SIDE IMPACT AIR BAGS – THE GENERAL MOTORS APPROACH

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ABSTRACT

In 1998, side crashes are estimated to have resulted in 9482 fatalities or approximately 25% of all vehicle fatalities in the United States. Side air bags, which are designed to intersperse themselves between the occupant and the vehicle, are considered to be effective in reducing injuries for both children and adults. To increase side air bag effectiveness they must be carefully engineered to address the potential for causing injury while at the same time provide as much restraint capacity as practicable.

Unlike frontal impact air bags whose designs in the United States are constrained by governmental regulations, side air bags have no such constraints. As a result General Motors had the flexibility to use a fundamentally different approach for the design of its side air bags than what was required for frontal impact air bags. For side air bags General Motor's approach was first to design systems that minimized the risk of injury to children and lower tolerance adults and then secondly to provide as much protection as practicable for various size occupants in a variety of crash conditions.

To achieve this objective General Motors established a policy of evaluating its side air bags using the standard 3 year old ATD in carefully selected out of position test locations to determine that injury performance criteria were satisfied. As a result, good side impact protection is provided while reducing the potential for producing unintentional injury to vehicle occupants.

BACKGROUND

In the late 1980's and early 1990's automakers were rapidly implementing frontal air bags in North America. As required by FMVSS 208, these frontal impact air bags were required to provide protection to an unbelted adult male occupant in a severe 30 mph frontal rigid barrier impact test condition. Due to the physics associated with the crash test severity and the mass of the unbelted adult occupant the resulting air bag is required to deploy with significant force.

While frontal air bags are effective in reducing injuries in many frontal crash conditions, they also have potentially contributed to injuries to occupants who are out of position and too close to the air bag at the moment of deployment. Engineers must design frontal air bag systems to balance the inflation capacity for the unbelted adult occupant while not being overly forceful for the out of position occupant. As the industry's general knowledge of the air bag system's restraint capabilities and limitations increase, it is natural for engineers to consider utilizing air bags to address injuries associated with other crash conditions such as side crashes.

GENERAL MOTORS FUNDAMENTAL APPROACH TO NEW SAFETY TECHNOLOGY DEVELOPMENT

General Motors strives to continually improve the safety performance of its vehicles. New technologies and features are always being evaluated in an attempt to extend the vehicle's safety capabilities.

The general approach used by General Motors in the design of a new vehicle is to first examine the field injury performance of vehicles of similar design to identify potential areas of design improvement. Several sources of field data are utilized such as the National Highway Traffic Safety Administration's National Automotive Sampling System (NASS), State motor vehicle collision databases and Fatal Accident Reporting System (FARS) database.

By studying various types of crash conditions, as well as the injuries resulting from those crashes, the engineer can gain some understanding of the interactions between the occupant and the vehicle. Understanding these interactions allows the engineer to assess whether new technology can be developed to help improve the vehicle's performance.

The vehicle is a complex system consisting of many balanced interacting components and sub-systems. As new technology is added to the vehicle care must be used to not adversely upset that delicate balance and potentially degrade the vehicle's performance or utility under other operating conditions. Inherent to any new technology may be advantages and disadvantages. Therefore before any new technology is added to the vehicle its performance must be assessed to determine that it not only provides an overall safety benefit to the customer, but does not necessarily contribute to injuries.

SIDE AIR BAG PERFORMANCE EVALUATION CONSIDERATIONS

Unlike frontal air bags which have been government mandated for vehicles sold in the United States, side air bags are not regulated and have no government mandated performance. As a result General Motors established its own side air bag performance evaluation considerations. These performance evaluations were established in 1995 near the beginning of the side air bag development program and General Motors vehicles with side air bags are assessed using them.

The side air bag performance evaluation considerations were configured to first minimize the potential risk of injury to children and lower tolerance adults and then to provide additional protection beyond that which is afforded by the vehicle's side structure.

The comprehensive set of side air bag test evaluation considerations essentially center around meeting occupant injury assessment reference values for the 3 and 6 year old child as well as the 5th percentile adult female in specific test configurations representing foreseeable out of position occupant locations. The rationale for choosing the 3 year old was considered reasonable since children four years old and younger should be restrained in a child seat and hence are likely to receive some benefit from the child seat itself.

The side air bag performance evaluation considerations consist of a regime of tests using the 3 year old and 6 year old Hybrid III ATD as well as the 5th adult female Hybrid III ATD in out of position locations such as leaning against the door, facing and looking into the rear seat or lying across the front seat cushion. The test positions where selected to represent locations in which the air bag module would impart significant loading into the ATD's transducers.

The original regimen of tests including ATD type, injury assessment reference values, test locations and set up procedures were those already used by General Motors. These original side air bag evaluation considerations have been revised to comprehend the test procedures recently developed by the Industry Technical Work Group on side air bags. The outcome of this Work Group will be discussed later in this paper.

In addition to assessing potential injury causation, side air bags are also evaluated for their ability to provide protection. This is accomplished in a several ways and varies among vehicle programs depending on structural changes. In addition to government regulated impact tests and consumer information tests, side air bags are evaluated using a variety of computer simulations.

INITIAL SIDE AIR BAG CONFIGURATIONS AND SUBSEQUENT EVOLUTIONARY DESIGNS

As fundamental knowledge and understanding of the restraint capabilities of frontal air bags increased, engineers considered other applications for air bags. Analysis of field crash performance data indicated that side crashes were a significant source of injuries. Therefore engineers explored the feasibility and occupant performance benefits of using air bags for side crash protection.

