

The Front Center Airbag

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ABSTRACT

General Motors and the Takata Corporation have worked together to bring to production a new, industry first technology called the Front Center Airbag which is being implemented on General Motors' 2013 Midsize Crossover Vehicles. This paper reviews field data, describes the hardware, and presents occupant test data to demonstrate in-position performance in far side impacts.

The Front Center Airbag is an airbag that mounts to the inboard side of the driver front seat. It has a tubular cushion structure, and it deploys between the front seating positions in far side impacts, near side impacts and rollovers, with the cushion positioning itself adjacent the driver occupant's head and torso. This paper includes pictures of the technology along with a basic description of the design.

In-position occupant performance is also described and illustrated with several examples. Single occupant and two front occupant far side impact test data are included, both with and without the airbag present. Resulting performance differences are discussed leading to the following test observations: a) In a far side impact with a single driver occupant present, the deployed airbag functions as a restraint to help keep the occupant away from the intruded passenger compartment structure. b) When two occupants are present, the deployed airbag functions as a cushion between the front occupants.

In addition, field data from the Fatal Analysis Reporting System and National Automotive Sampling System - Crashworthiness Data System are initially presented to illustrate the challenges that this technology attempts to address.

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INTRODUCTION - FIELD DATA ANALYSIS

The primary purpose of the Front Center Airbag is to provide restraint and cushioning when a front seated occupant is in a far side impact, where the impacting object is on the opposite lateral side of the vehicle from the occupant.

As the Front Center Airbag was being contemplated, a field data analysis approach was configured and undertaken in order to learn as much as possible about how vehicle occupants are injured in various types of far side impacts, so that this information could be used to guide the design and develop performance evaluations.

Two National Highway Traffic Safety Administration (NHTSA) data sources were examined for this study: a) The

Fatality Analysis Reporting System (FARS) which is a national census of traffic fatalities and b) the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) which is a sampling of approximately 4,000 to 5,000 crashes annually, with detailed investigation.

FARS Data Analysis

FARS cases from the 2004 through 2009 calendar years were examined for vehicle models from 1999 through 2009 model years based on the following logic. In order to capture a larger quantity of recent models, study data included only the most recent six year window of field data available at the time this study was undertaken. The model year range was selected so that the data population consisted of more modern vehicles containing a higher level of air bag content.

The goal was to focus on belted outboard seated front occupants in non-rollover impacts for this analysis. This dataset was thus limited to belted occupants in outboard seating positions, and ejected occupants were excluded. The subset of cases was further restricted to remove those with rollovers present, since injuries in rollovers may occur during the actual rollover event and may or may not be due to the event that causes the rollover to occur in the first place. With these selection criteria, a subset of belted occupant data could then be analyzed. The number of cases was not restricted beyond this, because a significant sampling of far side impacts was needed for this analysis.

Some assumptions that were made for this study were: a) The principal impact point attribute (impact2) was chosen to define the impact type for each case. b) Vehicle body types for passenger cars, SUVs, vans, pickups or other light vehicles were included. c) Referring to [Figure 1](#), Far Side Impacts were defined using impact2 having clock directions of 2, 3 or 4 with a seat position of 11 or plus impact2 of 8, 9 or 10 with a seat position of 13. d) Near Side Impacts were defined using impact2 having clock directions of 8, 9 or 10 with a seat position of 11 plus impact2 of 2, 3 or 4 with a seat position of 13. e) Front Impacts were defined by impact2 of 11, 12 or 1. f) Rear Impacts were defined by impact2 of 5, 6 or 7. g) A category of Other/Unknown Impact included all other non-rollover impact types as well as those with unknown impact2.



Figure 1. Clock Directions for Impact2 and DOF1 with Seating Positions

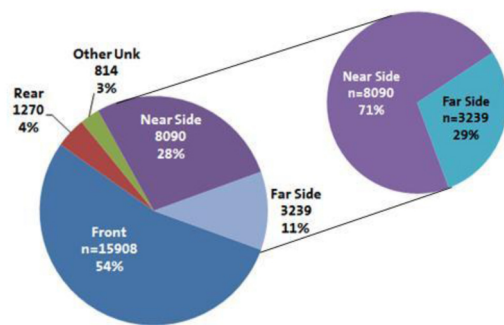


Figure 2. Percentage of Belted Outboard Front Occupant Fatalities in Non-Rollover Impacts by Impact Type - FARS 2004 to 2009, 1999 model year and newer vehicles

[Figure 2](#) presents the fatality picture for this range of data. Excluding rollovers, far side impacts comprise approximately 11 percent of belted front outboard occupant fatalities. When side impact fatalities are considered by themselves, far side fatalities comprise almost 30 percent of the total.

NASS-CDS Data Analysis of Far Side Impact Cases

The NASS-CDS data collection provides detailed injury information for the occupants in the investigated crashes. In addition, the NASS variable "body region" provides insight into which regions of an occupant's body are most commonly injured in far side impacts.

