Design and Development of Simulation Computer Software for Safety Siding in Regional Expressed Railway

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Abstract—The safety siding is an isolated line used to ensure safety on traffic operating. Too short a safety siding does not guarantee the safe operation of the train, while too long a safety siding will increase the cost and design difficulty of construction. The prior art specification says the length of the safety siding required is not less than 50m. Obviously, there is still uncertainty about the setting length of safety siding on specific line. This paper combines the characteristics of the suburban railway to design and develop a setting simulation system of safety siding. The safety siding calculation model is established by the traction calculation method, which includes different factors such as braking ratio, train speed, line parameters, signal system and application scenarios. Moreover, it designs the structure and function of the simulation system and discusses the key techniques of simulation. Finally, taking the Fuzhou Railway Station as an example to verify the simulation system. The results show that when the different lines and train parameters are configured, the design length of the result is also different. The simulation system could accomplish the design of the safety siding in different scenes. The calculation results are reliable and have engineering application value.

1. INTRODUCTION

The regional expressed railway refers to the railway passenger transport system in the developed and densely populated urban area, taking the main urban area as the center, connecting the central urban area and the suburbs or the central city and satellite city. The safety siding of regional expressed railway is an important safety equipment in the station and an important part of ensuring the safety of railway transportation[1]. In the code for design of regional expressed railway, the effective length of safety lines for urban express lines is not less than 50m[2]. However, due to the lack of theoretical basis, some research results have been made on the length design of safety siding in China.

Reference[3] pointed out that the safety siding used as "separation" route can no longer adopt the current design standard, and the safety siding must have the function of stopping and slipping into the runaway train; Reference[4] optimized the design of safety siding from the perspective of traffic safety, and designed a roll over safety siding to effectively control the direction of train derailment or rollover.
Gu Reference [5] put forward the basis that the effective length of safety siding can be appropriately shortened. The main function of the safety siding of regional express railway is preventing the incoming trains from rushing into the main line and affecting the operation of the main line. From the point of view of the norm, the design of length is based on the standard of subway. However, regional expressed railway is different from Metro Line in vehicle type and equipment selection. In the actual station engineering design, the length of safety siding should be designed according to the type and setting scene of safety siding. According to the function of safety siding, the factors influencing the safety line include the type of safety line, the terrain and location set, vehicle performance and the influence of signal system. It is necessary to determine the length of safety line through traction calculation of train and considering the working characteristics of signaling system [6].

The reasonable setting of safety siding can not only ensure the safety of daily train operation, but also reasonably control the construction scale to avoid unnecessary construction fund waste. It is impractical to use the actual equipment in the field, which consumes a lot of manpower and material resources. Therefore, it is necessary to develop the safety siding simulation software which can meet the requirements of different stations, operation modes and train braking system based on the theory of safety siding design. general scheme

1.1. Requirement analysis
The simulation software has the characteristics of strong operability and high reliability, which can not only reduce the cost of test equipment, but also meet the needs of safety siding simulation test and driving operation simulation. The requirement analysis are as follows. The simulation software can meet the simulation needs of various scenarios, identify the information of safety siding and match the corresponding route information. The system needs receive the real-time control information of the train travelling process, and reflect the current position of the train in the station. Analyze the mileage information according to the curve of train operation, and according to the safety siding calculation model to get the simulation results of the safety siding in the current scene.

After the simulation, the rain operation in the real station yard is analyzed, and compared with the existing design scheme or standard, and the rationality of the current scheme and standard is analyzed.

1.2. Frame design
The overall structure design of the simulation software is shown in Fig.1. It mainly includes CBI station subsystem, train control subsystem and safety siding simulation subsystem. The basic environment of safety siding simulation is established by interacting the speed and position information of train braking process between station subsystem and train operation control subsystem, and the simulation design of safety siding is realized by connecting the output results of safety siding simulation subsystem and train operation control subsystem [7]. The signal equipment of CBI station subsystem is composed of signal, switch and track section unit. At the same time, the simulation software will record the real-time simulation operation records and simulation test results, store and output system files to meet the user's subsequent comparison and analysis to select the optimal simulation design.

