System of monitoring and early warning for temperature of truck Brake shoe

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Abstract. For truck brake shoe early-warning temperature dynamic detection, this paper proposes a temperature detection device for brake shoe based on thermocouple temperature sensor, and by using ANSYS finite element analysis method to analyse the brake drum brakes, brake shoe linings in the process of the location of the maximum temperature, and determined the brake temperature of the brake safety threshold. To liberate the acetate II heavy commercial vehicles for the test vehicle, MC9S12XEP100 microcontroller as the car terminal, designed and developed brake shoe temperature dynamic detection warning system platform, and researched. The experimental results show that the temperature measurement error is less than or equal to 4%, which verifies the accuracy and feasibility of this method for dynamic detection of the temperature of the warning hoof.

1. Introduction

When the truck is continuously braked, due to the heavy load of the brake, the friction between the friction plate and the brake drum causes the temperature of the brake shoe to rise rapidly, which is easy to produce the phenomenon of heat recession, which leads to brake failure and brake failure, resulting in serious traffic accidents. The brake shoe is a consumable. When it is worn to the limit position, it must be replaced. Otherwise, it will reduce the braking effect and even cause safety accidents. The real-time monitoring of brake shoe temperature is one of the important ways to ensure the braking capacity and thermal stability of the brake.

At the same time, it provides a lot of theoretical reference for the optimization of brake disc temperature in domestic and abroad [1]. Meng Zhaohui of Jilin University analyzed the temperature rise of the leading-slave shoe type drum brake through the software of three-dimensional finite element analysis, and obtained the brake drum temperature at the end of braking at different initial speeds [2]. Aiming at the problem of friction brake failure caused by high braking temperature of disc brake, Ji Jingfang established the simulation model of disc brake temperature field with ANSYS, and carried out nonlinear regression analysis combined with regression analysis method, calculated the maximum temperature of brake disc under different initial speeds, which provided reference for temperature prediction in the process of brake design [3]. Day et al. carried out simulation analysis through finite element analysis method, established two-dimensional brake modeling, analyzed the pressure distribution of brake contact friction surface, and found out the influence relationship of different friction coefficient on braking performance [4]. Rajesh somnay, Shan Shih, etc. improved the drum brake...
performance by considering the thermal coupling and mechanical effects, and proposed a method to predict the brake torque according to the thermal and mechanical effects in the braking process [5].

2. Dynamic detection method of brake temperature

In the process of realizing the dynamic monitoring of brake temperature and timely warning, how to determine the monitoring point of brake shoe temperature, that is, the highest point of brake friction temperature, is the key of dynamic monitoring. In this paper, through the establishment of brake shoe mechanics analysis model, the finite element simulation method is used to analyze and obtain the highest brake shoe temperature position of the vehicle in emergency braking.

2.1. Position analysis of the highest brake temperature point

In this paper, the brake system of Jiefang Sailong II car produced by FAW Qingdao Special Purpose Vehicle Factory is selected as the research object. Through the actual measurement of Sailong automobile, the detailed parameters of the drum brake are obtained.

The solid model of brake shoe is established, and the brake shoe is meshed into 8-node hexahedral mesh element; solid35 element is used to grid the brake shoe model, which is divided into 4-node tetrahedral element. The result of brake shoe model meshing is shown in Fig. 1. After the brake shoe is meshed, there are 48005 units in total.

![Figure 1. Three-dimensional diagram of meshing for brake shoe](image)

In the process of vehicle braking, the temperature of brake drum and friction lining increases continuously due to the friction heat generated by the mutual movement between brake drum and friction lining. Therefore, in the simulation process, the braking situation is simulated, if ① braking with the maximum braking torque and keeping the torque unchanged; ② the vehicle braking deceleration value is constant; ③ at the moment of emergency braking, all the friction heat of the brake is absorbed by the brake drum and brake shoes. Through simulation analysis, the temperature field distribution of brake shoe at the moment of emergency braking is shown in Fig. 2.

According to the distribution of brake shoe temperature field obtained by ANSYS finite element analysis, it can be concluded that in the process of vehicle emergency braking, the highest temperature position of brake shoe friction lining is on the upper half of the friction lining, the specific position is at the upper half of the friction lining, the distance between the vertical direction and the water level position is, and the distance is the same as the friction lining width B in the z-axis direction, which is opposite to the horizontal direction The angle is.

