Proceeding of the 14th International Forum of Automotive Traffic Safety, 2017, pp 421-428
No.ATS.2017.501

The Effects of Curtain Airbag on Occupant Kinematics and Injury Index in Rollover Crash

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Abstract:

Background: In recent years, SUV models are the favor of Chinese consumers. Because the gravity of the SUV models is generally higher than the sedan, therefore, in the same case, the probability of vehicle rollover for SUV models is often higher than the sedan. However, in China there are less laws or regulations concerning about vehicle rollover, especially the dynamic rollover test, so the research on the vehicle rollover is rarely seen in China.

Objective: This study focuses on effects of curtain airbag on occupant kinematics in rollover crash based on the simulation with the MADYMO software.

Method and Material: The vehicle motion from the physical rollover test was introduced as the input for the numerical simulation, and the 50% Hybrid III dummy model from the MADYMO database was imported for the occupant kinematics simulation. A Curtain Airbag (CAB) was introduced in car for occupant ejection mitigation.

Results: The curtain airbag succeed to keep the head of occupant in passenger compartment during the whole rollover crash test. Besides, from the point of occupant injuries view, head and chest resultant accelerations were reduced when CAB was applied. Injury indexes including upper neck moment x, neck force y and neck force Z were improved as well.

Conclusions: With the help of CAB, the occupant injuries of head, neck and chest were all reduced in such rollover crash scenario. There are two important effects of CAB on occupant injuries. One is the energy absorbing function between head and vehicle body. The other is change of occupant kinematics from the contact time of head and CAB.

Keywords: Rollover crash, Curtain airbag, Occupant kinematics, Ejection mitigation

1 Introduction

In recent years, SUV models are the favour of Chinese consumers. According to statistics, SUV models accounted for 36% in all sales of passenger cars in 2016[1]. Consumers enjoy the large space of SUV model, but often overlooked their inherent defects. For example, there is an inherent defect about performance in terms of automotive safety. Because the gravity of the SUV models is generally higher than the sedan, therefore, in the same case, the probability of vehicle rollover for SUV models is often higher than that of the sedan. However, in China there are less laws or regulations concerning about vehicle rollover, especially the dynamic rollover of the vehicle, so the research on the vehicle rollover is rarely seen in China.

In this paper, a SUV model was taken as an example. A multi-rigid body dynamic model was setup according to the FMVSS 208 dolly rollover test[2]. Then the validation of simulation model was carried out by comparing with the physical test data. The effects of curtain airbag on occupant kinematics in rollover crash were investigated.

2 Method and Material

According to the FMVSS 208 dolly rollover tests, the simulation model of rollover crash test was set up by the method of MADYMO software.

2.1 Simulation Model according to FMVSS 208 dolly rollover test

For FMVSS 208 dolly rollover test [2], the vehicle is placed on the dolly, which having a platform in the form of a flat, rigid plane at an angle of 23 ° from the horizontal. At the lower edge of the platform is an unyielding flange, perpendicular to the platform with a height of 4 inches and a length sufficient to hold in place the tires that rest against it, as shown in figure 1.

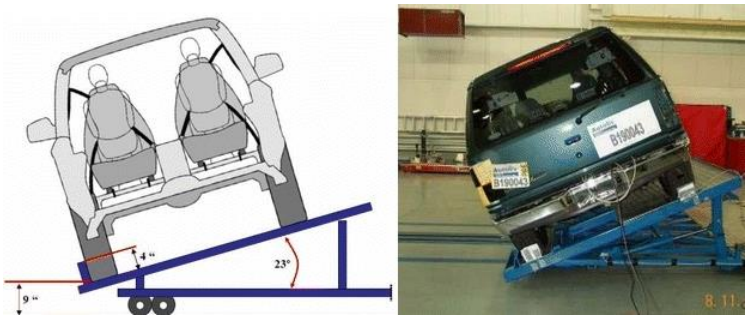
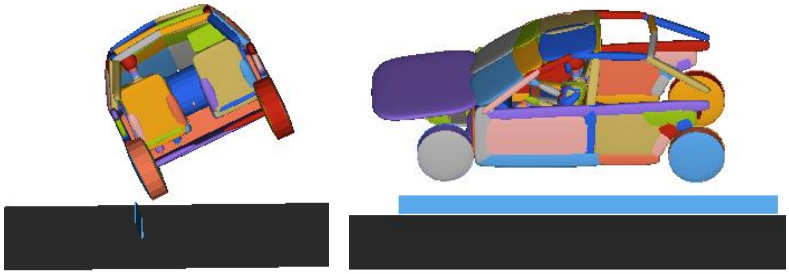


