DEVELOPMENT OF ROLLOVER CURTAIN SHIELD AIRBAG SYSTEM

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ABSTRACT

Many rollover accidents involving sport utility vehicles (SUVs) have been reported in the United States. More than half of the occupants killed in rollover accidents are totally or partially ejected from the vehicle. This finding has lead us to develop a rollover curtain shield airbag system. This system is made up of curtain shield airbags to help reduce the possibility of ejection of occupants wearing seat belts within the compartment at the time of rollover and a rollover sensor. This article is an outline of the curtain shield airbags and the rollover sensor.

BACKGROUND

Rollover accidents of SUVs have been drawing attention in the United States recently. The Fatal Analysis Reporting System (FARS) for 1998 reports that the number of occupants killed in passenger cars, SUVs, and light trucks and vans (LTVs) is 31,789, out of which 21,116 occupants are in passenger cars and 10,666 are in SUVs/LTVs. The breakdown by collision type indicates that for passenger cars the collision that occurs most is head-on collision (43%), followed by side collision (29%) and rollover (22%). On the other hand, in SUVs/LTVs, rollover is the leading collision type and accounts for 48%, which is followed by head-on collision (36%) and side collision (11%). (Figure 1)

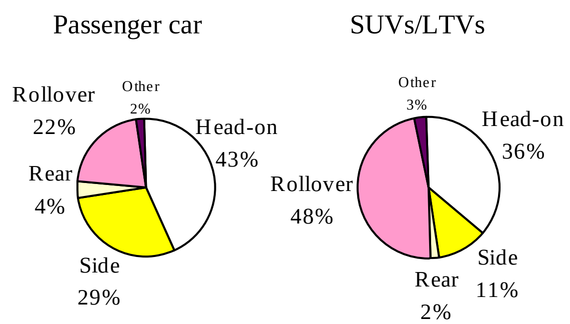

Figure 1. The fatality rate in passenger car and SUVs/LTVs (FARS1998)

The number of occupants, 5,068, killed by rollover in SUVs/LTVs is larger than the number of occupants, 4,671, killed by rollover in passenger cars. As is clearly apparent, rollover causes about half of the occupant fatalities in SUVs/LTVs.

Next, an investigation was conducted concerning whether the occupant was ejected or not from the vehicle in the case of SUVs/LTVs. 3,335 occupants, which corresponds to 65% of the fatalities in rollover were totally or partially ejected. This fact suggests that reducing the possibility of ejection from the vehicle may reduce the number of deaths associated with rollover.

When seat belt use rates are compared for each type of ejection, 3% of the totally ejected occupants, 19% of the partially ejected occupants, and 47% of the "non-ejected" occupants are using seat belts. This indicates that use of a seat belt has an effect on preventing the occupant from being ejected from the vehicle.

Next, ejection paths were analyzed for 905 occupants whose ejection paths had been identified out of the 3,335 occupants who are totally or partially ejected. The most common ejection path is the side window (54%), and the side door opening (17%) and the windshield (10%) follow. This fact indicates the importance of designing countermeasures to attempt to reduce the possibility of ejection through the side window portion.

Against this backdrop, our company has developed an SRS rollover curtain shield airbag system that covers part of the side window during a rollover. The development of this system is intended to reduce the possibility of ejection and as an addition to our continued efforts toward promoting safety through using seat belts.

SYSTEM CONFIGURATION

The rollover curtain shield airbag system is constituted by curtain shield airbags and a rollover sensor. (Figure 2)

The curtain shield airbag has been developed based on a module that was developed to protect the head portion by being deployed during a side collision. The module was adapted for use against rollovers by modifying the internal pressure and volume of the bags appropriately.

The rollover sensor is structured by a roll rate sensor and a lateral G sensor that are installed at the center tunnel portion of the vehicle body. This sensor senses rollover based on three physical quantities; a roll rate and a lateral G obtained from the above two sensors, and a roll angle obtained by integrating the roll rates.

When the rollover sensor senses rollover, it deploys right and left curtain shield airbags and activates seat belt pretensioners of the driver and passenger seats.

These operations aim to reduce the number of occupants wearing seat belts who possibly could be ejected from the vehicle.

