SIDE PRE-CRASH: A PRELIMINARY ANALYSIS & EVALUATION OF CRASH CAUSATION AND POTENTIAL SAFETY BENEFITS

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ABSTRACT

With significant benefits achieved with frontal/side and rollover passive safety systems and additional improvements coming on board with frontal active safety, it is natural to consider extension of similar systems to side impact. In this paper, we have made an attempt to understand the side impact crash causation, vehicle kinematics and occupant restraints benefits with early deployments to quantify the problem and evaluate potential benefits.

Using NASS/CDS & FARS 2000-2006 database, we have identified top 10 crash conditions (AIS 2+ injury and fatalities) and looked at select cases for each through accident reconstruction tools to better understand the vehicle kinematics prior to contact. This approach also has given us an initial view of potential 'zones' on the vehicle where active systems can best be deployed to improve detection while reducing potential for false alarm.

Also, a preliminary analysis through simulation and testing of early deployment of conventional passive systems compared to standard crash sensing shows a potential for significant injury reductions.

INTRODUCTION

Side impacts (SI) resulted in approximately 9,000 occupant fatalities per year in passenger cars and LTVs (light trucks and vans, including pick-up trucks, SUVs, minivans, and full-size vans) from 1975 through 2004. The proportion of fatalities resulting from side impacts are steadily increasing: from 30% of the fatalities in 1975 to 37% in 2004. Side impacts are the second highest cause of occupant fatalities in passenger cars. Near-side occupants are at a higher risk, close to 2 to 1 ratio compared with far-side fatalities. Striking or bullet vehicle types changed significantly through the years with over 50% of impacts being an LTV in 2004. LTVs are considered more destructive as a "bullet" vehicle in side impact due to their greater mass, height, and rigidity [1].

In the NASS/CDS 1995-2001 data analysis, 32% of AIS 3+ (seriously injured) occupant injuries were as a result of side crashes. Nearside occupants were involved in 49% of side crashes but accounted for 66% of AIS 3+ [2].

Based on the Traffic Safety Facts 2005 [3], a compilation of Fatality Reporting System (FARS) and General Estimates Sampling (GES) data, side impact incidents, involving passenger cars and LTVs, accounted for 28% of fatalities and 26% of all injuries. When analyzed separately, 34% of fatalities in passenger cars were due to side impact versus 21% in LTVs (Table 1, next page). In vehicle-to-vehicle type impacts, 23% of passenger cars were involved in a side impact. The ratio for passenger cars fatalities is 18% compared to 9% for LTVs (Figure 1, next page) yielding a ration of 2 to 1. It should be noted that FARS numbers are actual counts of fatalities or fatal crashes, whereas GES numbers are estimates of counts of crashes and injuries and are subject to sampling and non-sampling errors.

With the introduction of FMVSS-214 and the present 214 upgrade, many vehicles are expected to be equipped with life saving side airbags by 2010-13 timeframe. These airbags are typically designed to protect occupants in AIS 3+ type of injuries.

However, looking ahead of these technologies for the future, to address AIS 2+ type injuries, researchers are considering pre-crash technologies to help mitigate a higher number of side impact injury and fatalities.

Pre-crash sensing technologies are used to estimate the travel speed of a potential hazardous object or vehicle, its mass, and its principle impact direction.

Main intent of these technologies is to anticipate an imminent collision and deploy the countermeasures in a timely manner.

Table 1.

Occupants injured or killed by initial point of impact for passenger vehicles and light trucks (2005 crash data from FARS and GES) [3]

	Occupants Killed by Initial Point of Impact		Occupants Injured by Initial Point of Impact	
Initial Point of Impact	Passenger Vehicle	Light Truck	Passenger Vehicle	Light Truck
Front	9,658	6,946	741,000	392,000
Left Side	3,298	1,391	234,000	109,000
Right Side	2,986	1,271	194,000	105,000
Rear	998	659	369,000	206,000
Other	545	434	6,000	3,000
Non-collision	737	1,948	31,000	58,000
Unknown	218	326		

