Research on Testing Methods for Urban Rail Transit Braking Systems

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Abstract. Currently, with the rapid development of urban rail transit in major cities nationwide, the braking systems, with the brake control device as the core, are widely utilized. The train braking system is crucial for the safe operation of the entire train and plays a vital role in passenger safety. Considering the current needs, in order to enhance the testing of urban rail transit braking systems and align their development with national standards, this article reviews the testing methods for urban rail braking systems in recent years. The aim is to provide a theoretical basis for the future development of testing urban rail braking systems.

Keywords: Urban rail transit · Brake system · Test method

1 Introduction

In the urban rail transit system, the braking system of the train is the key to ensuring the safe operation of the entire train, and it directly affects the safety and stability of passengers during the operation of the entire train [1]. If the brake system fails to operate properly, it will directly affect the normal operation of the train and lead to delays in train schedules, disruption of passenger arrangements, and disturbances to public order, resulting in serious consequences for social order [2]. In modern urban rail transit, the importance of brake performance is no longer just related to safety, but also plays an important role in limiting the speed and acceleration of trains and increasing their running speed and acceleration. Modern urban rail transit vehicles are developing towards high-speed, high-acceleration modes, and as the speed and acceleration increase, the braking force and acceleration requirements also increase. If the speed and acceleration of the train can be increased without increasing the braking power of the braking device, then the train cannot stop and run at the same time, and the high-speed, high-acceleration mode cannot be achieved. The essential function of the braking device is to slow or stop the train at any time, ensuring safety, and also to increase the speed and acceleration of the train. Therefore, testing and improving the performance of urban rail transit braking

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systems is of great significance for improving the reliability and application level of brake systems in urban rail transit vehicles and has important practical significance.

2 Overview of Research Methods at Home and Abroad

In the testing of urban rail transit vehicle braking systems, foreign countries widely use on-vehicle testing technology for brake system testing. The principle is that faults are introduced into the on-board computer system of the bus, and the fault testing module is installed in the bus communication network. The real-time status of the brake system is recorded, and the location of faults is displayed. This technology has advantages in that it can accurately and quickly complete maintenance work both on the road and in the repair shop. At the same time, the fault testing module also has an interactive interface for the human operator, allowing them to easily identify and resolve faults through the interface. For example, Siemens's SIBAS32 system, Japan's NEC's ATCS (Advanced Train Control System), and MICAS system developed by ADTranz Corporation [3].

In China, different scientific research units employ various braking system testing techniques. Since the 1990s, comprehensive testing of urban rail vehicle braking systems has been carried out in our country. Representative examples include the testing of braking systems with the core being the brake control device, conducted by the China Academy of Railway Sciences, and the actual operational testing of vehicle braking performance at the Dongjiao Circle Railway Test Base [4, 5]. Qingdao Sifang Locomotive & Rolling Stock Co., Ltd. has developed a braking test system for urban rail vehicles. This test system simulates the speed signal, air spring pressure signal, and regenerative braking signal encountered during actual train operations and sends them to the train's braking system. Additionally, the test system can receive output feedback signals from the train's braking system. By analyzing these signals, the performance indicators of the braking system can be evaluated to determine if they meet the requirements. With continuous technological advancements, Tongji University has developed a testing platform for urban rail vehicle braking electronic control units (EBCUs). This platform can simulate various signals present in the actual operating conditions of urban rail vehicles and perform comprehensive testing of the brake electronic control unit [6].

In China, major scientific research units are dedicated to the research and development of braking technology and testing. However, due to a relatively late start in the research of braking technology as a whole, although significant progress has been made in braking system testing technology through the joint efforts of institutions such as China Academy of Railway Sciences, Tongji University, and various railway research institutes, a universally applicable and reliable testing method for braking systems has not yet been established for various reasons [7–10]. At present, the urban rail vehicle industry in major cities across the country is rapidly developing and is also placing higher demands on reliable testing technologies for braking systems with the brake control device as the core.

3 Testing Methods

3.1 Urban Rail Vehicle Braking System Test Platform

The urban rail vehicle braking system test platform mainly consists of six vehicles equipped with car control braking devices, six vehicles equipped with bogie control braking devices, two operating control consoles, train bus, piping system, independent data acquisition system, and other components, as shown in the diagram below. Following the configuration conditions that simulate actual vehicle braking system equipment, tests are conducted on a 1:1 ratio for car control braking control units and bogie control as braking control units. This includes testing the braking force configuration for different train formations, suitable for different trains and braking system networks and hardwire interfaces, including PWM, MVB, HDLC, CAN, etc. Based on different braking system configurations and technical requirements, pre-installation tests, interface tests, and functional tests are carried out. These tests involve real-time network control, electro-mechanical brake hybrid relationships, fault-oriented safety tests, braking performance analysis, and testing. The aim is to optimize braking system control methods and strategies, improve braking performance, and enhance the technical quality of the vehicle's braking system (Fig. 1).

Fig.1. Urban rail vehicle braking system test platform

3.2 Urban Rail Vehicle Braking System Braking Modes

According to the operational requirements of the vehicles, the braking system primarily employs the following braking modes:

(1) Service braking: This mode is used for normal operation to regulate or control the train's speed, including braking during station approaches. It features gentle action, continuously adjustable braking force, and automatic adjustment of braking force

based on the vehicle's load (the maximum service braking force is known as full service braking).

