Looking for Evidence of Inadequate Airbag Energy: Methodology for Evaluation

May 1998
INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) amended Federal Motor Vehicle Safety Standard (FMVSS) 208, Occupant Crash Protection, in March 1997 to address the issue of airbag-related fatalities and injuries in relatively low-speed crashes. This amendment specifies alternative certification procedures that allow vehicle manufacturers to install airbags that deploy with approximately 20 to 35 percent less force than currently installed designs (NHTSA, 1997a). Although overall reductions of serious and fatal airbag-related injuries are expected from depowering airbags, NHTSA has stated that protection may be inadequate for some unbelted occupants in higher speed crashes. In its final regulatory evaluation of airbag depowering, NHTSA estimates that depowered airbags may result in additional driver deaths because these airbags would not have sufficient energy to prevent fatal chest injuries in higher severity crashes, offsetting some of the benefits from depowering (NHTSA, 1997b). As a result of this concern, the agency is investigating crashes of vehicles with depowered airbags to closely monitor airbag performance and detect as soon as possible if any of these airbags are providing inadequate protection in frontal crashes. How does one determine that an airbag was inadequate in a crash or, more precisely, that an airbag with more power might have prevented the observed injuries? The crash experience of cars with depowered airbags is limited, but an examination of experience with first generation (non-depowered) airbags can be instructive.

An Insurance Institute for Highway Safety study of driver fatalities in airbag-equipped vehicles in the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) from 1989-93 found no cases where unbelted drivers were fatally injured because their airbags deployed too slowly or with too little energy (Lund et al., 1996). Fatal injuries were classified into one of five categories of probable cause: intruding vehicle surface, non-intruding vehicle surface, ejection, airbag, or non-impact causes. An update to this study to include driver fatalities in airbag-equipped vehicles in 1994 NASS/CDS again found no evidence to indicate that drivers died because of their airbags’ insufficient capacity to restrain them. This study of 67 cases, 25 of which were frontal crashes, concluded that although airbags as currently designed are performing very well to protect drivers in frontal crashes, a reduction in airbag energy may benefit drivers, particularly unbelted and shorter drivers, in a wide range of crash severities (Ferguson, 1996). However, federal researchers have suggested recently that their review of the NASS/CDS data did indicate six cases where occupants appeared to have died from injuries that a more energetic airbag might have prevented. These cases were all high-severity crashes, and, although the airbags deployed, NASS investigators noted that the fatal injuries involved impacts between the drivers’ chests and the steering wheels. The presence of significant steering wheel deformation was noted as possible evidence of bottoming out the airbag (although only two of the six
cases had steering rim/spoke deformation in excess of 6 inches, in two cases deformation was less than 1 inch, and there was no deformation in the remaining two cases). The implicit conclusion is that these drivers’ fatal chest injuries could have been prevented had their airbags been able to absorb more crash energy.

Institute researchers have reviewed the six cases in question and still conclude there is no evidence that these driver deaths in vehicles equipped with first generation (non-depowered) airbags were due to inadequate airbag energy. Three of these cases were, in fact, included in the earlier Institute studies (Lund et al., 1996; Ferguson, 1996). Occupant compartment intrusion was a factor in five cases, and the fatal injuries in four of these appear to be most likely due to this intrusion. Based on inspection of slides from the NASS investigation, intrusion of interior components was so great in three cases that there was little or no space left for the driver to ride down the airbag and dissipate some of the crash energy. In the fourth case, the intruding steering column had rotated upward, leaving the bottom rim exposed perpendicular to the driver so that the airbag probably was not positioned to protect the driver. The fifth case was a complex crash involving multiple impacts, occupant compartment intrusion, and a driver who likely was out of position. In the sixth case, which had no intrusion or steering wheel deformation, the airbag was the likely source of the fatal chest injuries. The Institute believes this difference of opinion results from different approaches to evaluating the likely contribution of airbags to the prevention or, in some cases, causation of motor vehicle crash injuries. A consensus should be reached on how best to conduct this evaluation before NHTSA reaches any conclusions about the performance of depowered airbags in the fleet. For that reason, the six cases in question are reviewed in detail below in order to illustrate a procedure for evaluating the performance of airbags in severe crashes. The procedure focuses on three critical factors: occupant position, ride-down space, and airbag availability.