1.3. Function module
Refer to the existing universal CBTC (Communication Based Train Control System) interlocking simulation software development technology and train traction simulation technology. The simulation software has wide applicability.

1.3.1. Station subsystem
The station subsystem includes signal equipment simulation module and equipment attribute link module, which mainly realizes the following function. The station is automatically generated. According to the engineering data of station design and the topological structure of station yard, the station line environment required by simulation software is established, and the general method of station data processing is designed.
The station yard is scaled according to the engineering design drawing; the key points of trackside equipment and route in the interface are given corresponding coordinate mapping from kilometer mark to interface. It can edit track unit, modify coordinate mapping relationship, add or delete equipment quantity, change signal direction and switch type in database of station editing interface.

Figure 1. General scheme of safety siding simulation system

Receive route command and change equipment status on the interface. According to the route command issued by the user, the signal equipment unit is controlled, and the route is automatically generated, and the equipment status is changed by sending the simulation software control variables to form the device driving command after logical processing.

1.3.2. **Train operation subsystem**

Simulation of train departure operation. The user selects different types of trains through the interface provided by the system. The user is allowed to control the initial speed of the train and select the corresponding route. Monitor the running process of the train. By issuing route command and setting the working state of braking system, the operation condition of train braking failure on urban express line can be simulated in real time on the system interface. At the same time, it makes the calculation of the current train braking system based on the actual operation condition of the current train braking system.

1.3.3. **Safety siding simulation subsystem**

The safety siding simulation subsystem includes the effective length simulation module, simulation application and availability detection module and data storage module, which mainly realizes the following functions. Calculation of effective length of safety siding The simulation of safety line in the same scene is carried out by multi person and multi machine cooperation, and each terminal is used for independent simulation test; for a user, the length of safety line can be determined according to the type selection of the train, the route number related to the safety line, and the braking distance under the condition of the braking system set by the user, and the simulation results at the same time are compared to illustrate the simulation results Fruit accuracy and system stability.

The output of simulation results and construction suggestions. Combined with the actual scene and the type of signal equipment, the use of the required length of the safety line is detected by the position
 Unified storage of simulation results. The initial parameters such as vehicle type, route number, braking system discount coefficient and safety line simulation results are stored in the form of system files. The data structure of the system is unified, the access mode and location are consistent, and the data reliability is ensured, which provides the basis for users to choose the optimal design scheme.

2. INTERFACE DESIGN

The interface display part realizes the real-time and intuitive display of simulation results of safety siding on the interface. The main contents include station initialization display, drive command display and simulation results display. The interface design uses “Onvs croll” and “Onhscoll” to control the scroll bar to expand the display range of the interface, so as to realize the complete drawing of single station or "station yard + section" [8]. The interface initialization display is mainly used to select and read the engineering data table of the simulation station. According to the content of the data table, the software completes the fixed point of each coordinate on the screen and the initial state through the mapping relationship between kilometer mark and pixel point set in the software according to the content of the data table, that is, the signal machine displays the forbidden signal light position, the switch is in the positioning, and the track section is in the unlocking state.

The user can select the simulated station and input the data in the process of vehicle traction calculation in the safety siding simulation interface. Click the "safety siding calculation" button to calculate the safety siding length. Then click the "safety siding drawing" button to output the diagram and table data of the simulated safety siding on the main interface. The safety siding simulation interface is shown in Fig.2.

![Figure 2. The calculation interface of the length of safety siding](image)

3. CALCULATION MODEL OF SAFETY SIDING LENGTH

The calculation of the length of safety siding is essentially to calculate the distance between the actual stopping point and the specified stopping point after the failure of train braking system. Under the protection of ATP(Automatic Train Protection) system, the train has two sets of braking systems: service braking and emergency braking. When the service braking fails and the service braking is insufficient to provide the braking force required by the train, the emergency braking system is triggered to control the deceleration and parking of the train. Therefore, the difference between the end point of emergency braking curve and that of service braking curve after braking failure is the required length of safety siding. The principle is shown in Figure 3.

