Bus-Protection Device-Tank-type Vehicle System Collision Research

Guosheng Zhang¹, Haiyang Zheng², Ye Chen¹ and Hongli Liu¹

¹Research Institute of Highway Ministry of Transport, Beijing, 100088, China
²College of Mechanical Engineering, Shenyang University of Technology, Shenyang, Liaoning, 110870, China

*Corresponding author’s e-mail: 64892542@qq.com

Abstract. Aiming at the problem of insufficient protective performance of the rear protection device, a new type of rear protection device with high protective performance is proposed and designed. A new type of tank-type vehicle rear protection device is used to establish the collision environment of bus-protection devices-tank-type vehicle system collision, and the dynamic response characteristics of the collision system were simulated and analyzed. The safety of the rear protection device was analyzed and evaluated by the real bus impacting tank-type vehicle, and compared with the simulation results. The research result shows that the protective performance of the square tube protection device is effective.

1. Introduction

According to statistics, in all accidents that occurred on the expressway, the vehicle rear collision accident reaches more than 50%. In the case of a rear collision traffic accident on a high-grade highway, the difference between the rear collision of a dangerous goods vehicle and the rear collision of a general cargo vehicle is mainly due to the different characteristic of the cargo carried by the vehicle. In general, the rear collision of a vehicle is limited to the safety of the vehicle body, the cargo carried, and the occupants. However, in the accident of a rear collision of a dangerous goods transport vehicle, the characteristics of the cargo directly determine the severity of the accident, which may sometimes lead to unimaginable consequences.

This paper focuses on the accident pattern of tank-type vehicle being chased by large vehicle. Based on the problem of insufficient protective performance of the rear protection device, a new type of rear protection device with high protective performance is proposed and designed. On this basis, the combination of simulation analysis and real vehicle test is used to analyse the collision characteristics and protective performance of the protection device.

2. New rear protection device

This paper proposes a new type of tank-type vehicle rear protection device [1]. The cross beam and the supporting arm of the protection device are square tubes, and the transverse structure of the cross beam is an integral square tube, and the longitudinal structure is welded with the lateral structure. The cross beam is connected to the supporting arm through 8 welding points, and the two supporting arms in the center are welded by a cross structure to increase the strength of the device, as shown in figure 1.
3. Bus-protection device-tank-type vehicle system collision research

3.1. Establishment of finite element model for rear collision test
In this paper, the new protection device is applied to bus-protection devices-tank-type vehicle system collision research. The finite element model of the rear collision test was established by using finite element modeling technology and Pro/E and Hypermesh software, as shown in figure 2 [2]. 583,787 units and 1974 nodes were in the finite element model of the tank-type vehicle collision system with the square tube protection devices installed which being collided by bus. 463,075 units and 442,997 nodes were in bus; 82,714 units and 93,608 nodes were in tank-type vehicle; 36,194 units and the 35,369 nodes were in the square tube protection device.

3.2. Simulation analysis of rear collision test
In the simulation analysis of the square tube protection device, the wall thickness of the cross beam of the protection device was set to 3 mm, and the wall thickness of the supporting arm was set to 6 mm. Compared with the round tube protection device, the square tube protection device is simpler in processing and manufacturing, and the supporting arm of the square tube protection device is more solid, although the protection area is reduced a lot, the support point of the supporting arm reaches the upper end and the lower end of the protected area. It makes it easier to balance the diffusion of energy during the collision process, which is more conducive to the absorption of energy and the dispersion of impact force [3].

3.2.1. Deformation analysis of protection device. In this section mainly studies the protective effect of the protection on the tank body. In order to study the protective performance more clearly, the model of the bus was hidden, and the rear part of the tank-type vehicle was selected as the research object to
analyze the protective effect of the protection device. The collision speed was 40 Km/h, the total mass of the bus was 10 tons, and the total mass of the tank-type vehicle was 13 tons [4].

