The reliability design of inspection device based on the obstacles and the derailment

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Abstract—This paper introduces a kind of contact train obstacles and derailment detection device. It is composed of detection device and electric box. The energy produced by collision between obstacles and detection device and the train derailment is converted to electrical signal which can be measured, then it could control emergency braking. It can minimize the impact of foreign matter on vehicle safety or operation order after entering the vehicle limit. This system uses CPLD as the control core and adopts double redundancy design that improved the reliability of the device. It provides guarantee for train running safety and has good application prospect.

1. Introduction

In the backdrop of the rapid development of urban rail transit, it very important to the safety of the train. That becomes one of the biggest challenges for urban rail transit development.

The driving environment of subway is a relatively closed environment. Few big obstacles appear, but some small ones are still inevitable. When the speed and obstacle size of subway reach a certain degree, it will pose a great threat to driving safety. Even if the obstacle is small and the driving speed is slow, the collision will have a bad effect on the strength of the body parts. If there are obstacles on the road or derailment happened in the process of driving, it will lead to Serious accident endangering passengers’ life and cause immeasurable losses [1].

So far, the main means of obstacle and derailment detection are: obstacle detection technology based on image processing technology, which has the advantages of large coverage and strong adaptability, but has high requirements on hardware resources, complex algorithm, large amount of calculation, difficult to achieve. And the reliability and availability still need to be further improved and verified, there is no relevant application at home and abroad. Obstacle detection technology based on laser pulse ranging has the advantages of high sensitivity and long detection distance, but it has great limitations for curve detection, and severe turbulence may lead to false positives. In this paper, a new type of contact detection device is proposed, which adopts mechatronics design. When the obstacle on the track is detected, the obstacle will impact the vehicle under the beam detection equipment. the kinetic energy of the obstacle is converted into the mechanical energy of the beam, and the deformation of the beam triggers the travel switch in the vehicle under the control box, which is connected in series to the emergency circuit of the vehicle. The emergency braking loop of the train is
immediately disconnected, and the train braking is controlled to avoid the further deterioration of the accident[2][3]. It minimizes vehicle damage.

2. System composition
The inspection device of obstacles and derailment is composed of two sections: obstacle detection device and the electric box for data analyzing and processing and logic control. The track detection device is installed on the first bogie in the front of the car, and the logic control box for data analysis and processing is installed in the car.

2.1. Detection Device
Main structure of detection device is as shown in Fig. 1.

![Fig.1 The structure of detection device](image)

The obstacle detection device is installed in front of the first bogie at the bottom of the front of the train. The height of the beam of this obstacle is about 110 cm above the plane on the track. If the front beam collides with an obstruction on the tracks, the kinetic energy of this system will be converted to elastic potential energy of the plate spring and kinetic energy of obstruction to make plate spring deformation. The role of the travel switch connected with it is used to test the size of the deformation quantity for plate spring. When the variable shape reaches pre-set threshold, trip switch is moving to transfer signals to the main control box, then it disconnects the emergency braking loop. When the train derailment occurs, the front beam can produce impact with rail surface and upward at the same time. Another approach switch at the top of the plate spring will detect of deformation quantity in the vertical direction to determine whether a train derailment through electric box. If the train derails, the vehicle's emergency brake loop is immediately disconnected, and the vehicle applies emergency brake to stop.[4]

2.2. The Electric Box
Electrical box is mainly composed of five parts: power panel, input board, main control board, output board and date recording board. The overall structure is shown in Fig. 2.

(1) Power panel
It can isolate and transform the DC110V voltage provided by the train, provide low-voltage control power for the train, and power the power supply circuit of each subsystem inside the gas chassis.

(2) Input board
Through isolation circuit composed of TLP521 optocoupler, it adjusts proximity switch and travel switch input signal, train control signal, realizes electric isolation between the train 110V high voltage signal and electric box.
(3) The main control boards
It is the control core of electric box, judging whether the train collisions with obstacles or derailment accidents is happening, and then control train emergency braking to reduce the economic loss of the vehicle and the operation line and the life safety of the vehicle personnel.

(4) The output boards
It outputs three sets of contacts. They are respectively two groups of emergency braking contacts and a set of fault alarm contact. The former is connected in series in the train emergency braking loop. When the train encounters an emergency, the two sets of contacts are disconnected at the same time to control the train emergency braking. The latter informs TCMS of the fault status of the system.

(5) Data recording board
It is mainly used for recording operation parameters of system. Such as system parameters, working status, input and output data, and fault prompts and diagnosis. The recorded data can be downloaded using a USB flash drive to facilitate device maintenance and fault analysis.

3. System reliability design
Train obstructions and the derailment detection device has great significance in the protection of the train safety. In this paper, there are the two parts of design based on the detection system and electric box illustrates the. That greatly improve the reliability of the system. This provides system availability and prevents mis operations.

