The Development of Two panel Tucked Shape Passenger Airbag

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Paper Number 13-0358

ABSTRACT

Nowadays the most rising issues in the airbag industry are production cost and assemblability. Many car makers are considering applying low cost passenger airbag to their vehicle. In this paper, the inverse 'Ω' shape two panel passenger airbag was suggested to have cost competitiveness and good safety performance. The Sewing pattern that makes inverse 'Ω' shape, increases cushion depth and protects passenger more safely. This paper will introduce the advantages of the developed two panel passenger airbag and describe the superiorities of its performance through dynamic test results.

INTRODUCTION

As the installation of *PAB*(Passenger AirBag) has become mandatory, the developing airbag at low costs is getting more important. Therefore, in many other markets exept for the zone which puts relatively strict legal regulations depending on the regions, the specialized airbag with the low volume inflator and simple cushion is being widely used, achieving the cost competitiveness.

Figure 1. shows the application of the two panel *PAB* on *EURO-NCAP* official test vehicles. As of 2006, more than 60 percent of vehicles were installed with the two panel *PAB*, which makes it more important to apply more optimized and competitive two panel.

A typical *PAB* module, like shown on *Figure 2(a)*, consists of an inflator that produces gas, cushion that protects passengers, housing that stores the folded cushion and retainer that holds the inflator.

The current three panel *PAB* cushion, shown in *Figure 2(b)*, has two side panels and one main panel, which provides depth to protect passengers. But with its high costs and poor assembility, there has been an increasing need for a simple structured cushion. The two panel *PAB* cushion is produced with two panels, upper and lower one, which is a small structure that lightens an inflator and housing. This study intends to propose a more optimized structure by applying *TRIZ* tool to improve the current two panel *PAB*. Furthermore, it intends to prove the quality of a developed item with a collision simulation and dynamic test.

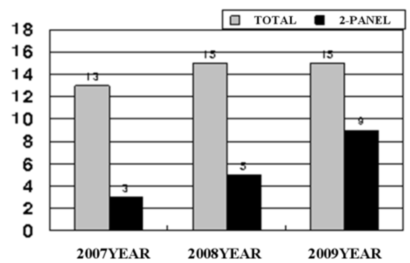
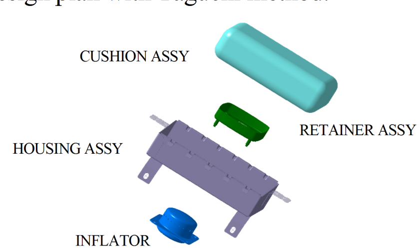


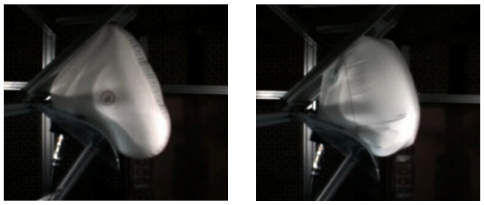
Figure1. Application of two panel *PAB* on *EURO-NCAP* test vehicles

TRIZ is the problem solving tool developed by Altshuller in 1964. Studies utilizing *TRIZ* tool are increasing today, and An Youngjun and his fellow researchers has described *TRIZ* as a concept design tool for an engineering application.

For the airbag collision simulation, Han Soonhong and other researchers in charge of an optimized airbag design, conducted a collision simulation with orthogonal array table and the parameter method that obtains an approximated solution by systemically changing design variables and proposed an optimized airbag design plan with Taguchi method.



