obtained from the test. The analysis frequency range is set to 315 Hz ~ 8000 Hz, and the grid is set to 0.1m × 0.1m (length × height). For numerical optimization, Array Shading is set to outdoor mode, the default Array Opening Angle for single-frame identification is kept at 70°, the data processing is iterated 200 times, and deconvolution smoothing is turned on.

2.3. Noise source area division of the test car

The noise source areas of the box car (P_{70}) are divided into two main parts: the lower area and the upper area. The lower area is up to 1.2 meters from the track surface, and it is further divided into Bogie 1 Area, Bogie 2 Area and Other Area. The division diagram is shown in Figure 2.



Figure 2. Noise source division diagram of box car (P_{70})

3. Test results and analysis

3.1. Total noise source analysis

Figures 3 to 4 show the 1/3 octave band noise data of the sensors at 7.5m from the track center line, and at 1.2m and 2m above the track surface, when the train runs at different speeds under the loaded condition. We get the characteristics like frequency bands and amplitudes of the main noise from freight trains by analyzing the frequency spectrum.

For the box car (P_{70}) under the loaded condition, the sound pressure level rises as the speed goes up. The frequency bands with a higher sound pressure level are concentrated in the range of 2000~5000Hz at the center frequency of the 1/3 octave band. The sound pressure level at the 1.2m noise measurement point is a little higher than that at the 2m point.

3.2. Analysis of noise source map test results of box car (P_{70})

Figures 5 and 6 show the sound intensity cloud maps of the box car (P_{70}) under the loaded condition at the speeds of 90km/h and 110km/h. We can see from them: the sound source amplitude of the box car (P_{70}) increases with the speed, and the wheel-rail area is always where the loudest noise comes from. The sound intensity in the upper area of the car is low.

The sound intensity cloud maps clearly show the spatial distribution rule of the noise around the car. To better understand the frequency spectrum characteristics of the noise sources, Figures 7 to 8 show the total sound power level and sound power level frequency spectrum of the box car (P_{70}) under the loaded condition at different speeds; Table 2 shows the total sound power level and its frequency spectrum at different speeds.

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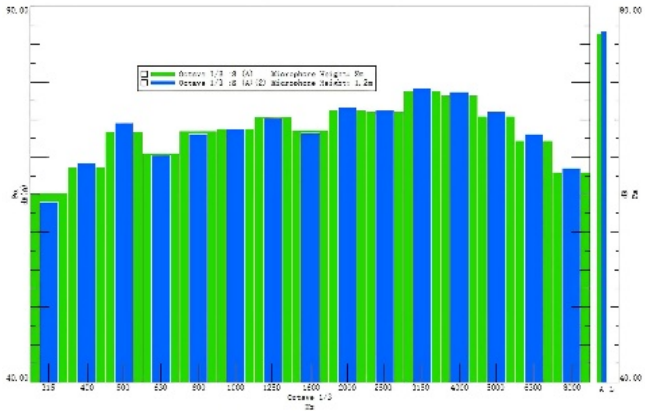

Figure 3. 1/3 octave band sound pressure level of noise at 1.2m and 2m above the track surface for box car (P_{70}) at 90km/h under loaded condition

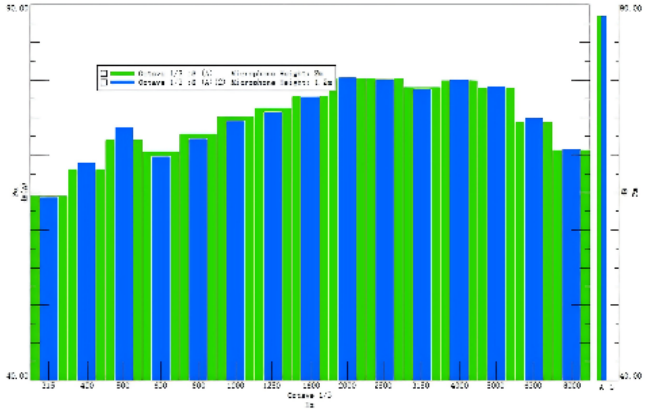

Figure 4. 1/3 octave band sound pressure level of noise at 1.2m and 2m above the track surface for box car (P_{70}) at 110km/h under loaded condition



Figure 5. Sound intensity cloud map of box car (P_{70}) at 90km/h under loaded condition

