**DEVELOPMENT OF A SIDE IMPACT CRASH USING INTEGRATED SYSTEM**

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## ABSTRACT

It was judged that it was difficult to prevent passenger injuries caused by vehicle intrusion into a side impact only with conventional airbags. So we considered ways to avoid intrusion. Existing restraint systems are not sufficient to prevent injury caused by vehicle intrusion during side impact. In this thesis, we considered ways to improve passenger injuries by applying new lateral air bag technology using the active system to improve injury caused by vehicle intrusion into existing and new collisions.

## INTRODUTION

The system using the active system is as follows.

Stage 1 uses sensors in the vehicle to predict the collision velocity and time of the MDB. It uses a frontal sensor or a lateral sensor to recognize the MDB and signal the ACU.

Step 2 serves to signal the active airbag (different from the existing airbag) in the ACU.

Step 3 operates the active air bag or other system to create a change in passenger movement. There can be many ways.

There are airbags located in the seatback side bolsters, airbags located in the lower section of the seat cushion, two simultaneously operated airbags and a structure that pushes the seat sideways.

Step 4 were tested to verify that actual passenger injuries had an improvement.

It is fully possible to recognize a car that will collide with the sidewall. Unlike the various crash conditions that could occur in a real accident, the prescribed car crash conditions were not difficult to recognize. Based on the sensing results, it was also possible to even implement the signals from the ACU and the airbags. Signaling the air bag from the ACU has varied passenger movement.

First, passenger movement was different depending on the kinds of the inflator deploying the airbags, and the required amount of movements was obtained through CAE. Static testing was conducted in a variety of ways to change actual dummy movement based on the results obtained from the CAE. It was implemented mainly under the design conditions of seats and airbags, and the required passenger movements were calculated and the airbags were developed. The purpose of this paper is to reduce injuries caused by vehicle intrusion by recognizing the difference in passenger movement before side impact. Implementing this required the use of various systems.

Seat bolsters and seat cushions have a form which is in contact with passengers and require a structure to maintain the restraint's resistance. There were also various structures in the seat cushion, which caused difficulties in designing mass-production that avoided them.

Nevertheless, tests were conducted using various structures to improve side impact by utilizing various products. In this paper, airbag-based testing was conducted.

## Side Impact Crash

Generally, the side impact mode increases the injury by intrusion of the body. Vehicle intrusion changes depending on collision modes, collision speed, and the like. The modified North American side impact mode and IIHS crash mode change dummies and impact speeds and can be sensitive to body infiltration as well as chest injuries as well as pelvic injuries. First, NCAP in North America is scheduled to change its dummy, which is expected to increase pelvic injuries. The IIHS test requires changes in impact velocity and dummy to improve chest and pelvic injury

## US Side Impact Crash Test Result

As a result of the actual vehicle test with the MID size vehicle, the chest and sacroiliac load was high in the new world SID Dummy

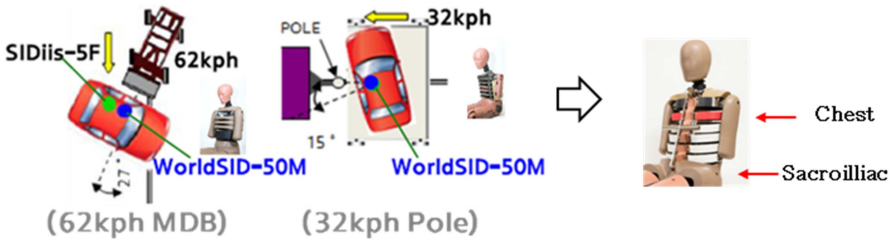



**Figure 1. US NCAP crash test.**

**Table 1.**
**US NCAP crash test result.**

| | Rib Deflection | Sacroiliac Force |
|---|---|---|
| MDB | 19mm (1.0) | 2534N (0.78) |
| POLE | 39mm (0.47) | 3183N (0.35) |

## IIHS Side Impact Crash Test Result

IIHS new crashes also resulted in higher chest and pelvic injuries, depending on the velocity of increase and the changed MDB. As the velocity increases, the collision energy increases and the penetration rate increases, leading to an increase in passenger injury