(2) Emergency braking: This mode is activated in emergency situations to bring the train to a stop as quickly as possible. It provides rapid and full utilization of the train's braking capacity. The emergency air braking system follows the design principle of "loss of power braking, power release braking" in case of faults. Emergency braking is implemented in urgent situations or unforeseen circumstances to bring the train to a stop as quickly as possible. The braking force is the same as in rapid braking. Emergency braking takes into account faults such as pantograph disconnection, coupler separation, or power failure. It exclusively utilizes air braking and cannot be released before coming to a stop. Specific restrictions on the impact force are minimized to prevent excessive impacts.

(3) Rapid braking: Rapid braking is employed to bring the train to a stop as quickly as possible and provides a higher braking force than full service braking. This braking mode is used in emergency situations when all components of the braking system are functioning normally. It has the same characteristics as service braking and allows for brake release during the braking process. It also includes features such as anti-skid protection and load correction, subject to the limitations of the maximum impact rate. The main controller handle returns to the "0" position when released.

(4) Spring parking brake: To prevent slippage during train parking on the tracks, urban rail vehicles are equipped with parking brake devices. The parking brake typically applies spring pressure to the wheel treads to create braking force. Previously referred to as parking brake or spring parking brake, the term "parking brake" is preferred to differentiate it from the concept of stopping brake used in subway trains. When parking inside a depot, this mode resolves the issue of gradual loss of braking force due to leakage or insufficient pressure replenishment in the brake cylinder. Under normal conditions, the spring force remains constant over time, providing the required braking force for extended periods of power outage parking. The spring parking brake can be released when the pneumatic release cylinder is pressurized and applied when the pneumatic release cylinder is vented. It also includes a manual release function. The parking brake is a braking mode used after the train has come to a stop to maintain its stationary position.

(5) Stopping brake: For subway trains, the segment of air braking before coming to a stop is commonly referred to as stopping brake or holding brake. As the train decelerates to very low speeds, the braking force is gradually reduced to minimize impact. Stopping brake shares characteristics with service braking.

Functional testing of the parking brake: Press the apply/release button for the parking brake and observe the TCMS display screen. The parking brake indicator should display green/gray, and the parking apply indicator light should be on/off. Observe the functionality of the parking brake status display on the TCMS screen. During the testing of the parking brake release state, check the brake pipe pressure. When the air pressure is not greater than 5.8 bar, the display shows "Parking Brake Applied." When the air pressure is equal to or greater than 5.8 bar, the display shows "Parking Brake Released." The triangular symbol on the TCMS screen will be green when the parking brake is applied and gray when the parking brake is released.

Functional testing of the service brake: Move the direction lever to the forward position and gradually move the main control lever from the zero position to the maximum service brake position. Observe the pressure change in the brake cylinder. The white needle on the dual needle pressure gauge indicates the brake cylinder pressure (3.1 ± 0.2) bar, and the red needle indicates the brake pipe pressure. Read the maximum service brake pressure from the TCMS brake interface.

Functional testing of the emergency brake: Press the emergency brake button and observe the TCMS brake interface. The command level will display EB, and the brake cylinder pressure will be as follows: Tc car (3.6 ± 0.2) bar, T car (3.0 ± 0.2) bar, M and M1 car (3.8 ± 0.2) bar. In the brake release state, turn off the air compressor. When the brake pipe pressure drops to (6.0 ± 0.2) bar, the emergency brake will be applied, and the air compressor will be turned on to charge the air. When the brake pipe pressure reaches (7.0 ± 0.2) bar, the emergency brake will be released normally. In the emergency brake state, release the emergency brake by moving the driver's controller to the middle position. Observe that the TCMS brake interface displays the command level as C. The brake cylinder pressure will be as follows: Tc car (1.7 ± 0.2) bar, T car (1.5 ± 0.2) bar, M and M1 car (2.0 ± 0.2) bar.

3.3 Urban Rail Vehicle Braking System Brake Testing

In the testing of urban rail vehicle braking systems, the main experimental tests conducted include brake system testing and parking brake testing. The specific standards and equipment used for each test are shown in Table 1.

For the brake system testing, the standards used are《IEC61133:2016 Railway applications–Rolling stock–Testing of rolling stock on completion of construction and before entry into service》and《GB14894:2016 Rules for inspecting and testing of urban rail transitvehicles after completion of construction 》. The testing equipment includes a digital multimeter, speed radar with corresponding data acquisition equipment, a laptop with testing software, and a pressure gauge.

For the parking brake testing, the standards used are《IEC61133:2016 Railway applications–Rolling stock–Testing of rolling stock on completion of construction and before entry into service》and《GB14894:2016 Rules for inspecting and testing of urban rail transitvehicles after completion of construction》. The testing equipment includes a digital multimeter, a laptop with testing software, and a pressure gauge.

4 Conclusion

This paper primarily focuses on the analysis and method research of urban rail braking system testing, aiming to provide a theoretical foundation for the testing of urban rail transit braking systems.

Table 1. Urban rail vehicle braking system brake testing

Test name	Standard	Equipment
Brake system test	《IEC61133:2016 Railway applications–Rolling stock–Testing of rolling stock on completion of construction and before entry into service》 《GB14894:2016 Rules for inspecting and testing of urban rail transit vehicles after completion of construction》	Digital multimeter Speed radar and corresponding data acquisition equipment; Laptop with testing software Pressure gauge
Parking brake test	《IEC61133:2016 Railway applications–Rolling stock–Testing of rolling stock on completion of construction and before entry into service》 《GB14894:2016 Rules for inspecting and testing of urban rail transitvehicles after completion of construction》	Digital multimeter Laptop with testing software Pressure gauge

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