From the cloud picture of the collision process of the protection device from figure 3 to figure 8, the stress contours are transmitted from big to small, from the middle of the protection device to the sides and the back end, which fully conforms to the transmission route of energy and force during the collision process. The protection device has large plastic deformation during the collision process, and the longitudinal beams of the protective end have different degrees of bending deformation. And the protection device is composed of a square tube, due to the structure of the square tube itself, different degrees of folding deformation have occurred and the energy is well absorbed in the collision. Meanwhile, during the collision process, due to the collision of the rear vehicle and the object itself contained in the tank, the tank body is also subjected to a certain degree of impact, but the tank body and the rear vehicle are not in direct contact, and the strength of the tank body itself is sufficient to withstand the impact. The tank body can remain safe during the collision [5].

![Figure 3. 0ms moment collision response](image1)

![Figure 4. 20ms moment collision response](image2)

![Figure 5. 50ms moment collision response](image3)

![Figure 6. 80ms moment collision response](image4)

![Figure 7. 100ms moment collision response](image5)

![Figure 8. 120ms moment collision response](image6)

3.2.2. Collision energy analysis. The car collision is actually an energy conversion process. The quality of the energy transfer path also shows the quality of the structure [6]. During the simulation process, due to the finite element unit, the hourglass energy will be generated during the simulation. The research shows that the hourglass energy can account for less than 5% of the total energy of the system, so the simulation system is credible. Figure 9 is a graph showing the energy variation of the system.
4. Real vehicle crash test and evaluation

4.1. Real vehicle rear collision test
The speed of the real vehicle rear collision test was set to 40 km/h. The bus departed 300 meters from protection device, and the traction system provided power for the bus. It reached 40 km/h at a distance of 60 meters from the protection device and travelled at a constant speed to the traction car deceleration device 20 meters away from the protection device. The traction system disengaged and traveled forward through inertia and collided with the protection device [7]. During the test, a high-speed camera was placed on the left and right sides of the tanker to record the entire process of the collision test, and the sequence diagram of the collision test process recorded by the camera is shown in figure 10.

![Figure 10. Collision test process sequence diagram](image)

After colliding with the rear protection device of the tank-type vehicle, the bus continued to travel a distance with the tank-type vehicle. Meanwhile, during the forward journey, the bus rebounded slightly relative to the tank-type vehicle [8]. The protection device still maintained the original shape during the collision process, the overall deformation was small, the local changed slightly, and the performance was relatively "hard". The protection device was slightly sunk during the collision but was not disengaged from the tank-type vehicle and did not intrude into the front structure of the bus and the tank body. During the entire collision process, the front structure of the bus did not collide with the tank body, the tank body was not damaged, the liquid did not leak, and the protection device had good protective effect.

4.2. Real vehicle test and simulation comparison
It could be seen from the comparison that the deformation of the protection device in the real vehicle collision and simulation analysis was very small, and the protection device was effective to buffer and prevent the bus from striking the rear of the tank body. From the rear collision process, differences still existed between the two. In the rear collision test, the protection device and the tank-type vehicle were separated from the junction, but because the extrusion of the bus did not leave the tank-type vehicle, the upper inclined arm of the protection device was squeezed and opened, meanwhile, the two vertical
beams on the cross beam were deformed by the extrusion of the bus frame, and the upper solder joint was cracked. In the simulation analysis, the connection between the protection device and the tank-type vehicle was good, the protection device was not separated from the tank-type vehicle, and the force was evenly spread around the center of the protection device to achieve the desired effect [9].

![Relative position of bus and tank-type vehicle after real vehicle test](image1.png)

![Relative position graph of bus and tank-type vehicle after simulation](image2.png)

![Rear view of the square tube protection device of the real vehicle test](image3.png)

![Rear view of the simulation of the square tube protection device](image4.png)

Figure 11. Real vehicle collision and simulation analysis

5. Conclusion

A new type of tank-type vehicle rear protection device is used to establish a bus-protection device-tank-type vehicle collision environment. Through the test of the real bus rear-end tank-type vehicle, the safety of the rear protection device was analyzed and evaluated, and the simulation results were compared. The research result shows that the protective performance of the square tube protection device is effective.

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