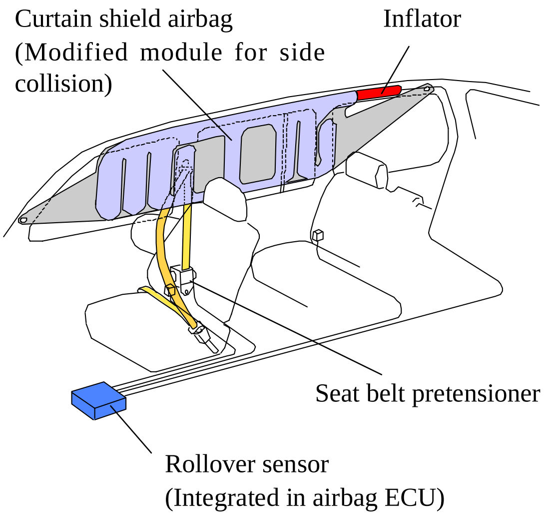

Figure 2. System configuration

DEVELOPMENT OF CURTAIN SHIELD AIRBAGS

Study on internal airbag pressure holding time

A rollover occurs taking a longer period of time than a side collision. In order to prevent the occupants from ejecting from the vehicle during this rollover period, the internal airbag pressure needs to be maintained at a certain pressure or higher. The result of various rollover tests conducted at our laboratory showed that if the internal pressure is maintained for 6 seconds or more, it is possible to reduce the chance of partial ejection.

Study on bag specifications

In various rollover tests conducted at our laboratory, the heads of test dummies (HBIII AM50%) wearing a seat belt were partially ejected from the vehicle at speeds of 0.5 to 5.6 m/s. At this time, the head ejection position was within ±50 mm with respect to the height of the head gravitational center. (Figure3) Under these conditions, bag specifications were designated such that the head of the dummy remained within the compartment up until AF05%, for which the head position is low.

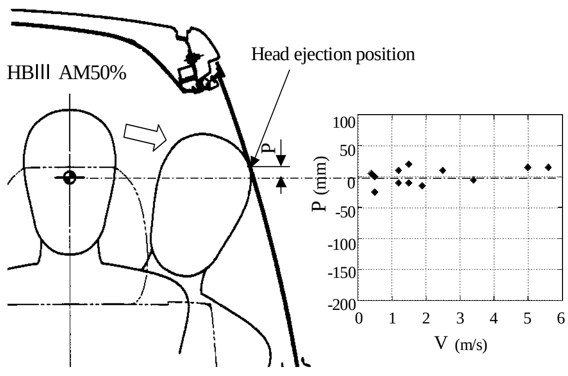

Figure 3. Head ejection position vs. velocity in various rollover tests

Bag structure

In the case of the vehicle we studied for this research, in order to satisfy the above requirements, the volume of the bag needed to be larger than that of the bag for protecting the head during side collisions. Meanwhile, since the curtain shield airbags are also used during side collisions, the timing at which bag deployment is completed needs to be the same for both types of collision.

In order to achieve this, an inner tube was inserted into the upper portion of the airbag so that gas generated by the inflator flows into the inner tube first, and subsequently, is blown out into the bag through multiple vents. (Figure4)
Accordingly, the bag is designed such that the entire bag, from the front to the rear portions, is deployed almost simultaneously, and the timing at which bag deployment is completed is the same as for side collisions.

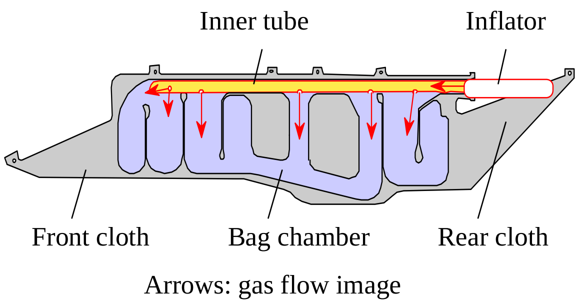

Figure 4. Bag structure and gas flow

Study on OOP performance

The OOP performance was evaluated with the bag as described above. The evaluation results for each posture are as shown in Figure 5 ~ 7.

It was confirmed that all values indicating injury of the dummies in the various postures were lower than the Injury Assessment Reference Values (IARV).