NASS-CDS cases from calendar years 1999-2009 were screened for non-rollover side impacts with belted outboard occupants in far side seating locations. Each case was reviewed in detail, examining the vehicle impact, occupant injuries and the sources of those injuries. Cases with significant second impacts were excluded. In addition, only injuries that were AIS 3 or greater were considered, and only the most severe injury per body region was counted. (AIS3+ injuries are injuries coded as serious or more extreme, based on a threat to life medical assessment.) In this manner, a single occupant could have more than one significant injury in this study, but no more than one injury per body region. Where multiple injuries of the same severity were recorded in NASS-CDS for a single body region, the first one listed was used. The body region coding was also modified with the cervical spine regions being included with the neck injuries. Pelvis injuries were assigned to their own body region though they normally fall within the lower extremity category.

For reference, some other sorting parameters that were applied to this study were: a) A small number of cases with subject vehicle pictures showing impact directions that did not match the case's impact direction coding were eliminated. b) AIS 7 injured, unknown category injuries were included. c) The data for each body was weighted using the summed Ratio Inflation Factor. (NHTSA applies this weighting to each case to estimate the types and severities of crashes in the U.S. in a one year period.) d) A torso body region was created by combining the thorax, spine, abdomen, and pelvis body regions, e) Un-weighted NASS-CDS cases were excluded. f) Passenger car, SUV, van and pickup truck body types were included. g) Direction of force (DOF1) equal to 02, 03, 04, 08, 09, and 10 was selected. h) Combinations of DOF1 of 08, 09 or 10 with seat position 13 plus DOF1 of 02, 03 or 04 with seat position 11 were used to define far side occupants, i) Cases with ejection were individually examined and included, where occupant injury was thought to result from impact to the vehicle interior. Several of the included cases involved partial ejections, where the occupant's body remained in the vehicle. Two cases involved complete ejection.

This screening resulted in 119 NASS-CDS cases, involving the same number of occupants with AIS 3 and

greater injuries in seating positions that were on the side opposite the impact.

The data for belted driver and passenger occupants are shown in the following figures:

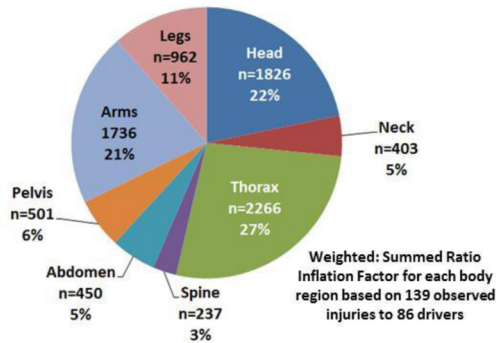


Figure 3. Injured Belted Driver Body Regions in Far Side Impacts - NASS-CDS 1999 to 2009, 1999 model year and newer vehicles

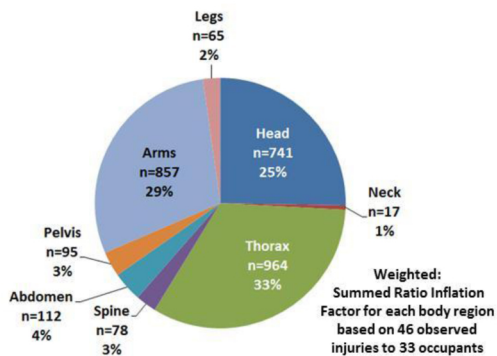


Figure 4. Injured Belted Front Outboard Passenger Body Regions in Far Side Impacts - NASS-CDS 1999 to 2009, 1999 model year and newer vehicles

The NASS-CDS data analysis identified the head, thorax, and arm regions of the belted driver and front outboard passenger as the body areas most frequently injured in far side impacts. These three body regions were also found to be the most frequently injured regions in Gabler et al (2005). [1] The following figure illustrates occupant kinematics that may have been involved in some of these injuries:

The single far side occupant in the top left view can be observed to rotate out of the shoulder belt and pivot about the lap belt and the center console, loading the center console with the torso. This type of movement out of the shoulder belt was also shown in simulations by Fildes et. al (1998). [2] The occupant also moves head first cross-vehicle, where contact could occur with other interior objects or the intruded structure that would be present, to some degree, in a severe impact. The occupant illustrations in Figure 5 are from sled tests which did not involve any structural intrusion. However, the pulse used was that of a pole impact, and the intrusion in the barrier test for this pulse places the intruded door

structure in proximity with the centerline of the near side front passenger seat, which is approximately the distance the driver's head traveled in the sled test. This is illustrated in the lower right view.

