Research on a new type of train control system used at 350km/h

J. F. Wang, H. H. Wang & Z. Lin
State Key Laboratory of Rail Traffic Control and Safety,
Beijing Jiaotong University, P. R. China

Abstract

This paper describes a new type of train control system that meets the speed demand of 350km/h on the basis of CTCS-2. This system realizes safety train control for 350km/h, meanwhile, it solves the key problems of train control information content and train safety tracing interval by increasing the information of track circuit and changing the setting of block section and so on. Besides ETCS-1 and CTCS-3, it also implements safety train control for 350km/h. This system overcomes the shortcoming of the poor real-time performance of spot transmission of ETCS-1 and solves some problems of ETCS-2, such as its complicated realization and compatibility with CTCS-2 due to the incompatibility between information transmission of track circuit and GSM-R. This system has simple structure and good compatibility. The implementation is low cost and easy.

With the necessity to create a new kind of train control system, this system has been proven by analyzing the possible problems existing in the combination between CTCS-3 and CTCS-2. The components and working principle of this system is elaborated in this paper. The key techniques for 300~350km/h trains are described, such as information-content, block section settings, compatibility, reliability and safety. The performance and characteristics of this system are compared with CTCS-2, ETCS-1, and CTCS-3.

Keywords: high-speed railway, train control system, system constitution, working principle, compatibility.

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1 Introduction

The China Railway is developing the high-speed railway vigorously with a strategy of leap-forward development, and it plans to complete 13000 kilometers of high-speed Dedicated Passenger Line (DPL) by 2012. The development of the Chinese Train Control System (CTCS) makes a breakthrough, as the existing CTCS-0/1 is being upgraded to CTCS-2/3. In recent years, the China Railway has increased the speed of existing lines by six times, and in the last occasion, it adopted CTCS-2 to make the speed up to 200~250km/h. At present, China is speeding up the construction of high-speed DPL of 300~350km/h, so, this kind of train control system is to be used as a focus. The Beijing-Tianjin high-speed railway uses CTCS-3D, which is compatible with CTCS-2. The Wuhan-Guangzhou line, Zhenzhou-xian line and Beijing-Shanghai line under construction are going to adopt CTCS-3. Relevant technical specifications of CTCS-3 have already been completed, including Functional Requirements Specification (FRS), System Requirements Specification (SRS), and Functional Interface Specification (FIS/FFFIS).

The CTCS-3D of the Beijing-Tianjin high-speed railway adopts the balise to transmit information, which belongs to intermittent Automatic Train Protection (ATP). It is characterized by simple structure, easy to implement, but its real-time performance is poor. The train cannot receive Movement Authority (MA) and Automatic Parking Information between two active balises, which has a bad influence on the system's capability of responding emergency of endangering traffic safety. The CTCS-2 is the stand-by system in CTCS-3. When there is an equipment failure or radio communication interruption, as well as out of service from high-speed railway, the train will be controlled by CTCS-2. To combine CTCS-3 with CTCS-2, there will be problems like compatibility, reliability, real time, and interface with existing signal equipment, etc. It is very difficult to complete the compatibility of this combination, because CTCS-3 transmits train control information by GSM-R, while CTCS-2 uses track circuit.

For the reasons above, it is very significant to study a new train control system with Chinese characteristics, which should meet the speed demand of 200~350km/h, have minimum train headway of 3 minutes and be simple structure, compatible, low cost and easy to implement. Based on CTCS-2, we propose a new type of train control system that meets the speed demand of 350km/h, and it can be seen as a kind of enhanced CTCS-2 or upgrading version of CTCS-2.

2 The system description

2.1 System components

The system is using the track circuit and intermittent balise to transmit the Movement Authority and target distance mode to monitor train safety operation continuously. This system is suitable for trains with a speed of 200~350km/h. The equipment configurations of this system are basically the same with that of

CTCS-2 designed for high-speed DPL with a speed of 200~250km/h, and its structure changes a little. The system is composed of line side equipment and onboard equipment. The line side equipment includes TCC, ZPW-2000, LEU, active balise, section passive balise, the interface between interlock and TCC, the interface with CTC or TDCS, the interface with LEU, the interface with computer observation(microcomputer testing) and the interface with adjacent TCC. The onboard equipment includes vital computer, specific transmission module (STM), balise transmission module (BTM), driver-machine interface (DMI), recording unit, locomotive interface unit and speed testing unit.

2.2 System principle

Due to insufficient train control information, the CTCS-2 system isn't suitable for train with a speed of 350km/h. The system, as an extension of CTCS-2, has solved the problem of insufficient train control information. So it meets the requirements of 200~350km/h train control and train's safety tracing interval.

