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S9-O-21

Design Considerations of the Passenger Airbag System

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Abstract

As a major part in the design processes of an airbag for use in the front passenger seat, airbag specifications defining the bag deployed shape, bag deployment direction, module location and bag storage methods were

prepared based on various tests. The tests were conducted by taking into consideration the parameters specific to the passenger seat, i.e. wide range of age, physical size and weight of passengers, and seating conditions such as position, direction and posture. This paper analyzes the test results to find ways to obtain an effective protection capability of the airbag while reducing its impact on the passenger during deployment.

Introduction

Design of an airbag module for the passenger side requires a different approach than that for the driver side due to the fact that any occupant in the passenger seat may have various postures at various positions.

In order to effectively protect the passenger of various builds and postures with minimum impact from the deployed bag, design considerations for bag shape and mounting position are more important for the passenger side than for the driver side.

The two elements of protection capability and deployment impact have opposite effects on the passenger. Balancing between these elements are key points in designing the passenger airbag.

This paper describes how we studied theses elements in the course of our airbag design.

Considerations of Airbag Shape and Inflator Characteristics

The shape of the deployed airbag must be determined by taking into account elements that enable the airbag to have effective protection capability under various passenger conditions (passenger's physical size, weight, seating posture with and without a seat belt, etc.) with minimum injury to the passenger as mentioned above.

In this section, we concentrate on how to exclude such undesirable elements from the airbag design specifications.

Conditions Restraining Passenger after Airbag Deployment

First, to identify problems associated with the installation of an airbag, the occupant being restrained must be defined in terms of physical size, weight, posture and seat belt usage. The basic concept of the airbag is to act as a supplemental restraint system for the seat belt. Nevertheless, it should be considered to reduce injuries when the seat belt is not used.

Figure 1 shows cross sections of the same type of airbags (pillow type) deployed in different ways inside the cabin.

The bags were deployed, each with the same inflator, in 30mph frontal barrier crash tests with unbelted dummies.

Examples of the test data are shown in Table 1, which shows that both types of airbags work well and meet requirements of FMVSS 208.

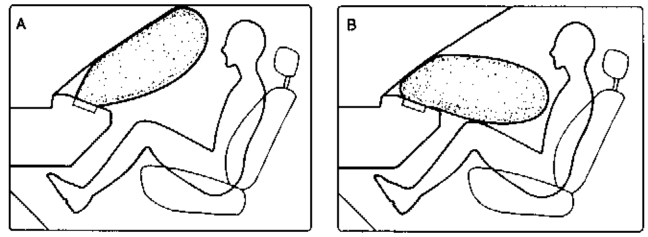

Figure 1. Bag Shapes During Initial Stage Development

Table 1. Frontal Crash Data for Two Types of Bags

Type / Data	A	B
HIC	204.3	108.3
Chest G	44.5G	26.5G

In the case of A in Figure 1, behavior of the passenger not wearing a seat belt must be given attention; case A has a problem for the neck. In a collision, first the head of the passenger contacts the bag and then stops its movement while the rest of body is moving forward because the airbag restrains only the head. A backward bending moment of the neck is caused. This may not occur if the airbag is not installed and should be considered an additional injury.

Table 2 shows examples of backward bending moments measured at the neck.

Table 2. Neck Bending Moment Data for Two Types of Bags

	A	B
Neck Bending Moment (Backward)	130.4 N•m	0.0 N•m
	(Not including rebound)	

The possibility of injury due to installation of an airbag must be minimized. Case B indicates a low level of injury but it is only for the 50th percentile male dummy (AM50). Its design is not favorable. Therefore the most stable bag shape for the passenger in the normal position is triangular, in order to restrain all parts of the passenger's body evenly.

Conditions During Airbag Deployment

To evaluate the adverse effects of airbag deployment (i.e. its impact on the passenger), it is necessary to take into account for the occupant, not only in the normal position, but also out of normal position. To determine the effects of airbags due to different shapes, the size is measured in three directions; width, depth, and height.

The minimum width of the airbag should be one which assures coverage of the entire width of the passenger. Balancing between the increased protection capability and the decreased impact of airbag deployment must be considered by using an airbag greater than this width limit. The height of the airbag is to be determined to achieve proper protection capability, with the car ceiling as the upper limit. The depth will be described later in this paper.

The Effects of Airbag Width Variations

First, the relationship between the bag width and its impact on the passenger was analyzed. To achieve the same protection capabilities during head-on collisions among bags of various widths, the output tank pressures of the inflators were adjusted according to airbag volume capacity (Table 3).

