Experimental study on the characteristics of noise sources in high-speed railway

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Summary
In the noise control practice of high-speed railway, the basic characteristics of noise source intensity should be understood. Studied at the characteristics ofnoise sourceintensity of high-speed railway, this paper has obtained the frequency characteristics, andachieved its basic ruleswith speed change. The results showed that: (1)Thepeak frequency of noise sourceof high-speed railway appeared at low frequency, and it showed wideband characteristics; (2)With the increase of speed, growth coefficient of radiation noise level is 45.2 ~ 45.7.

1. Overview

At present, 16 countries and regions have been operating high-speed railway in the world, Such as China, Spain, Japan, Germany, France, Sweden, Britain, Italy, Russia, Turkey, Korea, Belgium, Holland, Switzerland etc. According to statistics of the International Union of Railway (UIC), there are 11,600 kilometers high-speed railway that are operating, 5,000 kilometers are being built, 1,3000 kilometers are being planned by the end of November 1, 2013 in the world, which was not include China. So far, China has the world's largest high-speed railway network,the operating mileage of high-speed railways reached 11800 kilometers, 1,1000 kilometers of which are being built, the operating EMU train exceeded more than 2600 daily[1]. China has become the country who has the fastest growing, longest operation mileage, the largest scale of the construction of high-speed railways network in the world. High-speed railway provides fast and convenient mode of transportation, at the same time, noise is being one of the main environmental problems in a period of operation time. Therefore, an important basic work is to study the characteristics of high-speed railway noise source.

2. Research contents and methods

2.1 Research contents

Lots of scientific and technological personnel have carried out the research on the characteristics of high-speed railway noise source. French scientific personnel had tested on noise source intensity of high-speed train, which speed reached 400km/h~500km/h at 25 metersoutside the nearer track center line, the noise source intensity was at the range of 90 ~97dB(A). The foreign research results showed that, the growth coefficient between environmental noise and the speed of high-speed railway is 33~58. With the construction of high-speed railway in China, China's scientific research personnel alsohave been carried out a large number of research aboutnoise source intensity characteristics of high-speed railway at joint commissioning and testing and related comprehensive test. In combination of the study achievements at home and abroad, the main content of high-speed railway noise source characteristics include: the intensity of noise source, noise characteristics in time domain, noise characteristics in frequency domain, the interrelation between noise source intensity and train speed [2,3,4,5,6].

2.2 Research methods

On the basis of "Railway applications-Acoustics-Measurement of noise emitted by railbound vehicles (ISO-3095)" and "Acoustic-Measurement of noise emitted by railbound vehicle (GB-T5111)", themulti-channel noise test and analysis system (B&K3560C) was used to test the high-speed running train, the test system was shown in figure 1.Test factors were the following: Test and analysis indexes was by the train transit exposure level (TEL), the measurement position was at 25 meters outside the nearer track center line and above 3.5m from the track surface.This experimental study was selected on the site of typical bridge of high speed railway, the bridgeheight is 9.9 meter and the bridge deck width is 12 meter, using CRTS II-type slab ballastless track and 300-type fastening system, the bridge section protective wall height is 0.75m which is at the same height with the track surface. Test train was CRH380A and CRH380B,a new generation main EMU for China high-speed railway. Test site was around open terrainwhich was meeting the semi-free sound field conditions. There was no interference caused by temperature variation, strong magnetic field and strong wind, the weather conditions was meeting the test requirements. Noise real-time data acquisition and analysis system were inspected and calibrated, according with relevantstate standards and regulations.