2.2.1 Block section and balise setting

The train's forward running uses Automatic Block, while the train's reverse running uses Inter-station Automatic Block. Each block section is made up of the two track circuit which are designed of 1000~1200m long initially, so the length of each block section is 2000~2400. The stop signs and passive balise are set up at the entrance of each block section, and the passive balise is set up in pairs in order to transmit the line parameters, track circuit parameters and location information and so on (Fig. 1). For the section that has a long distance between stations of 300~350km/h route, it is necessary to set a relay station and controlled by TCC.

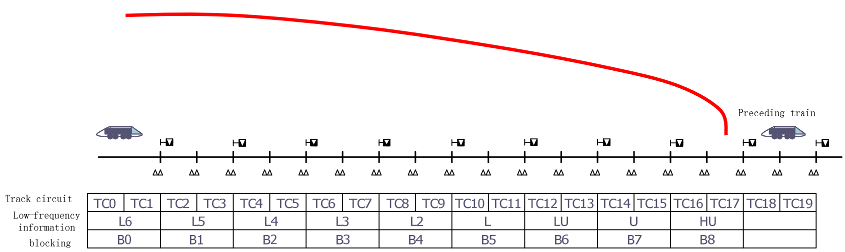

Figure 1: The settings of block section and balise.

The train's safety tracing interval is about 13500~17500m at the speed of 350km/h, so the train control information (it is mainly the quantity of track circuit low-frequency code) provided by CTCS-2 can't meet the demand. This system set the last bit of low-frequency code reserved by ZPW-2000 track circuit to L6, and this is a 9-display way. Consequently, the system can predict the number of idle block sections in the front 8 ones. If each block section composes of two track circuits and its length is 2000~2400m, train's safety tracing interval is 16000~19200m. Therefore, it totally meets the demand of train control at a

Table 1: The length of block section, transmission content and train's safety tracing interval.

Title / Contents	CTCS-2	CTCS-3	Our system
MA of continuous transmission	Tracking code sequence of track circuit: L5, L4, L3, L2, L, LU, U, HU (8 display)	GSM-R transmission MA information is sufficient	Tracking code sequence of track circuit: L6, L5, L4, L3, L2, L, LU, U, HU (9 display)
Maximum forecast idle block sections	7	sufficient≤ 15	8
The number of track circuit in a block section	1	2	2
Length of block section	1200~1500m	2000m	2000~2400m
Train's safety tracing interval	8400~10500m	>13500m	16000~19200m
Passive balise setting	Every 2 block section has 2 balises in high-speed DPL CTCS-2; every 2 or 3 block sections has one balise in the existing line CTCS-2	Each block section has 2 groups, each group has 2 balises	Each block section has 2 groups, each group has 2 balises

speed of 350km/h. The length of block section, transmission content and train's safety tracing interval are presented in Table 1.

2.2.2 Onboard equipment with ATP

The onboard subsystem of this system controls the train's operation using the target distance control mode curve (or a continuous speed control curve of the brake). The onboard subsystem receives MA and the quantitative information of front idle sections from the track circuit, and block section length, line speed, line slope and other fixed information from balise. According to the information of "quantitative information of front idle sections" and "block section length", the subsystem can calculate the safety protection distance and target distance. It can caculate the speed monitoring curve in real time from the fixed parameters and dynamic information, and monitor the train's actual speed to make it under the curve in order to ensure the train safety operation. The fixed parameters include line speed, line slope and brake performance and the dynamic information includes train route and temporary speed restriction message. The six kinds of this system's control mode (FS, PS, SH, OS, IS and SB) is essentially the same with CTCS-2s. It is only needed to change the value of emergency brake intervention curve into 320km/h, and the restrictive speed value of service braking into 305km/h.

2.3 System compatibility

The system is suitable for controlling train with a speed of 200~350km/h. Both of this system and CTCS-2 are the train control system using track circuit and intermittent balise to transmit train control information, and adopt target distance mode to monitor the train safety operation. The basic configuration of this system is higher than that of CTCS-2, so it can provide all train control information of CTCS-2 and that of 300~350km/h train. The data sources of CTCS-2 onboard system are unchanged, so does the computational method of monitoring curve. The system is compatible with the CTCS-2 of the existing line and high-speed DPL.

3 Characteristics and advantages with this system

The system uses a set of train control equipments to control the trains at different speeds of 200~250km/h and 300~350km/h, and achieve the seamless joint of equipments. The system has many advantages, such as simple structure, good compatibility, easy integration with the domestic signal equipment and high localization rate, etc.

Table 2: The systematic functions of our system, CTCS-2, ETCS-1 and CTCS-3 are contrasted.

