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Analysis of radiative noise spectrum of high-speed train

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Abstract: The spectrum characteristics of noise energy distribution of high-speed train at different locations are obtained by calculating the percentage of noise energy distribution. The results show that noise ratio in the middle of train body is the largest, followed by the bottom of the train body and the top of the train body is the smallest. The proportion of noise energy distribution of high-speed train at different speeds is compared, analysis shows that the noise energy percentage at high frequencies increases with speed, while the noise energy percentage at low and medium-low frequencies essentially unchanged with speeds. Our work has certain guiding significance to guide the development of noise control technology of high-speed train.

1. Introduction

High-speed railway is considered to be one of the most important modes of transportation at present due to its advantages of large passenger volume and high efficiency [1]. The railway network has already covered a large area all over the world, making high-speed railway trains an indispensable mode of transportation in modern society [2]. However, the environmental cost of high-speed railway trains cannot be ignored, especially noise pollution, such as aerodynamic noise and wheel-rail noise, has become a prominent environmental problem [3-4]. Therefore, it is necessary to accurately describe the main characteristics of radiated noise in high-speed railway train operation, such as location, intensity, frequency spectrum and energy contribution of different motion noise sources, so as to guide the research on noise reduction measures.

The noise sources outside the high-speed train are distributed all over the key positions of the train, and the noise sources are broadband noise. Liu Lanhua [5] obtained the law of change of noise source intensity in the speed intervals of 200-300km/h and 300-350km/h for bridge and subgrade lines in China, on the basis of a large number of field test studies on radiation noise of high-speed railways, and discussed the variation mechanism of noise source intensity and velocity in different speed intervals. HU wen-lin [6] analyzed the location and amplitude of noise source based on the field test of high-speed rail noise source identification. The noise source is divided into five areas according to the height of wheel and rail, lower part of vehicle body, upper part of vehicle body, collector system and bridge structure. Ju Longhua[7] tested and analyzed the noise source on the surface of high-speed train with a speed of over 300km/h by using a planar microphone and a high-sound microphone. The sound source of high-speed train was equivalent to that of the bottom line, the middle line and the pantograph point.

The above analysis shows that there are few studies on the noise energy distribution of high-speed railway. On the basis of existing research, this paper calculates the 1/3 octave noise energy distribution percentage and obtains the frequency spectrum characteristics of the noise energy distribution at different positions of the high-speed railway train. It also compares the noise energy distribution of high-speed railway trains at different speeds, which provides some ideas for further research on noise reduction measures.

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2. Analysis of Radiation Noise Sources in High-speed Railway Train

The noise generated by the high-speed railway is similar to the radiated noise of other rail transit, but the radiated noise of the high-speed train has different characteristics and laws due to its higher running speed.

Wheel/rail noise, aerodynamic noise and traction noise are the main sources of noise generated outside the high-speed railway [2-4]. The test results of He Bin et. al. [4] show that the noise sources outside the high-speed train are mainly distributed in the wheel-rail area, pantograph and workshop connection area, as shown in Figure 1.

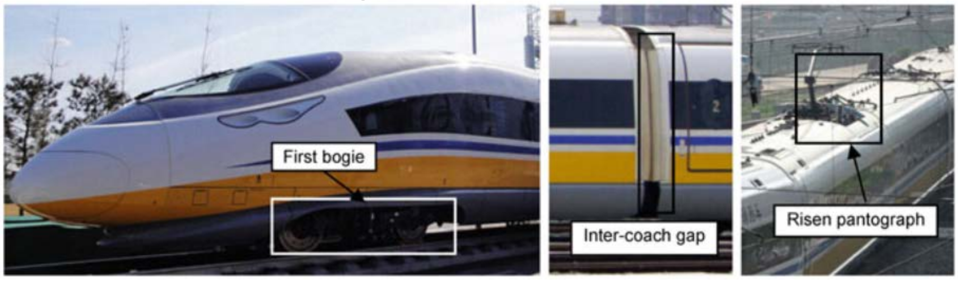


Figure 1 Noise sources outside high-speed trains.

3. Analysis of radiative noise spectrum characteristics of high-speed train

In addition to the weight sound pressure level of A-meter, noise frequency characteristics of high-speed train at different locations also have significant differences. In order to analyze the spectrum characteristics of high-speed railway noise and exclude the influence of sound pressure level, the noise energy rate of 1/3 frequency band spectrum was calculated based on the test results of noise source on high-speed train body surface by Ju Longhua et. al.[7].