Figure 1 FMVSS 208 dolly rollover test configuration (left) and example (right)

Based on CAD data of SUV model, a multi-rigid body model of vehicle was built. The platform model for rollover test was also built according to FMVSS 208 regulation. For occupant model, the 50% Hybrid III dummy model from the MADYMO database was imported for the occupant kinematics simulation [3]. The occupant model was belted with shoulder belt and lap belt. The total simulation model was shown in figure 2.



(a) Rear view (b) left side view

Figure 2 Rollover simulation model

Vehicle kinematics from the physical rollover test was introduced as the input for the numerical simulation. The kinematics is defined by prescribing the motion for all degrees of freedom of a free joint at the vehicle center of gravity (COG) position. The occupant restraint and occupant protection can then be studied without having to simulate the vehicle suspension response in each simulation.

As an important parameter of vehicle rollover, the rotational velocity was introduced to simulation model as shown in figure 3.

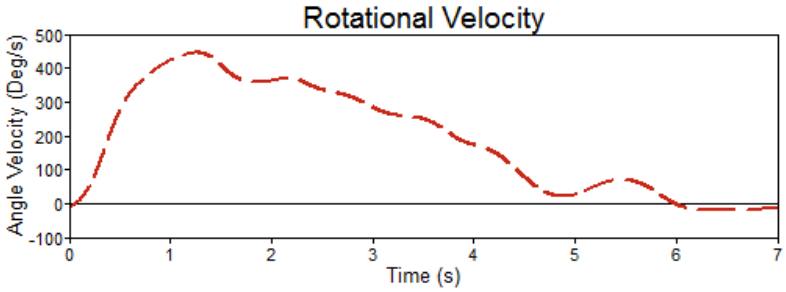


Figure 3 Rotational velocity of the rollover test

2.2 Validation of simulation model

The validation of simulation model is done carried out by comparing with the foreign test datathe kinematics of the test with that of the simulation [4]. In the rollover crash test, the front camera view was chose as validation information. The vehicle kinematics of simulation correlated well with that with that of rollover crash test, as shown in figure 4.

