Inflator Performance Optimization with New PAB Concept for OMDB, LRD

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ABSTRACT

A new crash mode will be introduced in the North American market
If the existing 56kph frontal crashworthiness was one of the most important challenges for the manufacturer, the 90kph 15 ° inclined 35% overlap collision is an issue in the future. Major injuries that occurred during frontal collision were head acceleration and neck injury, while in new mode, head rotation and neck injury were major injuries. This is to protect passengers in actual crash mode based on actual accident investigation.

In addition to the new crash mode, the use of new mode makes it difficult to satisfy passenger injuries with the characteristics of existing airbags. Accordingly, various tasks are being performed by the manufacturers of passive safety systems. Especially, the pressure and performance of PAB are very important because the THOR dummy located in RH side is greatly influenced by PAB performance. In this paper, we analyze the passenger Movement of the RH side and improve the injury through the airbag performance. The thor dummy of the far side is of interest in the left-leaning collision.

Plus, North America regulations must also satisfy LRD testing with the same inflator and cushion.
In this paper, I propose improvement of airbag which can satisfy both BRIC injury and LRD performance which are main items of OMDB crash test. Especially, we will seek improvement through the inflator optimization and new concept of cushion which is the most important factor of the passenger airbag

INTRODUCTION

In the new collision mode, the deformable barrier moves at 90 kph on the left side, causing a collision with the vehicle. Existing crash mode and passenger Movement are very different. To improve this, the design concept of the constraint device must be changed. As a result of the existing restraint system, the passenger injury target will not be met.

Main NCAP crash mode: 56 kph Full Frontal → 90KPH OMDB
Dummy change: HIII 5% → THOR
Head injury: HIC, NECK → BRIC

$$BrIC=\sqrt{(\max \omega x/\omega xC)^2+(\max \omega y/\omega yC)^2+(\max \omega z/\omega zC)^2} \quad \text{(Equation 1)}$$

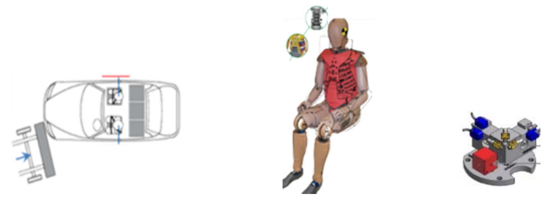

Figure 1. New Crash Mode (Vehicle&OMDB, Dummy, Sensor)

CRASH and LRD REQIREMENT

1) Rating method for OMDB

1-1) THOR 50% : HIC15 500, BRIC 0.71, Nij 0.39, Cd 37.9mm Less than full scale

- ▶ However, it is judged that Nij 0.39 is relatively easy to obtain by increasing CRITICAL VALUE when THOR 50% Nij calculation,
- ▶ +Fzc : 2520N->4200N, -Fzc : 3640N->6400N, +Myc : 48Nm->88.1Nm, -Myc : 72Nm->117Nm
- ▶ HIC Satisfaction value made easy

Below is the result of the new collision mode actual vehicle with the existing restraint system

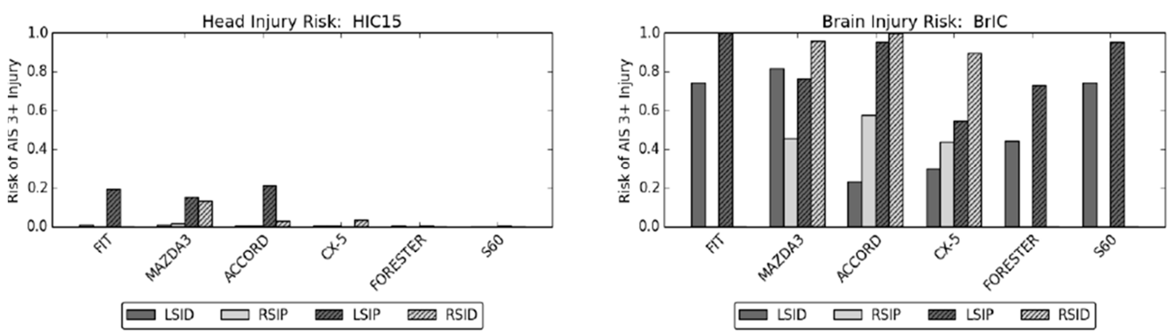

Figure 2. Crash Test Result (References to existing papers)