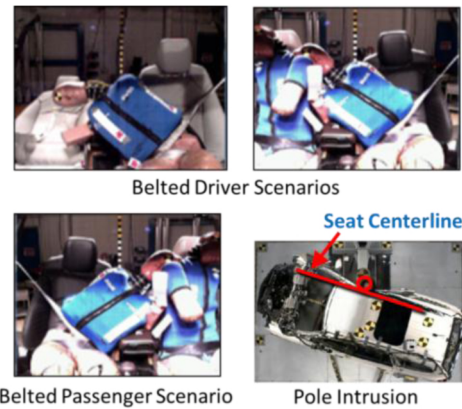


Figure 5. Examples of Belted Front Outboard Occupant Motion In Far Side Impact Sled Tests in a Rigid Buck (No Buck Intrusion Present)

When two occupants are present, the occupants can also contact each other as illustrated in two of the views in Figure 5.

Field Data for the Single Driver Occupant

Both sets of field data were further divided into single driver occupant cases and cases with two front occupants in order to understand the field exposure that has occurred for these conditions. This section presents the single driver occupant data.

As shown in Figure 6, the FARS database study revealed that 58% of the front outboard occupant fatalities and 73% of the driver fatalities in far side impacts were to a single driver occupant.

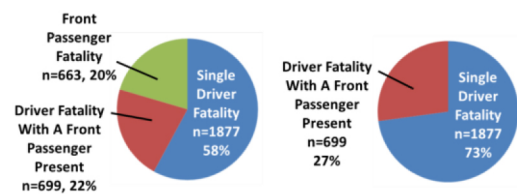


Figure 6. Percentage of Single Front Outboard Occupant Driver Fatalities - FARS Front occupant belted fatalities in non-rollover far side impacts, 1999 to 2009, 1999 model year and newer vehicles

The NASS-CDS database was also analyzed for this type of impact. The NASS-CDS data identifies the body region injured, and the probable source of injury. This information was studied for the two most frequent and critically injured body regions -the head and torso. For this analysis, a torso

region was created by combining the thorax, spine, abdomen, and pelvis body regions.

As part of this examination, the General Motors engineering team grouped the coded injury sources into common categories and compared them to the cited injuries and vehicle pictures. As an example of the grouping, some cases with the following NASS-CDS codes were combined into the passenger door injury source category if there were impact marks on the door in the pictures: Right Interior, Right Windowsill, Right Rear Upper Quadrant, Right Rear Lower Quadrant, Right Forward Upper Quadrant, and Right Hardware/Arm Forward Lower.

In the cases where apparent discrepancies were noted, the injury sources were modified to reflect what was thought to have happened. For example, in 29 of the cases that the GM team coded as involving center console related injuries, the NASS-CDS coding is shown as the transmission lever even though the text in most of these cases indicates the center console as the injury source. Those cases with observed center console loading and no observed transmission lever contact in the pictures were changed to the center console category. Figures 7 and 8 illustrate two such cases.



Figure 7. Example of Torso to Center Console Contact in a Far Side Belted Single Occupant Impact, NASS-CDS Case - Rigid Console



Figure 8. Example of Torso to Center Console Contact in a Far Side Belted Single Occupant Impact, NASS-CDS Case - Deformed Console (Forward in Vehicle is to the Left)

There were also 32 cases where an injury source was coded but the GM team placed the injury in the unknown category as it was not clear from the pictures or the case

description that the coded source was accurate. In many of these, the confidence level listed in the case for the injury source coding was less than "certain." A small number of cases also had the injury source changed based on the GM team analysis. For instance in one passenger side impact case, the driver had a right orbit facial fracture that had the steering wheel cited in NASS-CDS as the probable injury source. In this case, the adjacent passenger occupant had an upper injury attributed to the driver occupant and it appeared that the occupants were laterally aligned in the vehicle. The GM team changed the driver orbit fracture injury source to the passenger occupant since it was thought that this was more probable. Figure 9 shows a picture of the vehicle interior.



Figure 9. Driver Orbital Fracture NASS-CDS Case

From this work, Figure 10 shows the sources of head injury to the single belted driver far side occupant.

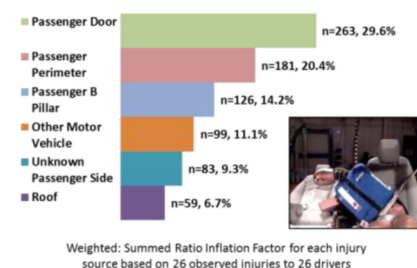


Figure 10. Sources of Head Injury to Single Belted Driver Occupants Front occupant belted fatalities in non-rollover far side impacts, 1999 to 2009, 1999 model year and newer vehicles

In the NASS-CDS data studied, the head injuries to single belted driver occupants in far side impacts were primarily due to contacting portions of the intruded interior, including the categories of passenger door, passenger perimeter (where a specific vehicle region could not be identified), and passenger B-pillar. Figure 11 provides graphics from a NASS-CDS case where the head injury was attributed to contact with the intruded interior. The compression of the arm rest in the bottom picture appears to have been caused by the driver's