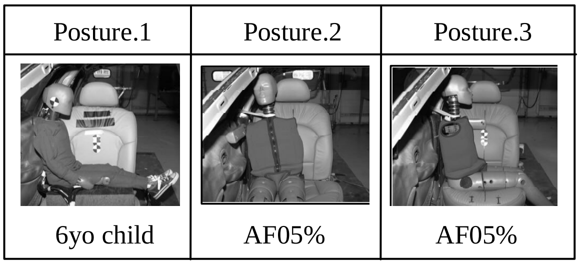

Figure 5. OOP test postures

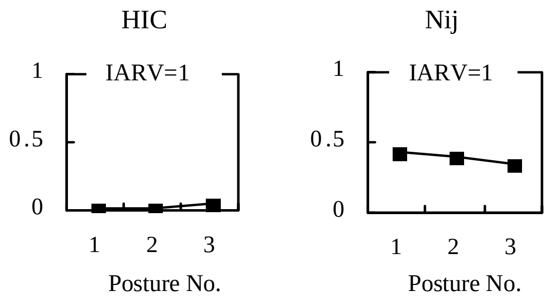

Figure 6. Dummy injury index in OOP test (HIC, Nij)

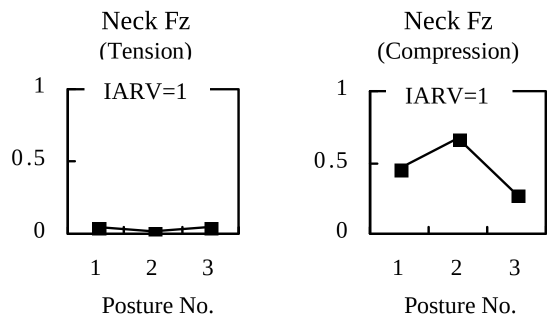

Figure 7. Dummy injury index in OOP test (Neck ;Fz)

DEVELOPMENT OF ROLLOVER SENSOR

Investigation on required time to fire for each rollover test

Roll over tests included a trip-over test, a flip-over test, and a fall-over test. In each of the tests, the required time to fire (RTTF) for a vehicle that is going to rollover was investigated. Rollover, as defined here, refers to a case where dynamic maximum roll angle is 90° or more, and RTTF refers to the timing at which the inflators are fired allowing the dummy's head to be held within the cabin by the curtain shield airbags.

Trip-over

Trip-over tests included a curb trip-over test and a sand pit trip-over test. Test conditions were as shown in Figure 8 and 9.

It was found that RTTF for rollover is at a time point when the roll angle is small. That is, the sensor needs to sense possible rollover at a time point considerably before the vehicle reaches the rollover point. This is because the lateral G generated during the early stage of the rollover causes the dummy's head to move toward the side window relatively early.

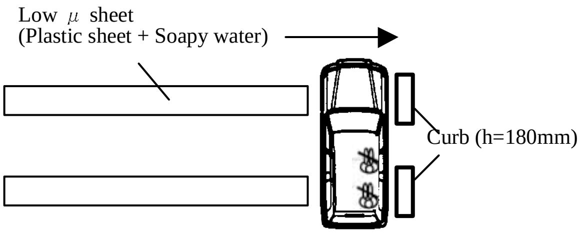

Figure 8. Curb trip-over test condition

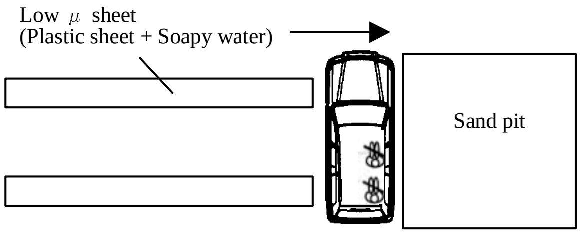

Figure 9. Sand pit trip-over test condition

Flip-over

The test conditions of the flip-over test are below shown. (Figure 10)

RTTF for rollover was after the roll angle became relatively large. This means that there is a degree of leeway before the time at which the sensor needs to sense rollover. This is because the dummy's head moves in the direction opposite to the side window during the early stage of rollover.