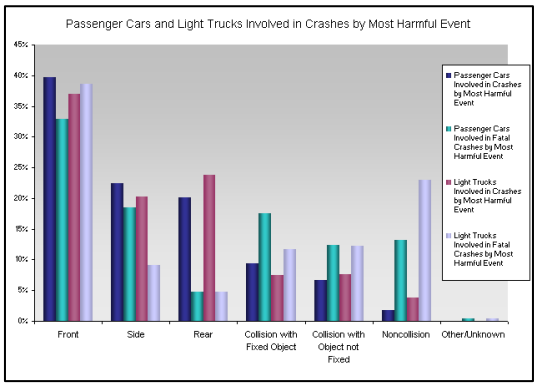

Figure 1. Passenger Cars and Light Trucks involved in crashes by most harmful event (2005 crash data from FARS and GES) [3]

The objective of this study was to focus on side crashes and to identify the most common collision scenarios. For this purpose, latest available accident data was analyzed. The results are used to help define and prioritize some of the requirements for the pre-crash sensing & countermeasure developments.

Methodology

The data was obtained from the NASS/CDS and FARS databases from 2000 to 2006. The crashes investigated in NASS/CDS are a probability sample of all police reported crashes in the U.S. A NASS/CDS crash must fulfill the following requirements to be included in the database: must be police reported, must involve a harmful event (property damage and/or personal injury) resulting from a crash and must involve at least one towed passenger car or light truck or van in transport on a traffic-way. AIS2+ side impact incidents were filtered from NASS/CDS. The AIS stands for Abbreviated Injury Scale consisting:
AIS - 0: Uninjured, 1: Minor, 2: Moderate, 3: Serious, 4: Severe, 5: Critical, 6: Maximum, 7: Unknown.

For example, AIS 2 is coded when the victim is unconscious due to the accident for 1hr. or less and/or has 2 to 3 sternum/rib fractures (connected to rib-cage but not flailing).

NASS/CDS study population included light vehicles with primary damage to the left or right side of the vehicle, and no rollovers with AIS 2 and above (AIS 2+). FARS study population consisted of light vehicles with angle collision and included AIS 2+.

Results

In NASS/CDS database, an average of 5,000 accidents is investigated per year and the results are projected nationally. From 2000 to 2006, out of 22 million towed vehicles due to accidents nation-wide, almost 5 million was a result of side impact incidents (23%). Approximately 321,000 vehicles included injuries with AIS2+.

Fatality information derived from FARS includes motor vehicle traffic crashes that result in the death of an occupant of a vehicle or a non-motorist within 30 days of the crash (caused as a result of the accident). FARS analysis showed that there were a total of 262,893 fatalities between 2000 and 2006. 55,200 of them were due to side impact.

Types of Objects Contacted - The analysis of 2000-2006 NASS/CDS AIS 2+ SI incidents showed that 81% of them were due to vehicle-to-vehicle impact and 19% were due to an impact with fixed objects. Figure 2 shows the distribution of vehicle-to-vehicle impact and types of fixed objects contacted.

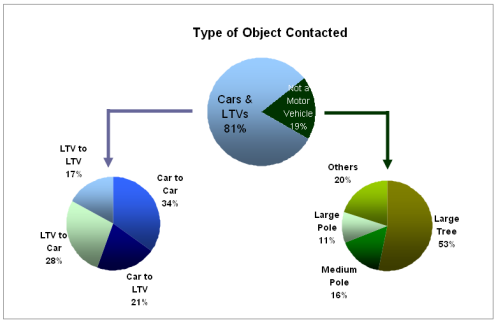

Figure 2. Type of Object Contacted

Class of struck vehicles – 65% of the vehicles was categorized as cars and 35% as LTVs. When the car was a struck vehicle, 71% of them were classified as 4-door sedan / hardtop, 17% as 2-door sedan/ hardtop / coupe, 7% as 3-door / 2-door hatchback, 3% as convertible, and 2% as 5-door/4-door hatchback.