Table 3. Four Kind Width Bag and Crash Test Data

Data \ Type	I	II	III	IV
Bag Width (mm)	400	500	600	700
Bag Volume (Liter)	116.8	134.8	154.8	169.0
Inflator Maximum Pressure (KPa) (60 L. Tank)	332	385	445	485
Inflator Max.Press / Bag Vol.	2.84	2.86	2.87	2.87
Frontal Crash Data (Chest G)	51.1	47.3	47.7	50.5

Figure 2 shows the tank pressure curve of the inflator used. The maximum values of the inflator in Table 3 were measured at point (f) at fill time (the bag is fully inflated to the design form). Maximum inflator output capacity refers to the inflator output per unit volume of the bag at fill time and is almost a equal in all cases (i.e. the inflator output depends on the bag capacity).

Four modules, each made to specification I, II, III, and IV respectively, were prepared. Static deployment tests were performed accordingly. Figures 3 and 4 show the impact from bag deployment on the passenger sitting in and out of normal position.

The 5th percentile female (AF5) dummy was used to represent a passenger sitting in normal position. The seat position was set to bring the dummy as close as possible to the module (i.e. seat position and recline were set to frontmost positions). Furthermore, the dummy was placed at the position equal to the distance it would

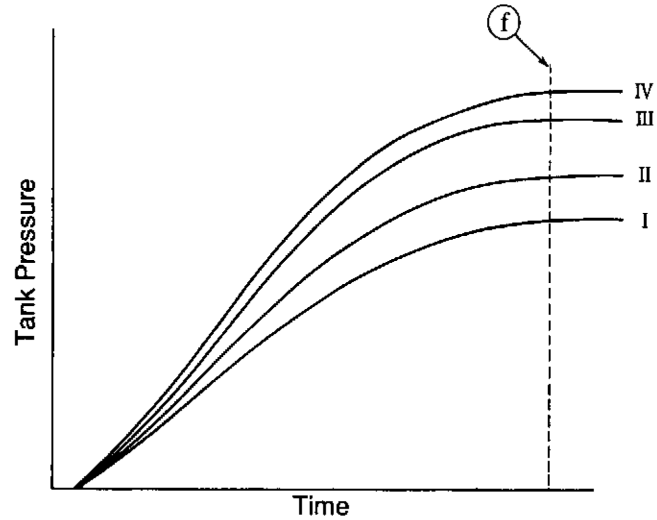

Figure 2. Four Types of Inflator Tank Pressures

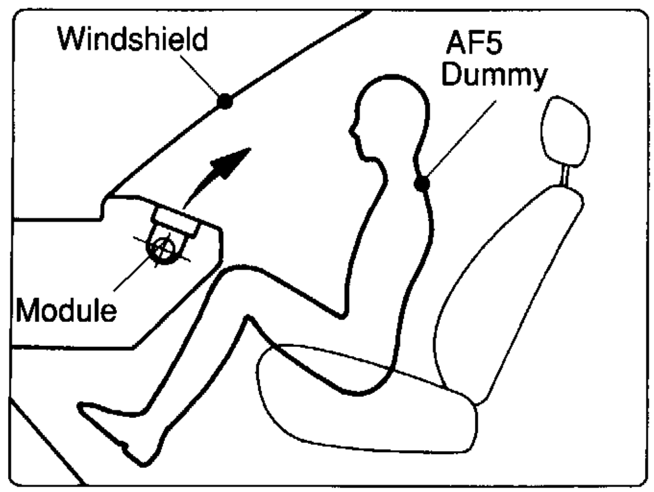

Figure 3. Deployment Impact Test Position (AF5 Dummy)

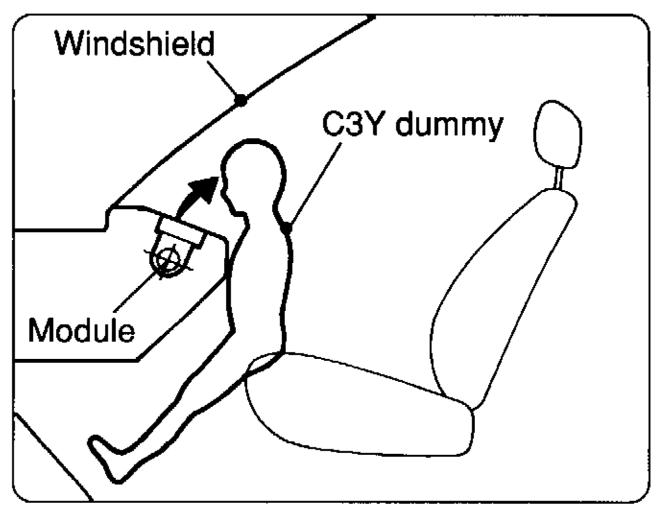

Figure 4. Deployment Impact Test Position (C3Y Dummy)

move before the airbag sensor senses the collision. Position of this dummy is illustrated in Figure 3.