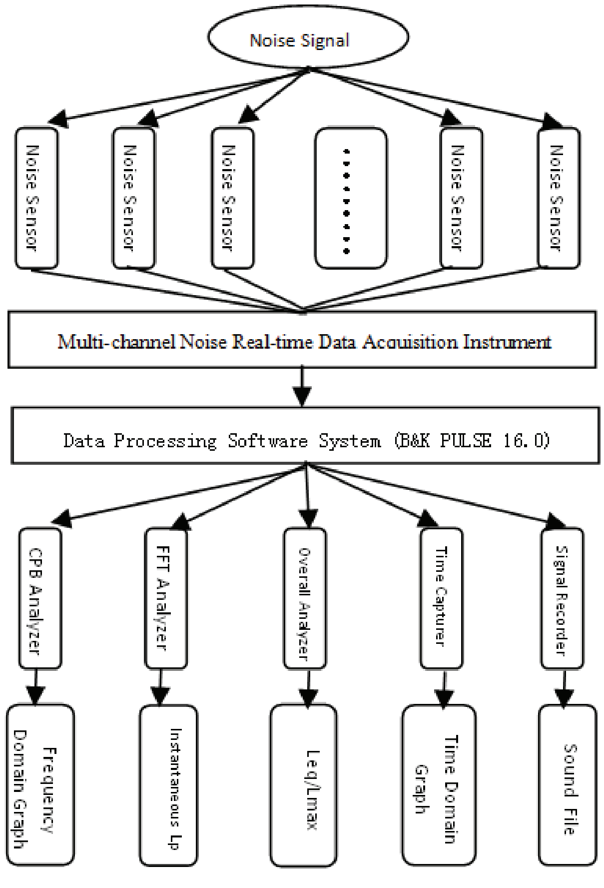


Figure 1. Multi-channel noise real-time data acquisition and analysis system

3.Test results

3.1 Relationship between noise source intensity and the running train speed

High-speed EMU CRH380A and CRH380B rushed through the test section of the bridgeat speed of 300km/h~380km/h, the relationship between the radiated noise and speed changes was shown in figure 2. Figure 3was showing the radiation noise comparison results between CRH380A and CRH380B under the condition of typical operating speed (300km/h, 350km/h and 380km/h).

The following formulas are showing that the relations between radiated noise and different EMU with different speed:

CRH380A: $$TEL = 45.7 \times \lg(V/V_0) + c_1 (dB(A)) \quad (1)$$

CRH380B: $$TEL = 45.2 \times \lg(V/V_0) + c_2 (dB(A)) \quad (2)$$

The above formula, V is referredto the EMU running speed and the reference speed: V0=300km/h.

We can see from Figure 2.withinthe test speed range, EMU radiated noise showed a gradual increasing trend with speed raise overall. At the same time, it is close that radiation noise level of different EMU with speed increase growth rate, and the growth coefficient range is within 45.2~45.7, which is consistent with the research results of France, Germany and Japan[7].It was shown that the radiation noise level increased about 4.6~4.7dB (A)when EMU speed was increased from 300km/h to 380km/h.