Crash severity and Delta-V – In a previous study [4] based on the field data analysis using UK data, median delta-V was found to be 31 km/h for seriously injured near-side struck occupants and 43 km/h for fatalities in car-to-car collisions. In a small study of 39 car-to-car side impact collisions, mean delta-V for AIS 3-5 injuries was found to be 30 km/h. The typical delta-V resulting in AIS 3+ injuries are in the region of 30 km/h while 75%ile delta-V for these injuries at 38 km/h.
In our analysis of NASS/CDS AIS2+ side impact incidents, the mean delta-V was calculated as 27.4 km/h, while lateral component of that averaged at 22.8kph.

Police Reported Travel Speed - In our analysis of NASS/CDS AIS 2+ SI incidents, the average police reported travel speed was found to be 44 km/h. This information is indicated on the police report by the investigating officer and is missing in approximately 60% of the cases. The speed limit of the area where incident occurred averaged at 65 km/h.

An analysis of FARS data for 2002-2003 showed that the average travel speed was 61 km/h for perpendicular side crashes [5]. In our analysis of FARS data for 2000-2006 supported this finding and the average speed was 60.8 km/h.

Accident Types – Top accident types in NASS/CDS 2000-2006 side-impact analysis is shown in Figure 3. For example, 22% of AIS2+ side impact accidents happened when the vehicle was impacted on the left side while taking a left turn which is coded as type 82.

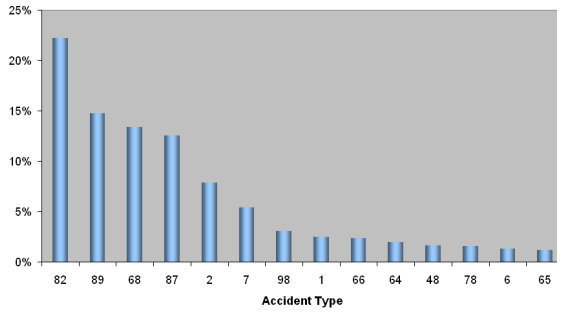

Figure 3. NASS/CDS 2000-2006 AIS2+ SI Top Accident Types (by frequency - %)

According to the analysis, the top six accident types (type 82 to 7 in Figure 3) covered 76% of all AIS2+ side impact accidents. Figure 4 illustrates these top accident types.

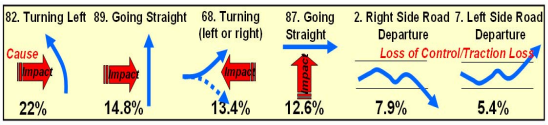

Figure 4. Representation of top six accident types (NASS/CDS 2000-2006 AIS2+ SI)

Pre-impact Stability and Location - In 71% of the AIS2+ SI incidents, vehicle continued along its intended path without rotation. Vehicles mostly stayed in lane in 70% of AIS2+ SI incidents, and departed the roadway in 19% of incidents. Table 2 displays the distributions for pre-impact stability and location.

Table 2

Pre-Impact Stability and Location, AIS2+ Side Impact Incidents NASS/CDS 2000-2006

1. Pre-impact stability	Frequency
Tracking (along original path)	71.35%
Lateral skid-counterclockwise	8.79%
Missing information	8.51%
Lateral skid-clockwise	7.02%
Others	4.33%
Longitudinal skid	4.18%

2. Pre-impact location	Frequency
Stayed in lane	69.32%
Departed roadway	18.56%
Left travel lane	10.24%
Others	1.88%

Intrusion - First location of the intrusion was mostly to the left or right side of the front row (65%). In 31% of the incidents, intrusion was to the second row left or right side (Figure 5.) Door panel was the first intruding component followed by B-pillar and floor pan, and front side panel.

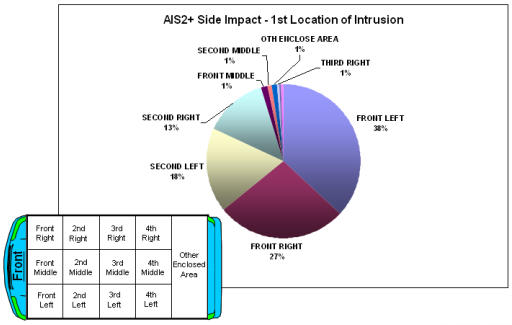

Figure 5. First Location of Intrusion of AIS2+ Side Impact Incidents, NASS/CDS 2000-2006

The magnitude of intrusion was between 15 and 29 cm in 37% of the AIS2+ side impact incidents, and in 22% of the incidents, the magnitude was 30-45 cm. Passenger compartment integrity is shown in Figure 6 with the side window glazing having the highest percentage.