As a representative of a passenger sitting out of normal position, the lightest, 3 year old child (C3Y) dummy was used. Its sitting position data is presented as SAE J1980 No.1 in Figure 4. These test results are shown in Figures 5 and 6.

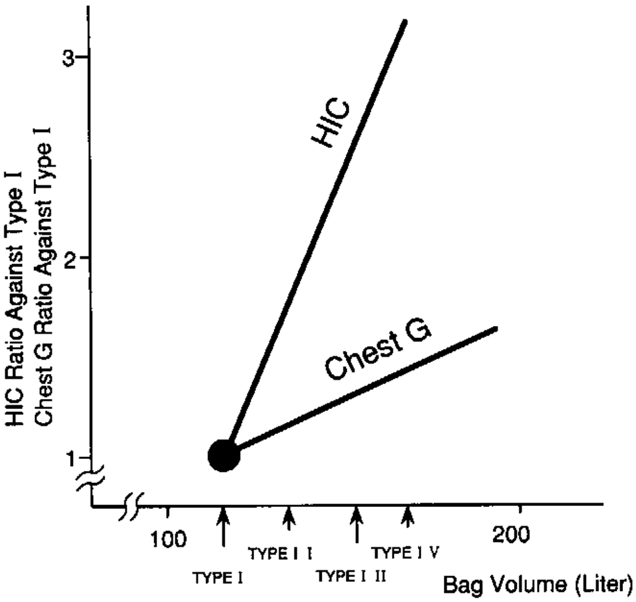

Figure 5. Deployment Impact Test Result (AF5 Dummy)

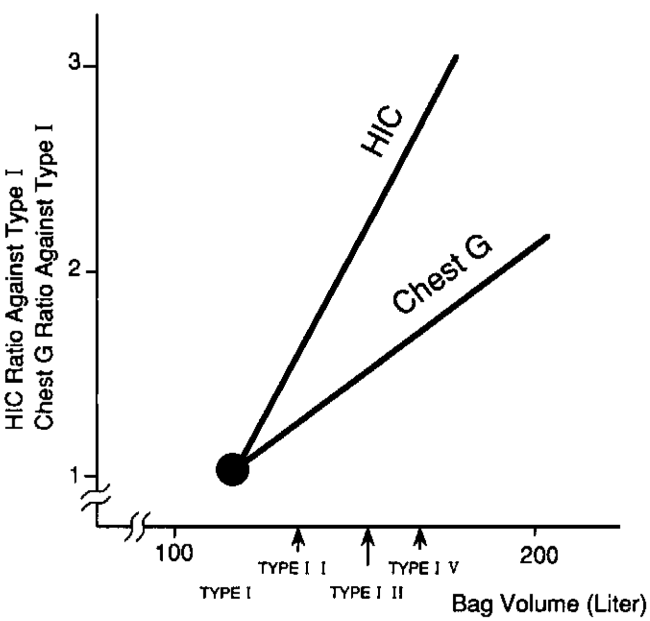

Figure 6. Deployment Impact Test Result (C3Y Dummy)

From the results it can be seen that the impact from the deployment of the airbag on the passenger linearly increases as its width increases, provided that the passengers have the same energy absorption characteristics. This is applicable to passengers in both normal and out of positions. This is because (1) the maximum deployment stroke of a wider bag (S in Figure 7) deployed by a higher capacity inflator is larger than those of a narrow bag (2) initial pressure rise of the tank pressure curve becomes faster as the inflator capability increases (Figure 2) and consequently, bag deployment speed increases.

