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Analysis and control measures of vibration and noise sources in urban rail transit under the perspective of standard governance

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Abstract. With the rapid and large-scale development of rail transit engineering in China, the vibration and noise problems caused by rail transit operations are increasingly receiving widespread attention from all sectors of society. This paper is based on literature research and comprehensively analyzes the vibration and noise sources of urban rail transit. It systematically analyzes the composition, characteristics, and causes of vibration and noise in rail transit, and provides systematic governance measures for vibration and noise reduction in rail transit from two aspects: noise sources and propagation paths. The research results of this article have significant reference value for the engineering practice of vibration and noise reduction in rail transit.

Keywords: urban rail transit, operation period, vibration, noise analysis, governance measures

1. Introduction

In recent years, urban rail transit in China has developed rapidly. According to data released by the Ministry of Transportation, as of August 2023, 54 cities in China have opened urban rail transit operation lines, with a total operating mileage of 9,771.8 kilometers. The large-scale development of urban transportation has significantly increased the proportion of green travel in cities, brought more convenience to people's travel, and effectively alleviated urban traffic congestion. However, With the increasing attention and decreasing tolerance of people towards vibration and noise issues, the problems caused by vibration and noise in urban rail transit have received more and more attention and research. The issue of subway noise has become an important part of the 12345 citizen service hotline appeals in various parts of the cities. The vibration and noise of rail transit not only affect the comfort of passengers and the daily life of surrounding residents, but also affect the normal operation of surrounding buildings, precision instruments and other facilities and equipment. At the same time, it can also cause safety risks caused by the continuous wear and tear of trains and rail systems. How to effectively carry out vibration and noise reduction in urban rail transit has become an important issue for all sectors of society. In January 2023, the Ministry of Ecology and Environment and 15 other departments issued a notice on the issuance of the "14th Five Year Plan for Noise Pollution Prevention and Control (No.2023)", emphasizing the need to standardize the prevention and control of urban rail transit noise pollution, and further improve the scientific, rational and effective management of noise pollution.

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With the increasing attention paid to the living environment, the number of complaints and work orders related to rail transit vibration issues on mayoral hotlines in various regions is rapidly increasing, which puts forward higher requirements for the development of rail transit vibration and noise control technology. The vibration and noise reduction of rail transit has become a key issue that needs to be urgently addressed, and controlling the pollution of the environment caused by vibration and noise generated by subways has become a research focus. Scholars have conducted extensive research on vibration and noise reduction in rail transit, and have achieved rich results. China national knowledge infrastructure publishes 300 papers on "Rail Transit Noise" every year. Wang Yi et al. conducted a comprehensive study on the causes and control methods of vibration and noise in rail transit, summarizing relevant research results in recent years, and providing methodological guidance for the study of vibration and noise control in rail transit [1]. Gu Jinchao conducted research on the application of vibration and noise reduction technology for urban rail transit based on the Zhengzhou Metro Line 5 project, and proposed three main measures for vibration and noise reduction in rail transit: installing rail damping, floating rail fasteners, and prefabricated floating plates [2]. Hu Lianjun et al. summarized the principles of sound absorption and the main sound absorbing materials, and outlined the main measures for noise reduction in subway sound absorption [3]. The current research provides the necessary technical references for the control of vibration and noise in rail transit to a certain extent. However, there is currently a lack of systematic research on the analysis and control measures of vibration and noise problems in rail transit. In response to the shortcomings of current research, this paper first analyzes the generation, composition and characteristics of noise sources during the subway operation period, and then discusses the engineering governance measures for reducing vibration and noise in rail transit from two aspects: noise sources and propagation paths.

2. Analysis of noise sources during subway operation period

The noise sources during the operation period of the subway mainly include the subway vehicles and the track system. The characteristics of subway noise sources change with different train operating speeds. At low speeds, the main noise source is wheel rail noise, while at high operating speeds, the main noise source is aerodynamic noise. Conducting noise source analysis during the operation period of urban rail transit is the basis for conducting research on vibration and noise reduction measures. This section will carry out noise source analysis work during the operation period of urban rail transit from two aspects: subway vehicles and track systems, and study the generation, composition and characteristics of noise.

2.1. Analysis of noise sources of subway vehicles

The noise of subway vehicles mainly includes the noise of braking system equipment, traction system equipment, auxiliary equipment (air conditioning units, air compressors, ventilators, etc.), as well as the noise generated by self-excited vibration between train brake shoes and brake discs [4]. The noise of subway vehicles is mainly at medium to low frequencies, and the noise levels vary at different positions within the vehicle. In a stationary state, the operation of auxiliary equipment is the main source of noise. The noise of traction system equipment mainly consists of aerodynamic noise, mechanical noise, electromagnetic noise, and noise from motor cooling fans. The noise of the air conditioning unit is mainly caused by the vibration generated by the operation of the unit equipment and the noise generated by the unstable airflow in the ventilation system; The noise of air compressors is mainly caused by their own vibration and the aerodynamic noise caused by the intermittent suction and discharge of airflow [5].