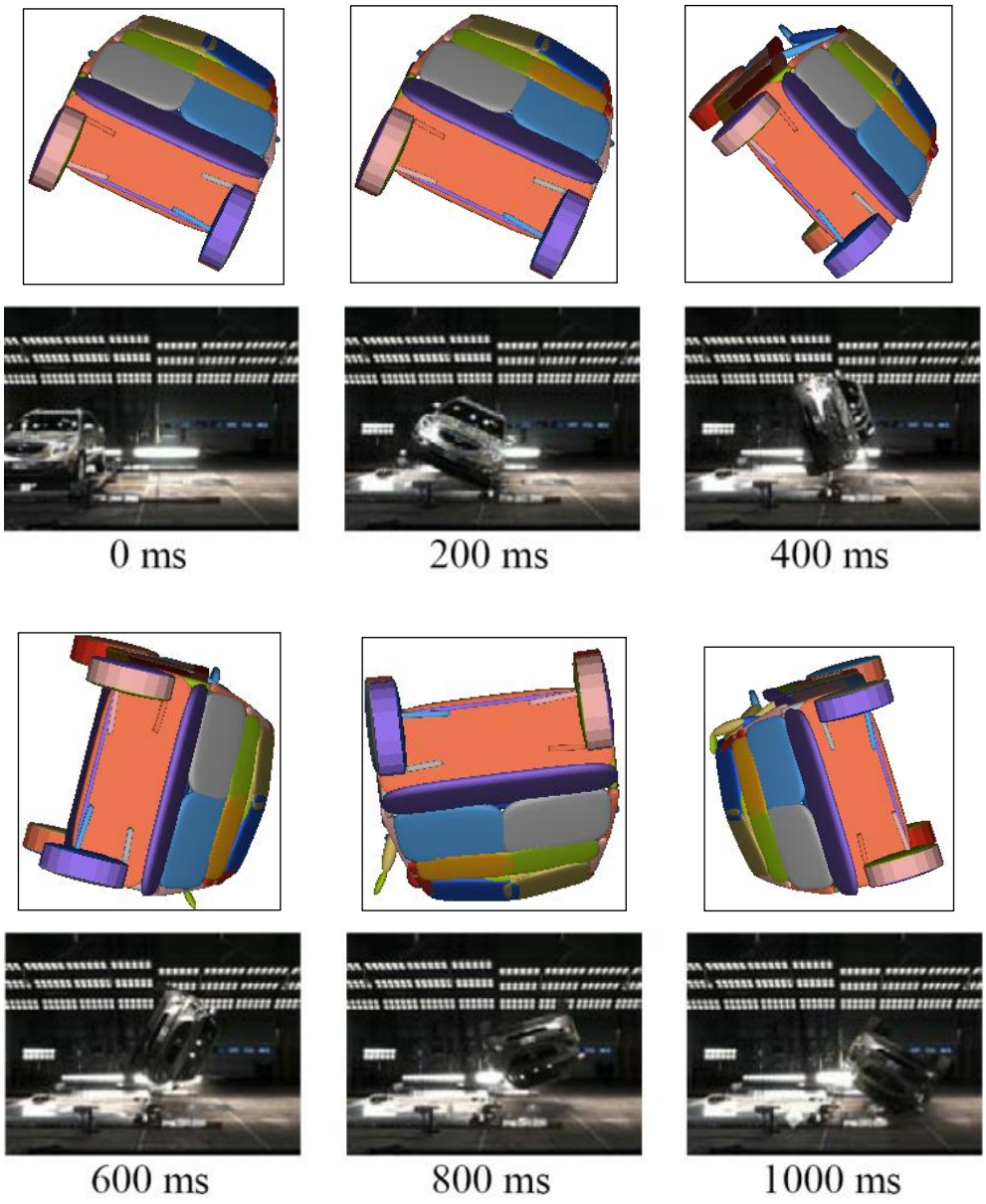


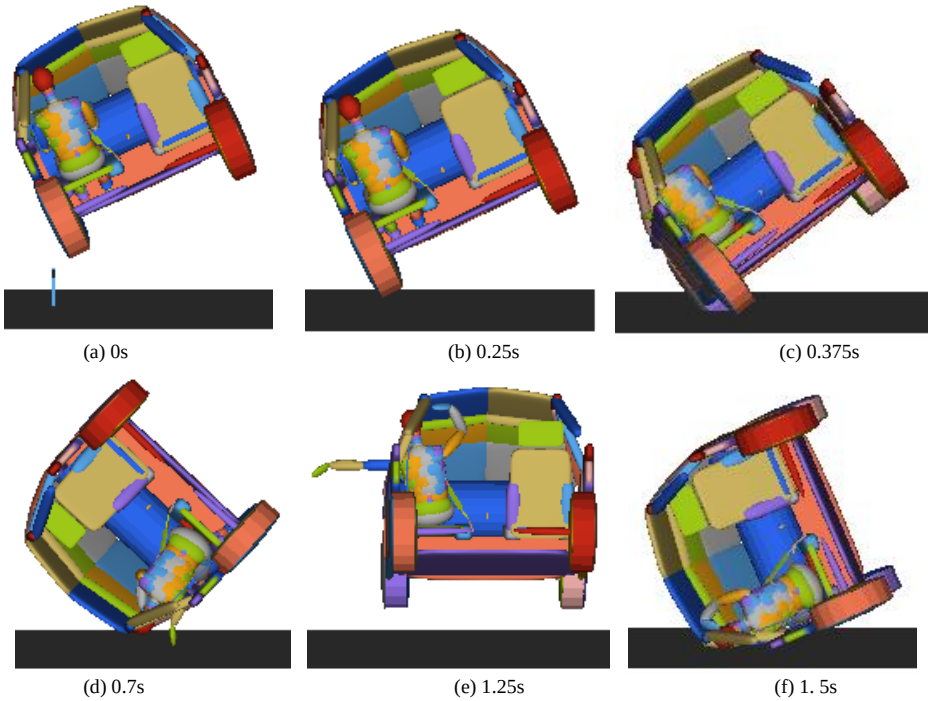
Figure 4 Vehicle rollover kinematics comparison

2.3 Occupant kinematics

Occupant kinematics of the simulation from 0s to 1.5s was shown in figure 5.

From figure5, it was found that the head of occupant was ejected from left front door at 0.375s while the left arm of occupant was also ejected at 0.7s. Besides, head of occupant contacted made contact with vehicle