(a) Component of *PAB*



(b)Three-Panel (c) Two-Panel

Figure 2. *PAB* component parts and cushion shape

CONCEPTUAL DEVELOPMENT

Determining a Concept for the Two panel tucked cushion

For the two panel to achieve the same or better quality than that of the current three panel, a new and detailed design needs to be adopted. *Table 1* illustrates the three panel *PAB*, two panel *PAB* and two panel tucked structure *PAB* proposed in this study. The two panel cushion has its limit in protecting passengers to the level of three panel cushion due to its low deploying depth. What is more, the two panel has an excellent assembility and low production costs, but does not provide adequate depth to protect passengers. To efficiently protect passengers, a frontal depth should be thick enough with adequate volume that suits the two-panel structure. To find an ideal final result, *TRIZ* theory has been adopted in this study. The basic two panel is one of the most basic concepts that are widely used at *DAB*(Driver Air Bag) and *SAB*(side airbag). For all its low unit price and excellent package, it is not suitable for a two panel *PAB* model as it is challenged by its technology limit. As a solution, the two panel tucked structure has been newly introduced. It is a tool to overcome the frontal depth limit, which gives an enough depth and reduced volume. Genrich Saulovich Altshuller's 40 principles have been used in this. *Table 2* shows the main problem solving factors to overcome the technology limit of the two panel. The item 4, 7, 16 of the *TRIZ* 40 principles were used at the two panel tucked structure development. *Table 3* shows the tucked structure of the two panel cushion as a solution for expanding the deploying depth. The tucked structure is the two-panel structure before folding process, but when deployed, it expands to the three-panel structure by adding an inverse Ω structure to the front panel.

Table 1
Main solution factor

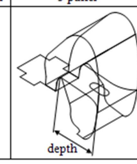
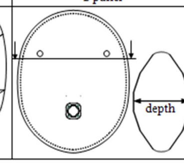
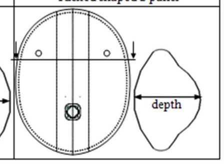
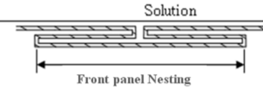
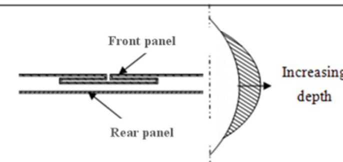
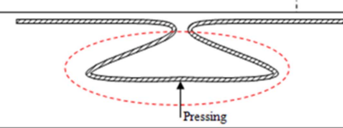
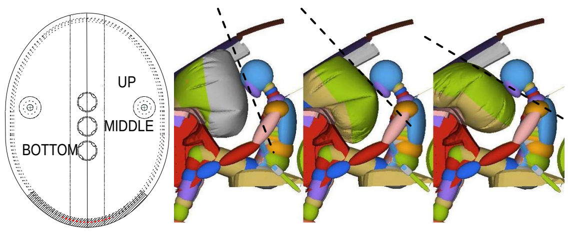
Classification	3 panel	2 panel	Tucked shaped 2 panel
shape			

Table 2
The concept for increasing the deploying depth

Classification	Solution
Nesting	
Asymmetry	
Partila or Exessive	

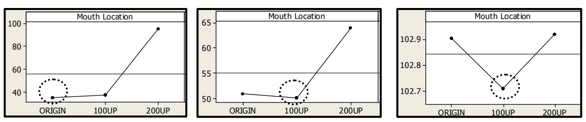
Determining the Best design through the analysis

The most critical aspect of this study is the deploying shape of the two panel tucked structure and the resulting level of injury. *Figure 3*. shows the deploying example after analyzing *EURO-NCAP* mode. In this analysis, the structure's tucked amount and vent size were fixed with the location of the mouth, into which gas is entered, varied. *Figure 3(b)* is the deploying shape of the two panel *PAB* that the mouth is located at the bottom. *Figure 3(c) and 3(d)* are the deploying shapes as the mouth was moved by 100mm from the original location at the bottom. Further analysis was conducted by varying the tucked amount by 100mm, 140mm and 180mm, and the vent size by 15mm, 25mm and 35mm. The *EURO-NCAP* dynamic analysis was conducted by varying the level of factors. Here, the noise also was considered by selecting vehicles that represent Compact, Midsize and SUV which are currently in mass production. This system also includes Smaller the Better Characteristics as it is advantageous to have a low injury level from the viewpoint of the robust design strategy.

