IDENTIFYING AND PROVING AUTOMOTIVE ALGORITHM DEFECTS AND AFFECTING RECALLS

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ABSTRACT

The societal cost in lives lost and injuries sustained from electronic defects, such as occupant size algorithm misclassification and ignition switch failure, was studied. In addition, the societal cost of ineffective production restraint systems in frontal and angled-frontal crashes was evaluated. Fatalities due to electronic defects were compared to the total fatalities from frontal and angled-frontal crashes.

Accident statistics show that, from 2001 to 2013, there were only 50 electronic algorithm defect deaths annually compared to 10,676 deaths annually from frontal and angled-frontal crashes involving vehicles that met the Federal Motor Vehicle Safety Standard (FMVSS) 208 test requirements. Our research indicates that many more deaths would have been prevented in a single year than electronic defects caused in 20 years if certain features of passive restraint systems proposed in the 1970’s had been implemented. The same trend applies to injury mitigation.

The research question explored here is: Should “WE” prioritize identifying and repairing:
• algorithm defects that cause only 50 of the 10,676 fatalities annually, or
• ineffective production restraints systems in vehicles compliant with FMVSS 208 test requirements that cause 10,626 of the 10,676 fatalities annually.

Since NHTSA cannot specify design requirements, a simple solution is to substitute for the right and left angled barrier test a compartment angled at 20º to the right and then 20º degrees to the left on a sled simulating a 30 mph crash.

BACKGROUND

Since the first Drive-by-Wire (DBW) systems, independent engineers, manufacturers, and government have been aware of algorithm defects in production vehicles. Unintended acceleration, occupant size algorithm misclassification, and ignition switch failures are newly-reported, not newly-identified defects. To affect a recall, complaints and accidents must occur. Then, the NHTSA directs research and testing to identify and prove a defect. Litigation often accelerates the research and testing phase of the recall process. However, crashworthiness testing does not prove causation. Electronic defects are proven by downloading and analyzing control module stored functional data for a specific crash; this stored data does prove causation. The population of affected vehicles are identified. The cost of the defect is assessed in terms of lives lost and injuries mitigated. Technical service bulletins are issued. Recalls are implemented. Today’s media informs the public.

Automotive DBW systems interconnect at least 40 microprocessors, their algorithms, hundreds of sensors and millions of lines of software code. Industry has developed DBW systems to improve engine fuel efficiency and responsiveness, reduce emissions, enhance occupant comfort, improve injury protection, and streamline repair and service diagnostics. In spite of rigorous testing, the DBW system is so complicated that it still has previously-identified, but unfixed bugs. Those bugs are generally discovered in litigation and lead to millions of recalled vehicles to mitigate potential deaths and injuries.

In 2014, millions of vehicles were recalled for unintended acceleration, ignition switch engine cut off, and/or failed airbag inflator housings. Congressional oversight investigations urged NHTSA to penalize manufacturers for delaying notification of such defects for up to 10 years. Press coverage highlighted the potential for death and injury.
in this paper, the annual fatalities and injuries caused by automotive electronic defects are compared with the thousands of deaths that occur annually in vehicles that meet all applicable FMVSS test requirements due to ineffective restraint systems. An example of the cost in lives is presented here.

METHODS

Accidents Statistics Data

In 2013, the Fatality Analysis Reporting System (FARS) identified 27,051 vehicle fatalities categorized as frontal, side, rear and rollover. Of those, there were 10,676 fatalities in non-rollover frontal impacts and angled-frontal impacts between 11 o’clock and 1 o’clock. That amounts to an average of 29 deaths per day in the United States [1]. These deaths are valued at $9.1 billion in accordance with Department of Transportation Policy Guidance, amount to a societal loss of $96 billion in monetary terms, not moral terms.