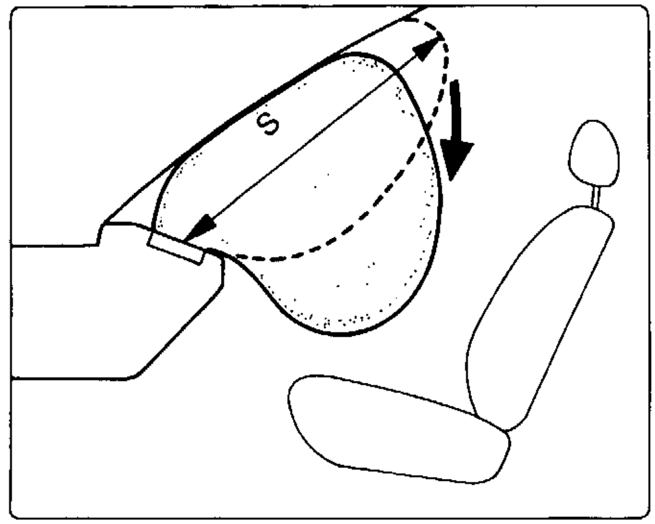

Figure 7. Bag Deployment Process

The Effects of Airbag Depth Variations

When bags of varying depth are set to have the same load characteristics of restraint, the deeper bag will make a greater impact on the passenger because they have a higher bag deployment speed and a longer maximum deployment stroke.

Although the wider bag and the deeper bag have similar increased impacts, their effects on passenger protection are slightly different from each other: the starting time of restraint depends on the airbag depth variations.

As seen in Figure 8, bag (α) has stroke 'a' and bag (ß) has a shorter stroke 'b'. When bags (α) and (ß) have the same load characteristics, bag (α) can absorb energy a/b times that of bag (ß). And when the same energy is encountered, bag (α) can protect the passenger with a load b/a times that required by bag (ß). These comparisons are made on the assumption that both bags are now fully deployed and ready for generating a load to protect the passenger.

Also, these comparisons are made on the basis of bag energy absorption capacity: effects on the passenger will greatly vary as the position and load of the bag changes.

In the next test the larger capacity bag (α) was deployed by the same inflator as the small capacity bag (ß). This combination, called bag (α'), is somewhat different from that of bag (ß). The load characteristic (load vs stroke) of bag (α') is somewhat different from that of bag (α). That is, the initial load curve is lower than that of bag (α) becomes closer to the curve of bag (α) as the passenger moves forward (in this case, bags (α) and (α') have the same vent hole characteristics).

Table 4 shows the impacts upon the passenger by bag (α') (test was conducted in the same way as with the C3Y).

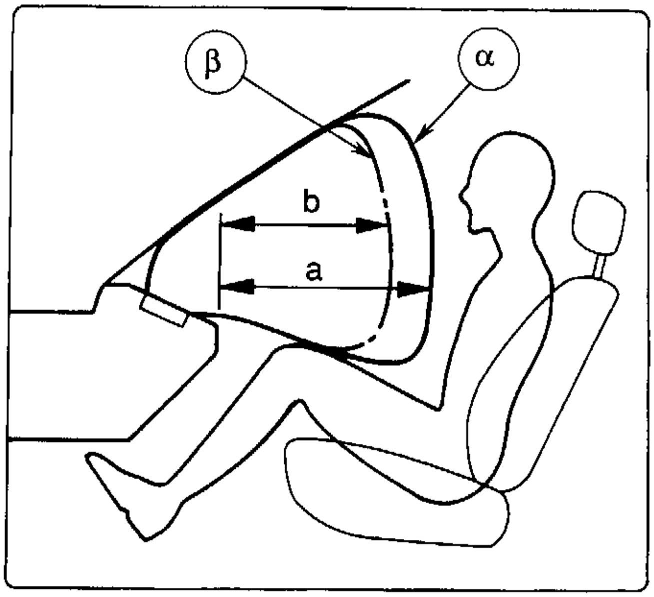

Figure 8. Comparison of Two Types of Bag Shape (Type α and ß)

Table 4. Deployment Impact Test Result (Three Types of Bag and Inflator Combinations)

	α	β	α'
HIC	351.8	200.7	140.7
Chest G	30.4	22.5	12.5

These test results show that bag (α) has a smaller impact than not only bag (α) but also bag (ß). This is due to the fact that the larger bag (α), insufficiently deployed by the smaller capacity inflator, wraps around the passenger in front of the module, and the tension of the bag at fill time is small (Figure 9). But the peak impulse G caused by bag (α') contacting the passenger after the bag deploys is larger because the larger bag (α') has larger mass using the same inflator.