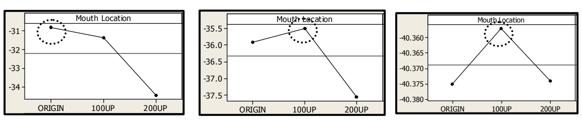


(a)Location (b) Bottom (c) Middle (d) Upper

Figure 3. Analysis result according to the mouth locations.

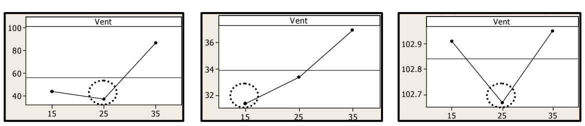


(a) HIC36(Mean) (b) Neck EXT(Mean) (c) Chest CD(Mean)

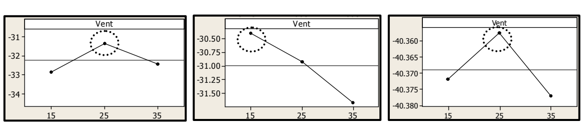


(d) HIC36(S/N) (e) Neck EXT(S/N) (f) Chest CD(S/N)

Figure 4. Analysis of the controlling factors(the mouth locatoin)



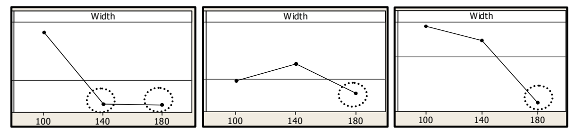
(a) HIC36(Mean) (b) Neck EXT(Mean) (c) Chest CD(Mean)



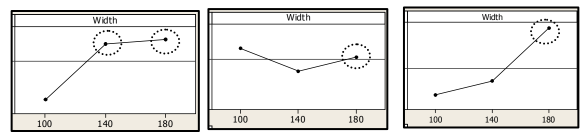
(d) HIC36(S/N) (e) Neck EXT(S/N) (f) Chest CD(S/N)

Figure 5. Analysis of the controlling factors (Vent diameter size(mm))

Figure 4., *Figure 5. and Figure 6*. show the Smaller the Better Characteristics results of the analysis for an optimized design. Generally, the ouput was the most robustic when the mouth was located at bottom (origin) or 100mm up and theirfore requires an appropriate tunnig according to vehicle types. And the analysis output showed the lowest level of injury when the diameter of the vent was somewhere betwen 15mm and 25mm. Meanwhile, the robustness level was the highest when the tucked amount was somewhere between 140mm and 180mm. In this analysis, the mount location up by 100mm, Φ15mm of the vent size and 140mm of the tucked amount for the Sled test were chosen, taking the test vehicle layout into account.



(a) HIC36(Mean) (b) Neck EXT(Mean) (c) Chest CD(Mean)



(d) HIC36(S/N) (e) Neck EXT(S/N) (f) Chest CD(S/N)

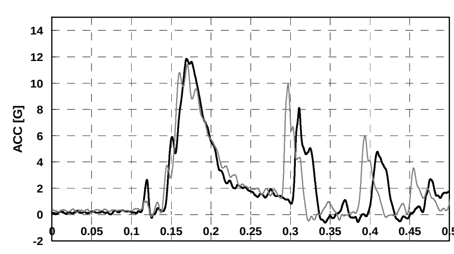
Figure 6. Analysis of the controlling factors (the tucked amount (mm))

CONCEPT EVALUATION

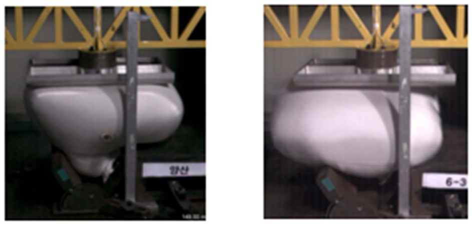
Sled test Result

The vent specification, the criteria for the Sled, was chosen after verification through the *DROP* tower test shown in *figure 7*. and the optimum analysis results. The black solid line in *Figure 7(a)* is the acceleration data of the three-panel drop and gray solid line is the acceleration data of the two-panel drop. *Figure 7(b) and (c)* are the illustrations of the drop tests conducted under the same condition (three8kgf, 19.6kph).