**Figure 2. IIHS crash test.**

**Table2.**
**IIHS crash test result.**

| Speed | Dummy | Overall Rating | Injury(Front) | |
|---|---|---|---|---|
| | | | Chest | PELVIS |
| 50 km/h | SIDⅡ | G | A | G |
| 50 km/h | W-SID | G | G | G |
| **60 km/h** | W-SID | M | P | M |

**Major Impact of Collision Score**

As the MDB velocity increases, the slope and maximum value of the passenger injury increase. The head, chest and pelvis and vehicle showed the same tendency. In conclusion, it was judged that passenger space was enough to avoid vehicle intrusion. The graph below shows the tendency of bust injury according to increase of collision speed and crash severity, and it can be considered to represent not only chest injury but also all injuries

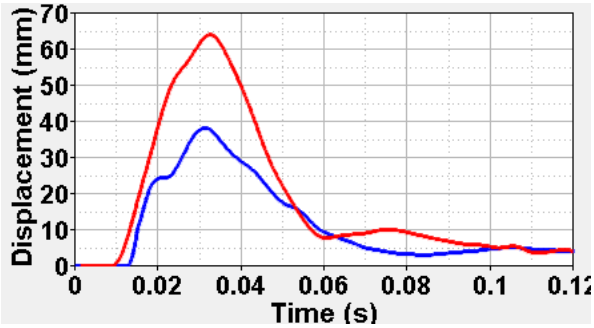



**Figure 3. Increased severity**

**Integrated System Airbag (Reusable)**

The purpose of this paper is to develop an air bag system in conjunction with active systems. In this paper, airbag-focused research activities will be recorded. In the conventional side collision mode, the airbag is activated after collision with the MBD. It is not possible to use seat as well as airbag after vehicle breakage and airbag deployment. However, the use of active systems requires the reuse of airbags and seats because airbags can operate even when no collisions occur. The products for the test that have been made this time are as follows. Inflators used compact hybrid type and cold gas. Airbag cushion products are rib bolster product, seat cushion product, seat back product, and combined product. The hybrid small-size Product and cold gas inflator were judged to be reusable cushions and were used in actual tests. Such an inflator would be very advantageous not only in terms of price but also in terms of reliability

**Other company applications (References)**

Before starting this study, I have investigated existing developed or already mass-produced Products. mercedes-benz developed and produced an active passive integrated airbag called Pre Safe Impulse, and Audi developed a side active passive integration system through vehicle control. Both products are in conjunction with active safety to protect passengers after impact. In this paper, we have conducted additional tests based on existing developments and have conducted better performance or more various tests. We also used HIP SAFE airbags for elderly care made by HELITE. It is a product designed to protect the elderly, etc. It is a concept to protect passengers by sensing the pedestrians that fall when the pedestrians fall and activating the airbag.

The existing articles were used to identify active side systems as beneficial to passenger injuries. (Refer to the articles or products on the market for reference.)

This project is similar to the above products because it is an air bag system for passenger protection of side collision using active system.

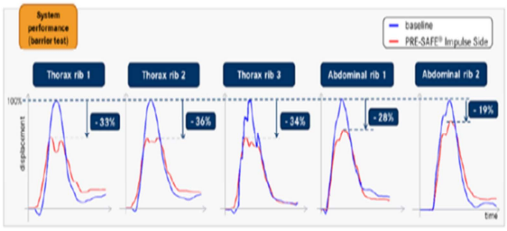
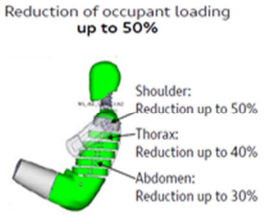
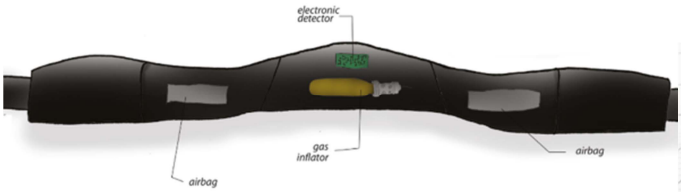