3.1. The reliability design of the detection system
One travel switch and two proximity switches are respectively installed on both sides of the detection system. Travel switch contains two sets of contacts, when present threshold value is reached, one group of contacts open, at the same time, another group of contact close. the two groups of contact respectively are in series in modulation circuit as shown in Fig. 3.

When the stroke switch works normally, one of the contacts is closed, and the master chip will receive a high level after being isolated by the optical coupler. At the same time, another group of off contact, the optical coupling isolation after got the low level, only two at the same time receive held high level system to control train emergency braking, if a group of travel switch contact failure, the state of the output is likely to be two of the same high level or low level, the main controller will know travel switch failure, at the same time inform the TCMS. The trip switch conditioning circuit effectively improves the reliability of the detection system and avoids the misoperation problems caused by the internal faults of the trip switch.
The proximity switches used for derailment detection also adopt redundant design. There are two proximity switches on the left and right sides of the beam respectively. Both proximity switches work normally, and the action results are output to the electrical chassis as the discrimination basis.  

3.2. The reliability design of the electric box

(1) The power board design

The system adopts the form of double power supply to provide power supply. Two sets of power supply in parallel operation and load balance improve the reliability of power supply.

When one of the power boards fails, the other redundant power supply is put into use without interruption to bear all the load and ensure the normal operation of the system, as shown in Fig. 4.

(2) The main control board design

Main control board is the core of the logic control. Master control chip, using EPM7256 in MAX7000 series produced by ALTERA company, and it has function of System programmable ISP (In System Program). The design can still configure hardware design through the JTAG interface.

Working process of the main control board is as follows: after the electricity system initialization, the clock and I/O pins are configured. A main control board A has self-check and communicate with the main control board B if there is no failure. Then the main control board B has self-check later if it also works normally. Both work at the same time waiting for the adjusted signal of sensor send from input board, meanwhile, if received bypass signal sent by the train, the system has failure to stop work. After receipt of the displacement sensor signal, they analyse and judge what kind of accident happened, at the same time directly drive corresponding relay of the output board to make the train emergency braking.

The program flow of the main control board is shown in Fig. 5:

(3) Data recording board design
Record board working status and related parameters of the instrument is not only, more important is to keep a record of fault state of operations centre to understand the failure condition in time, thus threatening the system for monitoring device to a record and could be divided into three categories: system fault record board their own fault, failure of relay output board and main control board, the greatest degree to improve the reliability of system.

Data recording board selects the STM32F103RBT6 that is 32-bit processor architecture base on the kerne of Cortex-M3 produced by STMicroelectronics company. The kerne of Cortex-M3 is specifically designed to meet the requirements of high performance and low power consumption, real-time applications, competitive price in the embedded field. STM32F103RBT6 is equipped with 128KB Flash, 20KB RAM, 12-bit AD, 4 16-bit timers and 3 USART communication ports, with a clock frequency up to 72MHz, embedded with 3 12-bit successive approximation AD converters and 4 universal timers that can run synchronously. Data recording board also extends a ST company's M25P32 flash chips of 32 M bit, used for real time recording system working condition [7].

After the system is powered on, complete the initialization of clock, I/O pins, RTC and interrupt. Data recording board is equipped with the watchdog circuit, when the program of master control chip run error, data recording board automatic restart, at the same time record fault number 1. When braking signal is received, relay contact in emergency braking circuit cannot be disconnected, fault number 2 is recorded. When data recording board did not receive heartbeat signals of master control board CPLD within the prescribed time, record the fault number 3. The data is stored into the flash chip M25P32 through the SPI bus, at the same time through the CAN bus fault information will be sent to the TCMS.

4. Conclusion
The obstacle detection system introduced in this paper consists of two parts. One part is the mechanical detection system of the equipment under the vehicle. The mechanical system consists of a detection beam and a conversion device to realize the detection function of the vehicle hitting
obstacles or derailment in the process of running. The other part is the car's electrical control system. The electrical control system consists of five parts: power supply board, input board, main control board, output board and recording board, which can integrate obstacle or derailment signal into the emergency braking circuit of the vehicle. The combination of the two systems realizes the passive obstacle and derailment detection.

Under the environment of vigorously developing urban rail transit in China, the safety of train operation has become a top priority. Once an accident occurs, it is bound to cause casualties and huge economic losses. At present, accidents affecting vehicle or operation safety have occurred in some domestic cities because equipment on the track exceeds the limit or foreign matter enters the track range. In order to reduce the impact of the above problems on vehicle safety to the minimum, especially from 2010 after the boom of fully automatic driving projects in China, by 2025, more than 1000 km of fully automatic driving projects will be built in China.

This paper presents a protective device for track obstacles and derailment accidents using contact detection method, and optimizes its design, which greatly improves the reliability of the device. This device can effectively avoid the further expansion of driverless vehicle accidents, improve the safety factor of operation, and adapt to the future development direction of railway and urban rail transit.

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