Investigation of Damage Location for Passenger Vehicle in Front-to-Side Impact Collision

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Abstract: The goal of this study was to identify MAIS 3+ injured occupants of struck vehicle which are associated with specific location of damage in two passenger vehicle front-to-side impact collisions. NASS/CDS database was used to investigate the distribution of MAIS3+ injured occupants and five main seriously injured body regions (including head/face/neck, chest, pelvis, upper extremity and lower extremity) of MAIS3+ injured occupants by lateral location, horizontal location, and vertical location of damage for the struck vehicle according to the SAE Standard J224. The results indicated that: 1) Vehicle-to-vehicle crash type accounted for over 55% of real world traffic accidents. 2) The injury risk ratio of total occupants for struck vehicle is several times than striking vehicle in CAR-to-LTV side impact collisions. 3) The lateral crush zone contributed to MAIS3+ injured occupants and 50% injury risks when extended into zone 3. 4) The crush zone contributed to 50% injury risks of occupants comparatively was zone "D+Y" and zone "E" in horizontal location and vertical location of damage. Finally the protection strategies to improve safety of occupants for the struck vehicle were discussed from perspective of anti-crushed location of damage.

Keywords: specific location of damage; front-to-side impact; NASS/CDS; injury prevention

1. Introduction

Since 1980, there has been an increase in fatalities resulted from the collision of passenger cars and light truck vehicles (LTV), which include sport utility vehicles (SUV), pickup trucks, and vans weighted no more than 2041kg[1]. The reinforcement of passenger cars are most commonly a single beam at the mid-door or lower door cage, leaving the upper portion of door unprotected. When LTV collide with passenger car, the higher bumper frame contacts the door above the reinforcement, creating upper thoracic and head injuries. Therefore, vehicle mismatch between passenger car and LTV is associated with death and serious injury of occupants in automotive crashes[2]. The objectives of this research program are to investigate side impact serious injury to occupants of passenger cars and LTV, and explore new countermeasure approaches for side impact injury prevention.

2. Materials

The objective of this paper is to investigate injury risks of passenger and extent of damage for impacted vehicle in front-to-side impact collisions used 2007 real world traffic accidents extracted from database of National Automotive Sampling System/Crashworthiness Data System (NASS/CDS). In 2007, the number of crash cases is 4,963 and after weighted is 2,454,014 collected by National Highway Traffic Safety Administration (NHTSA). If there have not specially pointed out in the rest of this paper, the investigated data is from the weighted cases.

Table 1 shows the number of people injured except pedestrians and accidents in various types of vehicle collisions in 2007 in the U.S. The information presented in this table shows that about 55% of road vehicle accidents result from vehicle-to-vehicle impact collisions. These collisions also cause about 62% of the injuries to the occupants. As it can be seen, vehicle-to-vehicle collisions result in more serious injuries per collision than single-vehicle collisions and multiple-vehicle collisions.

Table 2 shows the injury risks ratio of MAIS (Maximum Abbreviated Injury Score) 3+ injured occupants involved in two vehicle front-to-side collisions. The highest risk ratio of MAIS 3+ injuries is 1 versus 2.09, which result from Car-to-Car side impact collisions. Comparatively the LTV-to-LTV side impact collisions caused the lowest injury risk ratio for MAIS 3+ injured occupants. The summary of injury risk ratio in front-to-side impact collisions is that occupants of struck vehicle have a sixty-nine percent higher MAIS 3+ injury risk than occupants of striking vehicle. The reason is that the striking vehicle occupants are, to a greater extent, protected by the presence of a larger structural crush zone, i.e. including the energy-absorbing bumper and front-end structure, the vehicle's engine, the front suspension and wheels, the engine-mounting frame and integral firewall, supplemental safety systems. However, the struck vehicle crush zone is comprised of only the side doors and the relatively light framework of the occupant cell, plus

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interior foams which offer some limited protection, or some vehicle types are now also equipped with supplemental side airbags or curtains which have increased the level of side impact protection available to the occupants, but the level of protection does not reach the level which currently exists for frontal collisions. Hence, it is valuable guideline and necessary to do some research for improving the protection of struck vehicle side in front-to-side impact collision.