roof and ground at 1.5s. Different vehicle roof strength also resulted in different intrusions of vehicle roof during rollover crash[5]. Large intrusion

of vehicle roof may cause severe injuries to the head or other body. So it does not meet FMVSS 208 regulation and was very dangerous if any body region of occupant was ejected from carvehicle.



(a) 0s (b) 0.25s (c) 0.375s

(d) 0.7s (e) 1.25s (f) 1. 5s

Figure 5 Occupant kinematics in rollover crash

2.4 Curtain Airbag (CAB)

The role of curtain airbag is protecting the occupant's head during rollover crash accidents. So it was a good way to add a curtain airbag in car for ejection mitigation[6].

A type of curtain airbag which was validated in certain side impact simulation was imported for ejection mitigation analysis in this study, as shown in figure 6.

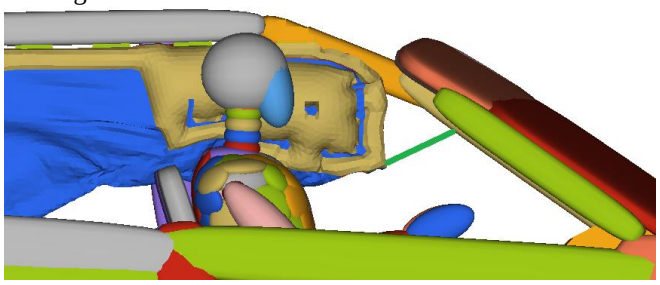
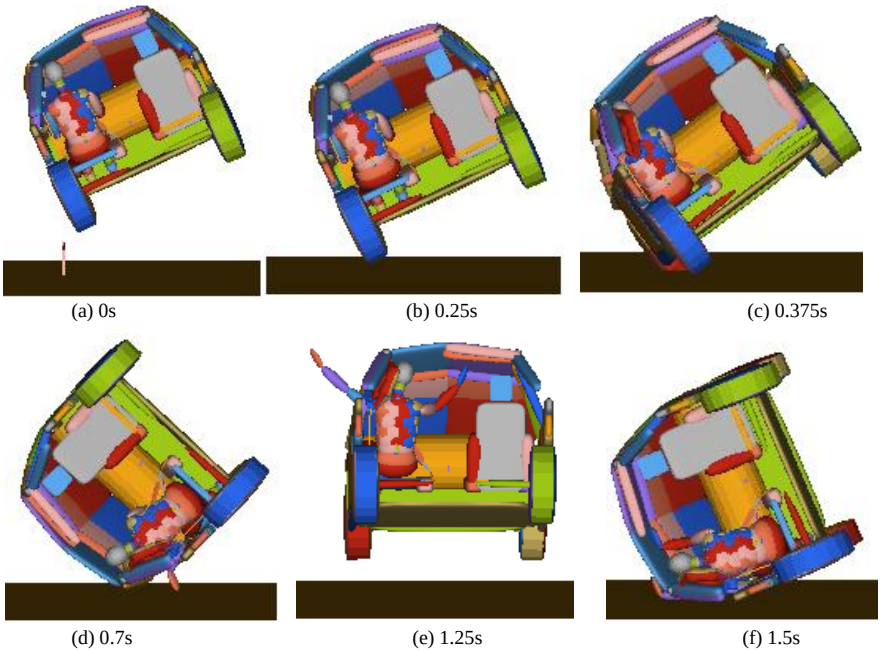