Title / Contents	**CTCS-2**	**ETCS-1**	**CTCS-3**	**Our system**
Running speed	200~250km/h	The Beijing-Tianjin line:300~350km/h the foreign line :200~250km/h	300~350km/h	200~350km/h
Block mode	Up traffic: automatic block Down traffic: Automatic inter-station block	Route settings according to idle block sections, active balise transmits MA	Up traffic: automatic block Down traffic: Automatic inter-station block	Up traffic: automatic block Down traffic: Automatic inter-station block
Control mode	Target distance (one time braking)	Target distance (one time braking)	Target distance (one time braking)	Target distance (one time braking)
Train-ground information transmission channel	Track-circuit (ground →train) balise	Balise	GSM-R (ground →train) track-circuit, balise	Track-circuit (ground →train) balise
Train integrity check	Track-circuit	Bad	Track-circuit	Track-circuit
System characteristics	Continuous ATP	Intermittent ATP	Continuous ATP	Continuous ATP
Route between station and section	Non-integrated	Integration of station and section	Integration of station and section	Non-integrated
Interlocking mode	Non-area-interlocking	Area-interlocking	Area-interlocking	Non-area-interlocking
Transinformation	Sufficient	Sufficient	Large	Sufficient
Combined with domestic signal equipment	Easy	Normal	Hard	Easy
Compatibility	Good	Normal	Bad	Good
Localization rate	High	Low	Low	High

The system is combined with the CTCS-2 signal system easily. There are fewer changes in software and hardware interface. It is easy to realize and does not exist system risk in combining process.

The system is completely compatible with CTCS-2 system, and realizes seamless docking. A set of control system is instead of two sets, and control the speed of trains by 200~250km/h expanded to 200~350km/h.

It is safe and reliable to use ZPW-2000A track circuit to send the train control data. Compared with GSM-R, the effect on train operation caused by communication interrupt is localized and can be controlled.

Compared with centralized control method of RBC, this system using automatic block distributed control has more flexibility and adaptability. It has less effect after the failure.

There are no problems of systems overlap and information cross-transmission. It has high real-time and emergency response capability.

This system of using integration design means that the problem of system overlap like building blocks doesn't exist and it has high reliability.

The system functions of our system, CTCS-2, ETCS-1 and CTCS-3 are listed in the following table 2.

4 Reliability and security with this system

The system is the improved, with its higher configuration, version of CTCS-2, which is used in both high-speed passenger special line and the existing speed up line. The reliability and security of CTCS-2 in existing line has been well verified in practice. The reliability and security of this system can be summarized in the following areas:

1) The key components of the line side equipment and train borne equipment adopt multi-redundancy technology in this system. Such as: the structure of 3 out of 2 in VC, the structure of double 2 out of 2 in BTM, STM and TCC, etc.

2) The active balise data including temporary speed restriction message should be redundant cover, and the coverage can ensure that there is enough braking distance to stop from maximum operating speed by service braking. It adopts dual sets of BTM to ensure that the train borne equipment can receive the temporary speed restriction message in time.

3) The safety information transmits on a point to point mode in order to keep the information source corresponding to the destination address. It improves the reliability of train control information transmission by using methods including channel redundancy, isolation, safety data, coding and decoding technology, proven dedicated safety communication protocols, etc.

4) The system uses an integrated design of the line side equipment and train borne equipment, non-overlapping mode. The engineering characteristics boost up the overall reliability of this system.

5) All key equipment is designed on the basis of fault-oriented security principle in signal system, which is able to achieve the Safety Integrity Level-4 in IEC61508.

6) The continuous ATP, receiving the movement authority from line side equipment in real time and continuously, enhance the system's response efficiency towards emergency traffic situation.

7) It can further improve the security by installing the balise group which is composed of the active and passive balise at arrival and departure track stating signal and provide absolute stopping, route parameters, temporary speed restriction, shunting risk, etc.

8) It minimizes the accidents of man-made faults by using CTC, interlock automatic processing route, unattended operation and ATP.

5 Conclusion

Based on the application experiences of CTCS-2, the system adopts a set of train control equipment to control the trains at different speeds of 200~250km/h and 300~350km/h by increasing the track circuit information and changing the block section settings, and it solves the problem of the train's safety tracing interval, as well as the shortage of train operation control information for trains at a speed of 300~350km/h. The system is characterized by simple structure, good compatibility, low cost and high localization rate. The security and reliability of the system has been partially verified in the application of CTCS-2. The system can make full use of the application management and maintenance experience in CTCS-2 used in high-speed DPL and the existing line, and it is easy to implement and popularize.

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