In this study, some relevant factors are reviewed and the collision performance proving test with the two panel *PAB* was conducted by utilizing the Taguchi method.



(a) test acceleration



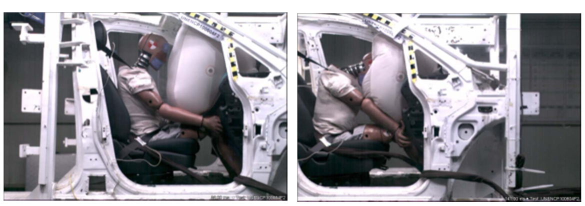
(b)3-panel(50ms) (c)2-panel(50ms)

Figure 7. drop tower test results

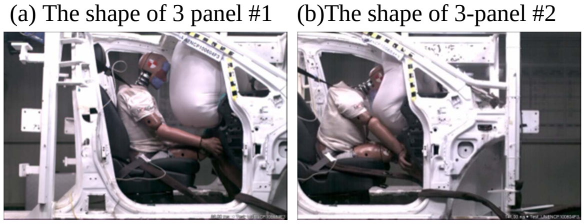
The main collision modes are *EURO-NCAP* offset frontal crash test (64kph) to evaluate injury at the passenger seat, the tree panel *PAB* of mass produced compact SUV vehicle, which has been the target of review. Other relevant parts except for the cushion have the same specification as the mass produced ones.

Figure 8. shows general deploying features of the three panel and two panel. The three panel cushion in *Figure 8*(a) and (b) deploys as a form of main side panel to protect the upper body of a passenger, and it's lower cushion gives enough protection to the chest. At the lower part of the chest, chest deflection or chest viscous, caused by the pressure of the seat belt and cushion, occur a lot.

In contrast, the two panel, as shown in *figure 8(c) and (d)*, protects a head and neck rather than chest, separating the restraining force of the belt and airbag, which minimize a passenger's upper body injury.



(a) The shape of 3 panel #1 (b)The shape of 3-panel #2



(c) The shape of the 2 panel #1 (d) The shape of 2 panel #2

Figure 8. The deploying comparison of the three and two panel *PAB*

Sled test Results Analysis

Table 3 shows the results of the *EURO-NCAP* three-panel Correlation Sled test and two-panel tucked structure Sled test. Airbag is a safety device that protects mainly the upper body of passengers and injuries on head, neck and chest are the most critical evaluation criteria. *Table 3* shows that occurrence of injuries decreased when the two-panel *PAB* was used, compared to the specification for mass production. In particular, the specification for mass production scored 3.2 points with 28.0mm at the injury evaluation, but the new two-panel model earned the perfect score with 4.0 and 22.1mm. This was possible due to the fact that the two-panel cushion came in contact with part of the head first, rested the head early, reducing chest injuries with the restraining force puts by the belt load only.

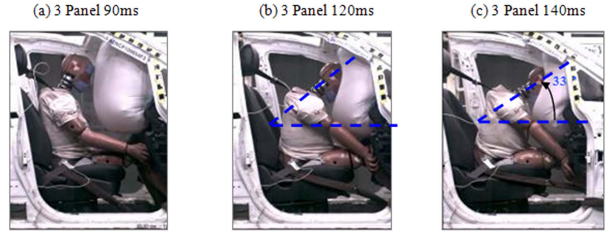
Table 3

***EURO-NCAP* vehicle and Sled injury**

UPPER BODY			3-PANEL (CORR.)	2-PANEL (SLED)	BELT
EURO-NCAP	HEAD	HIC36	127 (4.0)	100 (4.0)	SLL
		3ms G	28.3 (4.0)	24.5 (4.0)	
	NECK	Shear (N)	610 (4.0)	340 (4.0)	
		Tension (N)	984 (4.0)	525 (4.0)	
		EXT(Nm)	5.7 (4.0)	4.9 (4.0)	
	CHEST	C (mm)	28.0 (3.2)	22.1 (4.0)	
		V*C (m/s)	0.0 (4.0)	0.0 (4.0)	

Figure 9. shows that a passenger's head and neck are bent by 29° and 33°, smaller than the angle in the mass produced three-panel specification. It is considered that the overall injury performance enhanced thanks to the low load on the chest and the smaller bending angle on the head and neck.

