A DEVELOPMENT OF PANORAMIC SUNROOF AIRBAG

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ABSTRACT

NHTSA released the Standard FMVSS No. 226 final rule in January 2011 for the protection of passenger from ejection through side windows during rollovers or side impact events. However there is no safety device to protecting the occupants from the roof ejection. Furthermore, the sunroof market size is increasing every year. For these reasons, the ejection to the roof is exposed to great danger. Therefore, in this study, the panoramic sunroof airbag was developed for the passenger protection from the ejection. Based on a vehicle rollover behaviour, the TTF and deployment times were derived. And the cushion structure was designed to prevent the ejection of passengers from a confined space within the roof.

INTRODUCTION

The sunroof has a market size of $4,924.5 million in 2015. And the average growth rate was projected to grow by 10.9 % by 2022.[1)] In particular, the growth rate in the premium automotive market in China, India, and Korea has become more pronounced.

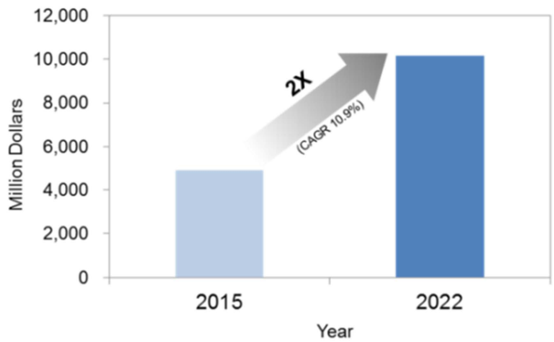
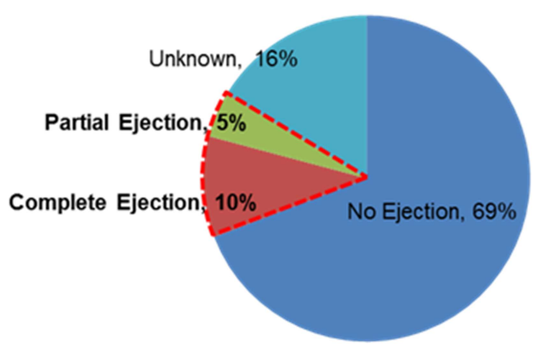


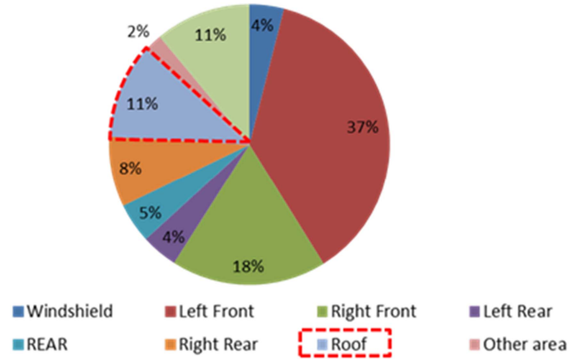
Figure 1. Global sunroof market size

Depending on these mounting rates, the proportion of the vehicles with the sunroof is gradually increasing, resulting in an increase in the number of accidents driven by the sunroof.
According to NASS-CDS data[2)] analysis in 2000 to 2015, the total accidents caused by ejections from the overall crash rate are 15%, and the departure of the roof is up to 11%. In case of panoramic sunroof, there is mush higher risk in the ejection than conventional sunroof cause of its larger size of the window.



(a) Ejection in rollover

In the case of the ejection through the it side window, the regulation of the FMVSS No. 226 is protected, but there is no safety device to protecting the occupants from the roof ejection. Thus, the ejection to the roof is exposed to great danger. To identify these risks, NHTSA conducted an evaluation of the risk of occupant ejection from the sunroof.[3)] As a result, there is a very high level of ejection in the center and border of the panoramic sunroof.