2) Regulation for LRD

2-1) Based on 6 Year

- ▶ HIC 700 / Nij 1 / Tension 1.49kN

The inflator pressure must be sufficient to meet the crash test performance and it is advantageous for the pressure to be low to satisfy the LRD test. As a result, collision performance and LRD performance can have conflicting inflator pressures.
Therefore, in North America, a dual-type inflator is generally applied and the 1st gas is used for the LRD evaluation. However since the 1st pressure is higher than the 2nd pressure, LRD venting technology is used because the inflator does not satisfy the performance.

In this paper, we will develop an inflator capable of satisfying both collision performance and LRD performance, and introduce PAB cushioning technology which can be advantageous for collision performance

As with other products, passive safety devices are also an important issue, and cost reduction and weight reduction are also important issues. It is also intended to prevent the application of cylinder inflator or increase in the number of inflator

Analysis

OMDB Vehicle Movement Analysis

In the existing North American front 56kph fixed wall test, the Delta V including rebounding is about 63-67kph Except in special cases. In the left side OMDB collision, the X-directional acceleration is about 50kph in Delta V at the RH side. However, lateral movement (Y direction) occurs and the vehicle moves with yawing in the Y direction. The characteristics of each vehicle vary, but the average of the five models is as follows.

The travel distance in the Y direction will vary from vehicle to vehicle, the vehicle was analyzed with an average approach. Analysis shows that the vehicle starts to move to 60ms. In other words, it can be seen that the passenger in the vehicle also starts moving in the Y direction with respect to the vehicle in 60 ms. In addition, a movement of about 400 mm occurs until 120 ms when passenger injury ends. In summary, the PAB is able to improve the BRIC injury by early restraining from the start of 60 ms and by controlling the lateral directional Movement of the passenger for a long time up to 120 ms

TABLE1. Y Direction Movement according to time

Time	60ms	70ms	80ms	90ms	100ms~120ms
Vehicle Movement	50mm	100mm	150mm	200mm	250mm~400mm

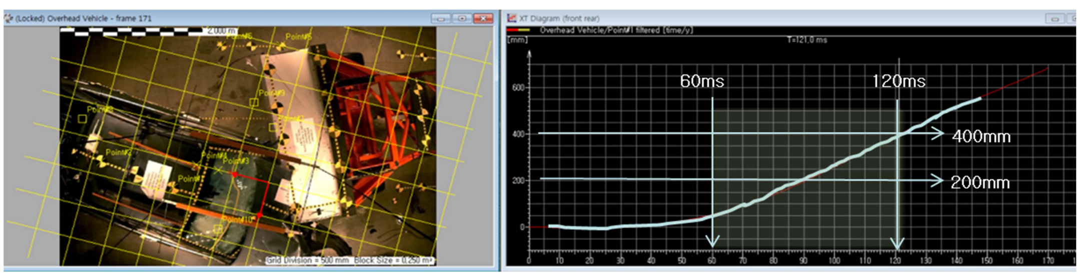

Figure 3. Vehicle Movement (Y Direction)

Passenger Injury and Movement Analysis

The Movement of passengers also depends on the Movement of the vehicle. Rebounding injuries are not taken into consideration, and injuries of passengers generally occur between 60 ms and 120 ms. At the 50ms, it was not easy to improve with the airbag, so the start time of the passenger injury was 60ms. This means that from the moment the vehicle travels in the Y direction by 50 mm in 60 ms, the airbag can limit the head Movement in the Y direction, thereby improving the BRIC injury. It is not easy to improve the Y-direction Movement in the existing airbag shape, and the volume increases in the Y direction or the X direction with respect to the existing airbag, and new technology is applied.