The emergency braking process includes traction cutting stage, coasting stage after cutting traction and braking stage. Therefore, the emergency braking distance consists of three parts: the train running distance within the traction cutting off time, the train running distance within the empty running time, and the emergency braking distance [10]. The calculation formula of emergency braking distance is as
follows.

![Figure 3. Schematic diagram of safety distance calculation](image)

Figure 3. Schematic diagram of safety distance calculation

\[
S_e = \left( v_0 \cdot t_d + \frac{1}{2} a_{\text{max}} \cdot t_d \right) + v_e \cdot t_e + \left( \frac{v_e}{3.6} \right)^2 / 2a_e + S_r \tag{1}
\]

\[
v_0 = v_i + 5 \tag{2}
\]

\[
v_e = v_0 + V_{\text{tol}} + a_{\text{max}} \cdot t_d \tag{3}
\]

\[
V_{\text{tol}} = 2 + \frac{v_0 - 30}{47} \tag{4}
\]

Among them, \( v_i \) is the train running speed, is the initial speed of emergency braking, \( v_e \) is the speed after the braking is effective, \( V_{\text{tol}} \) is the speed tolerance, the unit of all speeds is km/h; \( t_d \) is the delay time required in the traction removal process, \( t_e \) is the effective time of emergency braking, the time unit is s; \( a_{\text{max}} \) is the maximum acceleration of the train, \( a_e \) is the deceleration of emergency braking, \( S_r \) is the distance from the nearest transponder and the measurement error. The calculation formula of service braking distance is as follows.

\[
S_s = \left( \frac{v_e}{3.6} \right)^2 / 2a \tag{5}
\]

\( a \) is the actual braking ratio of the train. When the current braking ratio and running speed of the train are given, the emergency braking distance of the train can be obtained. Combining with formula (5), the calculation principle is shown in Fig.3.

4. SIMULATION EXAMPLE

4.1. Simulation parameters

The system takes the up line of Fuzhou railway station of Fuzhou airport line as an example. The train's entry mode is considered to be straight, and the lateral speed limit of turnout is not required to be considered. Therefore, the maximum speed adopted in this simulation is set according to the maximum speed limit of the line (considering certain redundancy). Some parameters are shown in Table I.

| Parameter (Unit)  | Value |
|------------------|-------|
| slope(%)         | -2    |
| curve radius (m) | 2000  |
| Line speed limit (km/h) | 100 |
| total mass of train (T) | 335.4 |
| length of train (m) | 140  |
4.2. Simulation results

According to the actual operation situation, the length of safety distance should meet the requirement of safe parking when the braking failure ratio is 0.25. The calculation results of safe distance of train in traction calculation process at different positions obtained by software simulation are shown in Table II.

| Distance between train and parking point (m) | Initial speed of emergency braking (km/h) | Emergency braking distance (m) | Safety distance (m) |
|--------------------------------------------|------------------------------------------|--------------------------------|-------------------|
| 355.00                                     | 90                                       | 435.77                         | 80.77             |
| 281.64                                     | 80                                       | 358.84                         | 77.20             |
| 215.26                                     | 70                                       | 289.17                         | 73.91             |
| 158.08                                     | 60                                       | 227.19                         | 69.11             |
| 110.91                                     | 50                                       | 172.01                         | 61.10             |
| 70.87                                      | 40                                       | 125.13                         | 54.26             |

It can be seen from Table III that the safety distance under automatic driving mode should be at least 80.77m, and the situation that the train is allowed to hit the stop at 15km/h and affect the comfort of passengers is not considered. In this case, the length of safety line required to ensure traffic safety is 37.12m; and the results show that the 55m currently used in Fuzhou railway station fully conforms to the role of safety siding in ensuring traffic safety.

5. CONCLUSION

The safety siding simulation software of regional express railway takes C++ language as development language and Microsoft Visual Studio as development environment. According to the safety siding length calculation model established, the simulation software suitable for the design of safety siding in different scenarios of regional express line is developed. The software takes Fuzhou railway station as an example, simulates the safety siding at different initial speeds according to the actual operation situation. The results show that the simulation software can meet the requirements of simulation design of safety siding length in various special scenarios. It can save the construction cost to a certain extent, and has good guiding significance and reference value for the field design.

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