*Figure 5: Benefit of PRE-SAFE® Impulse Side in barrier test configuration*



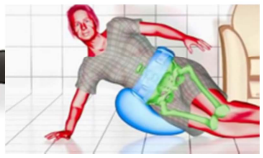



**Figure 4. References**

## MAIN SUBJECT

The main purpose of the study is to improve passenger injuries in side crash tests and side crash room accidents. As mentioned above, major injuries were caused by vehicle intrusion, and it was also found that passenger injuries could be improved if the vehicle intrusion could be avoided. The main goal is to develop products that work in conjunction with the active system to operate the airbag, minimize the impact on the seat, and secure passenger and vehicle infiltration spaces to prevent injury from vehicle intrusion

## Method

The main purpose of the study is to improve passenger injuries in side crash tests and side crash room accidents. As mentioned above, major injuries were caused by vehicle intrusion, and it was also found that passenger injuries could be improved if the vehicle intrusion could be avoided. The main goal is to develop products that work in conjunction with the active system to operate the airbag, minimize the impact on the seat, and secure passenger and vehicle infiltration spaces to prevent injury from vehicle intrusion. Side and diagonal sensors are used to sense the collision of the opponent vehicle and receive a signal from the ACU. The ACU signals the ACU before the collision to move passengers to reduce passenger injuries by avoiding vehicle intrusion after the collision. The approximate active system is shown below, and in this paper we refer to the airbag as the center..

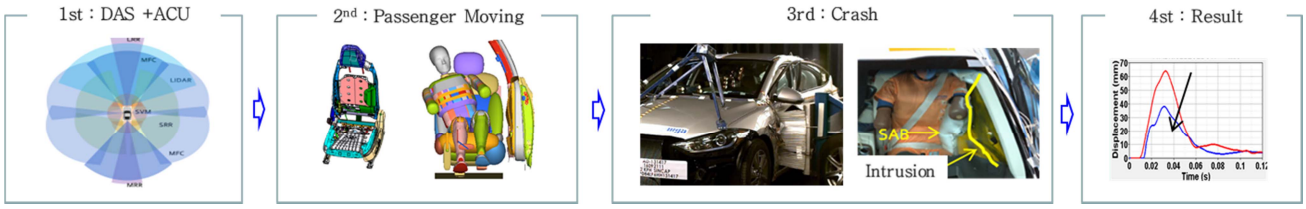



**Figure 5. Operating system**

## CAE Test Result

We conducted analytical tests to find a better concept. The # 1 (RIB) product is mounted on the side bolster on the seat and pushes the dummy shoulder, while the # 2 (RIB & BACK) pushes the shoulder and back. The # 3( HIP) product raised the hips on one side and the # 4(SEAT MOVE) slid the seat sideways to try to figure out the passenger injury trend. It is medium-sized vehicle standard and MDB 62kph speed. The passengers were moved on a static basis without moving them by time zone. Tests were conducted on the four Products, and the tendency that chest injuries were improved with more dummy movements was identified. All four Products were similar, so the actual single item test and the sled test proceeded. It was also confirmed whether the injured Sacroiliac (Pelvis) injuries.

All analytical tests were performed on the basic posture, the 30mm movement, and the 100mm movement. As the distance from the door (or car body) increases, the injury tends to improve. Based on the results, all the products were manufactured, and single item tests and crash tests were conducted. Especially, it was confirmed that not only the improvement of the chest but also the improvement of the pelvic side load, which is a future issue.