Passenger injury characteristics in LRD test

The results of analysis of the injury characteristics of the 5 - car model, 6 - year - old pile are as follows. In Head on IP mode, Neck Compression is the main cause of injury. In Chest on IP mode, Tension is the main cause of injury. Generally speaking, in Head on ip mode, the maximum injury time is usually 40ms before and Chest on IP occurs before 60ms. Since the 1st pressure characteristic and the cushion pressure are a very important part of the LRD performance, it is assumed that the early inflator characteristic is a key factor in improving the LRD performance

Method

In order to simultaneously improve collision response and LRD performance, the first thing we have done is optimizing the inflator. In order to satisfy the increased volume of the airbag cushion, optimization work was carried out to reduce the 1st inflation gas volume and increase the Full pressure (1^{st} + 2^{nd} Pressure)

In general, at the development stage, the inflator takes a long time to improve the performance, so the performance is improved in the cushion and the like. However, it is necessary to optimize the performance of the inflator from the beginning of development of the airbag system to strengthen the performance of the airbag.

First, the inflator was improved to fill the increased cushioning volume for collision response and improve the LRD performance as follows. It is considered that the performance effect can be improved by the simplest method.

In some cases, it may be argued that using of cylinder inflator or inflator increases due to the excessive volume of the cushion. In this paper, we will cover the contents to improve the performance of the inflator to prevent the application of cylinder inflator or increase in the number of inflator.

The 1st pressure is minimized to improve the LRD performance and to increase the Full pressure to increase the PAB cushion volume to improve the OMDB crash performance. In addition, we will introduce new cushioning technology to improve OMDB collision performance in the next section. The inflator optimization concept is shown in Figure 4 below. Simply put, I want to lower the 1st pressure as much as possible and the full pressure as much as possible. More specifically, the 1st pressure before 50 ms is lowered, and the 1st + 2nd pressure after 60 ms is higher.

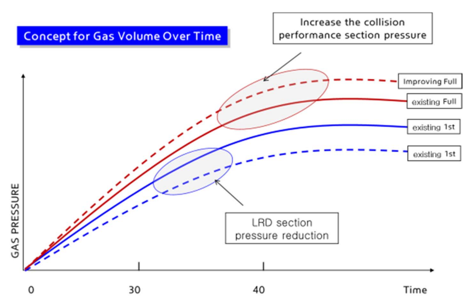

Figure 4. Gas Volume Concept Over Time

CAE Tank Test

The CAE was carried out to find the proper value of the 1st pressure by time. New # 1 and New # 2 values compared to existing mass production specifications. The New # 1 specification was targeted as a test to lower the 50ms upstream pressure which is most sensitive to LRD performance test. New # 2 specification did not go into production due to a problem with the actual inflator manufacturing. Considering the characteristics of inflator production, we set the pressure target as # 1.

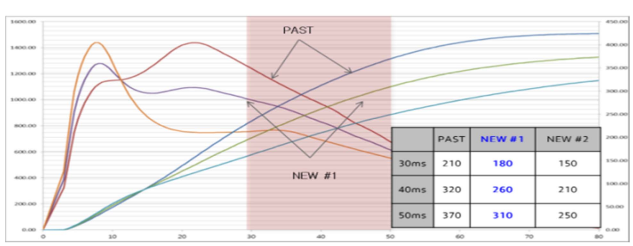

Figure 5. CAE Result for Inflator Pressure

LRD CAE TEST

The pressure of 370kpa was reduced to 310kpa on the basis of 50ms, and the LRD analysis test was performed according to the pressure, and the improvement effect was confirmed. The LRD vent was not applied in the test. It is in 6-year-old Chest on IP mode. The results of the LRD analysis test with the improved inflator are as follows. It can be confirmed that the LRD injury is improved by the pressure reduction.

TABLE 2.