(b) Ejection area in rollover

Figure 2. Ejection in rollover (NASS-CDS 2000 to 2015)

Futhermore, the roof is exposed to a very high degree of risk when it has no protection against any rollover incidents in the event of a field crash. Heudorfer et al. had conducted research the airbag which is installed and deployed from the vehicle seatback.[4)] And airbags are positioned between the passenger's head and ceiling, reducing the injuries both head and neck. However, due to the structural limitations of the cushion, it was not possible to fulfil the role of the occupants from the ejection of the passengers.
In this study, we developed the panoramic sunroof airbag that protects the passenger from the ejection, which increasing risk of accidents with continuously growth of mounting rates. Based on a vehicle rollover behaviour, TTF and deployment times were derived. A cushion structure was designed to prevent the ejection of passengers from a confined space within the roof.

MODULE DESIGN CONCEPT

The panoramic sunroof airbag is an integral structure that is mounted on the rear of the inside panoramic sunroof panel and is deployed from the rear to the front. In Figure 3, the airbag module consists of an inflator, cushion, mounting bracket, cover and deployment guider, and the deployment guiders are a bar-shaped steel structure with the moved mounting tabs along it. In addition, the mounting tab has plurality of the steel annular sturctures, and the mounting tabs are slid along guider. In this case, the deployment guiders play a role that the panoramic sunroof airbag can be deployed smoothly to the front in full deployment and at the same time controls the upward or downward movement of the cushion in the full deployment, thereby preventing occupant ejection because of the coverage of cushion. The concept of full deployed cushion is deployed inside the panoramic sunroof as shown in Figure 4, and is positioned between the roll blind and panoramic sunroof glass to prevent the occupant ejection. Moreover, the zigzag folding was applied to induce the sequential deployment of the cushion and to reduce the friction between the roll blind and the panoramic sunroof glass. In the present study, three types of cushion patterns were proposed as follow. Figure 5 shows each cushion pattern.

(a) Parallel chamber type

During the deployment, the gas can be rapidly distributed from the diffuser to each horizontality chamber.

(b) Edge chamber type

During the deployment, gas is flowed from the diffuser into the left/right outter chambers to induce rapid coverage.

(c) Dual step chamber type

It is concept that 1st row chamber is deployed after 2nd row chamber is fully deployed. The 1st row chamber and 2nd row chamber are independently separated from center pillar of the panoramic sun roof to avoid interference with the center pillar of the panormic sun roof.