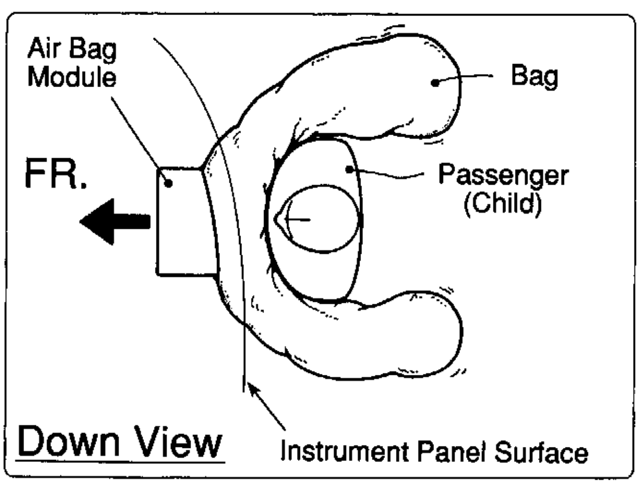

Figure 9. Bag Deployment Shape with Standing Child

Next, the passenger protection capabilities of these bags are compared. Table 5 compares the capability of the bags for a passenger wearing a seat belt to those for a passenger not wearing a seat belt. The values in Table 5 are with respect to bag (α) which is given a base value of 100 (a smaller value means high performance). The type (α) good for a passenger without a seat belt and type (α')is good for one with a seat belt.

Table 5. Frontal Crash Test Results (Three Kinds of Bag and Inflator Combination, With and Without Seat Belt Occupant)

	With Seat Belt			W/O Seat Belt		
	α	β	α'	α	β	α'
HIC (Ratio)	100	108	78	46	—	105
Chest G (Ratio)	100	85	90	89	—	145

The tests on various bag sizes proved that when airbag specifications and inflator characteristics are determined, it is important to identify the kinds of protective effects that the bag can offer to various kinds of passengers (while wearing and not wearing a seat belt). Bag selection affects the type and amount of impact from the deploying bag to the passenger. The final design must be made after considering the trading offs.

Module Layout for the Best Location

Location of the module and direction of the bag deployment must be determined by taking into consideration the elements mentioned in the bag shape section. This is to provide the most effective protection for the passenger and minimize the impact on the passenger given by the deploying bag.

This section reviews the location of the airbag and deploying direction of the bag.

Deploying Direction of Bag

First, assume that the bag is deploying in either of the directions shown in Figure 10.

We then evaluated the passenger protection capability. The tests show that the bag offers the same protection independent of deployment direction when it is completely inflated after the fill time.

In Figure 11, both bags deploy toward the passenger and windshield in the similar formation at fill time, t3.

During the time period t1 to t2, before fill time (Figure 11), the two bags deploy in different ways and in different shapes. The covered area and stroke toward the passenger of two bags differ from each other.

The balancing between these characteristics and impact on the passenger must be taken into considerations during the design phase.

Next, a discussion is made about the airbag deployment impact.

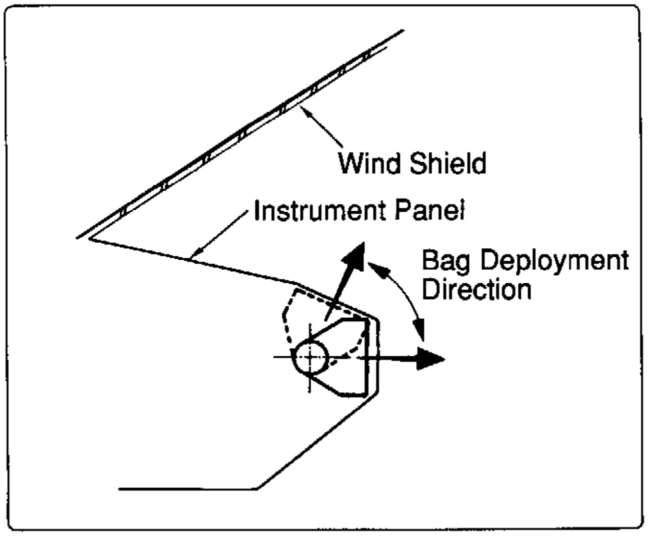

Figure 10. Angle Deployment Test

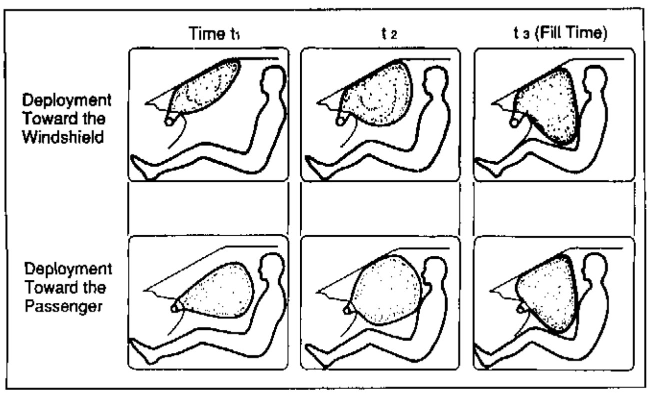

Figure 11. Comparison of Two Types of Bag Deployment Directions

Impacts from the deploying bag were measured while the dummies were placed in (AF5, Figure 3) and out of normal position. (C3Y, Figure 4). These are the same positions that were used for the bag shape effect test on AF5.

