Analyse and Control on the Flexible Body of Tractor Semi-trailer Rollover

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Abstract. Based on the tractor semi-trailer modal test results, a rigid tractor semi-trailer frame was built. Then the rigid one was flexibilized. Conventionally the tractor semi-trailer was used to be treated as a rigid body in lateral stability control, which differs from the actual situation. Flexible tractor semi-trailer was used to study rollover effect due to the longitudinal torsional deformation of tractor semi-trailer in emergency obstacle avoidance process.

Introduction

Longitudinal beam of tractor semi-trailer frame is an important part of the tractor semi-trailer. Its structure characteristics are long longitudinal beam, large wheelbase, bear a variety of load inside and outside tractor semi-trailer, and complex stress. So, in order to ensure the main frame beam has enough strength and stiffness at the same time and need to prevent the frame has large torsional deformation. Fig. 1 for tractor semi-trailer rollover test, tractor semi-trailer appeared larger longitudinal torsional deformation, which would accelerate the trailer rollover.

Figure 1. Tractor semi-trailer rollover test.

Basically it is tractor semi-trailer considered as rigid body in the existing literature. If it used for rollover research, this is quite different from the actual situation. Because tractor semi-trailer are usually very long. In emergency obstacle avoidance will occur larger longitudinal torsional deformation. And this deformation will have an important influence on the rollover. In the 9 degree of freedom dynamics model of tractor semi-trailer, tractor
semi-trailer increases the longitudinal torsional stiffness and damping. In this paper, tractor semi-trailer frame is flexible. This research results obtained by this method will be more accurate [1].

**Construction of the Frame of Flexible Body**

**Modal Test**

According to the structure and working characteristics of the frame, the model is simplified and assumed without affecting the accuracy: Ignore the less rigid embossing plate (flat) and slender skid strip; The removal of parts and components, such as the tool box and the protection network, have no effect on the stress distribution of the whole structure of the frame; To simplify and neglect the structure (such as small bending, rounded corners, etc.); The welding structure of each component is assumed to be equal to the strength of the welding. And the strength of the welding is equal to the strength of the component itself; The parts material of whole frame is consistent and the material has the same characteristics [2].

**Finite Element Model**

The structure and shape of frame are more complex, but in the ANSYS of the model is relatively monotonous, and modeling efficiency is relatively low. In this paper, a three-dimensional modeling software Pro/E is used to establish the entity model of the frame (as shown in Fig. 2). The interface of ANSYS and CAD is introduced into the ANSYS software. Fig. 3 is the finite element model for the grid.

![Figure 2. CAD model of tractor semi-trailer.](image1)

![Figure 3. FEM model of tractor semi-trailer.](image2)

Application of material properties: The steel of frame selection is 16MnL. In the work, the deformation can be considered as the elastic deformation and the isotropic material. Elastic modulus of materials \( E = 2.06 \times 10^5 \) MPa. Poisson's ratio \( \mu = 0.29 \). Density \( \rho = 7.8 \times 10^{-6} \) kg/mm3. Yield limit and strength limit are 350MPa and 520MPa respectively.

**Analyze and Control on Flexible Body to Roll**

**Effect of Rollover Threshold of Flexible Body**

Rollover threshold of tractor semi-trailer is established by two main mechanisms. The most important of mechanisms is the ratio of wheel length and two times height of the center of gravity. If the vehicle is ideal for rigid and does not take into account the tilt of the road itself,
this ratio \( \frac{T}{2H} \) is equal to the vehicle rollover threshold (When the vehicle turns, the inner wheel is just off the ground. Multiple of the acceleration of gravity to the acceleration of gravity, unit: g) [3].

However, due to the influence of lateral acceleration and load transfer, the lateral suspension will have a large deformation, which will cause the body to tilt. This is bound to reduce vehicle rollover threshold. In the rollover test station of rollover simulation test (such as shown in Fig. 4. By changing the parameters of suspension and tire can be found the rollover threshold changes (between the 0.3~0.5g changes). If we consider the gravity loading of goods abroad, rollover threshold may drop to 0.25g.

