Train Headway Calculation and Simulation System for High-Speed Railway

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Abstract. Train headway is very important for the operation efficiency and safety of high-speed railway. With the demand of high-speed train headway calculation and simulation, based on the principle of traction effort calculation and the control in train operation system, train headway calculation and simulation system for high-speed railway was designed. For the system, some key issues were discussed such as automatic train traction effort calculation, train headway calculation and simulation method. With this system, it will be benefit for signal-block layout and train operation optimization.

Keywords: High-speed railway · Train headway · Train traction effort calculation · System design

1 Background

High-speed railway was characterized as high speed and punctuality, comfort, safety and reliability, which developed fast in China for recent years.

For high-speed railway operation, traffic density directly affects the operational efficiency and the transport capacity. To ensure the safety of the train operation and adequate braking distance, the traffic density will be expressed as a certain train headway. Train headway is an important part of high-speed railway train operation technology standard system, its calculation process and the result are the basic theoretical basis of train operation and management.

Gill D.C used a heuristic gradient algorithm to solve the signal block layout [1]. Chang C.S. studied signal arrangement of urban rail transit system by genetic algorithm at 1999 [2]. Wong determined the inert point in train running process accurately [3].

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Chen Rongwu et al. proposed a new algorithm for train headway based on the IEEE CTBC recommendation model [4–6]. According to above studies, this paper will discuss the system design for Train Headway Calculation and Simulation System for High-speed Railway.

2 System Demand Analysis

2.1 Business Demand

According to train headway simulation calculation process, the main application of train headway calculation and simulation system for high-speed railway could be divided into the following categories:

1. High-speed railway train operation facilities simulation data management
2. Train traction effort calculation
3. Train headway calculation
4. Simulation results output.

2.2 Data Demand

The business data is composed of rail line profile data, signal data, EMU data and train traction effort calculation parameters.

1. Rail line data: station, track, ramp, curve, bridge, tunnel and speed limit;
2. EMU data: EMU attributes and EMU traction effort, braking, energy consumption data;
3. Signal data: signal mode, block and signal;
4. Train traction effort calculation parameters: working condition data, braking arguments.

2.3 System Interface Demand

The system should have the function of outputting the results in EXCEL report, PDF report and CAD graphical report, and interface should be designed for other system of railway operation such as Signal-block Layout System, Train Scheduling System etc.

3 System Functions and Structure

3.1 System Structure

According to the using logic, train headway calculation and simulation system for high-speed railway could be divided into three parts, data management, train traction effort calculation and train headway calculation. The structure of the system is shown in Fig. 1.

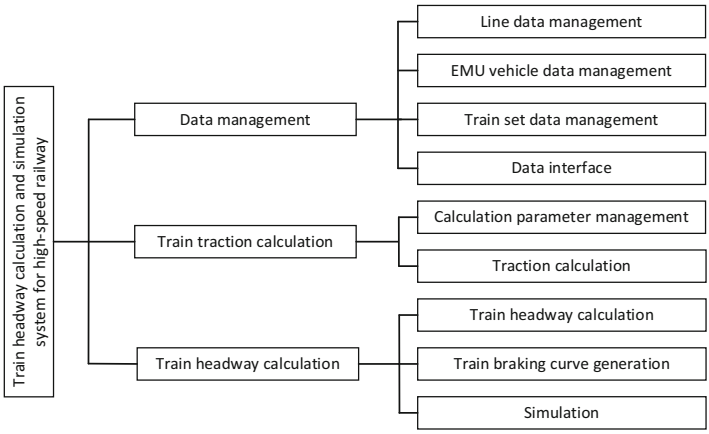

Fig. 1. System structure

3.2 System Functions

The main functions of the system could be designed as follows:

1. Data management
   (1) Rail line data management
   (2) Station data management
   (3) EMU data management
2. Train traction effort calculation
   (1) Train traction effort calculation pretreatment
   (2) Traction effort calculation pretreatment function includes: Rail line extraction, single track line automatic reverse, train speed limit serializes.
   (3) Automatic train traction effort calculation
3. Train headway calculation
   V-S data calculation according to train ATP, train safety protection distance and signal working time.