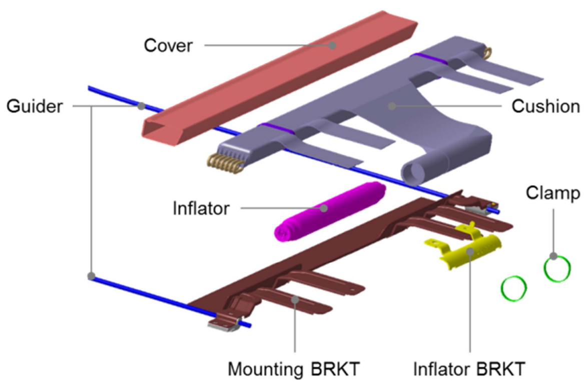


Figure 3. Panoramic sunroof airbag module

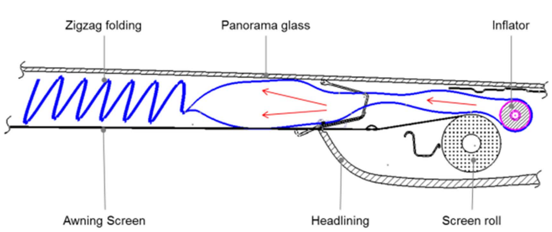
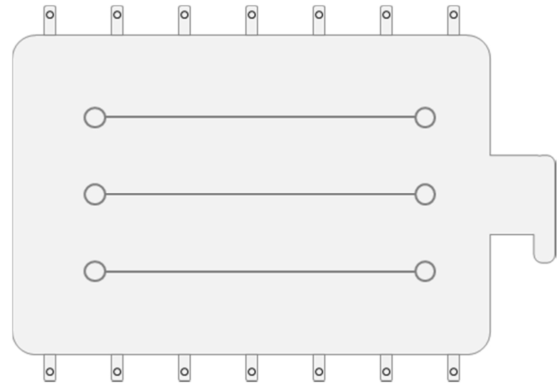
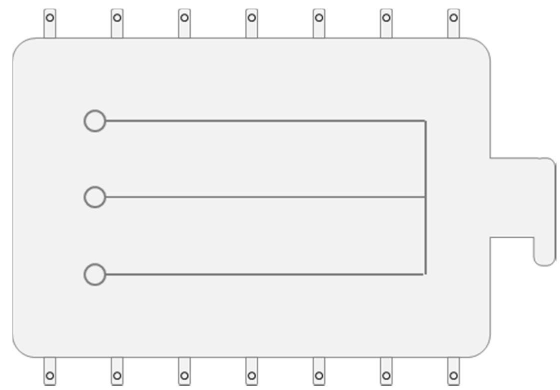


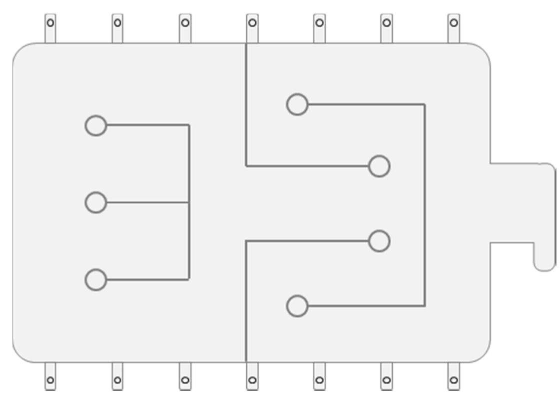
Figure 4. Panoramic sunroof airbag concept



(a) Parallel chamber type



(b) Edge chamber type



(c) Dual step chamber type

Figure 5. Panoramic sunroof airbag cushion pattern

DEPLOYMENT CHARACTERRISTIC

TTF and deployment time

In this study, the TTF and depolyment time was set according to the movement of dummy to the roof area at the rollover test (Test No. 6088) by NHTSA which the test mode was the unbelted condition of FMVSS No. 208 Dolly rollover.[5)] In this test, the driver dummy was moved to the roof area at 90ms after the full deployed time of curtain airbag. Therefore, the TTF was set by the full deployed time of the curtain airbag. And, the deployment time was set by 60ms in consideration of the marginal time about 30ms due to the movement the driver dummy to the roof area.

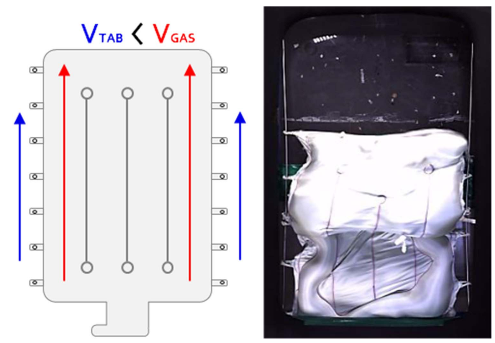
Cushion patterns

The static deployment test was performed to observe the deployment characterictics according to the proposed 3 cushion patterns. In the tests, to reflect the real world accident situation, airbag modules are installed in the panoramic sunroof system which is under mass production.

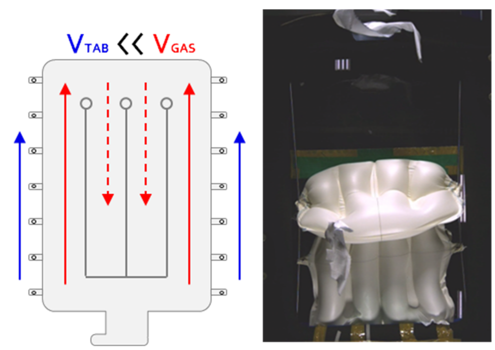
Figure 6 (a), (b), (c) shows the deployment test results of proposed 3 cushion concepts, respectively. In Figure 6 (a), parallel chamber concept is shown to be deployed abnormally due to an interception between the center pillar of the panoramic sun roof and the airbag cushion. As mentioned above, the gas flow uniformly to each chamber from rearward to forward direction. However, the tab velocity V_{TAB} is slower than the gas velocity V_{GAS} because of the friction induced between the tab and the guider pipe. It is observed that this velocity difference between the V_{GAS} and V_{TAB} result in the cushion to be twisted during its deployment.