3.1. Sound pressure level versus frequency

In the test of literature [7], the distribution of measurement points adopted is shown in figure 2.

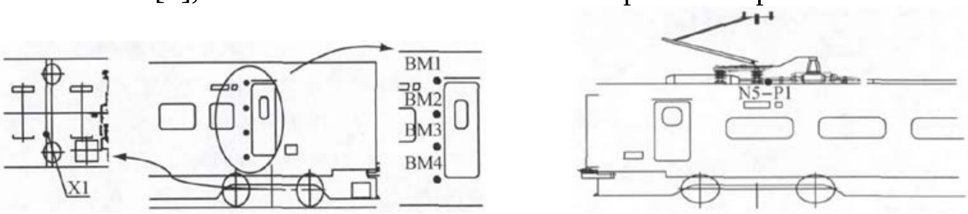
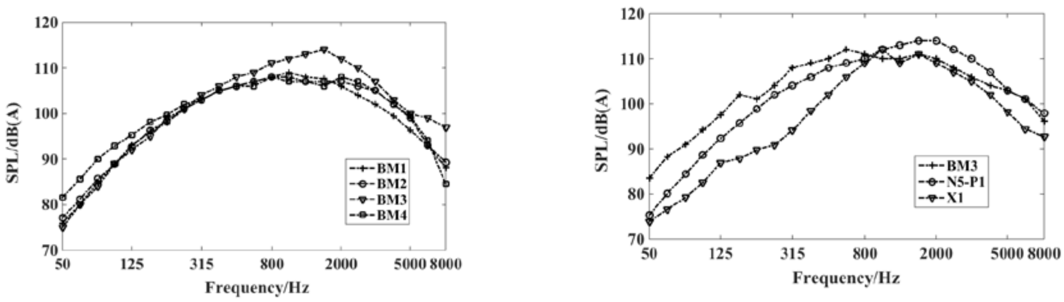


Figure 2 Arrangement of noise measuring points [7] (●for noise measuring points)

BM1, BM2, BM3 and BM4 are four measurement points on the side of the carriage door from high to low. X1 is a measurement point arranged to measure the noise source characteristics of the bogie position at the bottom of the car body. In order to study the noise source characteristics of the pantograph during high-speed operation of the train, N5-P1 measuring points are arranged directly under the pantograph on the roof.

When the high-speed railway is running at a speed of 300km/h, the A-weight sound pressure level (SPL) of BM1, BM2, BM3 and BM4 in four measurement points in the middle of the car body is shown in Figure 3(a). Figure 3(b) shows the A-weight SPL of measurement points X1 at the bottom of the car body, BM3 at the middle of the car body and n5-p1 at the top of the car body.



(a) SPL of middle measuring points (b) SPL of measuring points X1, N5-P1 and BM3

Figure 3 Spectrum curves of SPL[7]

The results of Figure 3(a) show that the A-meter weight SPLof BM3 is significantly higher than that of the other three detection points in the 4 measurement points in the middle of the car body. The important reason is that the aerodynamic noise of BM3 is obvious at the location, and aerodynamic noise is the main noise source in the middle of the car body. The results of Figure 3(b) show that BM3 in the middle of the car body has the highest SPL, followed by N5-P1 on the top of the car body, and X1 under the car body has the lowest sound pressure level.

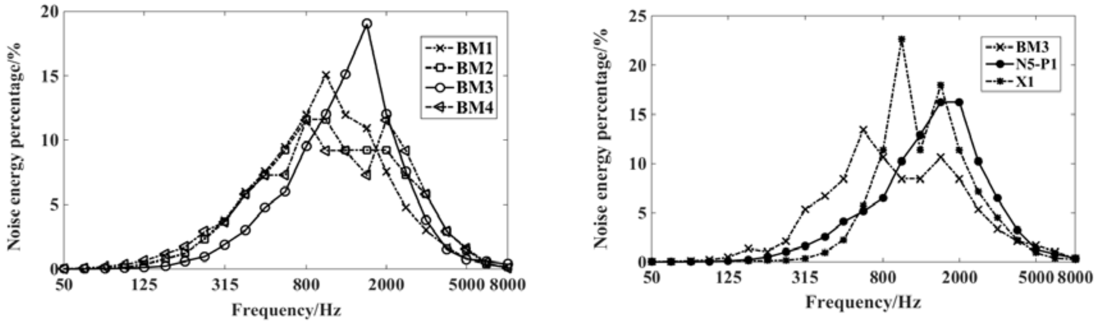
3.2. Noise energy percentage versus frequency

