Research on Collision Characteristics for Rear Protective Device of Tank Vehicle

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Abstract. During the accident of large commercial vehicle collision, the protective performance of rear protect device of dangerous goods tank vehicle is not enough to protect the tank. To address this problem, a new type of rear protect device with enough protective performance is proposed. The collision and protective performance of the device at different working condition as rear-end vehicle quality, impact velocity, and collision angle is analyzed with the method of combining simulated analysis with real vehicle test. The result shows that the performance of rear protective device is good enough to adapt to different conditions.

Introduction

With the rapid development of national economy and road transport, the requirement of liquid dangerous chemicals to different industries are increasing gradually, meanwhile, the transport accidents of liquid dangerous chemicals happened occasionally. Since Tianjin harbor industry-damage accident occurred on 8.12.2015, the transportation and store safety of dangerous goods has been concerned by society. 30% of the dangerous goods transportation accidents happened on the roads, this kind of accidents is the top of the whole accidents. 8% of the whole roads transportation accidents are rear-end collision, which is also one of the main type of road transportation accidents. Recently years, the second severe road transportation accidents happened occasionally due to the rear-end collision on Dangerous Goods Tank Vehicle have caused great losses on society property and people life. This is a prominent problem to the transportation management department, which also has been paid great attention from all sectors of society.

Many accidents have revealed the weakness of rear-end protective ability. Due to the danger of goods the Tank Vehicle loads, the loss from second damage is more than the rear-end accident itself. Especially Baomao highway accident happened on 8.26 and Jinji highway accident happened on 3.1, for example, have totally caused 76 people death. Compared with the European and the U.S standard, in China, the limit protection intensity of the bottom rear-end Tank Vehicle is lower in GB11567.2-2001 ’the protection regulation of vehicle and trailer’s bottom rear-end ’. It lacks in the regulation of the rear-end protective device. Some Chinese scholars have analyzed the bottom rear-end protective device and protection ability, besides, they have compared relative standards from other countries, finally, they have developed new bottom rear-end protective devices and gave advice and suggestions about improving protection standard.

The bottom rear-end protective device of Tank Vehicle aims to prevent passenger car from under-running, but its structure and intensity is hard to reduce the damage in collision by heavy service vehicle. This paper designed a high level of rear-end protective device, combined the CAE with real experiment, validated the effectiveness of the finite element model for rear-end collision. Further, the paper analyzed the collision characteristics of protective device and protection performance in different conditions including the weight of coach, collision velocity.

The Design and Installment of Protective Device

The protective device consists of protection rails, both sides strut member, front strut member and
link neck, as shown in Figure 1. The whole parts were welded together. To ensure the stability, the weld splices were fully-welded.

Figure 1. The CAD drawings of protect device
Figure 2. Installation of protective devices

After machining the protective device, this device was assembled to the experiment Tank Vehicle. The neck is an important part for linking protective device and carling of Tank Vehicle, welding the two parts together, as shown in Figure 2.

The Collision Model

The protective device model, Tank Vehicle model and coach model were imported to the pre-process Hyper Mesh. Running repair geometry, mesh generation, define unit type and metal property in proper order.

The Finite Element Model of Coach

First, the 6897 coach was selected as colliding vehicle. Second, the geometry model was built by using Pro/E and was imported to Hyper Mesh. Finally, the grid discretization was generated in shell unit. Totally the vehicle model consists of 463075 units, 442997 nodes as shown in Figure 3.

Figure 3. The FE model of the coach

The detail parameters as shown in Table 1.

Table 1. Parameters of the coach

| Items                | Dimension | Items                | Dimension |
|----------------------|-----------|----------------------|-----------|
| length[mm]           | 8970      | Front overhang[mm]   | 1905      |
| height[mm]           | 3480      | Rear overhang[mm]    | 2790      |
| width[mm]            | 2500      | Full mass[Kg]        | 9800      |
| wheelbase[mm]        | 4300      | Unladen mass[Kg]     | 6650      |
| Front wheel tread[mm]| 1900      | Rear wheel tread[mm] | 1800      |

The Finite Element of Tank Vehicle

The 5107 Tank Vehicle was selected as collided vehicle, the way to building model is as above. Simplify the outline dimension based on the real outline dimension. In accordance with the real vehicle collision load distribution similarly, the balance loading is used for the model vehicle. This model consists of 82714 units, 93608 nodes as shown in Figure 4.

Build the model of rear-end collision system and the finite element model of rear-end collision vehicle. The finite element model consists of 583787 units, 571974 nodes. The protective device model consists of 36194 units, 35369 nodes as shown in Figure 5.
The detail parameters as shown in Table 2.