LRD Test Result (CAE)

	HEAD	NECK						CHEST	
	HIC15	TEN.	COM.	Nte	Ntf	Nce	Ncf	3ms G	DIS.
Criteria	700	1.49	1.82	1	1	1	1	60	40
PAST	93.2	1.22	0.98	1.12	0.06	0.04	0.46	166.4	9
NEW #1	39	0.66	0.82	0.76	0.08	0.12	0.32	108.2	5.8
New #2	19.6	0.58	0.58	0.58	0.02	0.16	0.24	82.4	5

SLED CAE TEST

Based on development experience, the maximum pressure was aimed at 600kpa. Depending on the folding of the cushion, etc., it is based on the history of the company being developed or the history of other companies

- Existing inflator pressure: 450 ~ 500kpa & 100L
- Cylinder type or additional number) : 700kpa & 150L cushion
- Optimized inflator pressure: 600kpa & 120L cushion volume

The CAE test applied the new technology of cushion to inflator applying 600kpa pressure. PAB is a device that controls the lateral movement of the dummy by placing the chamber in the direction of the inboard. We were able to confirm the optimal volume and function of the chamber.

It was judged that the optimized inflator is suitable for 120L cushion and applied new technology. The main cushion is about 100L and the chamber is installed in the cushion to add 20L. The chamber has a vent that allows gas to pass through it, and it is a vent that keeps the pressure in the chamber closed when the vent is closed. The name was called the closed chamber. The structure is as follows.

It is a comparative test between Figure 6 applied a 5L chamber to a 100L cushion and Figure 7 applied a 10L chamber to a 100L main cushion. The results show that Wz value and BRIC are improved at 20L chamber.

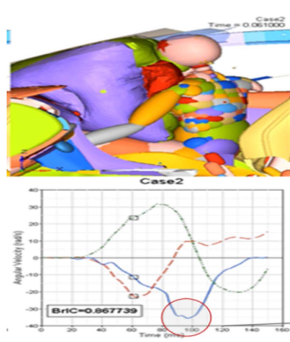

Figure 6. Small Chamber

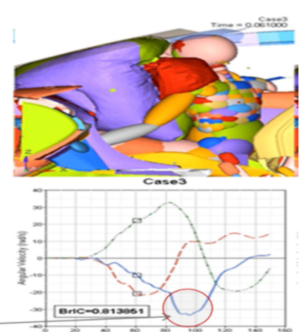

Figure 7. Big Chamber

Closing Vent Concept

The volume of the chamber increased by 20L and the test was performed by applying the new cushion technology.
First, I will briefly explain the new technology of cushioning. The chamber was attached to the existing PAB anterior cushion. The chamber on the inboard (LH) side is about 8L and restricts the movement of the passenger head in the inboard direction. In order to fill the internal pressure, a vent is present to inflate the chamber, and after the chamber swells, the vent is closed to maintain the internal pressure.

The concept of reducing the head rotation by preventing the left-ward(LH) movement of the passenger's head due to the high internal pressure of the chamber. There is also a 12L chamber on the outboard, which swells up through an open vent. It is a structure for early restraint of passengers. In some cases, 12L chamber on the outboard is possible to be deleted. The concept is shown in Figure 8. below.

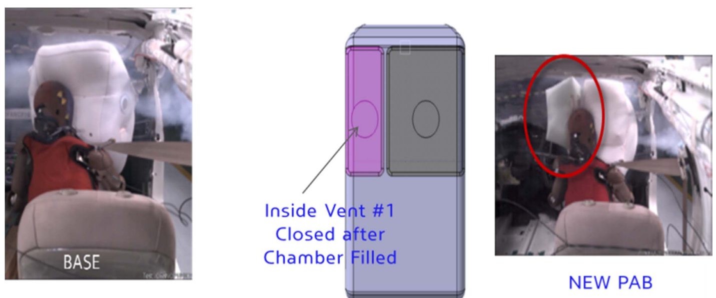

Figure 8. New PAB Concept

Inflator optimization

First, we set up 3 parameter for 1st pressure and five parameters for 1st + 2nd pressure optimization.
The amount of 1st gas to improve LRD performance was set as a factor of 1st Propellant, booster and diffuser. The amount of full(1st + 2nd) Propellant to improve OMDB was 1st Propellant amount, 2nd Propellant amount, booster, diffuser and TTF.
The parameter settings and levels are as follows. Noise factors are not covered in this paper, but deviations due to deviations between products, especially due to the characteristics of the explosives.