Figure 6 Simulation model with inflatable curtain airbag

3 Results

3.1 Occupant kinematics with CAB

Occupant kinematics from 0s to 1.5s with curtain airbag protection was shown in figure 7.



(a) 0s (b) 0.25s (c) 0.375s

(d) 0.7s (e) 1.25s (f) 1.5s

Figure 7 Occupant kinematics with curtain airbag in rollover crash

From figure7, it was found that curtain airbag help to keep the head of occupant in passenger compartment during the whole rollover crash test. However, the left arm of occupant was still ejected at 0.7s.

3.2 Occupant injuries with CAB

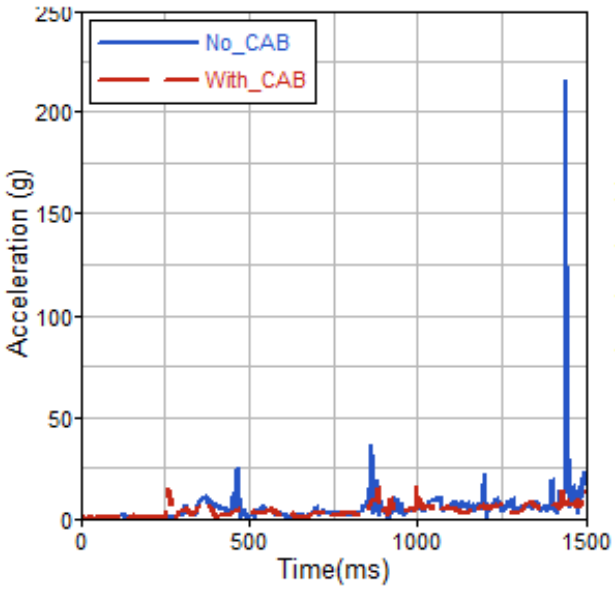


Figure 8Head Res. Acceleration

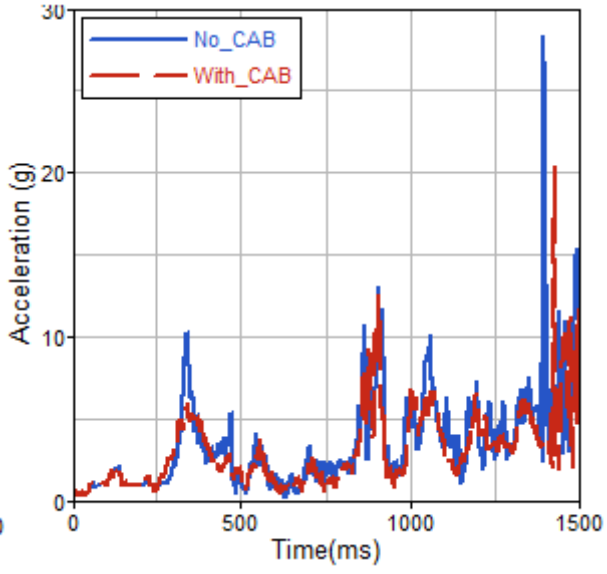


Figure 9 Chest Res. Acceleration

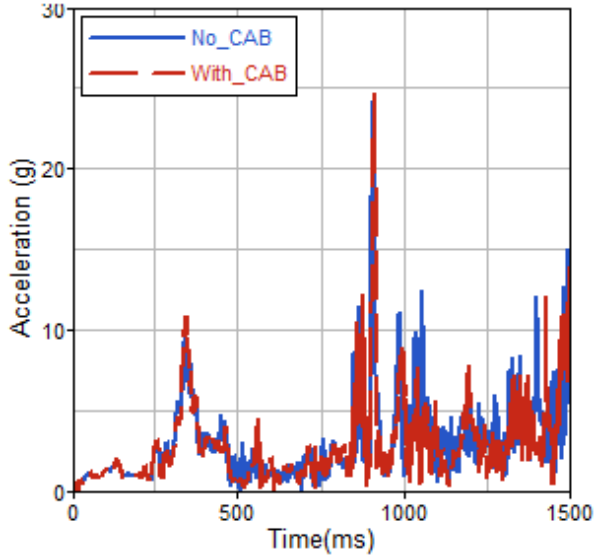


Figure 10 Pelvis Res. Acceleration

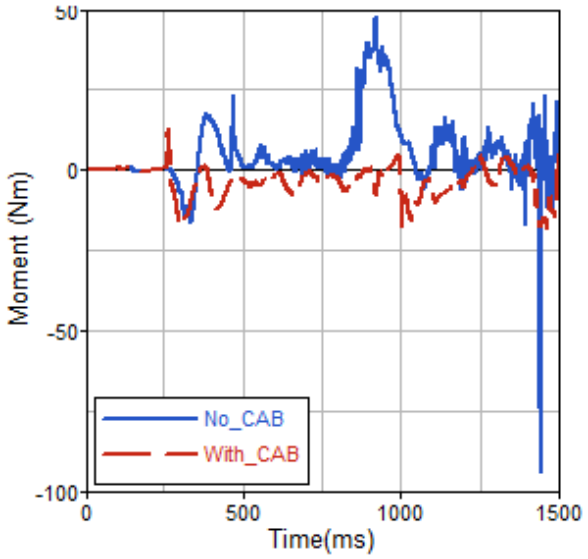


Figure 11 Upper Neck Moment X

Occupant injuries of both With-CAB case and No-CAB case were shown in figure 8 to figure 13. The curve of No-CAB case is blue line while the curve of With-CAB case is red line.

As shown in Figure 8 to Figure 10, head resultant acceleration and chest resultant acceleration were reduced when the CAB was applied in vehicle during rollover crash test, while the pelvis resultant acceleration was almost the same. It is very easy to understand because the influence of CAB to passenger region from greater to smaller is: head, chest and pelvis. With the protection of CAB, the contact force between head and vehicle is very small, so the peak of head resultant acceleration was reduced from 215.6g to 17.2g.