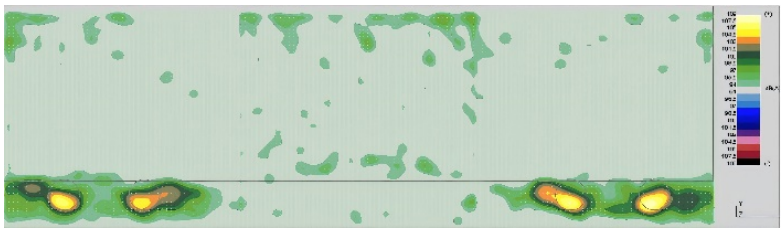

Figure 6. Sound intensity cloud map of box car (P_{70}) at 110km/h under loaded condition

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From the analysis, we can see that for the loaded box car (P_{70}) when speed rises from 90km/h to 110km/h, the total sound power level goes up with the speed. The spectrum distribution rules at the two speeds are almost the same, and the main frequency bands are both 2000~5000Hz. The center frequencies of the sound power level peaks are different. At 90km/h, the peak frequency is 4000Hz and the sound power level is 100.4dB(A). At 110km/h, the peak frequency is 2000Hz and the sound power level is 106.3dB(A).

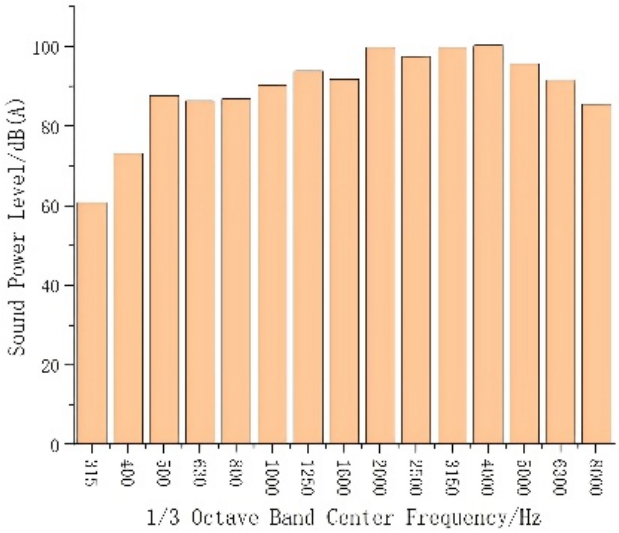

Figure 7. 1/3 octave band spectrum of total sound power level for box car (P_{70}) at 90km/h under loaded condition

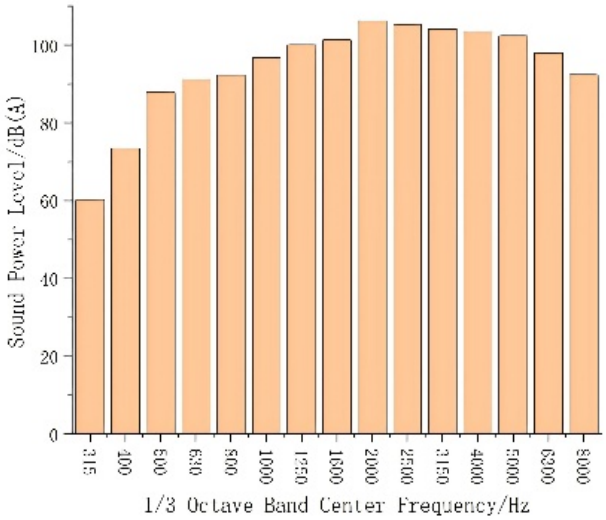

Figure 8. 1/3 octave band spectrum of total sound power level for box car (P_{70}) at 110km/h under loaded condition

The total sound power level and the sound power level spectrums of different areas for the loaded box car (P_{70}) at 90km/h and 110km/h are shown in Figure 9 and Figure 10. The sound power levels of the main areas for the loaded box car (P_{70}) at 90km/h and 110km/h are shown in Table 3.