4 Key Issues for System Design

4.1 Automatic Train Traction Effort Calculation

The driving tactics is an extremely important part of automatic train traction effort calculation. The strategies used by the system includes time saving, energy saving, fixed time, and the following aspects should be considered for the working condition:

1. Automatic working condition selection of train driving tactics.
2. Automatic optimization of train driving tactics.

Workflow of automatic train traction effort calculation could be shown as follows (Fig. 2):

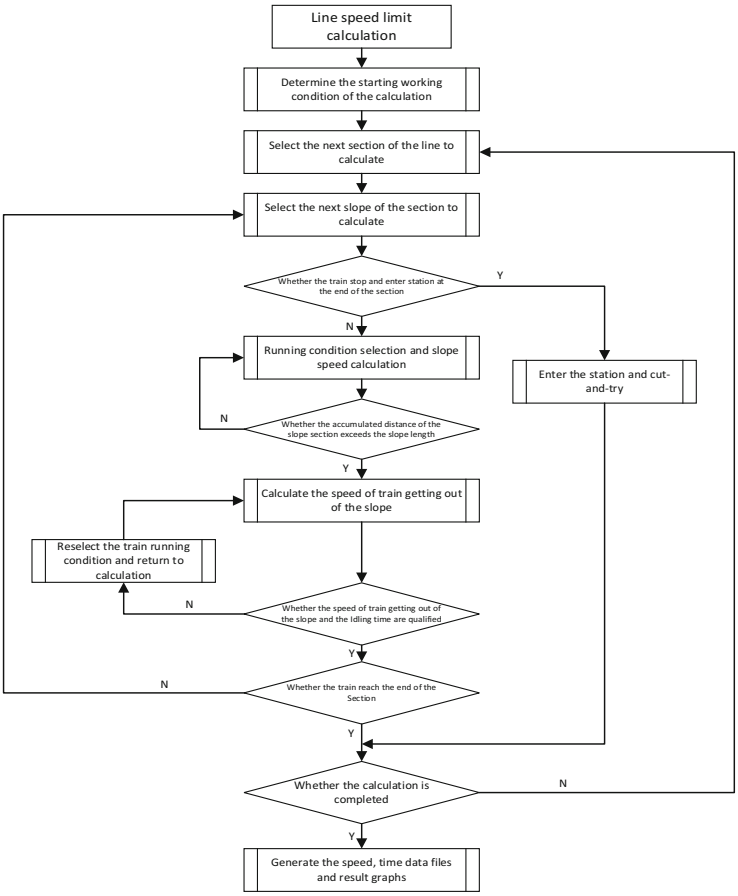

Fig. 2. Workflow of automatic train traction effort calculation

4.2 Train Headway Calculation

Train headway calculation is based on the train traction effort calculation and train simulation. Therefore, it's necessary to design the train simulation scheme and calculation method.

The simulation process could be divided into three stages: start and traction acceleration process, intermediate running process and braking process. According to above stages, the train simulation result could be obtained.

Usually, EMU uses a continuous braking mode curve for train operation control which could be calculated by reverse iteration method. The reverse iteration process could be shown as following (Fig. 3):

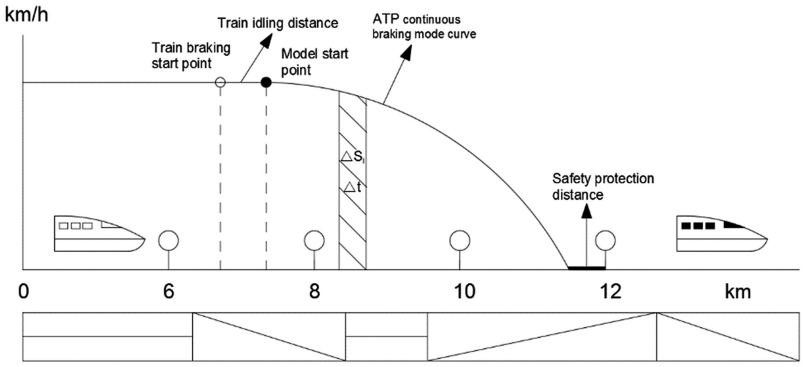

Fig. 3. Reverse iteration process of the continuous braking mode curve

The description of symbols in the calculation could be listed as Table 1.