In order to analyze the frequency characteristics of noise at different positions of high-speed railway and exclude the influence of sound pressure level, the noise energy rate of 1/3 octave frequency band spectrum at different position measurement points in Figure 3 (a) and 3(b) is calculated respectively, and the calculation formula is as follows [8] :

$$E_S(i) = \frac{E(i)}{\sum_i E(i)} \tag{1}$$

Where, $E(i) = 10^{0.1*SPL(i)}$, i is the frequency point, $SPL(i)$ is the sound pressure level of frequency i, $E(i)$is the relative value of noise energy (dimensionless quantity), $E_S(i)$ is the average percentage (%) of noise energy.

According to formula (1), the sound pressure level of each frequency of noise in different locations of high-speed railway is converted into the noise energy percentage of each frequency. Figure 4 shows the relationship between the average noise energy percentage and frequency of different measurement points when high-speed railway is running at 300km/h.



(a) Middle measuring points (b) Noise energy percentage of X1, N5-P1 and BM3

Figure 4 Average noise energy percentage of different measuring points

Figure 4 depicts the average noise energy percentage versus frequency for each different measuring points. It is obvious from Fig.4 (a) that the noise energy on BM3 is concentrated at much higher frequencies, and the noise energy of BM3 is concentrated at 1600Hz, while the noise energy of the other three measuring points at the middle of train body are all below 1600Hz. From Fig.4 (b), it is conclude that the noise energy on X1 has the largest energy percentage among X1, N5-P1 and BM3, next is N5-P1, and BM3 is the smallest.

3.3. Noise energy percentage at different speeds

Speed will not only affect the sound pressure level of a high-speed train, but also affect the frequency characteristics of a high-speed train. See Figure 5 for a comparison of radiation noise spectrum of a high-speed train running at 300, 350 km / h speed.

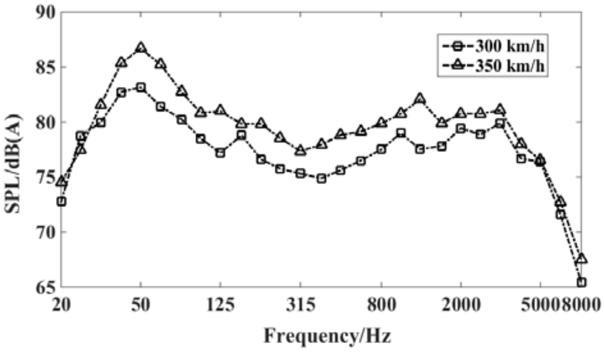


Figure 5 Spectrum comparison of train radiated noise at typical speed [5]

Figure 5 shows that with the increase of speed, the sound pressure level of each frequency band gradually increases, the increase of the high-frequency component is slow, and the rise of the low-frequency component is fast. This is related to the main noise sources of both and their sensitivity to speed. Compared with the high-frequency component, the low-frequency component mainly comes from aerodynamic noise, which is more sensitive to speed.

Figure 6 depict the average noise energy percentage at different speeds calculated based on Formula (1).

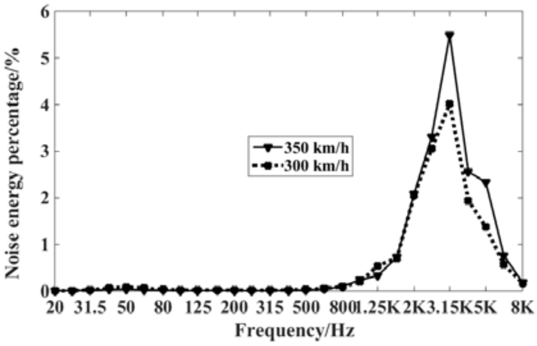


Fig. 6. Average noise energy percentage at different speeds

For a high-speed train, the noise energy percentage of frequencies varies with speeds. The noise energy percentage at high frequencies, 2–5 kHz, increases with speed, while the noise energy percentage at low and medium-low frequencies essentially unchanged with speeds.

4. Conclusion

The following main conclusions were attained:

(1) The noise energy ratio in the middle of train body is the largest, followed by the bottom of the train body and the top of the train body is the smallest.

(2) With the increase of speed, the sound pressure level of each frequency band increases gradually, the high frequency component rises slowly, and the low frequency component rises quickly.

(3) The noise energy percentage at high frequencies, 2–5 kHz, increases with speed, while the noise energy percentage at low and medium-low frequencies essentially unchanged with speeds.

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