Table 1. Investigation of vehicle collision types using NASS/CDS 2007 database[3]

accidents type	weighted-cases	weighted-occupants (not including pedestrians)
single-vehicle	832,385 （33.9%）	1,198,553 （19.9%）
vehicle-to-vehicle	1,361,888 （55.5%）	3,753,285 （62.2%）
multiple-vehicle	259,741 （10.6%）	1,082,825 （17.9%）
total	2,454,014 （100%）	6,034,663 （100%）

Table 2. MAIS 3+ injured occupants involved in two passenger vehicle front-to-side collision[3]

crash type	injury risk ratio of MAIS 3+ injured occupants (striking vehicle/struck vehicle)
Car-to-Car	1:2.09
Car-to-LTV	2.06:1
LTV-to-Car	1:1.84
LTV-to-LTV	1:1.49
total	1:1.69

3. Methods

According to the "J224 Collision Deformation Classification" of SAE surface vehicle standard[4], the extent of residual deformation induced by a vehicle was represented from horizontal, lateral and vertical direction as shown in figure 1 to figure 3. Figure 1 demonstrates how the lateral deformation is measured in case of a side impact collision. For initially vehicle, the extent of lateral damage is classified using a nine-zone extent system relative to specific points on the vehicle structure. The extent of damage recorded, is dependent on the maximum cross-section to which the deformation extends to within a vehicle as a result of an impact. This measure also can be used to indicate the vehicle severity of an impact.

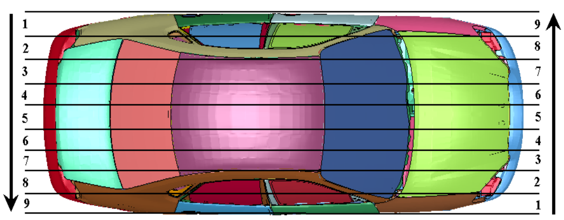

Figure 1. Specific lateral location of damage

Figure 2 shows the representation of horizontal location of deformation. The view of the vehicle illustrates the horizontal areas to be used in locating the deformation for three independent extents and three composite extents, such as zone "P", "F", "B" and "Y", "Z", "D", respectively. "F" and "B" are side deformation areas forward and rearward of "P", respectively.

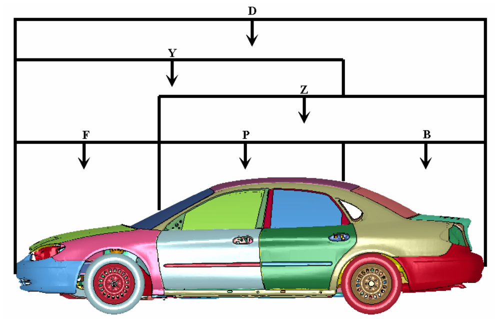

Figure 2. Specific horizontal location of damage

Figure 3 illustrates the classifications for the vertical location of deformations associated with impacts classified as "A", "E", "G", "M", or "L". The extents zone, "A", and "E" are used for vehicle with both side deformation located rear-end, while "G", "M", and "L" located front-end. "A" is used to classify impacts where the vehicle deformation resulted from an overhanging structure shaped like an inverted step in which the vertical surfaces are at least 760mm apart[3].

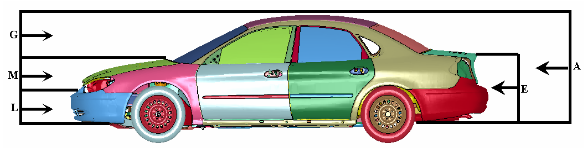

Figure 3. Specific vertical location of damage

4. Results

4.1. Specific Horizontal Location of Damage

The graph in Figure 4 shows the distribution of MAIS 3+injuries by the extent of damage to occupants in the struck vehicle. Approximately 39.5% of MAIS 3+ injuries were covered the extent zone 3 of damage. Zone 2 and zone 4 were comprised of only 19.9% and 23% of MAIS 3+ injuries. As it can be seen, the crush zone attributed to occupants serious injured were zone 2, zone 3 and zone 4. Assuming a car's width is 1.8 meters, the boundary of zone 3 for vehicle will be 60 centimeters. However, the distance commonly between occupant and interior panel is less than 20 centimeters. Therefore, crush intrusion of vehicle side components is almost up to 60 centimeters will cause the occupants to lose capacitating or even fatal injury. In current study, the risk ratio of MAIS 3+ injuries was 85% high resulted from the extent of damage extended into zone 3.