For a driver airbag to be effective, the driver first must be properly positioned — seated upright and away from the airbag. If the driver is slumped over the steering wheel or otherwise close to the airbag module prior to deployment, the energy from the deploying airbag can cause serious chest and/or neck injuries. There also must be enough space for the driver to ride down the airbag. In a severe crash, the steering column can be driven rearward toward the driver until there is insufficient space left for the driver and the airbag/steering wheel combination. In such a case, the driver can be injured by the inflating airbag due to movement of the steering wheel and other vehicle components and would not be better protected by a more powerful or larger airbag. In fact, in such a case, a more powerful airbag could actually increase injury severity. Finally, the airbag must be available — that is, not deployed due to prior impact (as might happen in a crash with multiple impacts), or out of position when it deploys (as
might happen with steering column movement). If the occupant is not properly positioned, if intrusion eliminates ride-down space, or if the airbag is not available, it is unlikely that a more powerful airbag could reduce injury severity.

CASE REVIEWS

1. CASE 94-74-157. This case was reviewed in an earlier Institute paper (Ferguson, 1996), which determined that the driver’s fatal chest injuries were the result of occupant compartment intrusion. A 1993 Dodge Intrepid driven by an unbelted, 70-year-old, 5 foot-10 inch, 180-pound male was struck head-on by a 1988 Oldsmobile Delta Eighty-Eight. A 46 mi/h delta V was estimated for the Dodge Intrepid. Steering wheel deformation was minor, measuring 1 inch at the upper half of the rim. With 7 inches of residual intrusion of the steering assembly and left-side instrument panel and 11 inches of A-pillar intrusion, there was little ride-down space left for the driver (Figure 1). Because dynamic crush is considerably greater than crush measured after the crash, it is likely that, at the maximum point of its travel, the steering wheel and airbag were pushed into the space occupied by the driver. The minor steering wheel deformation indicates the multiple severe chest injuries probably were sustained while the airbag still was deployed.

<table>
<thead>
<tr>
<th>Occupant in position:</th>
<th>Probable</th>
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<tbody>
<tr>
<td>Ride-down space available:</td>
<td>No</td>
</tr>
<tr>
<td>Airbag available:</td>
<td>Yes</td>
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Figure 1
(Case 94-74-157)
2. **CASE 95-49-213.** A 1992 Chevrolet Corvette struck a wall head-on, undergoing a delta V of 53 mi/h. The driver was an unbelted, 38-year-old, 5 foot-10 inch, 179-pound male. The lower half of the steering wheel rim deformed about 1 inch. With nearly 10 inches of steering assembly intrusion along with more than 20 inches of left-side instrument panel intrusion and other intruding interior components, there was virtually no survival space left for the driver. This fatality was classified by Institute researchers as intrusion-related and unsurvivable (Figures 2a, b).

<table>
<thead>
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<th>Occupant in position:</th>
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<tbody>
<tr>
<td>Ride-down space available:</td>
<td>No</td>
</tr>
<tr>
<td>Airbag available:</td>
<td>Yes</td>
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*Figure 2a (Case 94-49-213)*
3. **CASE 96-75-98.** A 1995 Plymouth Voyager struck and broke a wooden utility pole with its right front (offset) and then struck a steel utility pole with its left front (crash scene, with replacement wooden pole, shown in Figure 3a). Delta V could not be calculated due to the overlapping damage, but this was a severe crash, as shown in Figure 3b (CDC 12FYAW7). Figure 3c shows that the upper half of the steering wheel rim deformed significantly (coded in NASS as “15 centimeters or more”). The airbag likely would have deployed in the impact with the first pole and would have been unavailable to provide any protection to the unbelted, 33-year-old, 6 foot-1 inch, 190-pound male driver in the second impact. Additionally, the driver likely was thrown forward in the first impact and was out of position for the second impact. Occupant compartment intrusion (nearly 20 inches for the steering assembly, 14 inches for the left-side instrument panel, and more than 30 inches for the driver-side toepan) indicates this crash may have been unsurvivable even if the airbag had deployed in the second impact. Institute researchers classified this fatality as intrusion-related and unsurvivable.

