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Study on the Temperature Test System of Brake Disc for Subway Train

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***Abstract*—A test system based on 485 network is designed and built, with the industrial control computer PC as the control unit. It implements the on-board miniaturization, intelligent unmanned, distributed networked test of metro vehicle brake disc temperature rise. Meanwhile, personal PC can receive the data collected by industrial control computer PC through the serial port. Industrial control computer PC software and personal PC software are using LABVIEW graphical language. In the case of long unattended, the industrial control computer PC automatically and completely saves vehicle brake disc temperature rise data. Personal PC, at the same time, has access to historical data saved by industrial control computer PC through the local area network. It achieves a quick copy of historical test data.**

Keywords-485network; brake disc; temperature rise test; unattended

I. INTRODUCTION

Disc brake as one of the main braking methods of metro vehicles[1], the temperature rise characteristic of the wheel-brake disc friction pair in the braking process directly affects the reliability, service life and safety of the vehicle braking system. Because the distance between the adjacent stations in the metro line is relatively small, the heat between a brake relief and the next brake cannot recess in time, there exists a certain heat accumulation effect between the wheel-brake disc friction pair. Such frequent braking and large deceleration are so easy to cause thermal fatigue damage and the wear of friction pair, and then affects the safety of driving. In the long-term operation of train, to study the potential safety hazards of too high temperature during the braking process is becoming more and more important[2]. Therefore, it is necessary to carry out a long-term unattended and accurate temperature measurement of the wheel brake disc and the brake pad.

At present, the existing test system failed to do on-board intelligent unmanned measurement, test equipment is not small enough and measurement system is not enough networked. So it is necessary to design and build a more on-board miniaturization, intelligent unmanned and distributed networked metro vehicle brake disc temperature rise test system.

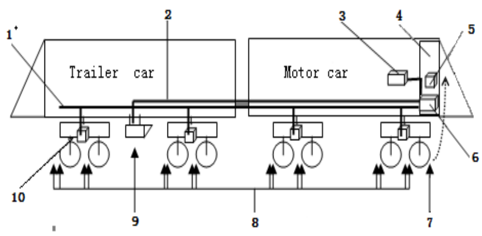
II. TEST SYSTEM

In accordance with whether the test sensor is directly in contact with the measured medium or not[3], temperature test can be divided into contact type temperature measurement and non-contact temperature measurement. The common temperature measurement methods of metro train basic braking device include thermocouple temperature measurement, infrared temperature measurement, thermal imaging temperature measurement, surface mount temperature measurement and temperature memory screw. The thermocouple can be directly put into the brake pad for measuring, and it is not affected by the intermediate medium. The measuring accuracy is higher, the performance is reliable, and the thermocouple temperature measurement cost is low. For the wheel brake disc, it is in the movement state for most of the time, and the temperature on the brake disc surface is roughly evenly distributed during braking, therefore the non-contact infrared thermometer measurement scheme is adopted widely[4-5].

A. The Overall Structure of Test System

In this paper, the train brake disc temperature rise test system is designed for a motor car and a trailer car. Figure 1 shows the layout of the full temperature rise test system.

For a motor and a trailer train, every car has two bogies, and each bogie has two wheelsets. Since two wheels have similar motion state, and the braking status is also similar, so their braking temperature rise can be considered similar. So we select one wheel of each wheelset, and install one thermocouple sensor and one infrared thermometer, to measure the temperature rise of brake pad and brake disc of corresponding wheel respectively. For a motor and a trailer train, eight thermocouples and eight thermometers are needed.



1-RS485 bus and power 2-Rader and power 3- personal PC 4-electric cabinet 5-signal acquisition card 1 6-industrial control computer PC 7- shaft speed sensor 8-eight thermocouples eight infrared thermometer 9-Radar 10--signal acquisition card 2-5

FIGURE I. TEST SYSTEM LAYOUT

1) The selection of thermocouple

The test system selects the thermocouple with the temperature measurement range of -20℃~ 500℃. For the installation of thermocouples, we play the blind hole about 4 ~ 5 mm in diameter behind the brake pad. The brake pads are left with a friction layer of about 6~7mm, then we put the thermocouple sensors in, encapsulated with silica gel. The thermocouple wire is led out of the groove through the side milling, so as not to affect the normal braking process of the train, as shown in Figure 2.