- 1st pressure: Mixing level (1 factor 4 level, 2 factor 2 level) _ large the better characteristics)
- Full pressure: Mixed level (1 factor 4 level, 1factor 3 level, 3 factor 2 level) _ the smaller the better characteristics)

TABLE 3.

Taguchi Method / L8 Orthogonal Array

Factors & Level

NO.	Propellant (1st)	Booster	Diffuser
1	1	1	1
2	1	2	2
3	2	1	1
4	2	2	2
5	3	1	2
6	3	2	1
7	4	1	2
8	4	2	1

No.	Propellant(1st)	Propellan(2nd)	Booster	Diffuser	TTF
1	1	1	1	1	1
2	1	1	2	2	2
3	2	2	1	1	2
4	2	2	2	2	1
5	3	3	1	2	1
6	3	3	2	1	2
7	4	3	1	2	2
8	4	3	2	1	1

The test was carried out with a 60L Tank machine. The 1st pressure was 285kpa based on 50ms similar to the optimal value of analysis. Full pressure resulted in 600kpa based on experience As mentioned earlier .

Table 4.

1st Gas Optimized Result (Left) / 1st + 2nd Gas Optimized Result (Right)

	Propellant (1st)	Booster	Diffuser	30ms	40ms	50ms
CAE Best		-		180	260	310
#1	1	1	1	228.75	307.5	367.5
#2	1	2	2	221.25	291.25	348.75
#3	2	1	1	207.5	273.75	327.5
#4	2	2	2	233.75	296.25	347.5
#5	3	1	2	203.75	247.5	285
#6	3	2	1	200	248.75	290
#7	4	1	2	211.25	255	288.75
#8	4	2	1	222.5	268.75	302.5

NO	Propellant(1st)	Propellant(2nd)	Booster	Diffuser	TTF	MAX Pressure
Target	-	-	-	-	-	600
#1	1	1	1	1	1	501.6
#2	1	1	2	2	2	495.6
#3	2	2	1	1	2	496.8
#4	2	2	2	2	1	516
#5	3	3	1	2	1	602.4
#6	3	3	2	1	2	601.2
#7	4	3	1	2	2	506.4
#8	4	3	2	1	1	532.8

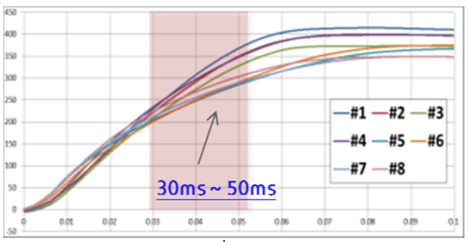

Figure 9. 1st Gas Graph

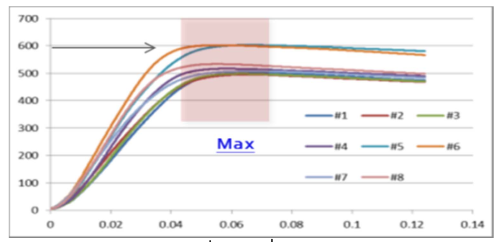

Figure 10. 1st + 2nd Gas Graph

The main influencing factor is the propellant, which is remarkable compared to other factors. See Figure 11~12 below. The final optimized graph is shown in Figure 13