During the test the bag was deployed in three directions: horizontally to the chest of the dummy (H, 0°) to the face of the dummy (M, 35°) and to the top of the head (U, 70°), (Figure 12).

The result is shown in Figure 13. Changes in HIC and chest G are expressed as a ratio to that of H direction which is 1.0. Both HIC and chest G are small for deployments in the upper direction.

The tests were continued, using a 6 year old child (C6Y) dummy which represented a taller passenger whose head is in contact with the windshield (dotted circle in Figure 12).

The result is shown in Figure 14 which is the same one that obtained from the C3Y test. The bag, when deploying to the dummy's face, U direction offers a better result than when it is deploying in the other directions, H and M.

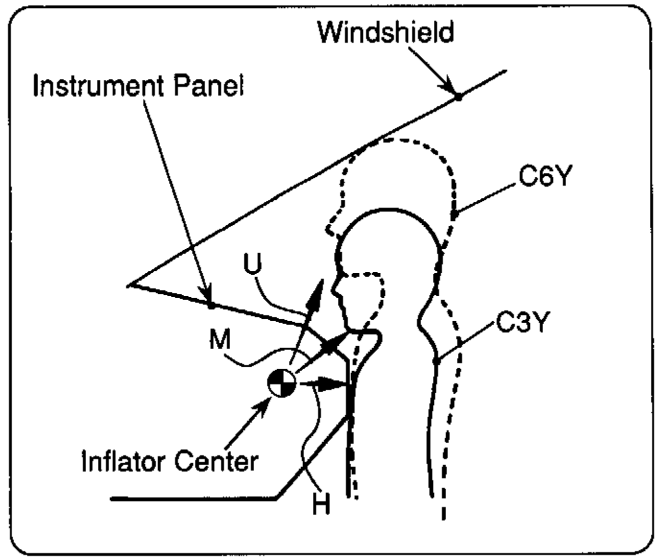

Figure 12. Angle Deployment Test for C3Y and C6Y

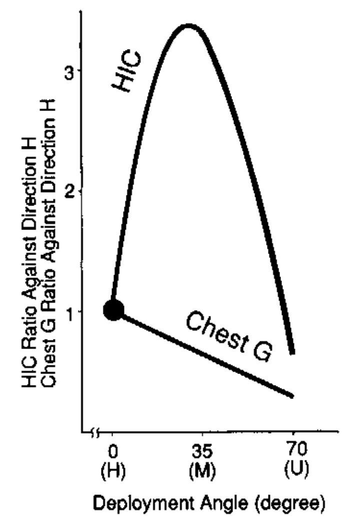

Figure 13. Angle Deployment Test Result (C3Y)

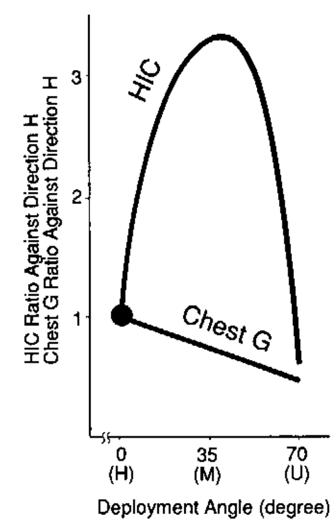

Figure 14. Angle Deployment Test Result (C6Y)

Module Position

The module was relocated to a position approximately 150mm closer to the windshield from the previous position and tested. The test data taken with C6Y dummy is in Table 6. The bag was deployed at 70°, the same as U before (Figure 15). (HIC and chest G when deploying at U', compared to those (defined 100 at U).