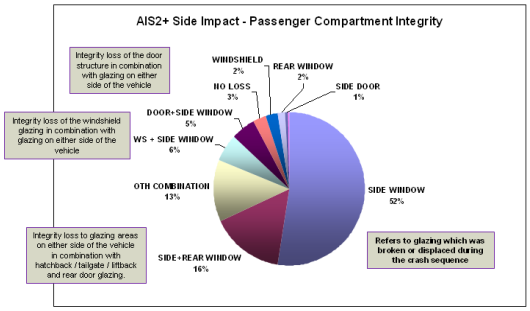

Figure 6. Passenger Compartment Integrity of AIS2+ Side Impact Incidents, NASS/CDS 2000-2006

Occupants – NASS/CDS 2000-2006 data showed that 76% of the occupants were at least 18 years old. 55% of the occupants were males. 36% of the occupants can be classified as fragile while 7% of these are very small females and the rest are children. The occupancy of the front row is 82% (note this is not 100% due to the fact front row includes right front passenger as well) and of the second row is 15%.

In 39% of the AIS2+ side impact incidents, drivers were non-attentive (either distracted or they looked but did not see any threat). Sole driver distraction (i.e., by an occupant, outside source, eating/drinking) were around 20% out of these non-attentive type incidents. Majority of the non-attentive type incidents were categorized as driver looked but did not see (72%).

Injuries - In terms of the injured body region of the occupants, head and face were the most injured areas (37%), followed by thorax, abdomen, and spine (27%). Upper extremities were injured at 20% level, and lower extremities were injured at 16% level. Right interior, roof, and left B-pillar were the top three injury sources that caused injuries on head and face. Thorax, abdomen, and spine were injured mostly by belt (webbing, pillar attachment, buckle) and left + right interior.

When a passenger car is struck by another car or LTV, head and lower extremities are the top two injured body regions. If a passenger car is struck by a pole, upper extremities and face were the top two injured areas.

Injury Patterns in the Literature - Struck-side occupant injury patterns showed that the torso and head were the most common sites of AIS 4+ injury in fatalities, while seriously injured survivors had legs, arms, and head as the most common sites of AIS 2+ injuries. Investigation of side crashes occurred in 1988-1992 revealed that head and chest were most commonly injured areas at AIS 3+ level but abdomen/pelvis and lower extremities were also important [2].

A sample investigation of UK data of 1992-1998 showed that 66% of MAIS 3+ survivors and 68% of the fatalities were near-side occupants. In terms of injury patterns, this study found that 55% sustained lower extremity injury of AIS 2+, followed by thorax at 49%, and head at 40%. However, regarding the key injuries of the fatalities (taken as AIS 3+), the most commonly injured body part was thorax with 89% followed by head with 70% [4].

In the NASS/CDS 1995-2001 data analysis for nearside AIS 3+ injured belted occupants in vehicles with MY 1995+, chest is the predominant injured body region (52%) followed by head (22%), pelvis (19%), and abdomen (12%). Side crashes with LTVs and narrow objects result in more occupants with head injuries compared with crashes with passenger cars. In modern fleet, the small size occupant (up to 5' 4'') is more at risk of serious injury in side impacts irrespective of crash partners [2].

A UK-based study that investigated injury outcomes in side impacts involving modern passenger cars found that the distribution of the 350 AIS 2+ injuries were highest to the head (28%) followed by the chest (22%) then the lower extremity (19%). These figures were for struck-side crashes only [6].

Environmental Conditions - A total of 67% of AIS2+ side impact incidents occurred at daylight, 11% of them in dark, and 18% in dark but lighted conditions. There were no adverse atmospheric condition in 82% of the incidents; it was raining in 15% of the incidents and snowing at 2% of the incidents.