An estimate of the distribution at 11 o’clock, 11:30, 12 o’clock, 12:30 and 1 o’clock of the 10, 676 fatalities from frontal and angled-frontal crashes [2] is shown in Table 1:

<table>
<thead>
<tr>
<th>Clock Position</th>
<th>Angle</th>
<th>Total Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00</td>
<td>-30°</td>
<td>843</td>
</tr>
<tr>
<td>11:30</td>
<td>-15°</td>
<td>Estimated 2,745</td>
</tr>
<tr>
<td>12:00</td>
<td>0°</td>
<td>Estimated 3,850</td>
</tr>
<tr>
<td>12:30</td>
<td>15°</td>
<td>Estimated 2,560</td>
</tr>
<tr>
<td>1:00</td>
<td>30°</td>
<td>679</td>
</tr>
</tbody>
</table>

It is important to note the large number of deaths attributed to angled impacts at 11:30 and 12:30 where the restraints are ineffective. In developing airbags for NHTSA in the 1970s, Minicars determined that the left and right frontal 30° angled barrier impacts corresponded to ±10° of real world angled impacts because corner friction between the vehicle and the barrier limits the equivalent real-world angle. In other words, compliance with the regulatory test only requires occupant protection in frontal and ±10° angled real-world impacts. Current supplemental airbags are sized to protect occupant head and neck from contact with interior components. The deployment algorithms preclude activation in angled impacts relying on the belts to limit motion. Therefore, occupants of real-world angled impacts greater than ±10° are virtually unprotected and account for the large number of fatalities at 11:30 and 12:30 clock positions. Apparently, NHTSA has not recognized this discrepancy in protection, where the industry can be in full compliance with the test requirements, but only protect less than half of the frontal fatality population.

Algorithm Misclassification An investigation of an essentially frontal crash in a 2008 sedan produced physical evidence of a defective occupant size algorithm misclassification defect. The Crash Data Retrieval (CDR) record confirmed the driver airbag deployment and right front passenger airbag deployment suppression. A download of the stored data in the passive occupant detection system control module was conducted. The stored data showed that a 170-lb belted right front seat passenger, who lifted off the seat, was misclassified as a small adult 1.5 seconds prior to impact, resulting in suppressed passenger airbag deployment.

An Office of Defect Investigation (ODI) petition called for a response from the manufacturer, whose analysis refuted the defect claim. The manufacturer:

1. did not deny that the algorithm resulted in occupant size misclassification, and
2. claimed the right front passenger was out-of-position.
**Ignition Switch Defect** Studies show that, over the 10-year period from 2003 to 2013, the ignition switch defect accounts for the 338 fatalities of the 3,806 claims. Based on the probable resolution of many of these claims, the annual cost of this defect is unlikely to exceed 20 fatalities and 100 serious injuries annually.

**Safety Belts and Airbag Defects** In the 1960s, there were no safety belts in cars and the concept of passive protection by automatically deploying airbag was born. In 1973, GM produced about 10,000 Cadillacs and Oldsmobiles with driver and passenger airbag protection.

In the context of the 1974 amendment to FMVSS 208, occupant protection is specified in Paragraph S4.1 Frontal Barrier Crash. “When the vehicle impacts a fixed collision barrier perpendicularly or at any angle up to and including 30° in either direction from the perpendicular, under the applicable conditions of S6, while moving longitudinally forward at any speed up to and including 30 mph with test device at each designated testing position, it shall meet the injury criteria of S5.” [3] A review of the latest post 2006 version of FMVSS 208 confirms this test procedure.

In spite of the amendment by 1981, the automotive industry drove the design of 3-point safety belts and associated supplemental airbags to perform in frontal and angle barrier impacts at the equivalent of ±10° of impact angle. This design strategy rendered occupants in crashes involving impact angles greater than 10° or 15° vulnerable to deaths and injuries. The annual cost of those impacts is in the range of 5,000 fatalities.

In the example frontal crash of the 2008 sedan presented above, the manufacturer claimed that there existed no proof that passenger airbag deployment would have mitigated the occupant’s injuries. The manufacturer made the following statement:

> “The Petitioner’s suggestion that the occupant would have benefited from passenger airbag deployment is not supported in the Petition and is pure speculation. The Petitioner has not supplied – and the manufacturer is not aware of – any evidence or argument that supports the conclusion that a passenger-side airbag should deploy in the conditions recorded by the vehicle’s AOS, or that the full deployment of the passenger-side airbag would have mitigated – and not exacerbated – the injuries allegedly sustained by the occupant during the accident.”[4]

The implication of this statement is that safety belts do not keep the occupant in close proximity to the seat and, if the passenger’s airbag had deployed, it would not have mitigated the passenger’s injuries as it did for the driver. In fact, the manufacturer claimed that deployment could exacerbate occupant injury.