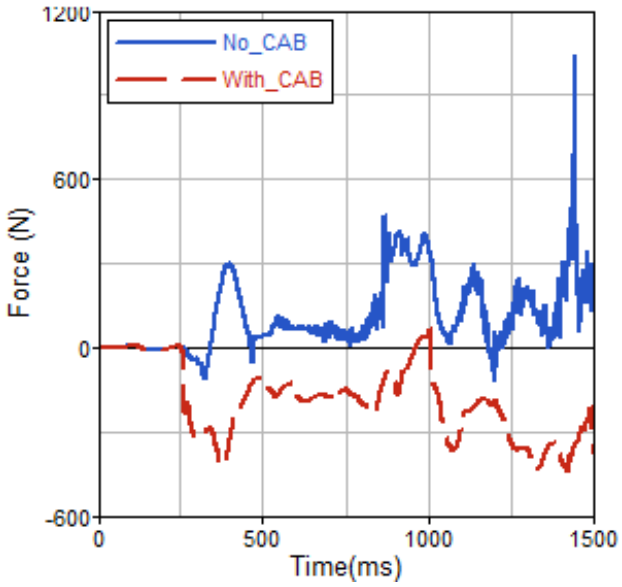


Figure 12 Upper Neck Force Y

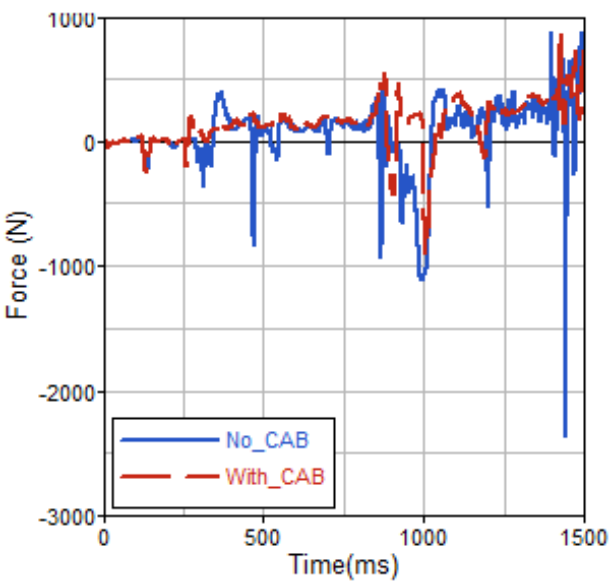


Figure 13 Upper Neck Force Z

From curves of upper neck injuries (Figure 11 to Figure 13), neck moment xX, neck force y Y and neck force Z were all improved. The peak of neck moment X and neck force Z were reduced dramatically. Besides, the curve of neck force

Y was changed from negative to positive. Due to the contact between head and CAB, upper neck force y Y turned toward to the right hand.

4 Discussions

The effects of CAB on occupant injuries were mainly on the area of occupant torso, especially on the head of occupantthe occupant upper region. The peak of head resultant acceleration was reduced from 215.6g to 17.2g. This is not only because CAB serves as an energy absorbing object, but also because the CAB protection for head changed the occupant kinematics. Just as shown in figure 12, with the help of CAB protection, upper neck force y Y turned toward to the right hand while upper neck force y Y turned toward to the right left hand when there is without CAB.

In the process of CAB effect analysis, a validated CAB was applied in the simulation model. While in the actual design process, there were still a lot of CAB parameters need to be optimized in the further study, such as time to fire of CAB, the pressure duration, protection area, CAB vent hole. All these effects need So a the follow-up studies needs to be done.

5 Conclusions

A rollover simulation model of SUV was setup according to FMVSS 208 dolly rollover tests. The vehicle kinematics of simulation result was correlated very well with that of rollover crash test, which indicated that simulation model can be used to investigate the effect of curtain airbag on occupant kinematics.

Simulation result showed that the head and left arm of occupant were ejected from left front door during rollover case without curtain air bag , which did not meet FMVSS 208 regulation.

A curtain airbag was introduced in car the vehicle for ejection mitigation. The occupant injuries of head, neck and chest regions were all reduced. The curtain airbag succeed to keep the head of occupant in car passenger compartment during the whole rollover crash tests cenario. This conclusion was similar with research of Kim B [7] and Newberry, W [8]. There are two important effects of CAB on occupant injuries. One is the energy absorbing object function between head and vehicle body. The other is change of occupant kinematics from the contact time point of head and CAB to the end of rollover crash test simulation.

Acknowledgement

In this study, we have deeply investigated the effects of curtain airbag in rollover simulation under the support of the Key Laboratory of Advanced Manufacture Technology for Automobile Parts（Chongqing University of Technology）, Ministry of Education Project (No.2016KLMT03) and National Natural Science Foundation of China (Grant No. 51405050).

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