<table>
<thead>
<tr>
<th>Occupant in position:</th>
<th>No</th>
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<tbody>
<tr>
<td>Ride-down space available:</td>
<td>No</td>
</tr>
<tr>
<td>Airbag available:</td>
<td>No, deployed on first frontal impact</td>
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4. **CASE 91-75-23.** This case was discussed in an earlier Institute paper (Lund et al., 1996), which concluded that the cause of death was related to occupant compartment intrusion. A 1992 Ford Tempo driven by an unbelted, 34-year-old, 6 foot-1 inch, 195-pound male struck a pole head-on, undergoing a delta V of 39 mi/h. The steering wheel rim was not deformed, but the wheel itself was bent upward with the airbag module cover nearly horizontal, pointing toward the roof (Figure 4). The edge of the steering wheel rim was the likely source of the fatal injury, a transected aorta. It is unclear why the steering wheel intrusion was so great or when it occurred in the crash. One possibility is that the steering column broke under the load of the 195-pound unbelted driver, allowing the rim to dig into the chest as the column rotated upward. If the column rotated upward early in the crash, the airbag would have deployed up toward the roof rather than out toward the driver. In either case, the driver probably contacted the steering wheel rim from beneath the airbag rather than through it.

<table>
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<th>Occupant in position:</th>
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<tbody>
<tr>
<td>Ride-down space available:</td>
<td>Yes</td>
</tr>
<tr>
<td>Airbag available:</td>
<td>Airbag out of position due to bending of steering column</td>
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5. CASE 95-13-208. A 1995 Nissan Maxima ran off the right side of the road, then back across and off on the left side into a ditch, striking a tree with its front end (estimated 36 mi/h delta V), and rotated counterclockwise, knocking down a mailbox with its right rear (crash scene shown in Figure 5a). The driver, an unbelted, 66-year-old, 5 foot-8 inch, 160-pound male, sustained injuries to the head, chest, abdomen, spine, and lower extremities. This very severe crash (50 inches of maximum external crush) caused approximately 19 inches of intrusion for the floorpan, 11 inches for the windshield, 9 inches for the A-pillar, and 6 inches for the left instrument panel. There was significant steering wheel rim deformation of more than 6 inches. Although there may have been enough room for the driver to ride down the airbag (Figure 5b), circumstances in this complex crash suggest the driver was not in position to take full advantage of the airbag. Running off the road and into the ditch may have thrown the unbelted driver forward and close to the wheel at the time the airbag deployed. It also is possible that the airbag deployed when the vehicle hit the ditch, just prior to the impact with the tree. Thus the airbag may have already begun deflating when the vehicle struck the tree. The downward and upward motion of the vehicle running into the ditch and striking a tree on the other side, along with the rotational component of the crash, almost certainly would have moved the unbelted driver toward the intruding vehicle components as evidenced by the multiple body regions injured. The General Vehicle form also notes a
medical problem as the critical precrash event, although it is not known how this may have affected the driver’s movements or position. Although this severe crash did leave some survival space for a properly positioned driver, the complex circumstances of the crash make it likely that the airbag actually contributed to the fatal injuries of an out-of-position driver.

**Occupant in position:** Unlikely  
**Ride-down space available:** Yes  
**Airbag available:** May have deployed early in the collision

**Figure 5a**  
(Case 95-13-208)
6. **CASE 91-79-21.** This case was included in a previous Institute study (Lund et al., 1996), which determined that the airbag’s deployment energy contributed to the fatal chest injuries sustained by the unbelted, 35-year-old, 5 foot-6 inch, 160-pound male driver of a 1991 Dodge Caravan. The NASS investigator found no passenger compartment intrusion and no steering wheel deformation (Figure 6a). According to the case summary, “the accident report states that there was no visible body trauma,” and there were no external injuries in the chest area listed on the Occupant Injury Data form. Although the source of the chest injuries ultimately was changed from unknown to steering wheel rim and hub/spoke, the injuries were more likely caused by the force of the airbag deployment. The lack of visible external signs of injury such as contusions or abrasions indicates the internal injuries were caused by a force more evenly spread, such as an airbag, than concentrated, such as the steering wheel rim or hub. The lack of steering wheel rim deformation and rearward movement are further evidence that the airbag and not the steering wheel caused these injuries. The unbelted driver of this vehicle had a blood alcohol concentration of 0.16 percent and could have been slumped over the wheel and close to the airbag at the time it deployed. Even had the unbelted driver been seated upright against the seat back at the beginning
of the crash, he would have moved closer to the steering wheel by the time the airbag deployed due to the very long and soft crash pulse (the soft rear-end structure of the struck vehicle, a parked 1958 Chevrolet Bel Air, crushed 50 inches, as shown in Figure 6b). The soft crash pulse also may have delayed the deployment of the airbag.

**Occupant in position:** Possibly out of position  
**Ride-down space available:** Yes  
**Airbag available:** Deployment may have been delayed due to soft crash pulse

**Figure 6a**  
(Case 91-79-21)
Figure 6b
(Case 91-79-21)
REFERENCES