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Table 2. Total sound power level and its spectrum of box car (P_{70}) at different speeds under loaded condition

Speed/(km/h)	Vehicle State	Total Sound Power Level/dB(A)	Main Frequency Band/Hz	Peak Frequency Band/Hz
90	Loaded	106.8	2000~5000	3150
110	Loaded	112.7	2000~5000	2000

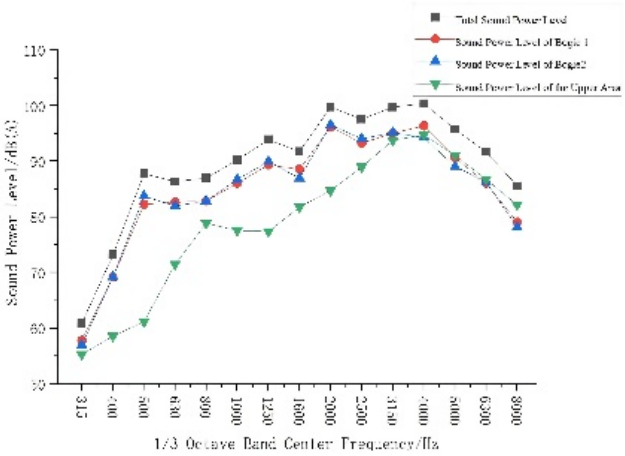

Figure 9. Sound power level spectrum of different areas for box car (P_{70}) at 90km/h under loaded condition

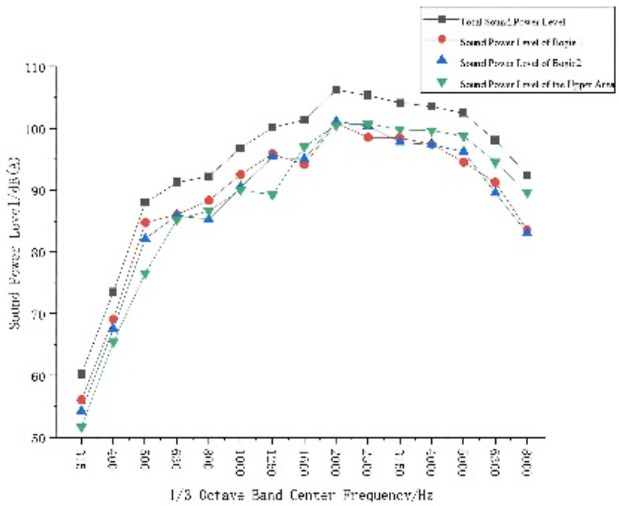

Figure 10. Sound power level spectrum of different areas for box car (P_{70}) at 110km/h under loaded condition

At a speed of 90 km/h for the box car (P_{70}) under loaded condition, the peaks of the total sound power level, the sound power level of Bogie 1 area and the upper area all appeared at 4000 Hz, which were 100.4 dB(A), 96.4 dB(A) and 94.8 dB(A) respectively; the peak of the sound power level of Bogie 2 area appeared at 2000 Hz, which was 96.6 dB(A). At a speed of 110 km/h, the peaks of the total sound power level, the sound power level of Bogie 1 area, Bogie 2 area and the upper area all appeared at 2000 Hz, which were 103.6 dB(A), 100.9 dB(A), 101.2 dB(A) and 100.6 dB(A) respectively.

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Table 3. Sound power level of main areas of box car (P_{70}) under loaded condition

Area	90km/h	110km/h
	Sound Power Level dB(A)	Sound Power Level dB(A)
Entire car	106.8	112.7
Bogie 1	102.6	108.1
Bogie 2	102.3	107.9
Upper area	99.5	105.9

The sound power values of noise sources in each area were calculated according to Formula (1).

$$W = 10^{\frac{L_W}{10}} W_0 \tag{1}$$

Where: W is the sound power, L_w is the sound power level, and W_0 is the reference sound power of 10^{-12}W.

The proportion of the sound power value of noise sources in each area in the total sound power value was calculated. Among them, the total sound power of an area is obtained by summing the sound power of all noise sources in the area. Figure 11 and Figure 12 show the sound power proportion results of noise sources in different areas at different speeds under loaded condition.

The analysis shows that for the box car (P_{70}) under loaded condition, with the increase of speed (from 90 km/h to 110 km/h), the proportion of noise contribution from the lower area decreased from 81.38% to 79.11%, and the main noise source was wheel-rail noise; the main noise source in the upper area was structural noise, and with the increase of speed (from 90 km/h to 110 km/h), the proportion of noise contribution increased from 18.62% to 20.89%.