An analysis of airbag effectiveness is tied to the frontal impact regulatory requirement test. The airbag is optimized to minimize head injury criteria in frontal ±10° impacts and sized accordingly. However, the slack in the safety belts is sufficient to put the occupant somewhat out-of-position, where the size of the airbag is insufficient to protect the occupant’s head. This analysis suggests that fatalities and injuries are the result of ineffective safety belts and/or airbags.

As early as 1972, the NHTSA sponsored the 1975 Minicars Research Safety Vehicle (RSV) project aimed at airbag development to protect occupants from interior impact at up to 30° at 30 mph [5-6]. Minicars found that a large-diameter chambered airbag had a significant effect on mitigating fatality and injury without requiring a revised test standard. The requirements for the airbags included frontal protection at 50 mph and protection from 11 to 1 o’clock at 30 mph. The RSV driver dual airbag was incorporated into the steering wheel on a stroking steering column with a foam knee restraint. The inner bag deployed first and vented into an approximately 30-inch outer diameter bag tethered to each other. The passenger airbag was chambered to fill in the bottom half and vent into a multichambered head impact bag. This design provided 50 mph occupant protection without safety belts at up to 30° off-axis (at 30 mph). Projected to the 1985 vehicle population, this design results in a 75% reduction in frontal fatalities.

The frontal crashworthiness compliance test and its vehicle rating system is based on a barrier crash at ±10° of 12 o’clock. The vehicle rating system assigns 3 of 5 possible stars if dummy injury measures meet the injury criteria and up to 5 stars if the injury measures are 50% of the injury criteria. This is a powerful incentive for manufacturers to optimize safety belt and airbag design for the test at minimum size, cost and weight.
Since NHTSA can only require performance criteria, an equivalent simple solution is to substitute for the right and left angled barrier test a compartment angled at 20° to the right and then 20° degrees to the left on a sled simulating a 30 mph crash. A further modification within NHTSA’s authority is to substitute a low durometer neck for the Hybrid III production neck to more appropriately represent current population of occupants. An experiment demonstrated the effect. Two identical sled tests of a restrained Hybrid III dummy, one with a production and the other a low durometer neck were tested at 15 mph. The low durometer neck allowed the head of the dummy to be extended forward approximately 4” further than the production neck as shown in Figure 1.

![15mph Hard Neck 15mph Soft Neck](image)

Figure 1. Production vs. Low Durometer Neck

RESULTS

The occupant size algorithm misclassification and the ignition switch defects account for only about 50 fatalities annually. In contrast, restraint systems that meet the regulatory requirements account for nearly 30 times the annual fatalities caused by electronic defects. The narrowly-defined FMVSS 208 requirements only protects occupants in direct frontal crashes. A variety of variables, each of which can account for several hundreds of fatalities in the real-world, are not adequately addressed in the existing standard. For example:

- the impact angle is greater than ±10°,
- occupants are frequently out-of-position,
- the dummy does not represent the current population,
- 30% of occupants do not wear their safety belts, and
- the DBW system fails.

CONCLUSION

Clearly, automotive safety efforts should prioritize reducing the 10,626 of 10,676 annual fatalities by improving safety belts for those occupants who wear them and expanding airbag passive protection for those who do not wear safety belts, instead of focusing on algorithm defects that cause only 50 of 10,676 fatalities annually.

Since FMVSS 208 is a performance, not design requirement, the most effective means of reducing fatalities and injuries is to substitute for the right and left angled barrier test a compartment angled at 20° to the right and then 20° degrees to the left on a sled simulating a 30 mph crash. A further modification would be to substitute a low durometer neck for the Hybrid III production dummy neck.

REFERENCES

[2] Ibid.