2.2. Analysis of track system noise sources

The noise of the track system mainly refers to the wheel rail noise, which is composed of friction noise, impact noise, and rolling noise, and is transmitted into the vehicle through various parts of the vehicle body and gaps such as poorly sealed doors, gangways, and side windows. Friction noise is mainly caused by the force generated by the contact between the wheels and the track, which causes local lateral sliding

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on the curve, and the harsh noise generated by the vibration response of the wheels and the track. Impact noise is caused by the impact of rail cars' wheels skidding and scratching on the rails, mainly due to the non-smoothness of subway wheels and unevenness of rails. The interaction between wheel and rail in poor condition can exacerbate vibration and increase noise. Rolling noise is mainly caused by the high-speed rolling of the wheels on the steel rail during vehicle operation, which is caused by the excitation of the wheels due to the uneven surface of the steel rail and defects in the wheel rail [5-6].

3. Measures for reducing vibration and noise in rail transit

Based on the detailed analysis of the two types of noise sources during the operation period of urban rail transit in the previous text, this section proposes targeted measures for vibration reduction and noise reduction engineering from two aspects: controlling the generation of noise at the source and controlling the spread of noise through the transmission path.

3.1. Control measures for subway vehicle noise

3.1.1. Measures for noise sources. (1) Optimize structural design. Adopting linear motor traction, simplifying the transmission mechanism, and reducing the noise of power and auxiliary equipment; Improve the structure of vehicle connection parts to reduce noise caused by vibration and mutual collision.

(2) Install the damping device. Install the ventilation unit on the vibration damping seat and apply sound-absorbing material on the outer surface of the air duct to reduce the gas noise of the air conditioning system; Install a sound insulation cover outside the air compressor, and install a muffler at special locations such as the return air outlet of the air conditioning system that can eliminate mid to low frequency noise; Add a damping device to the brake assembly.

3.1.2. Measures in terms of transmission path. (1) Set up sound-absorbing materials. By installing sound-absorbing materials inside and outside subway vehicles, the sound insulation performance of the vehicle body is improved, effectively reducing the impact of external noise sources on interior noise.

(2) Improve vehicle sealing performance. Reduce holes and gaps in subway vehicle doors, windows, ventilators, inspection holes, etc; Improve the sound insulation performance of car windows, such as using fixed double-layer glass windows with air layers.

(3) Install sound insulation covers on both sides of the bogie to effectively reduce the impact of train radiated noise on the surrounding area [6].

3.2. Control measures for track system noise

3.2.1. Measures for noise sources. (1) Optimizing rail materials for noise reduction. Especially in curved sections of rail transit lines, the steel rails are made of specially designed steel materials to reduce the noise of vehicles passing through the curves.

(2) Use low noise wheels or elastic wheels. The specific method is to install a sector shaped disc plate or annular plate with vibration damping characteristics on the wheels to reduce wheel rail noise.

(3) Reduce the roughness of the wheel and rail surfaces. By regularly maintaining the surface of steel rails and wheels, the surface smoothness is improved to maintain a smooth and intact state.

(4) Reduce the stiffness of the track structure. By installing rail damping, vibration reducing fasteners, elastic support blocks, and using prefabricated floating plates or trapezoidal sleeper track structures on the rail, wheel rail noise can be effectively reduced [2].

3.2.2. Measures in terms of propagation path. (1) Install sound-absorbing materials. By arranging sound-absorbing materials on the ceilings and walls of the station hall and platform, as well as spraying sound-absorbing coatings on the top and side walls of the railway tunnel, it is a more efficient and economical noise reduction measure.

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(2) Set up sound absorption barriers. For ground rail transit lines, sound-absorbing barriers can be installed outside the steel rails to cut off the propagation path of wheel rail noise and reduce the impact of wheel rail noise on surrounding residents [3].

(3) Build green passages. For ground lines, greening on both sides of the track can effectively absorb and hinder the spread of noise [1].

(4) Adopting vibration isolation structure. For underground track lines, the foundation of buildings at the sound receiving point can be effectively prevented from spreading noise by using damping piles, damping materials, and other methods.

4. Conclusion

The issue of vibration and noise in rail transit is the hotspot, focus and difficulty of current research topic. This paper comprehensively analyzes the vibration and noise sources of urban rail transit from three aspects: generation, composition and characteristics. It provides systematic governance measures for vibration and noise reduction of rail transit from two aspects: noise sources and propagation paths. The conclusion is as follows:

(1) The noise sources during the subway operation period mainly include subway vehicles, track systems. The noise of subway vehicles is mainly generated by the operation of equipment such as braking systems, traction systems, auxiliary systems (air conditioning units, air compressors, ventilators, etc.). Track system noise mainly refers to wheel rail noise, which is composed of friction noise, impact noise, and rolling noise.

(2) The governance measures for the noise sources of subway vehicles mainly include optimizing structural design, installing vibration reduction devices, etc. The governance measures for the propagation path include setting up sound-absorbing materials, improving the sealing performance of vehicles, and installing sound insulation covers. The governance measures for the noise sources of the track system mainly include optimizing rail materials, using low noise or elastic wheels, reducing the roughness of the wheel and rail surface, and reducing the stiffness of the track structure. The governance measures for the propagation path include laying sound absorbing materials, setting sound absorption barriers, constructing green passages, and adopting vibration isolation structures.

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