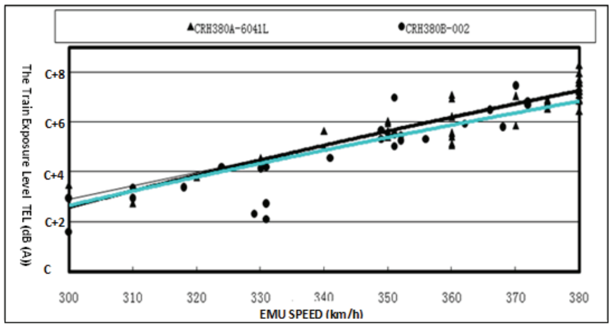


Figure 2. Diagram ofEMU radiation noise with train speed change

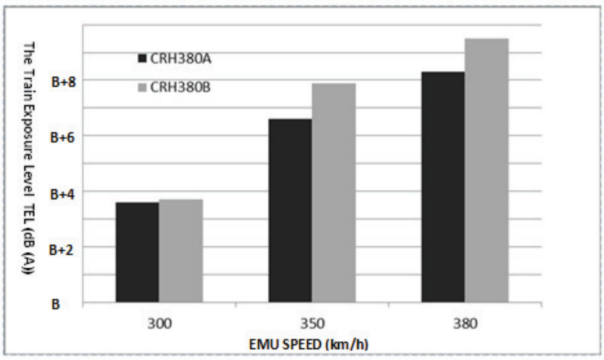
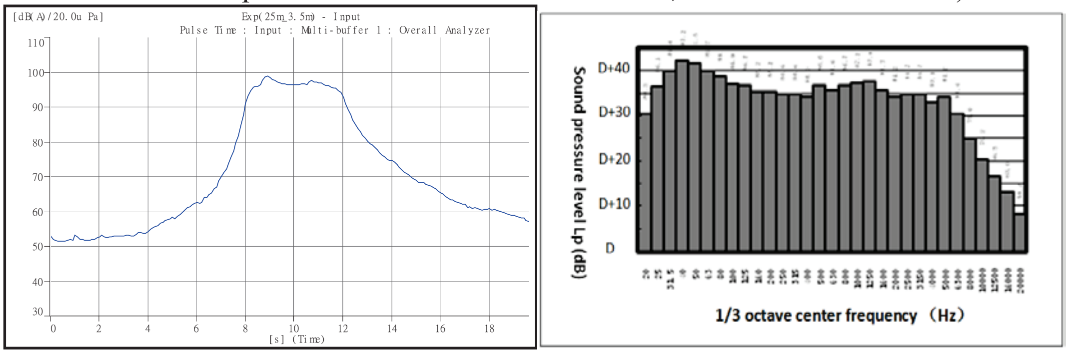


Figure 3. Comparison chart of different train radiation noise under typical operation speed

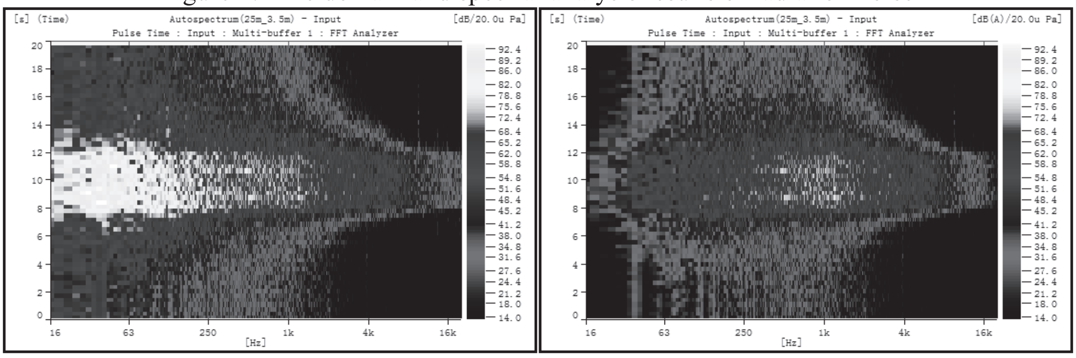
3.2 Characteristics of time domain and frequency domain

It was shown the characteristics of time domain and frequency domain of radiated noise in figure 4 and figure 5when the CRH380A EMUwas running at the speed of the 380km/h.In figure 6, it was shown the radiation noise spectrum ofCRH380B EMU under the different typical speed (300km/h, 330km/h, 350km/h and 380km/h).



(a) Sound pressure level change in time domain (b) 1/3 octave spectrum of radiation noise

Figure 4.Time domain and spectral analysis results of radiation noise



(a) Time domain and frequency domain variationcloud map of radiation noise sound pressure level

(b) Time domain and frequency domain variationcloud map of A-weighted radiation noise sound pressure level

Figure 5.Time domain and frequency domain variation results of EMU radiation noise