Table 2. Parameters of the tank vehicle

| Items               | Dimension | Items               | Dimension |
|---------------------|-----------|---------------------|-----------|
| length[mm]          | 10067     | Engine location     | Front     |
| height[mm]          | 2765      | Tank volume[m³]     | 8.9       |
| width[mm]           | 2400      | Full mass[Kg]       | 13000     |
| Wheelbase[mm]       | 4400      | Unladen mass[Kg]    | 5800      |
| Front wheel tread[mm]| 2026      | Rear wheel tread[mm]| 1986      |

Control Parameters Set

Single point gauss integration was used in the paper, set the solve time as 120ms, internal the vehicle was set as auto single-surface, between the collision vehicle was set as auto surface-surface. Set EDHIST as 0.05, both of dynamic friction coefficient (FD) and static friction coefficient (FS) were set as 0.15. The FD and FS between wheel and ground were set as 0.7 and 0.8. By using statistical approach in relative velocity from lots of dangerous goods rear-end collision accidents, this paper select the collision velocity to 40km/h.

Analyzing Real Vehicle Collision Experiment

The Conditions of Collision Experiment

The requirement of this experiment was the collision vehicle’s suspension, wheels and steering system should be normal working condition. Internal vehicle balance load was fix, and the totally weight was 10000kg. Marks were attached outside the vehicle. 85% of the tank volume was filled in water, and totally weight was 13000kg as shown in figure 6. The gear box was shifted to 3 in order to avoiding the wheels locking while colliding. Set 3 high-velocity cameras at the left, right and top sides in the collision area.

Analyzing Experiment Result

After real vehicle collision experiment, its deformation tendency agreed well with the simulation results about analyzing plastic zone. The high-velocity cameras showed the maximum deformation value of protective device was 718mm during collision as shown in Figure 7. The deformation error between experiment result and simulation result was not consistent, because machining parts and welding different parts maybe have influence on the final experiment result. Analyzed the relative error of structure deformation between experiment and simulation result, the position of maximum
The deformation error of the tank was found at the rear, meanwhile, but the basic deformation value of the experiment and simulation at the rear of tank was little. Besides, the deformation errors of protective device parts were all lower than 10%, so the simulation result and experiment result were regarded as consistency.

The wave form, the tendency, the value between simulation and test result showed a good consistency. The max error of acceleration was around 2.5%, it met the requirement of engineering application.

Figure 7. Result of real vehicle test

Figure 8. Comparison of acceleration of center of mass

The Influence on Collision Velocity

The Deformation of Protective Device in Different Velocity

Assuming the weight and the height of center of mass are constants, considering 3 different velocity groups. The kinetic energy as follow:

\[ E = \frac{1}{2} m v^2 \]  

(1)

In the equation, \( m \) is totally weight, \( v \) is collision relative velocity.

The relation of velocity and energy, deformation value as shown in Table 3.

| Collision velocity[km/h] | Initial energy [KJ] | Deformation value [mm] |
|-------------------------|---------------------|------------------------|
| 30                      | 395                 | 534                    |
| 40                      | 605.15              | 745                    |
| 50                      | 964.66              | 879                    |

Longitudinal support rods and knightheads were folded, the carling of protective device was bending deflection. The maximum deformation value of protective device increased as the collision velocity increasing. The deformation value of left and right sides were little, the deformation positions mainly occurred at the front. Although the device was deformation in different collision velocity, the protective device were not conquassation and fell off. This device could absorb collision energy by buffering based on its structure. Besides, the tank wasn’t damaged. It showed that the device protected the rear of the tank well.

Acceleration Characteristic in Different Collision Velocity

Acceleration can represent the shock degree the part suffered during collision, it’s also an important index for the structure safety. Analyzed the response of acceleration, the protective device buffered the shock during collision.

The peak acceleration occurred during the time 22ms to 35ms, in this time the two vehicles touched each other. With time goes by, the acceleration got little, the device began deformation, so it can absorb energy. The velocity up, the peak acceleration up, around 70ms the accelerated curve became flat. After the deformation, the coach and Tank Vehicle moved forward as the same velocity. The comparison of different velocity collision response as shown in Figure 9.
Assume the collision velocity was 40km/h, according to the statistic figure of the main vehicle types of road transportation vehicle in China, sorting the coach into weight as 8t, 10t, 14t, 28t, 25t. The comparison of different mass collision response as shown in Figure 10.

The acceleration tendency of the center of mass of tank was almost consistent, more weight, more peak acceleration. The tank also suffered the second shock during collision, the peak acceleration of the tank was around 56.32g at the weight 25t. The other peak accelerations were 38.21g and 47.62g at the weight 8t and 10t. The peak acceleration of coach at the weight of 25t increased by 45.18% and 16.93%, compared with those weight of 8t and 10t. Besides, when the tank suffered the peak acceleration during the second collision, the time was ahead as the weight of the coach increasing. Generally, the peak acceleration of tank kept lower than 50g at the collision load of 18t. Moreover, the tank absorbed the shock and wasn’t damaged. But at the collision weight of 25t, the peak acceleration of second collision could be 56.32g.

Conclusion
The research and analysis of the collision model system for the rear-end collision between the goods vehicle and coach, it showed as follow:

The new protective device showed a good adaptability of collision in different working conditions, and could absorb the collision energy so that the tank couldn’t be damaged.

The new protective device could reduce the acceleration during collision effectively, and it could protect the tank and the passenger of coach well.

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