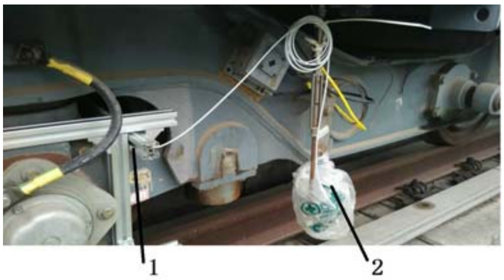
2) The selection of infrared thermometer

The test system finally selects the infrared thermometer with the temperature measurement range of 0℃ ~ 500℃. It can meet the temperature measurement requirements of wheel brake disc surface. It has fast response, high optical resolution, better system accuracy and temperature resolution. It has a variety of optional output mode. The test system select the 4~20mA analog output. Figure 3 shows the installation of point thermometer in the car. The infrared emissivity of the measured object should be set before the measurement.

3) Speed measurement

The test system adopts two sets of speed measurement scheme: (shaft end speed sensor, doppler radar sensor[6]), two sets of scheme can complement each other. The shaft speed signal is taken directly from the on-board BECU and the direct output is frequency. Use conversion module to convert it into analog output of 4-20 mA. There are two kinds of output mode of radar sensor: 485 serial port output and pulse output, and the system uses 485 serial port output[7] . Fixing the radar by means of the mounting bracket, as shown in Figure 4.

FIGURE II. THERMOCOUPLE INSTALLATION ON THE BRAKE PAD



1-INSTALLATION TOOL

2- THERMOMETER COMMUNICATION BOX

FIGURE III. THERMOMETER INSTALLATION ON THE VEHICLE

FIGURE IV. RADAR

B. The Hardware of Test System

The test system is based on the RS-485 bus network[8-9], with industrial control computer PC as the core of the distributed network test system, and its hardware structure is shown in Figure 5.

Figure 6 shows the installation of industrial control computer PC. It starts data acquisition when it has power supply[10]. It can automatically save data, achieve on-board miniaturization, intelligent automation unattended measurement. At the same time, personal PC can copy the historical data saved by industrial control computer through the local area network directly.

C. The Software Design of Test System

In this paper, industrial control computer PC software and personal PC software are based on the virtual instrument programming software LabVIEW developed by United States NI Corporation as the platform. It can be used in Windows XP/7 and other operating systems. The man-machine interface is friendly and the operation is simple and intuitive[11].

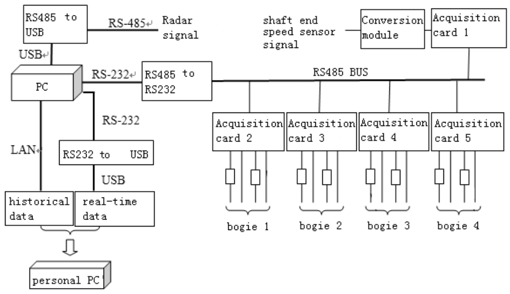


FIGURE V. THE HARDWARE STRUCTURE OF TEST SYSTEM

1- INDUSTRIAL CONTROL COMPUTER PC

2- INSTALLATION TOOL

FIGURE VI. THE INSTALLATION OF INDUSTRIAL CONTROL COMPUTER PC

Industrial control computer PC as the control unit, firstly, package acquisition data and send it to a specific serial port by sending module for personal PC use[12]; Meanwhile, the collected data recover to the temperature and speed of the actual measurement after signal filtering and data processing. It can realize data curve display and form alarm signal.(including the lower limit alarm and the upper limit alarm), and store data automatically[13]. Its software function structure is shown in Figure 7.

Personal PC receives the real-time data of industrial control computer PC through the serial port. Firstly, decode data. Then, the obtained data recover to the temperature and speed of the actual measurement after signal filtering and data processing[14]. It can realize data curve display and temperature alarm function. Finally, it can automatically store[15] the collected data. Its software function structure is shown in Figure 8.