2.2. Construction of brake temperature monitoring and early warning system platform

(1) Determination of brake failure temperature threshold

The relationship curve between friction coefficient and temperature is shown in Fig.2. When the temperature is less than 250°C C, the friction coefficient increases with the increase of temperature, showing an upward trend; when the temperature is higher than 250°C C, the friction coefficient decreases sharply with the increase of temperature, showing a downward trend. Therefore, when the friction pair temperature is higher than 250°C C, the friction coefficient of the brake lining of Jiefang
Sailong experimental vehicle will be greatly reduced, which will reduce the brake torque and affect the braking efficiency of the brake. According to the grade severity classification system developed by the Federal Highway Administration (FHWA), whether the temperature of the brake hub exceeds 260℃ is taken as the basis for setting up a refuge lane. Therefore, based on the domestic research results and foreign research results, the brake degradation temperature is set as 260℃, that is, the failure threshold temperature is set to 260℃.[6]

![Figure 2. Relation curve of temperature of fraction lining and fraction coefficient](image)

(2) Selection and installation of sensors

When the vehicle is braked in the running state, the friction between the surface of the friction lining of the brake shoe and the surface of the high-speed running brake drum occurs relative motion for friction. The high temperature generated by friction cannot be measured directly. Therefore, the temperature of the friction lining during braking is usually measured by thermocouple or infrared sensor. Considering the installation cost and measurement accuracy, the platinum thermistor method is used in this paper. The specific method is as follows: firstly, ANSYS software is used to carry out finite element simulation to find out the position of the highest temperature of the friction lining when the brake is braked, and then a platinum thermistor temperature sensor is installed at this position to collect the maximum temperature of the brake shoe friction lining during braking. The installation mode and position of the sensor are shown in Fig3.

![Figure 3. Mounting position of the sensor](image)

(3) Selection of vehicle terminal3

The mc9s12xep100 single-chip microcomputer of Freescale is used as the terminal of the on-board early warning control panel. The data communication between the vehicle terminal and the vehicle
terminal is carried out through RS-232, and the warning information of vehicle brake temperature status is displayed visually in real time.

When the vehicle is started, the warning system starts to enter the working state, and the first level indicator light on the control panel is displayed as green. If the warning system fails, the first level indicator light will be red and flashing continuously; when the brake shoe friction lining temperature is lower than the preset threshold value of the system, the secondary indicator light will be displayed as green; when the brake shoe temperature is higher than the threshold value, the secondary indicator light will be displayed as red. At the same time, the sound alarm is sent out to remind the driver that the temperature of brake shoe friction lining is abnormal, and appropriate safety measures should be taken in time to avoid traffic accidents.

(4) Design of temperature warning program for friction lining

After the temperature sensor signal of brake shoe friction lining of freight car is collected by dam3046 data acquisition module, the collected sensor temperature information is sent to vehicle terminal through duplex communication mode between acquisition module and vehicle terminal mc9s12xep100 single chip microcomputer. The brake shoe lining temperature threshold is set at 260 °C. when the temperature collected by the data acquisition module is higher than the threshold temperature, the warning system will send out danger warning information to the driver.

3. Experimental analysis

3.1. Data collection effectiveness and analysis

In the indoor experiment, firstly, the system collects the indoor test data to form the temperature sensor temperature data sample library. In the sample database, 100 groups of data of temperature sensor signal value are randomly selected from the sample database, which are divided into three categories: before the test, during the test and after the test. In this test, the indoor temperature at the time of the test is used for reference comparison, and the signal value of the temperature sensor is analyzed. The drawing software is used to compare the three types of data before, during and after the test. The drawing results are shown in Fig. 4.