Table 6. Deployment Impact Test Results (With Module Moved Closer to Windshield)

	HIC(Ratio)	Chest G(Ratio)
U	100	100
U'	41	71

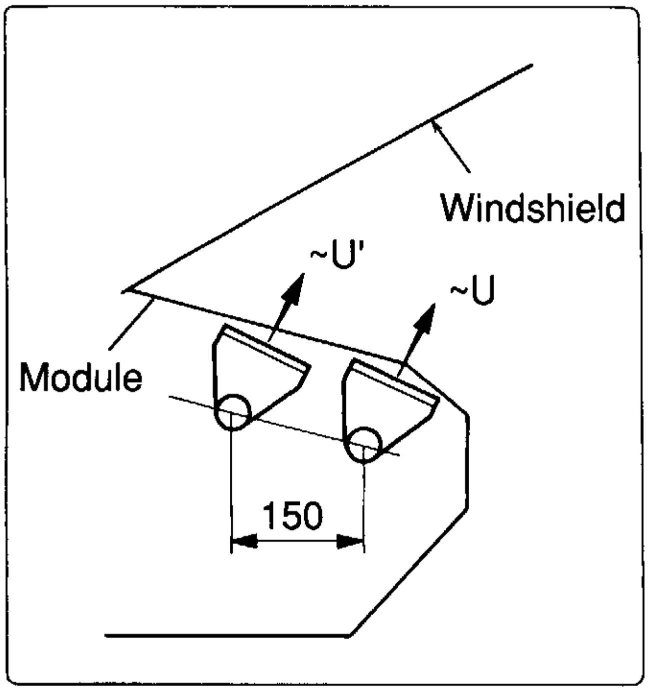

Figure 15. Deployment Impact Test with Module Moved Closer to Windshield

The impact from the bag further decreases as the distance between the module and the passenger increases.

These tests suggest that to minimize impact from the deploying bag, the bag is to be installed closer to the windshield and to be deployed along the windshield. When reviewing the point of passenger protection ability, differences in deployment directions and deployment modes (Figure 11) offer different passenger protection capabilities. These two parameters should be analyzed further.

The deployment mode of a bag can be fine tuned by modifying the internal design of the module as described below.

Controlling Bag Deployment Mode by Module Design

When the bag is deployed along the windshield (arrow (1) Figure 16), it is deployed at a high rate to form the shape (A) in Figure 16. Then the bag is deployed in arrow (2) and finally forms shape (B). It is desirable that the bag forms the shape (B) as quickly as possible to accommodate the passenger during crash. For faster formation of (B) in Figure 16, the bag must quickly deploy in direction (2). The following technique ensures the bag to deploy effectively in this manner.

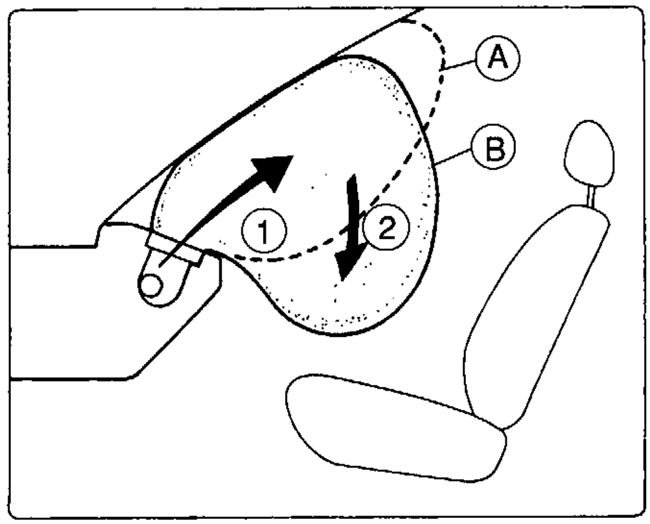

Figure 16. Bag Deployment Process

Modifying the Bag Storing Configuration

Figure 17 is an example of bag storage. There is an offset (a) between the physical center of the inflator and the center of gravity bag.

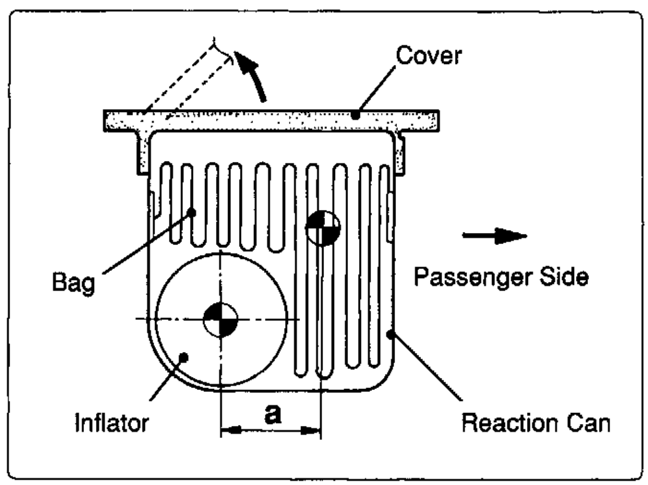

Figure 17. Example of Bag Storage

This configuration generates rotation during deployment of the bag. The rotating force increases as the distance (a) is increased.