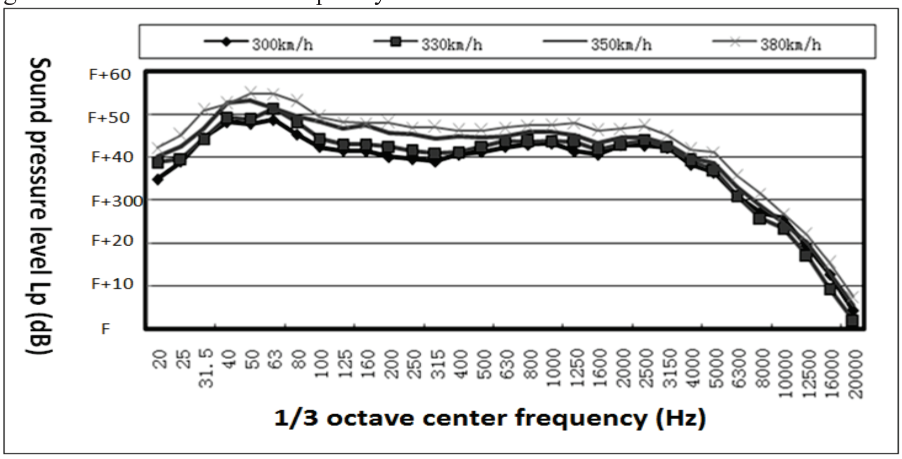


Figure 6.Comparison chart of EMU noise frequency spectrum under differentrunning speed

Within the range of test speed, it was shown the following conclusion from figure 4 to figure 6:

(1) when headof the EMU rushed through the test site, the instantaneous sound level increased rapidly, and the maximum sound level change rate was above 10dB(A) /s; when tail of the EMU rushed through the test site, the instantaneous sound level decreased rapidly, the maximum sound level change rate was above 8dB(A) /s; with the speed increasing, sound level change rate increased gradually.The instantaneous sound level is 40dB(A)higher than the background noise.

(2) By the radiation noise spectrum, noise energy was mainly distributed in the range of 20 to 4000Hz, which was showed the broadband spectrum characteristics.The maximum sound level was mainly concentrated in low frequency bandof 31.5 to 125Hz, and the high frequency component that was above 4000Hz decreased rapidly. A-weighted Noisespectrum results showed that: A-weighted noise energy was mainly distributed in 500 to 5000Hz frequency band, and which waspresented in 1000 to 4000Hz especially.

(3) It can be seen by the radiation noise spectrum of different speed, with the increasing EMU's speed, all the sound pressure level band showed an increasing trend.The high frequency band component (more than 1kHz) increasedslower than low frequency band components(below 250Hz), which was mainly due to that the high frequency bandcomponent, being produced by radiation noise of rail and wheel vibration,increased slower with speed growth relatively, and the low frequency band component, being produced by air dynamic noise, increased faster with speed growth relatively.
(4) Frequency domain change results of radiation noise sound pressure level showed thatlow frequency band noise influenced the sound receiving point longer than high frequency band noise relatively, its main reason was that the high frequency noise components decreased rapidly. The noise energy was mainly produced when the train was running through the test site.

4. Conclusion

(1) In the range of test speed, the radiation noise level growth rate of different type of EMU was close with the increase speed; the growth coefficient was within 45.2 to 45.7.
(2) Instantaneoussound pressure level changed obviously whenthe head and tail of high-speed EMU rushed through the test site; the maximum soundpressurelevel change rate was above 8dB (A) /s.The instantaneous sound pressure level is 40 dB(A) higher than the background. noise.
(3) Radiation noise spectrum of high-speed EMU presented the broadband spectrum characteristics, the maximum sound pressure level was mainly concentrated in low frequency band of 31.5 to 125 Hz; A-weighted noisespectrum results showed that A-weighted noise energy was mainly distributed in 500 to 5000Hz frequency band and which waspresented in 1000 to 4000Hz especially.
(4) With the increasing EMU's speed, all the sound pressure level band showed an increasing trend. The high frequency band component (more than 1kHz) increased slower than low frequency band components (below 250Hz).

Acknowledgement

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