Side impact crashes present additional challenges beyond those of front impact crashes. Two challenging issues in particular had to be addressed.

The first challenge to overcome was the lower amount of crush space associated with side crashes. Unlike frontal crashes, which involve considerable crush space between the point of impact on the front bumper and the passenger, side impact crush space only consists of the distance between the point of impact on the door outer surface and the occupant. This reduction in crush space places greater demands and limitations on the air bag deployment sensing system and inflation rate characteristics. In side impacts the sensing system generally must make the deployment decision within approximately 5 - 10 milliseconds as opposed to having approximately 15 – 25 milliseconds for frontal impacts. Air bag inflation times are also less and generally range between 10 – 15 milliseconds for side air bags as opposed to 30 – 45 milliseconds for frontal air bags.

The second challenge to overcome is the proximity of the occupant to the air bag itself. Due to the occupant seating location, side air bags, which are located in the door, roof rail or seat bolster, are by necessity designed to be closer to the occupant than frontal air bags located in the steering wheel or the instrument panel. The closer proximity of the side air bag requires careful engineering of the coverage area size, depth and inflation characteristics of the air bag so as to reduce the potential for unintentional inflation induced injury.

Balancing and optimizing the occupant protection benefits of air bags while reducing unintended inflation induced injury is a constant goal. Unlike the inflation force of frontal air bags, which in the United States is defined by the unbelted 50^{th} adult male occupant FMVSS 208 barrier requirement, side air bag inflation can be balanced to reduce unintended inflation induced injury while still providing reasonable side impact occupant protection.

For General Motors North America the first side air bags were implemented in the 1997 Cadillac DeVille. These side air bags were an adaptation of the driver side frontal air bag and were reconfigured and placed in the vehicle's door just under the surface of the door side trim panel. These side bags covered the occupant's thorax for a range of seating positions and occupant sizes.

During the late 1990's timeframe side air bag designs were evolving and air bags located in the driver and front passenger seat began to appear. The initial seat mounted air bags provided protection primarily to the occupant's thorax region. Since field crash data indicated that injuries to the head were also a source of harm, engineers attempted to enlarge the coverage area of side air bags to provide protection to the head. However, increasing the size and coverage area of the side air bag required larger air bag volumes and corresponding increases in inflator output. These increases in inflator output had to be balanced with the potential for unintentional inflation induced injury. One way to address this concern was to install the larger head/thorax coverage air bags on the driver side of the vehicle and to use the smaller thorax air bag on the passenger side of the vehicle where a smaller occupant of a child may be seated. This arrangement allows the engineer to tailor the protection capabilities of the larger head/thorax air bag to the higher human tolerance of an adult driver.

Other locations and configurations of side air bags, providing head protection, were pursued. These included inflatable curtains or inflatable tubular systems located in the vehicle's roof side rail just above the door side window. The roof rail mounted systems deploy downward toward the beltline of the vehicle and, depending on configuration, are designed to provide coverage for the head and a portion of the shoulder/thorax region.

Industry Standardized Test Procedures for Side Air Bag Out of Position Occupant Evaluations

By 1999 side air bags were being implemented in several automaker's models in the North American market. Different types of mechanizations such as thorax, head/thorax, curtains and inflatable tubular systems were utilized. Different locations such as door, seat, roof for both the front and rear seating positions were also beginning to appear. Customers expected designs to be reasonably safe under normal operating conditions.

In May 1999 the NHTSA's administrator, Ricardo Martinez, challenged automakers to establish public test procedures that would be used to develop future side air bag systems in a fashion that would not present an unreasonable risk of injury to vehicle occupants. To respond to that challenge automakers and automotive suppliers established a technical working group consisting of a broad range of technical experts in vehicle crashworthiness, air bag restraint systems and biomechanics. The Insurance Institute for Highway Safety (IIHS) was requested to chair the group. Additional technical experts from the NHTSA, Transport Canada, George Washington University and Nationwide Insurance were also invited to participate. The Technical Work Group (TWG) completed its work in August 2001 by publishing a recommended set of test procedures for evaluating occupant injury risk from deploying side air bags.

Since the TWG's proposed test conditions, test dummy sizes and injury criteria were similar to General Motor's existing internal Occupant Performance Evaluation Considerations, GM simply supplemented its existing internal guidelines with the TWG's proposed test procedures.

Potential Future Improvements in Side Impact Occupant Performance

In conclusion, as mentioned earlier, approximately 25% of all vehicle fatalities in the United States are estimated to occur in side crashes. Side air bags which intersperse themselves between the occupant and the vehicle may prove to be effective in reducing injuries to both children and adults. To increase the effectiveness of side air bags they must be carefully engineered to address the potential for causing injury while at the same time providing as much restraint as practicable.

Over time, the industry's knowledge of the side air bag protection is expected to increase. It is anticipated that further enhancements and performance improvements will be made. It is likely that side air bags, particularly curtain configurations, will be expanded into the rear seat and possibly even into the third row of passenger vans. It may also be possible to develop vehicle rollover sensors that would deploy side air bag curtains to assist in containing the occupant inside the vehicle during a rollover crash.

Side impact air bags are still a new and evolving technology. As with any new technology, automakers must determine that a safety benefit can be achieved and that an unreasonable risk to vehicle occupants does not result. Care must also be taken on the part of government regulators and consumer information organizations to assure that safety regulations and/or consumer information tests do not unintentionally bias side air bag performance toward one impact condition to the detriment of increasing overall protection for the broad range of real world crash conditions.