The software front panel interface is divided into three sections: the system overview, the channel test, and the temperature rise state. As shown in the Figure 9 below:

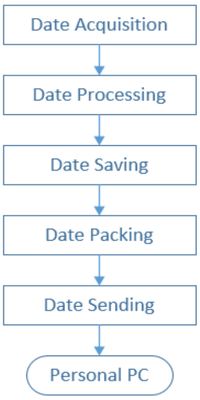


FIGURE VII. INDUSTRIAL CONTROL COMPUTER PC SOFTWARE FUNCTION STRUCTURE

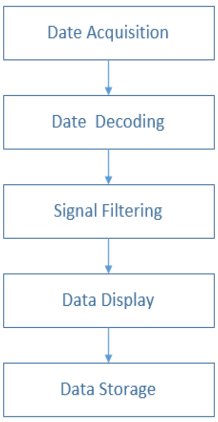


FIGURE VIII. PERSONAL PC SOFTWARE FUNCTIONSTRUCTURE

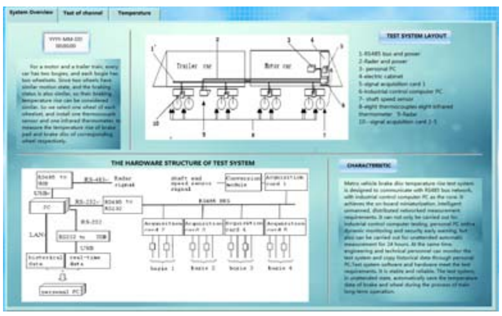


FIGURE IX. SOFTWARE INTERFACE SYSTEM OVERVIEW PLATE

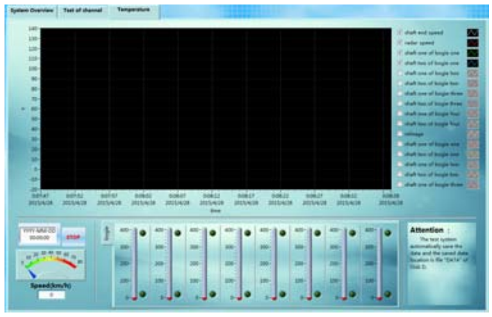


FIGURE X. SOFTWARE INTERFACE TEMPERATURE RISE STATE PLATE

The system overview plate in Figure 9 provides users with the basic situation of the test system. The temperature rise state plate in Figure 10 directly shows the vehicle running speed, distance, the temperature rise conditions of relevant brake parts, and it provides alarm indication function and data storage function.

III. TEST VERIFICATION

The test system is arranged on the test site, with the installation of radar speed sensor, thermocouple and infrared thermometer sensor. Metro vehicle test is carried out under pure air brake condition and part of the measurement data are used to map. As shown in Figure 11 and Figure 12.

Three curves stand for point thermometer measurement data, thermocouple measurement data, and running speed of the train. The variation trends of thermometer temperature and thermocouple temperature are consistent with train running state: In the process of pure air brake, the temperature of the brake disc and brake pad will increase; In the process of train traction and inertia, the temperature of the brake disc and the brake pad will reduce due to the heat radiation. Test results show that the test system in the test site is working properly and stably, and the test data is accurate.

FIGURE XI. TEST METRO VEHICLE

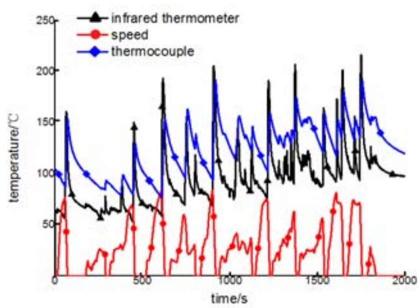


FIGURE XII. TEST DATA CURVE

IV. CONCLUSION

Metro vehicle brake disc temperature rise test system is designed to communicate with RS485 bus network, with industrial control computer PC as the core. It achieves the on-board miniaturization, intelligent unmanned, distributed networked measurement requirements. It can not only be carried out for industrial control computer testing, personal PC online dynamic monitoring and security early warning, but also can be carried out for unattended automatic measurement for 24 hours. At the same time, engineering and technical personnel can monitor the test system and copy historical data through personal PC. Test system software and hardware meet the test requirements. It is stable and reliable. The test system, in unattended state, automatically save the temperature data of brake and wheel during the process of train long-term operation. It is helpful to analyze the relationship between the friction pair temperature rise and the train operation. It provides strong data support for the train fault speed limit, the prevention of thermal crack, the replacement of used-to-limit friction pairs and so on, which has a very important practical significance.

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