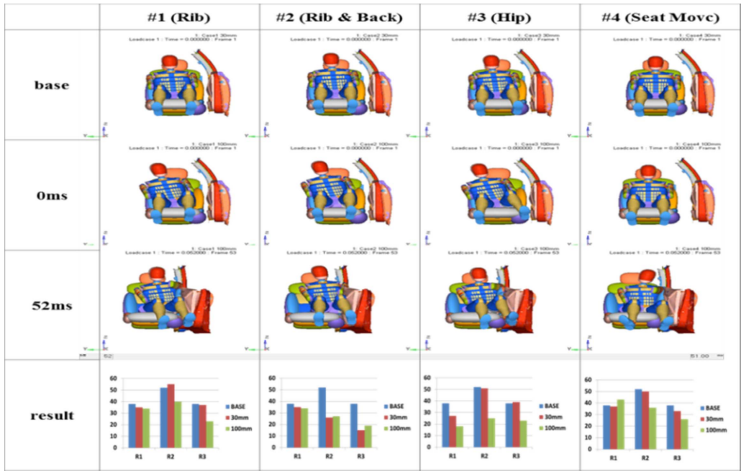



**Figure 6. Passenger CAE / Rib injuries results and video**

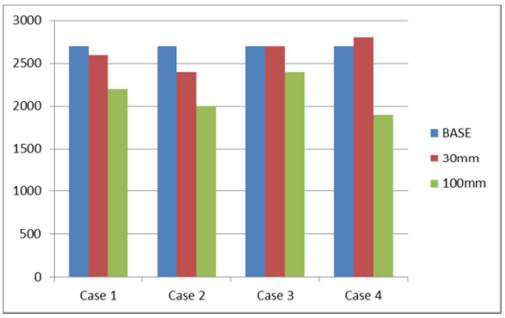



**Figure 7. Passenger CAE / Sacroiliac injuries results**

**Airbag and Inflator (Reusable) and Seat**

The actual products of the airbag are as follows. The seat uses the standard Product of the mass production model, the passenger hips and the back side have a hot wire, and the side bolster side has a guider. Airbags were installed on the side bolsters to minimize heat distortion, and it was not difficult to install the airbags on the side bolsters. Based on the CAE results, the actual product was manufactured as follows. The rubber hose connected to the inflator outlet is used as needed, and it can be used when the inflator temperature.

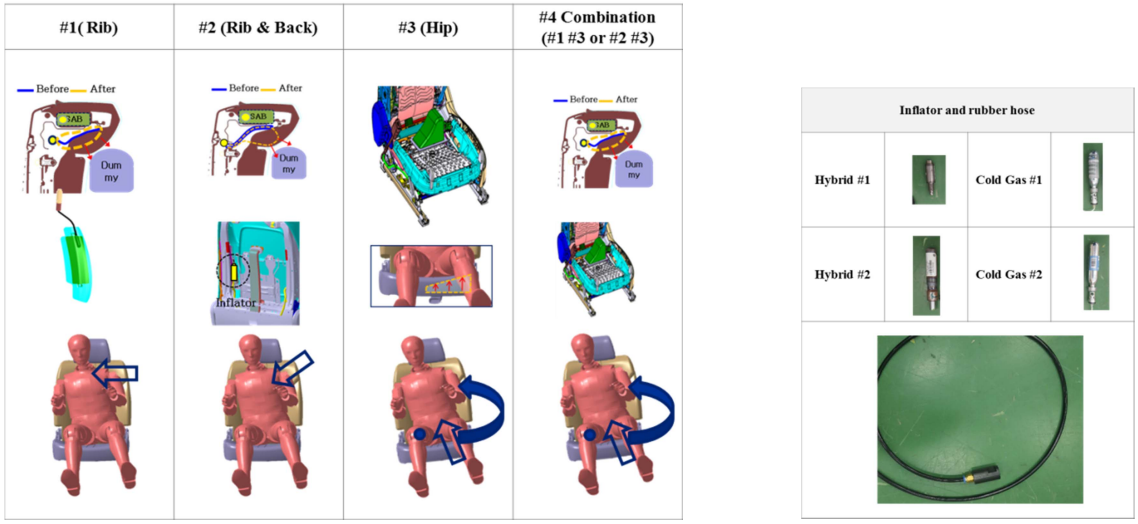



**Figure 8. Actual product shape and dummy movement**

**Static Deployment Test with World SID Dummy**

Static tests were conducted based on the above Products. It is to judge the moving distance of the actual world SID dummy and to check the effect and then to perform the collision test. The most effective Products are the combination of COLD GAS inflator and rib cushion, and the cold gas and combination product. The greatest amount of movement was in the dummy. Especially, the combination of RIB cushion and COLD GAS showed 30mm of pelvis .