Similar trend is also observed in the edge chamber concept as shown in figure 6 (b). In case of edge chamber concept, the speed of V_{TAB} is expected to be increased since the gas initially flow to the edge of the panoramic roof airbag cushion. However, still the gas velocity V_{GAS} is somehow larger than the tab velocity V_{TAB} and therefore the airbag cushion is twisted during the deployment. The only difference is that the time when the cushion be twisted is delayed compare to parallel chamber concept.

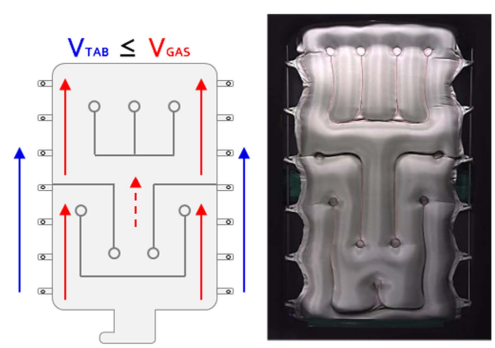
Figure 6 (c) shows the deployment test result of the dual step chamber concept. In the figure, it is shown that the cushion deploy normally without twisting and satisfy the coverage requirement to protect the occupants. Actually, in the dual step chamber concept, the gas velocity V_{GAS} should be very similar compare to edge chamber concept at initial stage since it flows gas to the edge of the airbag cushion together with the edge chamber concept. However, as mentioned, there exists an gas delaying region at the center of the airbag cushion in the dual step chamber concept. Therefore, the average of the V_{GAS} should be much slower than that of the previous proposed concepts and finally the gas velocity V_{GAS} and the tab velocity V_{TAB} become almost equal.



(a) Parallel chamber type



(b) Edge Chamber Type



(c) Dual step chamber type

Figure 6. Deployment test result of component level

Among the proposed cushion patterns, the dual step chamber pattern was finally chosen since it showed stable and robust deployment performance. The full deployment time of the chosen dual step chamber time was 70ms but the full deployment time of the airbag which seems to be insufficient to protect the occupant at proper time. As previously stated about deploymnet time, the airbag should be deployed within 60ms. An effort to increase the airbag deployment speed was needed for the completeness of the product. Therefore, the design concept of the tab was modified. The material of the tab was changed as steel material on behalf of previous fabric material (See Figure 6). The time for full deployment was reduced from 70 to 60 ms when adopting steel tab to the developed airbag system.

Deployment characteristic : System level

Additional tests were performed in order to guarantee the robust deployment characteristic in the real-world conditions. In general, awning screen is installed inside the panoramic sunroof device. It is easily expected that the position of the screens could affect the deployment characteristics of the panoramic sunroof airbag in the real-world rollover situation. Therefore, additional deployment tests were performed for the rigorous validation of the proposed airbag concept. The tests were performed in real vehicle level including all related parts of the panoramic sunroof devices.