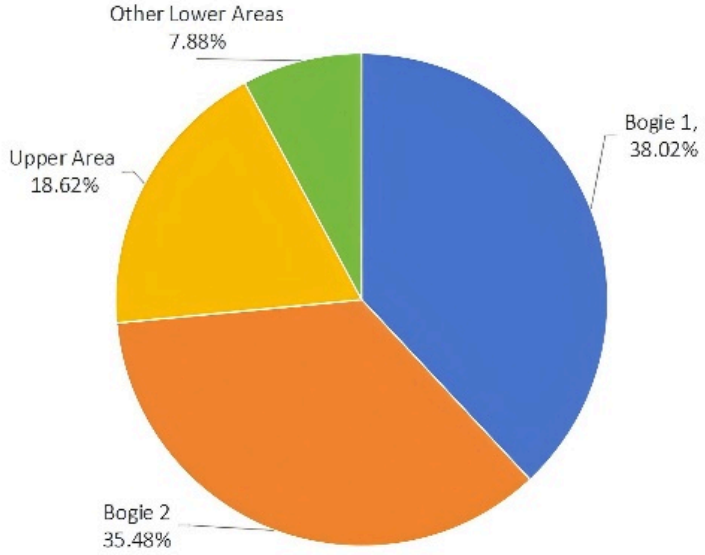

Figure 11. Proportion of sound power contribution of each area at 90 km/h under loaded condition

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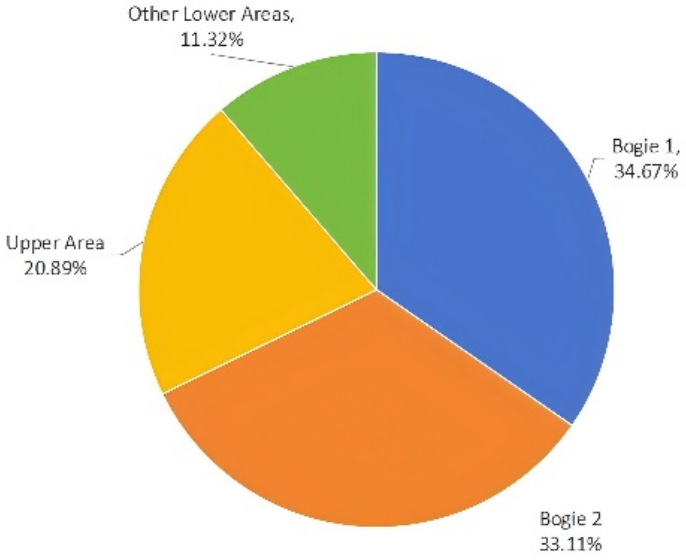

Figure 12. Proportion of sound power contribution of each area at 110 km/h under loaded condition

4. Conclusion

(1) The obvious frequency range of railway box car noise is 500~8000Hz at the 1/3 octave band center frequency. The frequency range with large noise energy is 2000Hz~5000Hz. We should focus on the noise sources in the 2000Hz~5000Hz frequency band when designing noise reduction for railway box cars and sound insulation barriers for rail transit.

(2) Wheel-rail noise is the biggest noise source of running railway box cars, and it is in the bogie area. Structural noise accounts for a small proportion, and it is mainly in the car body area. The sound pressure level and sound power level of box car noise go up as the speed increases.

(3) The bogie area is the part that contributes the most to box car noise. The frequency range with the largest sound power in the bogie area is 2000~5000Hz, and it is mainly wheel-rail noise.

References

[1] Wang, D. W., Li, S., Zhang, J., et al. (2018). Prediction modeling of exterior noise of high-speed trains and analysis of sound source contributions. Journal of Central South University, 49(12), 3313–3320.
[2] Wang, C. L., Wu, X. L., Zhang, L. T., et al. (2023). Experimental identification of exterior noise sources of elevated urban rail transit trains. Noise and Vibration Control, 43(2), 185–189, 236.
[3] Wang, J. (2018). Noise analysis of 30-t axle load coal hopper wagons exported to Australia. Rolling Stock, 56(8), 27–29.
[4] Liu, H. R., & Wang, B. T. (2012). Experimental study on operational noise of railway freight wagons. Rolling Stock, 50(3), 15–17.
[5] Wang, D. W. (2018). Analysis of sound source contributions and influencing factors of exterior noise of high-speed trains (Doctoral dissertation). Southwest Jiaotong University, Chengdu, China.
[6] Ni, X. S., Qi, Y. W., Yao, D., et al. (2022). Noise characteristics and evaluation analysis of virtual track train operation. Noise and Vibration Control, 42(2), 119–123.