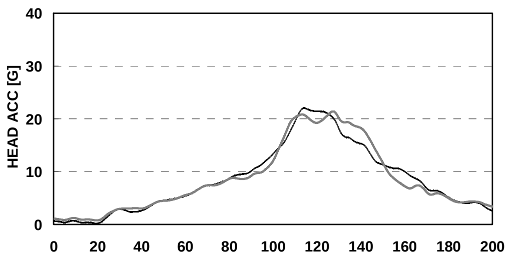
(a) 3 Panel 90ms (b) 3 Panel 120ms (c) 3 Panel 140ms



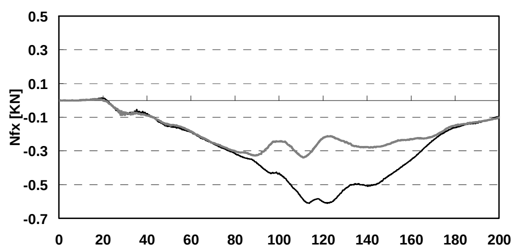
(d) 2 Panel 90ms (e) 2 Panel 120ms (f) 2 Panel 140ms

Figure 9. The deploying comparison of the Sled test.

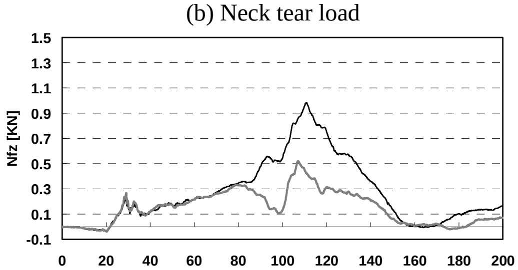
Figure 10. shows the results of the barrier test and injury graphs of the 64kph *EURO-NCAP* Sled test. The thick black solid line indicates the injury level of the mass produced vehicle, and grey is of the tucked two-panel Sled test. *Figure 10 (a)* show head injury characteristics of the 64kph *EURO-NCAP*. When the two-panel is applied, the head accelerations are distributed at low levels. *Figure 10 (b), (c) and (d)* show neck injury characteristics and *Figure 10 (e) and (f)* show chest injury characteristics. It is shown that the head and neck rotaition are lower than 3-panel cushion when the 2-panel is used.