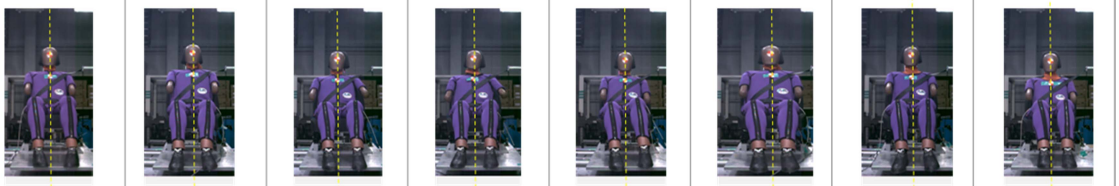
| | Rib (#1) | | Rib & Back (#2) | | Seat Cushion (#3) | | Combination | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | #1 #3 | #2 #3 |
| | Hybrid Small | Cold Gas #1 | Hybrid Mid | Cold Gas #2 | Cold Gas | Hybrid Mid | Cold Gas #1 | Cold Gas #1 |
| 0ms |  | | | | | | | |
| 100ms |  | | | | | | | |
| Chest Move | 30mm | 100mm | 20mm | 30m | 60mm | 30mm | 100mm | 100mm |
| Pelvis Move | 15mm | 30mm | 0mm | 15mm | 20mm | 30mm | 30mm | 30mm |

**Figure 9. Dummy Movement**

During the static test, the dummy injuries were found to be 2.5 mm in the chest displacement and the Sacroiliac was also in the level of 260, confirming that the injuries were not affected. Also, there was no difference in dummy movement when wearing the belt and when not wearing it..

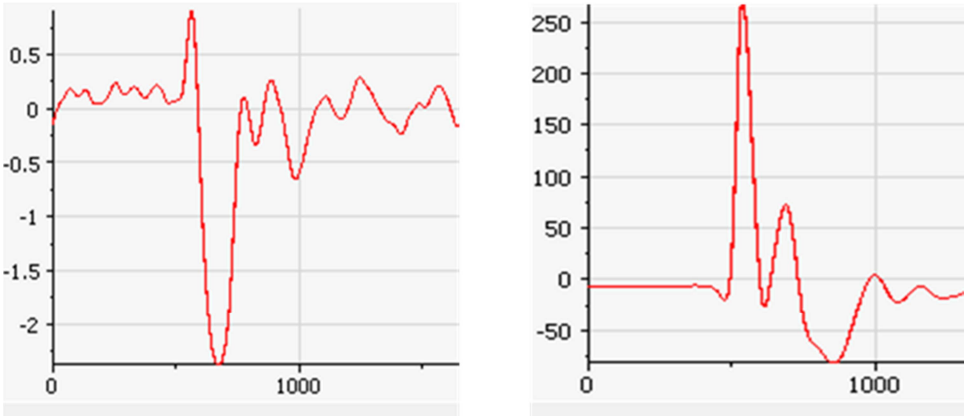



**Figure 10. Static test dummy injury**

**Sled Test Condition**

The sled test and the actual vehicle test may have different conditions. Vehicle intrusion and collision waveforms of the actual vehicle do not coincide with the sled test. However, we prepared the base test by using the sled technique

to match the actual vehicle and waveforms as closely as possible. Seats, trimmings, and dummy seating are identical to the drawing conditions. It is equipped with belt and SAB, both of which are in production Products. One side of the seat did not tighten the bolt, and the jumping of the vehicle was reproduced. The interior space of the door trim was filled with rigid blocks to reproduce the collision energy increase due to possible vehicle intrusion. The time for the Pre Safe SAB to operate is 80ms before impact. This is considered to be a sufficient time when the connection well.