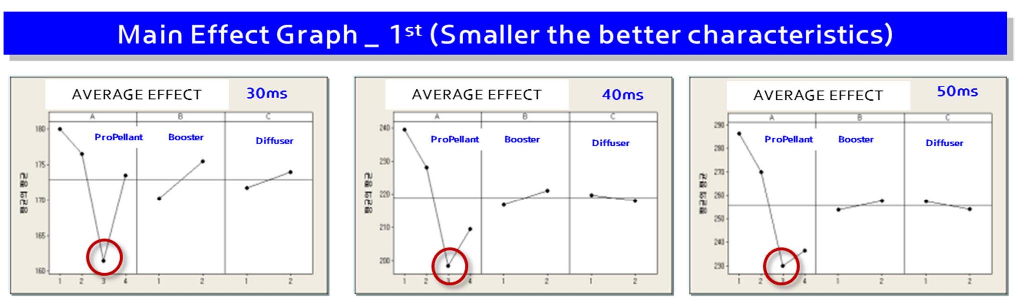

Figure 11. Main Effect for 1st Gas Pressure

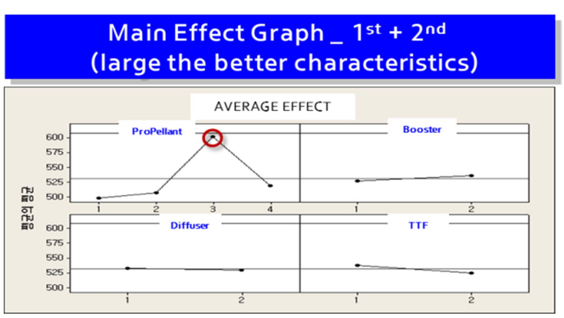

Figure 12. Main Effect for 1st + 2nd Gas Pressure

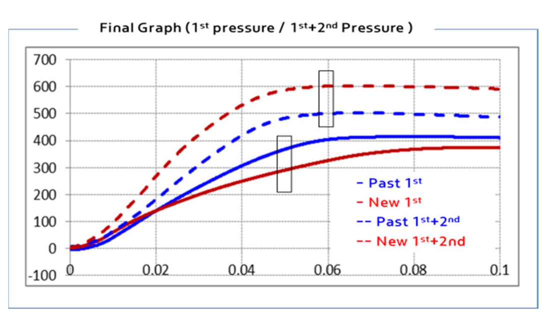

Figure 13. Final Graph

LRD VEHICLE TEST RESULT

LRD vents are in use by many companies. The best approach for airbags that can cause multiple deviations is judged to be a robust design that is insensitive to deviations. The test was conducted under the worst condition without applying the LRD vent, and the results were similar to those of the CAE evaluation. The inflator 1st pressure results were similar to the CAEl results. In the chest on ip mode, you can see that the tension Injury is greatly reduced, which is a test mode to demonstrate that the inflator pressure has been lowered.

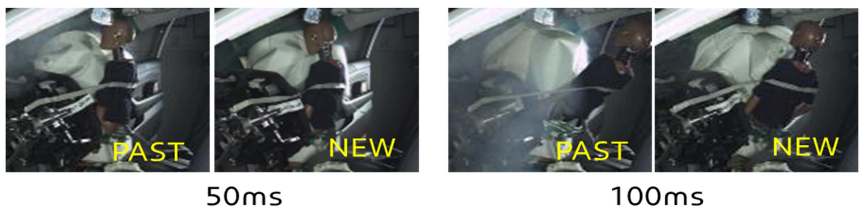

Figure 14. LRD Test View

Table 5.

LRD Test Result

Chest on IP	HEAD	NECK						CHEST	
	HIC15	TEN.	COM.	Nte	Ntf	Nce	Ncf	3ms G	DIS.
CRITERIA	700	1.49	1.82	1	1	1	1	60	40
PAST	43.8	1.29	0.05	1.29	0.38	0.01	0.04	23.9	23.8
NEW	12.8	0.61	0.05	0.66	0.18	0.01	0.03	12.6	8.7