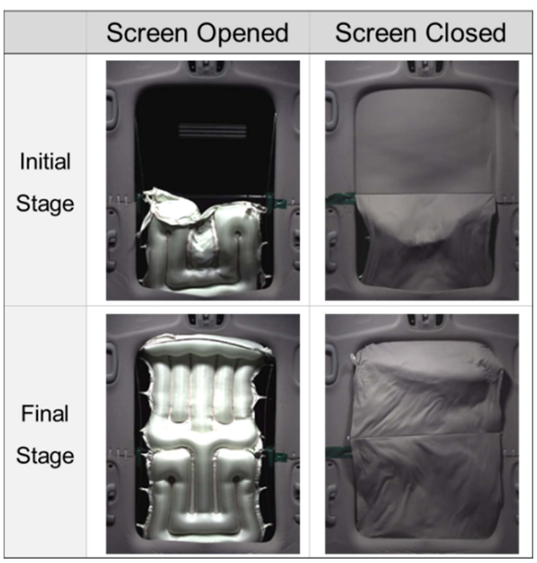


Figure 7. Deployment test result of System level

Figure 7 shows the test results. In the Figure 7, it is shown that the airbag deployed stably for both the screen-opened/closed conditions. However, time for full deployment is slightly increased in the closed conition. The tests were also performed in other conditions such as half closed condition and for all the cases the panoramic sunroof airbag deployed properly.

EJECTION MITIGATION TEST RESULT

In this study, the ejection mitigation(EJM) test of the panoramic sunroof was evaluated on NHTSA roof ejection research which was announced in 2016 SAE[3)] and FMVSS No.226[6)] which the curtain airbag is evaluated for the prvention of occupant regarding the occupant protection in a rollover accident. As shown in Figure 8, the impacted target was selected as 2 point by 1 point of the corner area and center area, which are expected to have high possibility of the ejection. The impactor weight is 18kg, time is 1.5sec, and the speed is set as 20kph.
The ejection mitigation evaluation of panoramic sunroof proceeded the dual stage chamber type cushion which is guaranteed. As shown in Figure 9 and 10, the corner area was 20% higher than the excursion value of the MOBIS standard due to the lack of thickness and absence of the support member, and the center area which has an additional hinge effect is 80% higher than the excursion value of the corner area.

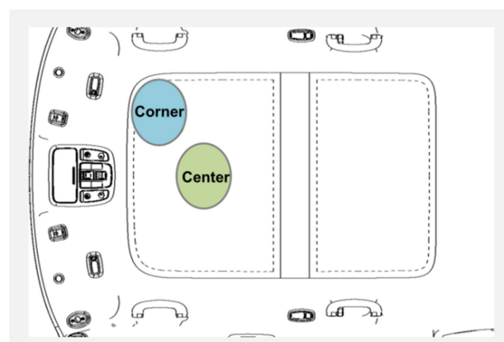


Figure 8. EJM test target positions

In this study, in order to solve excessive excursion value, the concept of the double cushion structure was applied to this issue as shown in Figure 11. The upper and lower cushion chamber patterns were designed to be orthogonal to each other in order to increase the thickness of the cushion and alleviate the reduction of the bending according to the hinge.
As shown in Figure 12, the evaluation result of the improved cushion improved 15% at the corner area and 90% at the center area compared with the primary evaluation, and it achieved similar performance to the curtain airbag of the current mass production level. The reason for the lack of improvement in the corner area compared with the center area is that the cushion thickness is increased but the support member with the correlation

componets is insufficient. Therefore, the double cushion structure added supporting chamber like tongue shape. This shape will be supported on headlining which area is front vehicle part for the reduction excursion value of corner area as shown in Figure 13. The verification of this improved cushion will be performed within the first half of this year.