![Figure 4. Curve of temperature sensor signal value](image)

In the sensor test, the temperature sensor used in this test is 3.5℃ higher than the actual temperature, and the mathematical formula of signal value and actual temperature is as follows:
Sensor signal value \( () = (\text{actual temperature} + 3.5) \times 100 \)

According to the test record, the indoor temperature is 26.6\(^\circ\)C before the test, so the corresponding sensor signal value should be 3010; when the test data is in the test, the indoor temperature is 28.4 \(^\circ\)C, and the corresponding sensor signal value is 3190; when the test data is tested after the test, the indoor temperature is 27\(^\circ\)C, and the corresponding sensor signal value is 3150. Through observing the image, before the test, the signal value is maintained at 3010, the fluctuation is not more than 10, and the relative signal value of variation is far less than 5%. Within the allowable range of error, the collected data are normal and effective; in the test, the signal value is maintained at 3190, and the fluctuation is not more than 10, and the relative signal value of variation is far less than 5%. Within the allowable range of error, the temperature signal acquisition is positive during the high temperature test. After the test, the signal value is maintained at 3150, the fluctuation is not more than 10, and the variation is far less than 5% relative to the signal value. Within the allowable error range, the signal acquisition is stable and normal and effective. And the structure and function of the system meet the requirements under normal conditions, and the parameter test is normal.

3.2. Temperature verification test of brake shoe lining

The connected test system operates in normal environment, collects test data and gives stimulation to each sensor respectively. The gasoline blowtorch is ignited to heat the local area around the sensor installation position of the brake shoe friction lining. During the heating process, the infrared thermometer is used to observe the temperature change in real time. After heating to a certain temperature, the heating source is removed to allow the friction lining to cool naturally. During the cooling process, the infrared thermometer is used to measure the temperature of the installation position of the friction lining sensor every other second, and the temperature of the friction lining output from the vehicle terminal is read and recorded for reference comparison. The experimental process is shown in Fig. 5.

![Figure 5. Confirmatory test for temperature detection of friction lining](image)

When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. According to the output temperature data of infrared thermometer and temperature sensor recorded and collected in the process of heating and cooling, the output temperature data of infrared thermometer and temperature sensor are compared by using drawing software. The drawing result is shown in Fig. 6.

According to the comparison of the temperature of the brake shoe friction lining measured by the above infrared thermometer and temperature sensor, the temperature error measured by the temperature sensor is less than or equal to 4%, which can achieve the goal of early warning error. The accuracy and reliability of the system measurement data are explained.
3.3. Road test
The system is installed on the Jiefang Sailong truck to carry out the real vehicle road test to verify the effectiveness and practicability of the analysis and development system in practical application. In the process of the experiment, the temperature data of the brake shoe friction lining are collected, and these signals are monitored in real time, and the fault information and occurrence frequency of the signal collection are counted. In addition, the warning panel is used to observe the early warning effect of the system, judge and analyze the working effectiveness of the system, and count the effective rate of the system early warning in actual operation.

The whole test truck runs 5000km in total and is divided into 10 times. In each test, emergency braking or strong braking are occasionally carried out in the normal driving process to make the temperature of brake shoe friction lining rise rapidly. Each sensor is stimulated to receive and save data continuously for reference. The experimental process is shown in Fig.7. During the whole 5000km real vehicle road test, the system accumulated 100 times of emergency braking and forced action, and the system gave a total of 99 alarms, one of which did not give warning. By looking for the cause, it is found that the line is not connected well. Therefore, the early warning system is effective. When the brake temperature is below the threshold, the system will no longer give an alarm and continue to operate normally.

After each test, the real vehicle test data stored in the notebook computer is exported through the data line, and the test data are saved and sorted out to complete the test. After many tests, the collected original data of brake shoe lining temperature test were processed, and the sample database was established after the preliminary processing. 50 groups of brake shoe friction lining temperature value and the change curve of temperature sensor signal value were randomly selected.
4. Conclusion

1) The process of heat generation and heat dissipation of brake lining is analyzed, and the main way of heat dissipation is obtained. At the same time, the energy relationship of the truck in the braking process is studied. Then through the ANSYS finite element simulation method, the highest temperature position of the brake shoe friction lining in the vehicle braking process is simulated.

2) The platform of truck brake temperature monitoring and early warning system is built. Through the design of system hardware and software, the specific implementation scheme of brake temperature monitoring and early warning technology is determined.

3) The stability and feasibility of the data collected by the system are confirmed through the indoor test and real vehicle test of the system installed on the experimental vehicle. Through the data analysis and comparison between the verification test and the real vehicle test, the accuracy of the system measurement data and the normal and feasible operation of the system are determined.

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