Head on IP	HEAD	NECK						CHEST	
	HIC15	TEN.	COM.	Nte	Ntf	Nce	Ncf	3ms G	DIS.
CRITERIA	700	1.49	1.82	1	1	1	1	60	40
PAST	30.9	0.21	1.11	0.01	0.27	0.39	0.67	10.6	2.9
NEW	2.70	0.07	0.51	0.01	0.00	0.23	0.32	4.7	0.3

Sled Final Test Results with New Inflator and New PAB

A sled test was conducted using an improved inflator and a new PAB concept. For comparison with existing products, chambers were applied to the cushion shape of existing products and tested.
The collision pulse and vehicle movement of existing similar vehicles were reproduced.
BRIC injuries start at 60ms, and after 120ms, no maximum occurred. It is possible to confirm that the head rotation is reduced by improving the movement of the head in the inboard direction (LH).
The results showed that the Wx and Wz injuries were improved and BRIC injuries were improved by about 0.32. Wy is not improved.

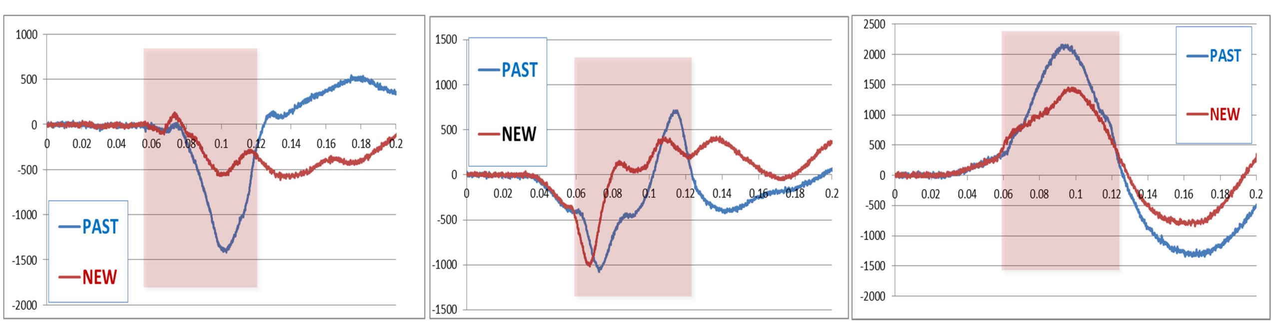

Figure 15. Sled Test Result Graph

Table 6.
Sled Test Result.

		BASE	NEW
Head	BrIC	1.00	0.68
	HIC_{15}	178.1	154.5
Neck	Nij	0.482	0.335

Figure 16. Sled Test View

Reference. Frontal Sled Test Result

New NCAP is subject to a frontal test with a 5% dummy. The difference with the existing test is that the seat track is moved backwards and the BRIC value is measured. The new inflator and the new cushion were applied and the results were as follows.

Table 7.
Sled Test Result (Frontal)

	PAB	Condition	Result					
			Head					Neck
			|Wx|	|Wy|	|Wz|	BrIC	HIC15	Nij
1	PAST	Foremost	667	1495	1095	0.67	154.3	Nte 0.44
2	PAST	Seat Track MID	598	1214	882	0.54	248.7	Nte 0.65
4	NEW	Seat Track MID	810	1160	632	0.49	211.1	Nte 0.56

CONCLUSIONS

I tried to improve LRD performance and OMDB collision performance by optimizing important inflator performance which is the most basic of airbag performance. LRD performance has been found to improve performance without lowering the inflator pressure and without applying LRD vents. For neuronal response, the PAB volume is basically increased and the inflator pressure needs to be increased. It also explained the new cushioning technology to limit passenger's Y-axis movement and showed test results.
It is necessary to increase the reliability of data through actual vehicle evaluation in the future, and additional tests for the products available by the inflator maker will be necessary.

REFERENCES

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[2] National Highway Traffic Safety Administration (NHTSA), Department of DEPARTMENT OF TRANSPORTATIONNational Highway Traffic Safety Administration “New Car Assessment Program” [Docket No. NHTSA-2015-0119]