“2014 ISST”, 2014 International Symposium on Safety Science and Technology

Research on the track dynamic monitoring system to assess the safety of train operation

LIU Linya, ZENG Yiyao, LI Jiyang*

Engineering Research Center of Railway Environmental Vibration and Noise, Ministry of Education, East China Jiaotong University, Nanchang 330013, China

Abstract

This paper discusses the present situation of train operation safety monitoring, proposing the use of wireless monitoring system for detecting track state. The collected data will be transmitted by the wireless broadband network system, storage in the console software, and train operation safety evaluation indexes calculated separately. Safety indexes include derailment coefficient, wheel unloading rate and overturning coefficient. Based on the indicators, whether they meet the standard conditions or not, we determine the safety of train operation and timely issue warning signal information to the dispatching station. This has a very good application value and practical significance for the train running safety evaluation.

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Keywords: wireless monitoring; train; safety evaluation

1. Introduction

With the increase of train speed, the evaluation of train operation safety is the premise to ensure the safety of railway transportation. How to monitor track safety is the key to evaluating train operation safety. It needs to send the monitoring data to the console through the wireless network and calculate the safety of train operation accurately by console software and then send out warning signals.

Wireless monitoring is the trend of the development of the railway detection in the current year. It has advantages of long online time, high safety performance and high transmission speed. It also has important significance in train safety monitoring.

* Corresponding author. Tel.: +86-139-7004-9547; fax: +86-0791-87045115.
E-mail address: lly1949@163.com

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Peer-review under responsibility of scientific committee of Beijing Institute of Technology
doi:10.1016/j.proeng.2014.10.488
2. Basic components of monitoring system

Track dynamic wireless monitoring system aims at ensuring the safe operation of the train. It is on the basis of track monitoring data and wireless transmission technology[1]. The system itself is composed of the following parts: distal data acquisition point, GPRS communication server and console software. Every part takes its duty and coordinates the operation, thus forming a track dynamic wireless monitoring system.

(1) Part of distal data acquisition point
This part includes: Strain gauges[2], sensors, GPRS data transmission device and a solar power supply device. The basic task is to detect, record track changes in different states, and all the measured data will be transmitted to the table through GPRS data transmission device.

(2) Part of GPRS communication server
In this part, the basic task is to realize the wireless data communication between the control room console software and remote monitoring GPRS data transmission device. Remote monitoring data transmission device sends the data to the GPRS network, and through service switch, it steps into the Internet network and transmits it to the GPRS server, and the GPRS communication server for words the data to the console software.

(3) Part of console software
In this part, the basic task is data storage, analysis and diagnosis, judging the track state whether or not to meet the conditions of operating safety, and based on the result, it gives an early warning to the dispatching station.

3. Design of wireless monitoring system

Wireless monitoring system uses strain age to test wheel rail force[3], relying on a wireless network for data transmission. After the console gathers the data, train operation safety coefficient can be calculated by the software. The safety evaluation is based on derailment coefficient, wheel unloading rate and overturning coefficient, on the condition that the warning signal goes through the alarm system in dispatching room.

3.1. The overall plan of the system

System device consists of remote acquisition module, data sending module, communication module, data receiving module and processing module, as shown in Fig. 1.

In order to solve the communication problem of remote terminal equipment and reduce the maintenance work, we use a fixed IP between the GPRS data receiving server and console software, providing an independent communication protocol[4] for data communication to improve safety.
3.2. Remote data acquisition scheme

Data collection includes the wheel rail vertical force and a horizontal force test of the rail shear method. The wheel rail vertical force, due to the weight of the vehicle and a variety of dynamic interference factors, is a kind of force that the wheel in parallel to the rail section symmetry axis direction of the rail. The inner and outer rail vertical force test method is in accordance with the Ministry of standard TB/T2489 - 1994 "wheel / rail horizontal force, vertical force ground test method", measurement point patch and bridge as shown in Fig. 2.

![Fig. 2. Wheel/rail vertical force patch and bridge.](image)

The horizontal forces between the rail and wheel are caused by the creep[5], friction and impact which wheel flange hit the rail head; Also the forces perpendicular to the rail section axis of symmetry. The horizontal force test method is according to the Ministry of standard TB/T2489 - 1994 "wheel/rail horizontal force, vertical force ground test method", measurement point patch and bridge as shown in Fig. 3.

![Fig. 3. Wheel/rail horizontal force patch and bridge.](image)
4. Application of system and design of software

The safety of train operation typically adopts the derailment coefficient, wheel unloading rate and overturning coefficient to evaluate. The track dynamic wireless monitoring system can test the wheel-rail vertical force and a horizontal force and transmit the data to control software, and then determine the track state whether meets the standards.

4.1. Train operation safety index

Derailment coefficient is the ratio of the horizontal force and vertical force \( Q/p \) acting on a wheel at a certain time. According to the National Standard GB5599-85 Railway Vehicles Specifications for Evaluation of the Dynamic Performance and Accreditation Test, the values of derailment coefficient should satisfy the inequalities:

\[
\frac{Q}{p} \leq 1.0 \text{(allowable limit)} \quad \text{and} \quad \frac{Q}{p} \leq 1.2 \text{(danger limit)}
\]

(1)

where \( Q \) is horizontal force, \( p \) is vertical force, for preventing train derailment.

Wheel unloading rate is defined as the ratio of the side wheel load reduction and average static wheel load\(^6\). And the wheel load reducing rate \( \frac{\Delta p}{\bar{p}} \) meets the safety criterion formula.

\[
\frac{\Delta p}{\bar{p}} \leq 0.65 \text{(danger limit)} \quad \text{and} \quad \frac{\Delta p}{\bar{p}} \leq 0.60 \text{(allowable limit)}
\]

(2)

The overturning coefficient is used in evaluating the vehicle stability against overturning when the vehicle is under the lateral wind, centrifugal and lateral vibrating inertia force. The formula for calculating the value of the overturning coefficient is:

\[
D = \frac{P_d}{P_0}
\]

(3)

where \( P_d \) is the unilateral vertical wheel-rail dynamic load; \( P_0 \) is the corresponding wheel rail vertical static load.

On the basis of the national standard GB 5599-85 Railway Vehicles Specifications for Evaluation of the Dynamic Performance and 95J01-M High Speed Train Bus Strength and Dynamic Specification, we can find that

\[
D < 0.8
\]

(4)

4.2. Design of system software

The design of the system not only needs to guarantee data accuracy and wireless transmission fluid, but also the cooperation of software for data analysis. In this way, it can truthfully report the train operation safety problem, and give a timely warning.

Early warning system regards the derailment coefficient, wheel unloading rate and overturning coefficient as formula prepared into the algorithmic procedure, when the data module receives data, software reads data and automatically updates, taking the data into an early warning algorithm program and entering the circulation section, calculating the safety indicators. If the result meets the requirements, then it goes into the next group of data operations. Conversely, it will be connected to an alarm and timely notify the dispatcher. Software flows diagram as shown in Fig. 4.
5. Conclusions

Track dynamic wireless monitoring system can real-timely grasp the track state, accurately and timely launch warning notice. It has a very good application prospect in the train running safety evaluation. Firstly, it makes full use of the characteristics of real time, wireless and high speed to obtain the train operation data and provides timely, reliable command basis for transportation management; secondly, it removes the inconvenience to field test caused by environmental factors, protecting the safety of operating personnel, improving the work efficiency at the same time.

Acknowledgments

The research reported herein was supported by the National Natural Science Foundation of China(Grant No. 51268014, No.51068007).

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