However, within the top ten accident types, 35% of single-vehicle incidents of this group took place when it was dark and 22% in dark but lighted conditions. Only 6% of vehicle-to-vehicle top ten accident types occurred in dark and 16% in dark but lighted conditions. 11% of the vehicle-to-vehicle impacts occurred when it was raining as opposed to 18% of the single driver accidents. Although snow condition was insignificant overall, 15% of the accident type 2 where a single driver lost control and caused a right roadside departure, occurred in snow.

75% of AIS2+ side impact incidents occurred in a not physically divided two-way traffic. 15% of them occurred in a divided traffic-way with median strip but with no barrier. 5% of the incidents occurred in a divided traffic way – median strip with positive barrier and another 5% in a one way. 64% of the AIS2+ side impact incidents were related to intersection. 7% of them were related to driveway and 3% to interchange (area around a grade separation which involves at least two traffic ways).

Restraints - Another variable category that was investigated was the availability, usage, and response of restraints in the vehicles. Lap and shoulder belts were used in 59% of the AIS2+ SI incidents. In 35% of the incidents lap/shoulder belts were either not available or not used. It should be noted that 44% of the vehicles were manufactured in 1995 or earlier in this database. Frontal airbags were available in 61% of the AIS2+ side impact incidents. 39% of the incidents included vehicles with no frontal airbags. In 24% of the incidents, frontal airbags were deployed. In terms of side airbags, only 10% of the AIS2+ SI included vehicles with side airbags, and those airbags were deployed in half of the incidents.

SUMMARY & CONCLUSION

An analysis of the US field data using NASS and CDS from 2000-2006 was conducted to understand side impacts in general. Data was filtered to look at only AIS2+ type injuries. Table 3 lists some highlights gathered from the field data analysis.

Table 3.

Major findings of NASS/CDS 2000-2006 AIS2+ Side Impact Field Data Analysis

Category	Major Finding
First Location of Intrusion	Front Row (Left/Right side) (65%)
Magnitude of Intrusion	15-45 cm (59%)
Occupants	Children (29%)
Drivers	Non-attentive (39%)
Most injured body region	Head & Face (37%)
Injury Sources	Right interior, Roof, Left B-pillar
Traffic-way flow and Intersection	Not physically divided two-way traffic (75%) Intersection (64%)
Single Vehicle Incidents among Top Ten – Lighting Condition	Dark (35% in dark, 22% dark but lighted)
Single Vehicle Incidents among Top Ten – Atmospheric Condition	Raining (18%)
Lap & Shoulder Belts	Used (59%)
Frontal Airbag	Available (61%) Deployed (24%)
Side Airbag	Available (10%) Deployed (5%)

Using the analyzed data, top ten important crash events have been identified and also additional supporting information such as weather condition, major impact location have been recorded. Some major findings are -

Among the top ten, top six types of events contribute to about 76% of all side events with AIS2+. 75% of AIS2+ side impact incidents occurred in a not physically divided two-way traffic. 64% of the AIS2+ side impact incidents were related to intersection. Also in 18% of cases vehicle departed the roadway.

These results have been compared to data available from UK trends being similar.

These findings (e.g. types of accidents) are helpful to both vehicle and restraint system (including electronics) designers to develop next generation safety systems specifically side pre-crash. A detailed discussion of this topic is planned for a future paper.

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REFERENCES

[1] U.S. Department of Transportation. An evaluation of side impact protection: FMVSS 214 TTI(d) Improvements and Side Airbags. DOT HS 810 748, January 2007.

[2] Samaha, R.S., Elliot, D., ‘‘NHTSA Side Impact Research: Motivation for Upgraded Test Procedures’’, 18th International Technical Conference on the Enhanced Safety of Vehicles Conference (ESV), Paper No. 492, 2003

[3] U.S. Department of Transportation, Traffic Safety Facts 2005, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, 2005.

[4] Thomas, P., Frampton, R., Injury Patterns in Side Collisions – A New Look with reference to Current Test methods and Injury Criteria. 99SC01, October 1999.

[5] Zini, Introduction to Feasible Innovations in Side Impact Safety, 18th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Paper Number 05-0066-W, June 2005.

[6] Welsh, R., Morris A., Hassan, A., Injury Outcomes in Side Impacts Involving Modern Passenger Cars, 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Paper Number 07-0097, 2007.

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