Table 1. Description of symbols

Symbols	Description
S_1	Stop position
v_1	Target limit speed
v_0	Initial speed
S_0	Initial position
$v_{[]}$	Speed array
$s_{[]}$	Position array
$V_{[]}^R$	Corresponding point speed array
$S_{[]}^R$	Corresponding point position array

The target limit speed is recorded as $v_1 = 0$. Initialize the train acceleration, running speed, running time and other related data and make $v_{[i]} = v_1 = 0$, $s_{[i]} = 0$, $i = 0$.

Set the acceleration at the initial speed $v_{[i]}$ in time step as the acceleration value. The speed variation dv and location variation ds are calculated by kinematic formula.

The algorithm of calculating the braking mode curve by the above data is shown in Fig. 4.

4.3 Simulation Method

Train headway is determined by the train operating conditions, such as the EMU type, rail line, driving tactics, train equipment type and climatic conditions, so it's necessary to check the train headway in different conditions.

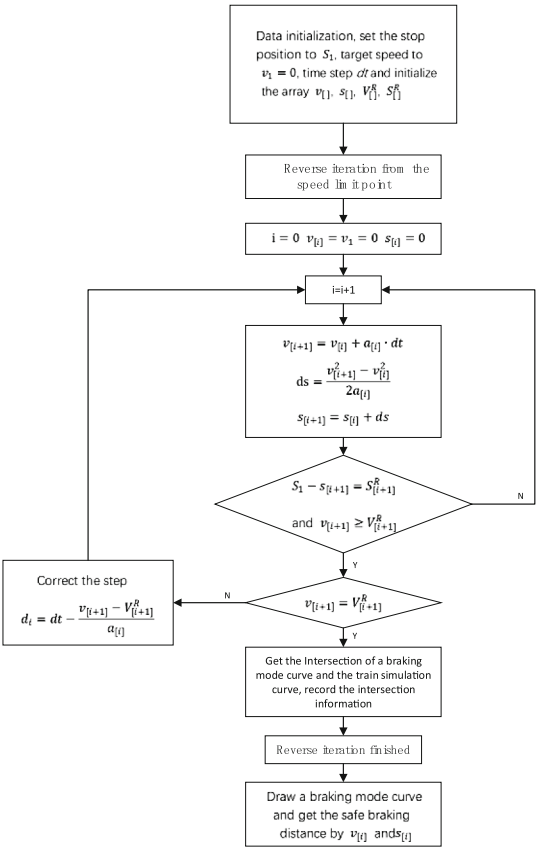

Fig. 4. Algorithm of braking mode curve calculating

For the current train control system used in China, users can check the train headway according to the following combinations:

(1) Train control system type: 200H, 200C, 300T, 300S, 3D and 300H.
(2) Driving tactics: maximum running speed, limit point retention and enter in speed control mode.
(3) Climatic conditions: wet and dry rail and wind speed.

For the series of combinations, they should be converted into system operating parameters by system, then the train running process simulation can be used to calculate the train headway under different conditions. Finally, generate the statistical charts to provide the basis for the analysis of train headway standard.

The statistical chart of train headway could be shown as following (Fig. 5):

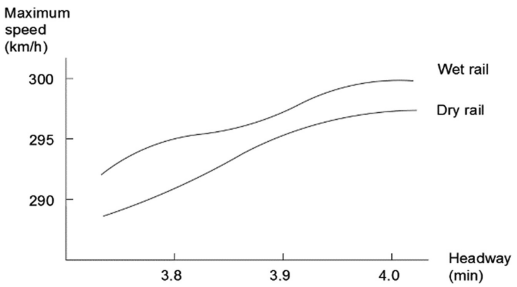

Fig. 5. Statistical chart of train headway

5 Conclusions

Based on train traction effort calculation theory and high-speed railway train operation control principle, a train headway calculation and simulation system was designed for high-speed railway by a certain train control program and train operating conditions. This system provides train tracing operation analysis under different equipment and operating conditions by simulation, and could provide a more scientific and effective method for determining the technical operation time standard of railway transportation system.

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