**Sled Test Result**

As shown in the bar graph, the RIB # 1 product and COMBINATION (# 1, # 3) injuries are better than the base test. This shows that the more the dummy movement amount, the less the injury. Especially for RIB # 1, PRE SAFE SAB shows the best performance with just one. For the RIB # 1 Product and COMBINATION (# 1 # 3), the SACROILIAC score is also improved. In the RIB # 1 Product and COMBINATION (# 1 # 3), SACROILIAC injury is expected to be improved by the effect of moving the dummy pelvis. However, it is expected that further improvement will be achieved if the structure avoids interference with the armrest portion of the door trim.

Especially, in case of # 1 (RIB) Product, the maintenance effect of cold gas inflator was excellent in pushing dummy chest from the beginning with good pressure.

| PRE SAFE | BASE | #1 Rib | #2 Rib & Back | #3 Hip | #4 Combi. (#1 #3) | #5 Combi. (#2 #3) | #6 Seat Moved 100mm |
|---|---|---|---|---|---|---|---|
| | N/A | Cold Gas #1 | Hybrid Mid | Hybrid Mid | Cold Gas #1 | Cold Gas #1 | N/A |
| 0ms |  | | | | | | |
| 80ms |  | | | | | | |
| RIB1(mm) | 30 | 5 | 12 | 14 | 9 | 10 | 14 |
| RIB2(mm) | 44 | 20 | 34 | 20 | 10 | 32 | 32 |
| RIB3(mm) | 17 | 5 | 8 | 14 | 12 | 8 | 16 |
| SACROILIAC (N) | 4193 | 2996 | 3949 | 4598 | 2989 | 3606 | 4097 |

**Figure 11. Dynamic Sled test dummy injury**

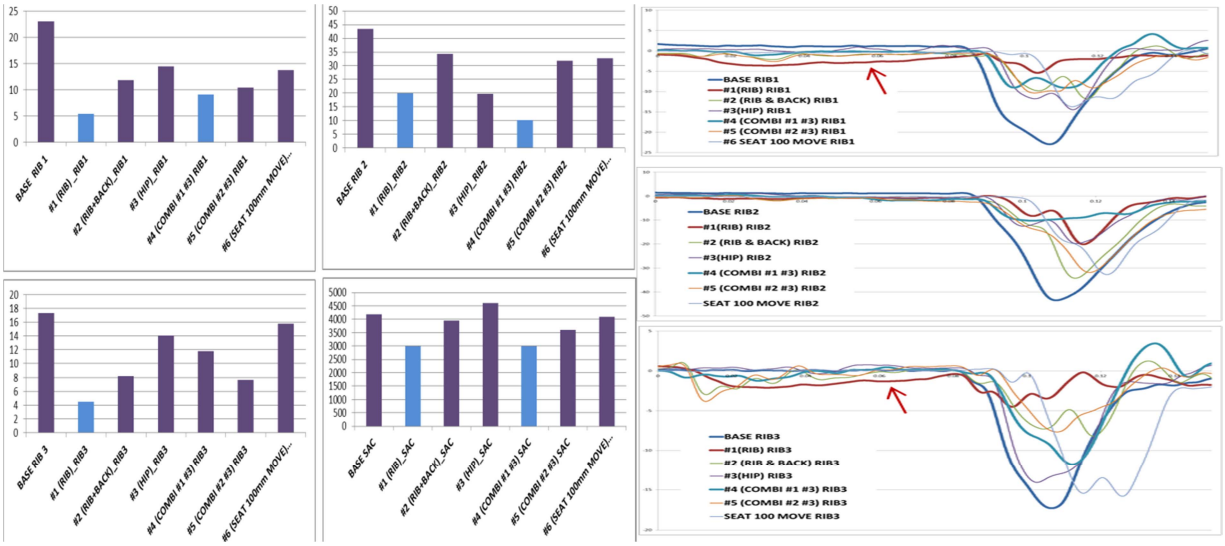



**Figure 12. Dynamic Sled test dummy injury graph**

It was confirmed that sacroiliac was improved by about 30% in # 1 and # 4 compared with base test. Both specs were a product with a large underbody movement. The # 1 Product shows that the lower body's Moment Z is higher and the pelvis is twisted relative to the Z axis. In the # 4 Product, Moment Y and Moment Z were changed at the same time, lifting their buttocks and making contact with the armrest part of the door trim, so that the improvement was less than expected, but the improvement may be different depending on the shape and position of the armrest.