![Figure 4. Rollover test for tractor semi-trailer.](image)

If vehicle is rigid and does not take into account the tilt of the road itself, the center of gravity of the vehicle in the horizontal direction from the outer wheel distance is 1/2 track. In the process of high speed turning, the distance between the center of gravity of the vehicle and the vehicle body, the traction seat and the traction pin will be reduced \( \Delta y_1 \) due to the influence of the suspension, the deformation of the tire, and the gap between the spring and the body, the traction seat and the traction pin. That is to say, it will be less than half of a track. This kind of change will make the rollover threshold decreases, reducing the vehicle antirollover ability. Similarly, in the process of high speed turning, due to the role of a strong centrifugal force, the load will occur in the axial direction, the tractor semi-trailer vehicle body will be a longitudinal torsional deformation, as shown in Fig. 1.

This torsional deformation will lead to a further reduction \( \Delta y_2 \) of the distance between the center of gravity of the tractor semi-trailer and the outer wheel. The rollover threshold will decrease again. So, compared with the ideal rigid vehicle, trailer actual more prone to rollover. Fig. 5 is the critical condition of the flexible body rollover tractor semi-trailer. From the figure can be found due to the effect of longitudinal torsional deformation, tractor semi-trailer automobile train rollover critical condition with a certain degree of decline.
Influence of Flexible Body Rollover Control

This article takes flexible tractor semi-trailer used for anti-rollover control, speed of 100km/h. The simulation results show that the tractor semi-trailer of the flexible body of rollover have obvious effect. Fig. 11 for the tractor semi-trailer car train in the absence of control of the 4 axis on the left side of the wheel method is the opposite force. Fz_L4o_R (Fz_L4i_R) is the opposite force acting on the surface of the left (inner) wheel of the fourth axis of the rigid semi suspension train. Correspondingly, the Fz_L4o_F (Fz_L4i_F) is the counterpart of the flexible body.

From Fig. 6 can be found, tractor semi-trailer automobile train through the first bend, the body tilted to the right, the left outer appeared briefly left the road. Through the second and the third corner, body were heavily skewed to the left, outer bearing most of the load, in this corner prone to rollover. Overall, the flexible body outer will withstand greater load. This also shows that the flexible body in the bend due to the longitudinal torsional deformation, the amplitude of the roll is larger than that of the rigid body, that is, the more prone to rollover.

Fig. 7 is a tractor semi-trailer in the anti-rollover control of 4 axis wheel force opposite the left. FZ Fz_L4o_F fFZ Fz_L4i_F f) for anti-rollover control closed semi flexible hanging car train 4th axis on the left (in) round by the method pavement opposite forces. Accordingly, Fz_L4o_Con is in the anti-rollover control method under the action of opposing forces. From the figure is not difficult to find, rollover is involved in work in the second and third corners. In other words, the roll rate reached a certain degree. Comprehensive index exceeds the preset threshold for rollover prevention intervention. From the chart we can see clearly that, in the anti-rollover control intervention, the outer loads decrease 20%. That is to say, in the same driving condition, anti-rollover control can apparently reduce the tractor semi-trailer body roll amplitude. It reached the purpose of anti-rollover control.
Summary
Tractor semi-trailer frame longitudinal beam is an important part of the tractor semi-trailer and its structure characteristics is longitudinal beam length, wheelbase and under tractor semi-trailers and the action of various loads, stress is very complex. So, to ensure the main frame beam has enough strength and rigidity of the frame at the same time, the need to prevent excessive distortion. The traditional lateral stability control is to simplify the tractor semi-trailer body into a rigid body, which has a large discrepancy with the actual situation. In this paper, the model test results of the real tractor semi-trailer are used to model the tractor semi-trailer, and the flexible body is used for dynamic simulation. Analysis effect of flexible body to roll and flexible tractor semi-trailer for anti-rollover control, to verify the effectiveness of the control algorithm.

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References