Modifying the Folding Configuration of the Bag

Figure 18 shows how the bag is folded to generate rotation. The bag is last folded over in the passenger direction when it is stored.

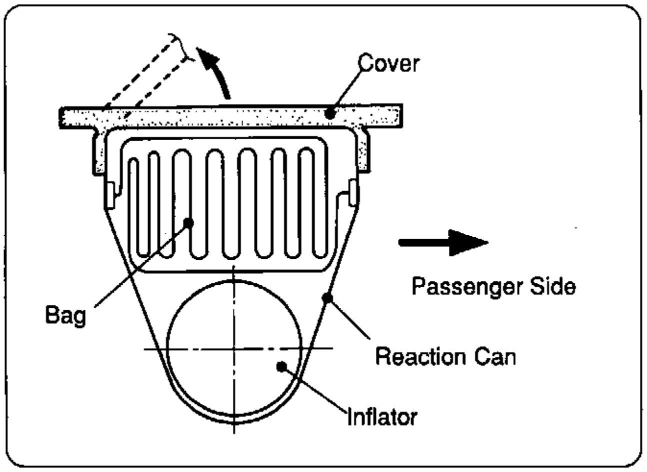

Figure 18. Example of Bag Fold Pattern

The dispositioned tension T generates rotation power during deployment. Because the bag is folded like a bellow, its deployment direction upon ejection from the module disperses in four directions with decreasing speed (1) in Figure 16.

Others

The deployment mode of the bag can be controlled by other ways such as the use of a strap and modification of the inflator characteristics, which are not covered in this paper.

Conclusion

A study is presented from the view point of "balancing between the protection capability of airbags and their impact during deployment" of the larger, passenger airbags.

A study about designing an airbag, more particularly an airbag having a larger bag deployment volume for front seat passenger, is presented from a view point of "balancing the occupant protection capability and the impact against the front seat passenger by the deploying airbag."

As the number of airbag-equipped cars is rising, automotive collision safety engineers are expected to continue their effort to study the airbag which well balances afore-said two conflicting elements so that motorists can benefit from the airbag.

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Achievable Optimum Crash Pulses for Compartment Sensing and Airbag Performance

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Abstract

Realistic achievable 30 mph (48 kph) vehicle to frontal barrier crash pulses (in the Delta-V domain) are defined for optimum single-point occupant compartment sensing, and total airbag performance. These optimum Delta-V pulse shapes are established through airbag system computer modeling, but are based on examination of many vehicle to barrier crash pulses to insure realistic achievability. To be useful, not only do "optimum" airbag crash pulses need to be defined, but also "upper and lower bounds" within which good performance can be achieved. Through computer modeling, upper and lower bounds are established that provide acceptable compartment sensing times (including allowance for sensor manufacturing tolerance bounds), and that should limit airbag injury measures to 350 HIC and 40 Chest G. Although established for a 30 mph frontal barrier crash, knowledge and experience have been used in defining the Delta-V pulse shapes such that good sensor performance would also be expected in the mid speed range. In accordance with this objective, undesirable Delta-V pulse shapes that are within or near the above optimum pulse boundary are also shown.

Introduction

Since an occupant's FMVSS-208 injury measures are essentially governed by his relative velocity during the application of restraint, evaluation of a vehicle's crash pulse performance should take place in the Delta-V domain. Within this domain, candidate 30 mph (48 kph) frontal barrier optimum crash pulse shapes and bounds were defined based upon knowledge of airbag system performance, and upon examination of many vehicle to barrier crash pulses to insure realistic achievability. For simplicity, the candidate Delta-V pulse shapes were expressed as piecewise linear segments.

Pulse shape optimization was performed for an unbelted driver restrained by an FMVSS-208 driver airbag system. However, deployment time constraints were imposed that should make the results applicable also for a passenger airbag system.

The optimization methodology that was employed was as follows: Candidate pulse shapes were divided into three regions—sensor trigger, airbag seating, and occupant ridedown—each of which was then optimized sequentially using sensor and airbag simulation models, and experience. A fixed airbag system design was used throughout, except for a scale factor on the column stroking force that was tuned to the crash pulse. Thus, the only variable affecting the predicted sensor trigger