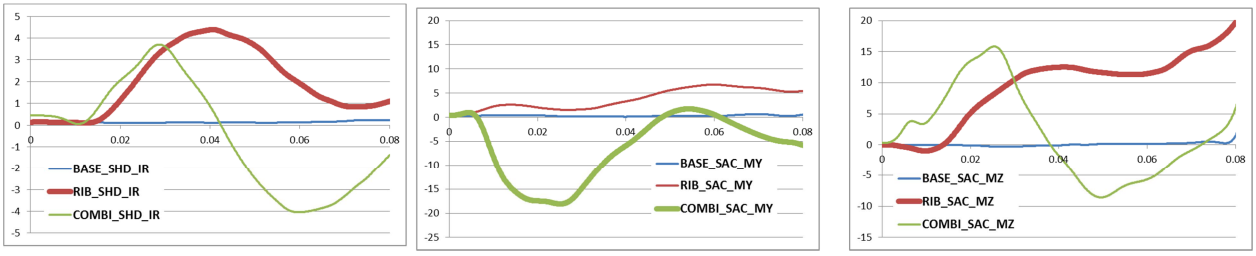



**Figure 13. Sensor values for prediction of chest and pelvic movement**

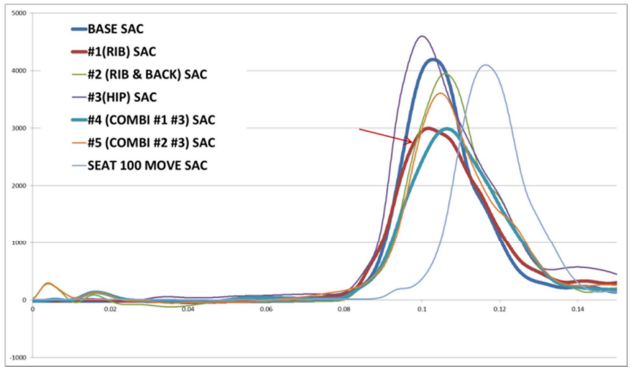



**Figure 14. Sacroiliac Injury Graph**

Compared to the base test, the injured products have a dummy motion changed (80 ms) before collision with the vehicle. In the case of the RIB Product, the angle of the shoulder was changed and the rotation of the pelvis in the Z axis was largely affected. In the case of the combination Product, the direction of the Y axis was largely affected. Although we could not quantitatively understand the amount of movement and injury of the dummy, it was confirmed that the dummy movement amount was large

## CONCLUSIONS.

In this paper, we applied the concepts of existing products and conducted new tests. It was confirmed through CAE and test that major injuries of the chest and sacroiliac injury were improved by the movement of the dummy before the collision at the side collision. Especially, PRE SAFE SAB attached to the chest seat bolster showed that not only chest injuries but also pelvis movements improved pelvic side injuries.

We did not carry out the actual vehicle test linked to the active system, but we will improve the completeness of the product through the actual vehicle test connected with the active system.

We examined ways to improve side impact considering future integration systems. There are already a number of studies being conducted that incorporate active and passive activities, and further progress is expected. We hope that products will be developed that can not only assess conflicts but also respond to accidents by integrating active activities and hands.

## REFERENCES

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[1] Michael Fehring. 2017. “Effectiveness Potential of PRE-SAFE® Impulse Using the Scenario of a Major Accident at an Intersection as an Example.” ESV 2017

[2] Christian Weiss,. 2018. “Pre sense side : Innovation for advanced occupant protection in side collisions” Airbag 2018

[3] B.C. Mueller 2018. “ Development of an updated IIHS side impact crash test program” Airbag 2018