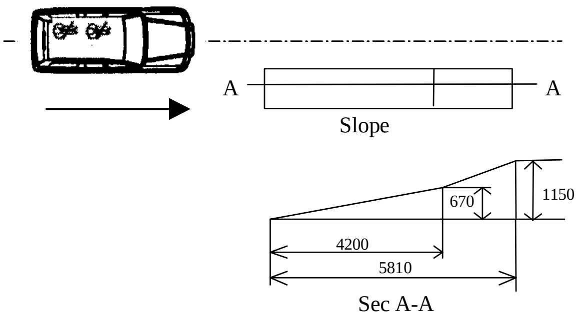

Figure 10. Flip-over test condition

Fall-over

The test conditions of the fall-over test are shown in Figure 11.

As in the case of the flip-over test, RTTF for rollover was after the roll angle became relatively large.

The dummy's head moved in a manner that was almost the same as the flip-over test.

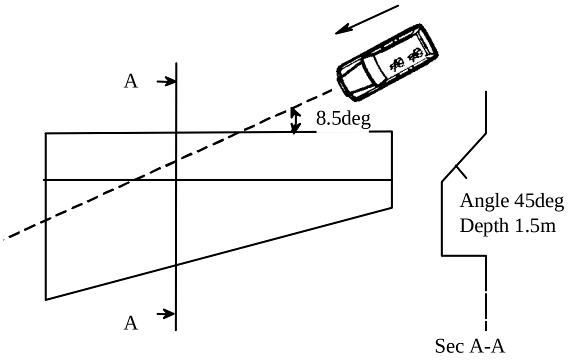

Figure 11. Fall-over test condition

Study on algorithm

In the flip-over test and the fall-over test, the sensor was able to sense rollover before RTTF based on a roll angle - roll rate map determination.

On the other hand, in the curb trip-over test and the sand pit trip-over test, the sensor could not sense rollover before RTTF based on the roll angle - roll rate map determination. Thus, attention was paid to the large lateral G that is generated during the early stage of the trip-over test, and an attempt was made to sense rollover based on a lateral G - roll rate map determination.

This arrangement enabled sensing of rollover before RTTF in the various rollover tests that were conducted this time. (Figure 12)

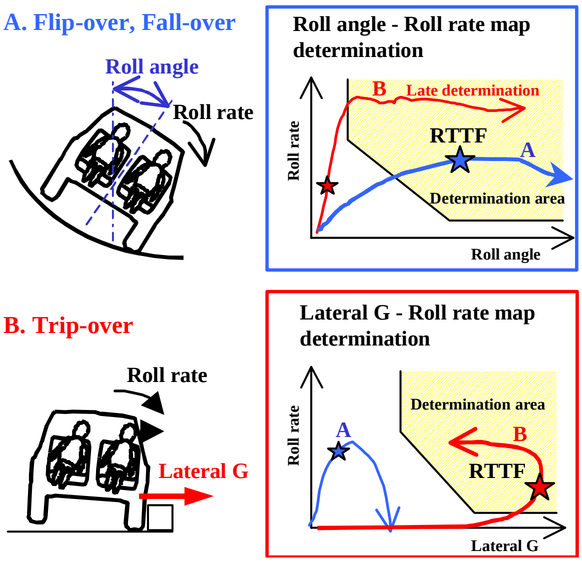

Figure 12. Characteristics of various rollover tests and rollover sensing algorithm

CONFIRMATION OF EFFECT

Confirmation tests included the aforementioned curb trip-over test, sand pit trip-over test, flip-over test, and fall-over test. (Figure13~16)

Figure 13. Curb trip-over test result

Figure 14. Sand pit trip-over test result

Figure 15. Flip-over test result

Figure 16. Fall-over test result

In the tests, the sensor was able to sense rollover before RTTF, and subsequently, the right and left curtain shield airbags were deployed and the seat belt pretentioners of the driver and passenger seats were activated.

SUMMARY

A rollover curtain shield airbag system has been developed which is constituted by curtain shield airbags that reduce the possibility of ejection of occupants wearing seat belts in the compartment during rollover, and a rollover sensor. This system, however, has been designed based on the prerequisite that occupants wear seat belts, and that this is still fundamentally essential. It should also be noted that use of a seat belt is still the primary and most effective measure for reducing the likelihood of an occupant being ejected from a vehicle during rollover.

Moreover, this system revealed some cases in which deployment of the bags occurs when the occupant's head has moved almost all the way toward or already is against the door glass. This will be studied in the future.

This system has been installed on the TOYOTA Land Cruiser 100 and the LEXUS LX470 manufactured from around the summer of 2002.

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