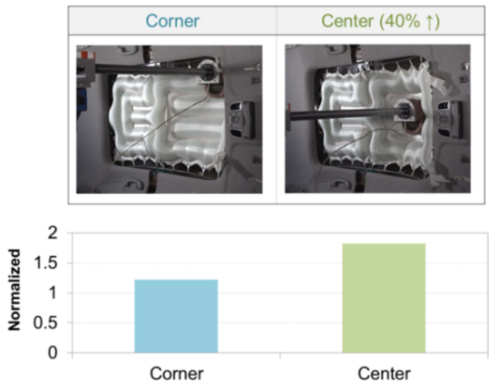


Figure 9. EJM result of dual step chamber cushion type

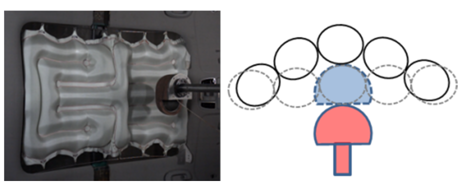


Figure 10. Cause analysis about excessive value

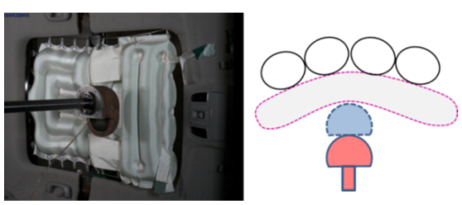


Figure 11. Improved cushion type for EJM

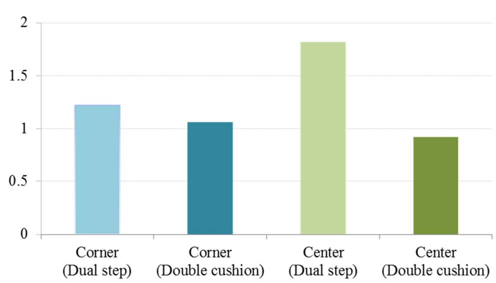


Figure 12. EJM result of double cushion structure type

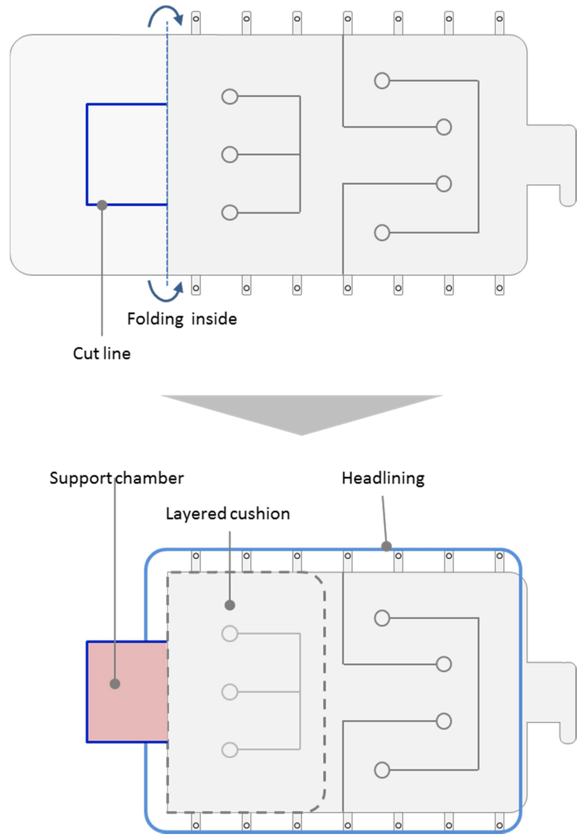


Figure 13. Additional improved type about double cushion structure for EJM

CONCLUSIONS

In this study, the panoramic roof airbag was developed to protect from the occupant ejection to the panoramic sunroof, which is highly dangerous in the field due to the increase of installation rate. The package and performance were developed on the basis of the current product of the panoramic sunroof module, and the conclusions are as follows.

1) The panoramic sunroof airbag was designed as an integrataed mounting module inside the panoramic sunroof module, that is deployed from the rear to the front along the development wire type guider.
2) The optimum cushion pattern was selected through the deployment test and also evaluated the worst condition that was the screen-closed. Through this, the robustness of selected optimum cushion pattern is secured.
3) In order to develop the ejection mitigation performance, the double cushion structure type of delay cushion type was applied to the optimum cushion type to secure the performance of the present level of curtain airbag.

4) In the future, the study will be performed on an improvement of the ejection mitigation performance with applying a cushion of the overlap structure to the headlining edge of the front.
5) When the panoramic roof airbag is applied, it is necessary to set up the test procedure and the test specification standard about the ejection mitigation through the study of the occupant ejection from the panoramic sunroof.

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