Development of brake system test-bed for high-speed train

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Abstract. As the speed of high-speed emu increases, the service conditions become more and more severe and complex. Brake system is an important guarantee of safety, so it is urgent to study the design concept and test method of brake system. There are relatively few researches on high-speed train brake test bench in China, and the existing test bench still has shortcomings in compatibility, real-time simulation and other aspects. Aiming at these problems, this work builds a brake test-bed for emu, which can complete the research test, performance test and reliability test of high-speed emu brake system and key components. At the same time, cooperate with Amesim, the braking process is simulated and predicted, and the braking process is analyzed by breakpoint, which provides a basis for the analysis, design and improvement of the braking system after experiment.

1. Introduction
With the development of micro-control technology, microcomputer is widely used to control direct electro-pneumatic braking system in high-speed emu, which can fully and reasonably distribute air and regenerative braking force [1-3]. The brake shoe material and brake structure of foundation brake are also being innovated continuously. After China increases the railway speed the sixth time, the speed of high-speed trains has reached 350km/h, and the condition of trains is more complex, which undoubtedly puts forward higher requirements for the braking system [4]. Therefore, it is urgent to study the advanced design concept and test methods. For reducing test cost and risk, the test-bed is the most effective means of design and inspection [5]. Chinese passenger train and wagons’s brake test-bed has gradually become mature in the process of independent research and development for many years. However, there are few literatures have been conducted on the braking system test-bed of high-speed emu with 300km/h or above [6]. In addition, the existing high-speed train braking test-bed still have deficiencies in terms of compatibility and real-time simulation, which is difficult to meet actual needs.

In this paper, a high-speed train braking system test-bed was built, which includes hardware and software. It can complete research test, performance test and reliability test of the key components of high-speed train braking system. On the one hand, the test data can be used to monitor braking system. On the other hand, the data can be imported through Amesim interface for simulation, prediction and breakpoint analysis of pressure, signal and other changes at different positions at each moment, which is convenient to adjust and improve the braking system after the experiment.
2. Conditions of test-bed
(1) Air source requirements:
   The air source of the test-bed ISO8573-1-1:2, 2 and Grade 2 is standard compressed air with rated pressure of 1000kPa [7].
(2) Power supply:
   Three-phase five-wire; AC380V; 50Hz;
(3) Environmental requirements:
   Operating temperature of system test-bed: -5°C ~ 50°C;
   Normally, the noise of test-bed should be less than 30dB (A). Except under special circumstances (such as exhaust air).
(4) System initialization:
   Adjust the pressure regulating valve to fill air to the total air pressure of 700kPa, and adjust the pressure regulating valve to make the pressure of two empty springs 400kPa.

3. Main functions and composition of test-bed
3.1. Main functions
With simple operation, the test-bed can conduct the air source control test; graduated braking and graduated release performance test of braking system; Brake performance test at different initial speeds; Emergency braking performance test at different initial speeds; Adjustment performance test of empty and load brake ; Anti-skid control test of electro-air braking system; ATP controlled braking performance test, etc. In addition, it can easily and intuitively shows the relevant acquisition signal data in the experimental management system.

In view of the characteristics of train control, the brake test bench was divided into two parts: hardware and software. The hardware mainly includes console, air circuit related devices, load simulator, driver control simulator, data server, power supply system and test bench. Software includes data acquisition system, analysis system and simulation system.

3.2. Hardware
3.2.1. Console. The console is located on one side of the test-bed, and acquire and monitor the information from the temperature of axle and brake shoe, speed, the pressure of brake shoe and cylinder, etc with serial communication. As shown in figure 1, the console include two parts: one is data acquisition and display, which is used for acquisition, processing, storage, and display the test data and results, it's the carrier of software part, and mainly is communication equipment( IPC,PCL818L and PCI11611U). Considering the poor anti-interference and low transmission rate of RS232 in industrial environment, the IPC is closely connected with the bottom layer by RS485 bus. And automatic acquisition and monitoring process is realized by software; the other is data acquisition device, which is consists of 4 data acquisition units to obtain test data. Each test point can be flexibly adjusted according to the actual test conditions.

   (1) air pipeline monitoring unit: It consists of seven MPM4730 pressure sensors, 250 Ω resistors, PCL818L data acquisition card, AC motor, elevator, etc. Pressure sensors are set at the air exits of 4 brake cylinders, 2 air springs and BCU, respectively. The pressure signal is A/D converted by PCL818L and transmitted to the IPC to monitor the brake air pipeline state in real time. Separate loading of the two air spring pressures can be achieved by an AC motor driven elevator. This unit can conduct the air tightness test of braking system pipeline and compressed air equipment, empty and load brake equipment's performance and other related air tests.

   (2) Pressure monitoring unit: composed of bk-4c pressure sensor, pressure transmitter, etc. The pressure sensor is respectively arranged on the brake shoe and brake cylinder's piston rod. The brake shoe’s pressure signal is amplified by the transmitter and converted to Data by PCL818L, and transmitted to the ICP. At this point, all the acquisition channels of PCL818L are configured.
Therefore, PC11611U data acquisition card is selected to acquire the pressure of the brake cylinder by rs-485 bus. This unit can conduct the graduated braking and mitigation test of braking system, brake system test, brake shoe performance test, adhesion test, transmission efficiency test and other related tests.