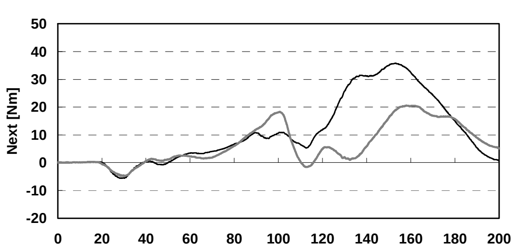
(a) Head acceleration X



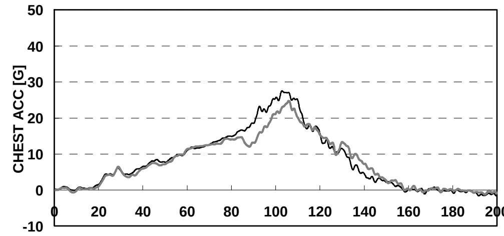
(b) Neck tear load



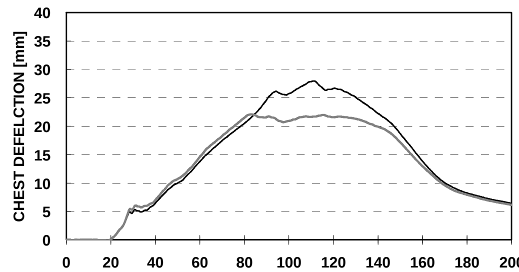
(c) Neck tension load



(d) Neck extension



(e) Chest acceleration X



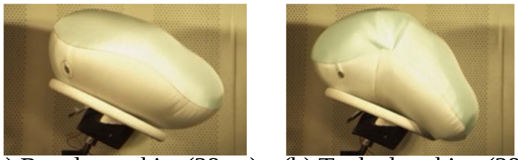
(f) Chest deflection X

Figure 10. The analysis of 64kph *EURO-NCAP* injury graph

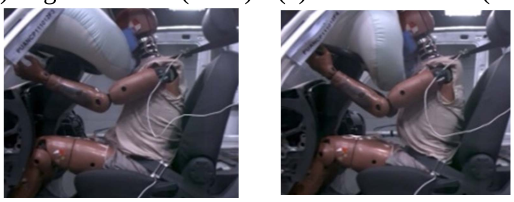
The load on chest was also reduced by lowering the load of pressure to chest. In addition, the vent sizes of the mass production specification and the two-panel were Φ25 and Φ15 respectively .

Application Examples of the Two-panel tucked structure

The commercial vehicle has its limit in protecting driver passenger as its steering wheel angle is larger than that of the regular passenger car or van. Furthermore, there has been no airbag developed so far that considers the layout feature of the commercial vehicle, leaving no choice but to install the airbag used in the current passenger/*RV* car. In this case, however, as the airbag deploys parallel to the steering wheel due to its installation angle, making it impossible to protect the upper body of a driver. Plus, the cushion gets stuck at throat, increasing the likelihood of chest or neck injuries. The tucked structure can solve this problem with an expanded upper deploying depth, which enables the early restraining of a driver's head and with lower part of cushion deploying to the area between the driver's chest and steering wheel, minimizing the driver's injury. Figure 11. Shows deploying features of specialized commercial vehicle *DAB*.



(a) Regular cushion(38ms) (b) Tucked cushion (38ms)



(c) Regular cushion (d) The tucked cushion

Figure 11. The deploying comparison of the static and dynamic test.

Unlike a passenger car/ban, the commercial vehicle has the middle seat, making it necessary to protect a passenger in the middle. In this type of vehicle, other components such as an audio are placed at the center fascia. Therefore, the protection area covered by the current airbag modules on each side should be expanded to protect a passenger in the middle as well. In addition, the tucked structure with an expanded deploying depth is used to cover possible injuries at the passenger seats. The protection area and the injury levels can be controlled by focusing on head protection for the middle passenger while keeping a similar protection performance to the current 3D cushion airbag for the passenger. Here, the air bag is developed in a way that only a passenger head is protected by minimizing passenger movement with the application of ELR(Emergency Locking Retractor) belt for the middle seat while sistemically satisfying the target performance to the level of the current passenger seat with Pre-Tensioner seat belt. Figure 12. Shows deploying analysis features of specialized commercial vehicle *PAB*.

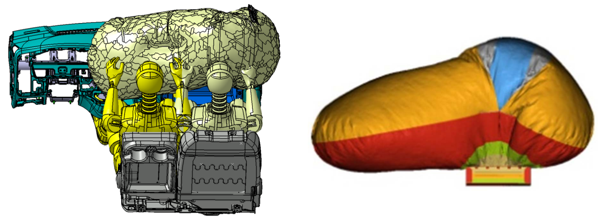


Figure 12. The expanded shape of the tucked structure

CONCLUSIONS

In this study, the main concept was determined for the two-panel tucked structure and the advantages of the determined model compared to the three-panel were analyzed through the comparison of the package, assembility and production costs. Moreover, the study proved the excellent collision performance of the two-panel *PAB* through the analysis of the current mass production barrier test and the two-panel Sled test results, reaching the conclusion as follows:

1) The technology limit has been overcome by the *TRIZ* problem solving method.
2) The robustness according to each factor and noise has been evaluated by adopting the Taguchi Robust Design concept.
3) It is proven that the two-panel tucked *PAB* has same or higher protection ability than the three-panel airbag through the *EURO-NCAP* tests.
4) Through the application of the tucked shape cushion, showed the possibiliy of new concept model airbags.

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