Study on dynamic characteristics of train collision based on Multibody Dynamics

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Abstract: In order to study dynamic response of train collision based on the theory of multi-body dynamics, a multi-body dynamic model of two trains of high-speed trains was established by using MATLAB software. The numerical method is used to simulate the collision process of 6 marshalling trains. This paper studies the influence of the configuration of energy absorber, such as buffer, crushing tube and anti-creeper at different speeds of trains and strength gradient of crushing tube and anti-creeper on impact characteristics of train connected. The results show that the rational allocation of energy absorption components can effectively control the average energy absorption of the train.

1. Introduction
With the development of the rail transportation industry and the improvement of the train running speed, a large number of casualties and economic losses will be caused when the train collision accident occurs[1-3]. How to quantitatively analyze the impact vibration and safety of vehicles in collision accidents and maximize the safety of passengers and minimize the loss caused by collision accidents is one of the hotspots in the field of rail transit [4]. In view of this, the train collision process is studied by simulation based on the theory of train system dynamics and the parameter characteristics of the train collision will be helpful to guide the design and configuration of the vehicle safety protection device[5-6]. It is of great significance to protect the safety of the life and property of the passengers.

In actual engineering applications, it is often necessary to configure the buffer and crushing pipe to meet the corresponding requirements according to the marshalling condition, vehicle parameters, running speed and loading state of metro vehicles[7]. In this paper, the energy absorption configuration of elastic clay buffer, crushing tube and anti- creeper is taken as an example to simulate the dynamic response of the train crash at different speeds and further study the influence of the strength matching of crushing tube and the anti-creeper on the impact of the train

2. Train collision process
Generally, crashworthiness structure at the end of railway vehicle includes the coupler bumper, the crushing tube, the safety shear device, the anti-creeper and the collision energy absorption structure of the end of the car[8]. In the process of train collision, the absorption energy is carried in turn.
Train collision characteristics as shown in Fig 1. The load threshold of each device in the collision system of train head car is designed to increase one by one[9]. During the collision process, they move in sequence according to the order before and after the collision, and the impact force increases with the increase of deformation stroke[10]. When the structure of car carriage has plastic deformation, it will cause damage to the living space of drivers and passengers. Therefore, it is necessary to make the coupler buffer device and the collision energy absorption structure of the car end to absorb all the energy produced by the collision, so as to avoid the deformation of the car carriage[11].

3. Establishment of train collision dynamic model
According to the current energy management (CEM) method widely used in train crash design, all energy absorbing components will act in an orderly and controllable way, and the working threshold of each energy absorbing element will increase sequentially[12]. In order to accurately analyze the dynamic response of train collision, a complete dynamic model of two columns of 6 marshalling trains is established. The coupler buffer device between vehicles is simulated by force element, and the force stroke curve of the buffer and the characteristic curve of the energy absorption structure of the body are used as the input function to give the connecting force element to each vehicle[13-15]. The actual collision occurred mostly in the form of rear end. Therefore, in the process of simulation, the rear train runs forward at a certain speed and collides with the front train. The vehicles and interfaces are numbered as shown in Fig 2.

4. Calculation parameters and initial conditions
(1) The speed of vehicle collision is from 5km/h to 25km/h, increasing at the speed of 5km/h.
(2) The number of vehicles running the vehicle is the same as that of the stationary vehicle, all of which are six and the quality of the vehicles at both ends is 37200kg, and the mass of the middle vehicle is 38500kg.
(3) The friction factor between the wheel and the rail is 0.15
(4) The head car energy absorber is EFG3, crushing tube and anti-creeper. The middle car energy absorber is EFG3 and crushing tube. The specific energy absorber is configured as shown in Fig 3.
5. Simulation and analysis

The numerical analysis is carried out by using MATLAB software. The influence of the dynamic response of the train collision, the configuration of the energy absorber and the strength of the anti creeper on the dynamic characteristics of the train collision at different speeds are studied. The coupler and buffer between all vehicles are exactly the same and are used in pairs.

5.1 Influence of speed on dynamic response of train collision

When a rear train collides with a stationary train ahead, the speed of 5km/h is from 10km/h to 25km/h at intervals. The impact force and displacement time curve of the two trains are shown in Fig 4 to 5. It is known from the interface impact force curve that with the increase of the longitudinal impact speed of the train, the crushing distance of the interface energy absorber increases continuously, and the impact force of the interface is constantly improved. When the speed is less than 15km/h, the impact kinetic energy of the train is absorbed completely by Workshop energy absorption device, and the plastic deformation of the car body is not appeared. When the speed is higher than 15km/h, the plastic deformation occurs in the vehicle near the head, and the number of the plastic deformed vehicles increases with the increase of the speed. It is known from the interface energy absorption curve. Energy absorption decreased gradually from the head car to the rear car. the energy absorption of the head car accounts for about 40% of the total energy absorption and aail car absorb less energy.

![Schematic diagram of train energy absorber configuration](image-url)

Fig.3. Schematic diagram of train energy absorber configuration
Fig. 4. Displacement curve of interface impact force at different speeds
Notes: Interface label as IF

Fig. 5. The energy absorption time curve of collision interface at different speeds

5.2 The influence of the strength gradient of the crushing tube and the anti-creeper
When the train collided with the stationary train at 20km/h speed, the influence of the strength gradient (F\text{anti-creeper} - F\text{crushing tube}) on the train crash dynamic characteristics was studied by changing the strength of the anti-creeper device on the end of the head car. Fig 6 is the energy absorption characteristic curve of the train under different strength gradient. It can be seen from the figure that when the strength gradient of the crushing tube and the anti-creeper is relatively less, the energy of the head car is larger and the crushing process is stable. With the increase of the strength gradient, the energy absorption of the head car decreases and the energy absorption of the middle car increases. The energy absorption of the energy absorber in each vehicle can be controlled by changing the strength of the crushing tube and the climbing device, so as to achieve the uniform energy absorption of the energy.
Fig. 6. Energy absorption time curves under different strength gradient of the crushing tube and the anti-creeper

6. Conclusion

Based on the establishment of a complete two train longitudinal dynamic model, this paper studies the dynamic response of two trains collisions at different speeds, and the strength gradient between the crushing tube and the anti-creeper device. The results show that:

1. When the vehicle speed is large, the energy absorbing structure of some cars near the head car is all compressed to the limit. The car body has plastic deformation and failure, and the acceleration is relatively large, which has a serious impact on the safety of passengers.

2. The energy absorption of the collision interface near the head car is large, but the energy absorption of the rear vehicle is less, and the closer to the middle collision interface, the greater the impact force.

3. The strength gradient of the crushing tube and the anti-creeper has a great influence on the train collision energy absorption, and the proper allocation of the crushing tube and the anti-creeper can achieve the average energy absorption of the train.

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