(3) Temperature monitoring unit: including hs-100rs non-contact infrared thermometer, thermocouple, IBF11-Z1-T1-P1-A4 temperature transmitter, ADAM4018, etc. Hs-100rs acquire axle temperature and transmits data through its rs-485 interface. The thermocouple is bonded to the surface of the brake pad to acquire brake shoe's temperature signal, and then amplified, integrated and isolated into electrical signal by temperature transmitter. After converted by ADAM4018, the electrical signal became digital and transmitted to the ICP by RS-485 bus.

(4) Speed monitoring unit: it is composed of SWKP IG20 magneto-electric speed measuring sensor, ADAM-4024, motor controller, servo motor, etc. The ICP converts the digital value of speed into the analog value and transmit to the motor controller through adam-4024. Furthermore, servo motor rotation is controlled to realize the speed control in the test; The speed signal is acquired by SWKP IG20 and output digital signal, which is divided into two channels, one is directly sent to the anti-skid device, the other is sent to the IPC though RS485 bus. The unit can conduct anti-skid test.

Siemens 300PLC is selected as EBCU to handle the switch of anti-skid solenoid valve, emergency solenoid valve, brake solenoid valve, release solenoid valve and other related solenoid valves. At the same time, I/O point is reserved as the interface of other test electrical appliances, which improve the universality of electrical appliances.

Figure 1. Test bench flow chart.

3.2.2. Air circuit related devices. As shown in figure 2, the air source is the special air source for the test-bed. The compressed air is provided by the air compressor, and the air storage cylinder (ARS) and brake cylinder (BCS) are established. Pipeline system simulates the real train, including main air pipe, train pipe and brake pipe. As a key component of brake control, BCU is composed of emergency valve, empty and load brake valve, relay valve, integrated air circuit plate, protective cover, pressure transmitter, pressure test interface, electrical connector and so on.
3.2.3. Load simulator. The load simulator consists of two air springs, two height valves, one differential pressure valve and an air spring loading system. The air spring loading part is driven by two three-phase ac asynchronous motors to drive the elevator and realize the separate loading of two air spring. By controlling the elevator, simulating the load change on both sides of train's body can conduct the height valve and differential pressure valve adjustment test. Height valve used for compensating the changes of the passenger weight, height valve should not be affected by vehicle and track vibration impact, differential pressure valve is installed in the middle of the connecting line of 2 air spring in the same bogie. When the air spring on either side is abnormal, it acts as a safety device to connect the air springs to prevent excessive lean of train's body.

3.2.4. Driver control simulator. Control controller and conversion device, used to provide brake level emergency button, forced release, key switch, etc. Considering the various and complicated transmission lines of voltage signal, it is converted into digital signals by the control signal conversion device and transmitted to PLC. The three-wire reg code method is used to simulate the 7 common braking commands of the control handle of the driver brake, such as 001 is the first braking and 010 is the second braking, etc.

4. Software

4.1. Data acquisition system
Data acquisition system is mainly used to classify and store data in a standardized format. As shown in figure 3, in this paper, based on the Win XP operating system, VB6.0 is used to develop a data acquisition system. MSComm is used to initialize baud rate, peer check, data bit and stop bit, and communication address and buffer are configured. After reading the buffer by 'Input' property, the data is written to Access by ADO to achieve automatic, timely, accurate acquisition.

For the convenience of monitoring, the C/S architecture server is established in the IPC, and 9100 port is opened as the client connection port. The SocketServer is developed for client connection, and transmit data, package with XML.

4.2. Analysis and simulation system
In order to study and analyze the braking system, in this work, VB6.0 is used to develop the analysis system. With the comparison of Amesim simulation, the breakpoint analysis of the process can be achieved, which provide a theoretical and Suggestions for the research, development, design and adjustment. The analysis system includes:

- Parameter setting: initialization parameter setting, such as time, precontrol pressure, speed, etc.
- Brake test selection: provide air source control test; graduated braking and graduated release performance test of braking system; Brake performance test at different initial speeds; Emergency
braking performance test at different initial speeds; Adjustment performance test of empty and load brake; Anti-skid control test of electro-air braking system; ATP controlled braking performance test, etc.

PLC control: upload/download data; PLC program development;
Amesim analysis: AMESim interface is used to develop AMESim analysis module in VB environment, which can be easily configured with AMESim. As shown in figure 3, simulation tests of mathematical models are organized more effectively and quickly by the gas and circuit models, and analyze the results.

Historical record: add, delete, change and search the data through the Access.

![Figure 3. Electro-air braking simulation model.](image)

5. Conclusion
In this work, a set of high-speed train brake system test bench is constructed for the deficiency of the brake test bench. The brake system requirements are analyzed in depth. The system is divided into hardware and software parts. For the simulation of braking system, the joint simulation principle of Amesim and VB is described, and the modeling analysis is carried out. The results show that the system runs stably and the test data is reliable.

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