Research Summary on Subway Noise and Controlling in China

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Abstract: During the operation of the subway, if the noise in the carriage is large, it will cause passengers to suffer from hearing impairment, headache, brain swelling, insomnia, memory loss, and other symptoms, threatening the health of passengers. This paper summarizes the sound source, propagation path, main control methods, research status, and development trend of subway noise, and puts forward the methods and ideas of subway noise control, which has reference significance for subway noise control and optimization research.

Keywords: Subway Noise; Noise Reduction; Wheel-Rail Noise; Hearing Impairment; Research Status

1. Introduction

On March 2, 2021, the World Health Organization released the World Hearing Report, which states that one in five people worldwide now has varying degrees of hearing loss, with more than 1.5 billion people affected. With the continuous improvement of people's quality of life, the importance of physical health is also increasing, and hearing loss can not be ignored.

Noise greater than 80dB can cause nerve cell damage, make people's ears uncomfortable, causing headaches, brain swelling, insomnia, and memory loss[1]. The vibration generated by subway operations will also have a certain impact on the surrounding environment. The precision of precision instruments near the local subway may decrease and affect the measurement results.

The noise of many subway lines in operation exceeds the limit. For example, the maximum noise in Shijiazhuang Metro Line 2 is 90 dB. The maximum noise in Shijiazhuang Metro Line 3 is 87 dB. At present, the subway noise problem needs to be further studied and control measures are proposed.

2. Noise Analysis

The common noise source identification methods can be divided into three categories: traditional methods, signal processing methods and acoustic array technology methods. The traditional sound source identification technology is relatively simple, but it can not quantitatively analyze the noise, and the characteristics of the noise are not comprehensive enough. Based on the signal processing method, the complex noise source can be identified and analyzed more effectively. The method of noise source identification based on acoustic vibration columns is more intuitive, and can analyze the noise source more accurately and in real time. It has been widely used in engineering[2~6].

Rail transit noise mainly includes traction noise, aerodynamic noise, and wheel-rail noise. At the speed of 350km / h, wheel-rail noise still dominates. Relatively speaking, the correlation between traction noise and vehicle speed is small. The noise is dominated by traction noise at low speed, wheel-rail noise at medium speed, and aerodynamic noise at high speed[7]. The noise that passengers hear can be divided into three categories. First, the noise outside the car is directly transmitted to the car through the car body structure. Second, the noise outside the car is reflected through the tunnel and then transmitted to the car through the car body structure. Third, the spontaneous noise inside the car. For the subway, the uncomfortable noise is mainly wheel-rail noise, especially the curve howling noise[8]. The frequency is single, the energy is large, and the volume is high, which makes the passengers feel extremely uncomfortable. Therefore, suppression of wheel-rail noise becomes the key

to subway noise reduction.

3. Noise Reduction Measures

Subway noise reduction can start from the sound source, and propagation paths, such as the use of low-noise wheels, low-noise rails and sound insulation car body. Commonly used track vibration reduction measures are mainly elastic support block tracks, elastic fasteners, floating slab tracks, etc. The floating slab track vibration and noise reduction effect are better.

The noise in the subway vehicle mainly comes from the wheel-rail noise and electrical equipment noise introduced into the vehicle through the vehicle body structure[9]. The contribution of structural noise to the total noise is less than that of aerodynamic noise to the total noise. The main reason is that the noise will be reflected in the tunnel, and then radiated by the car body structure, and enter the car through the gap of the car body structure[10].

3.1 Wheel Noise

Appropriately reducing the wheel size, increasing the thickness of the wheel web and the quality of the wheel surface can reduce certain wheel-rail noise[11]. Changing the dynamic structure to reduce noise requires further research to ensure that it will not increase the load on the vehicle.

In addition, the elastic and damping elements are combined with the wheel vibration system, and the damping effect is used to reduce the vibration. The hole is opened on the web to form the ' acoustic short circuit' phenomenon to reduce the acoustic radiation efficiency of the wheel[12]. Opening holes on the plate can effectively suppress the noise in the frequency band of 20 ~ 800Hz. With the increase in the number of opening holes, the noise radiation efficiency in the frequency band of 800 ~ 2000Hz will also increase to some extent.[13] The resilient wheel can effectively reduce the vibration and sound radiation of the wheel-rail system. The noise reduction effect is 13.0 dB above 1700 Hz and 1.5 dB below 1700 Hz[14]. But the vast majority of vehicles still use steel wheels.

3.2 Rail Noise

Measures for rail noise reduction mainly include elastic rail, damped rail and rail grinding. Proper rail grinding can reduce wheel-rail noise by about 10 dB [15], Feng(2018)[16] analyzed the problem of excessive noise in a subway car in China. It was found that the noise was up to 90.3 dB when the train passed through the rail corrugation section, and the noise could be reduced by 11.6 dB after grinding the rail in this section. The spectrum analysis of the noise in the car was carried out. It was found that the noise was mainly concentrated in 400 Hz ~ 700 Hz, which was consistent with the frequency of 30 mm ~ 50 mm wavelength in the rail corrugation section. The frequency of 160 mm ~ 200 mm wavelength was compared. It was considered that the short-wave long-wave grinding was the main reason for the excessive noise in the car.

The steel spring floating slab track has a good noise reduction effect on the wheel-rail noise and has the best vibration reduction effect right above the tunnel. On both sides, the vibration reduction effect is inversely related to the distance and does not affect the vibration within 10 Hz[17].

3.3 Structure Noise

The noise reduction measures of car body structure mainly include installing vibration damping structure, covering sound absorption material, etc. Such as the use of double-layer sound insulation glass, side wall-filling foam plastic, and floor covering sound insulation materials. According to the above description, the highest contribution to subway car noise is the floor, floor noise reduction can more directly reduce car noise[18~20].

4. Conclusion

This paper summarizes the sound source, propagation path, and main control methods of subway noise.

The noise source outside the vehicle is mainly the wheel-rail noise, and the noise source inside the vehicle is mainly the external noise transmitted into the vehicle through the floor radiation. The noise that makes passengers uncomfortable is mainly the curve howling and other noises in the tunnel.

For the subway, it is necessary to consider the noise problem from the design level, strengthen the monitoring and measurement in the operation stage, and solve the problem of excessive noise in time.

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