Figure 5 shows the cumulative distribution of MAIS 3+ injuries by the extent of damage. 50th percentile of MAIS 3+ injuries occurs when extent of damage crushes into zone 3 of the struck vehicle.

Figure 6 demonstrates the distribution of AIS 3+ injuries for five main body regions by extent of damage. The information in figure 6 shows that the majority of AIS 3+ injuries for head/face/neck (37.7%), chest (33.64%), pelvis (45.5%), upper extremity (43.6%) and lower extremity (42.7%) were associated with an extent of damage in zone 3. The extent of damage in zones 2 and 3 accounted for about 63.5% of head/face/neck injuries, about 56% of chest injuries, about 73% of pelvis injuries, about 63% of upper extremity injuries and about 59.5% of lower extremity injuries, respectively.

Following the analysis above, strategies and methodologies of occupant protection and injury reduction are developed from the extent of damage in zones 1, 2 and 3. Two methods are often used to improve vehicle safety in side impact collision, number one is enhancing the structural rigidity of interior panel of side doors, such as optimized design of impact bar, foam systems and door interior panels; number two is adding the airbags between the occupant and interior panel, i.e. supplemental head curtains and chest airbags which have increased the level of protection available to occupants.

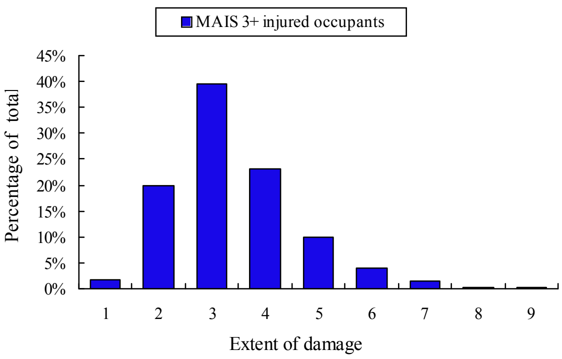

Figure 4. Distribution of MAIS3+ injured occupants by

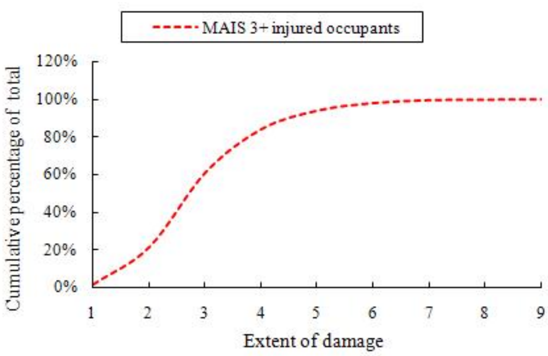

Figure 5. Cumulative distribution of MAIS 3+ injuries by extent of damage

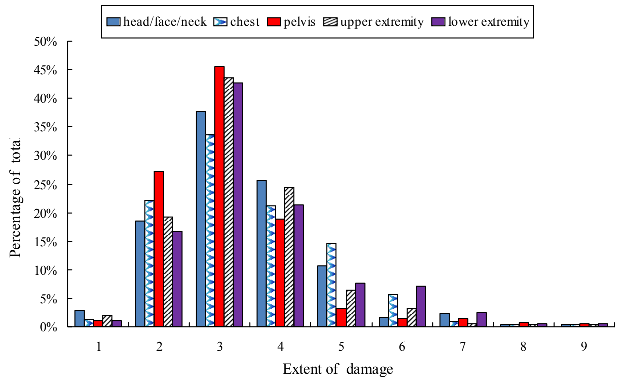

Figure 6. Distribution of MAIS 3+ injuries by body regions and extent of damage

4.2. Specific Horizontal Location of Damage

Figure 7 shows the distribution of MAIS 3+ injuries by specific horizontal location of damage of struck vehicle in side impact collision. The information from figure 7 shows that the two maximum injury ratios of MAIS 3+ injuries are 25.5% and 29.9% respectively covered the damage location “D” and “Y”; comprised the minimum injury ratio of MAIS 3+ injuries is only 3.75% covered the damage location “B”.

Figure 8 demonstrates the distribution of MAIS 3+ injuries for body regions by specific horizontal location of damage. Over half of all body AIS 3+ injuries were contributed to the damage location “D” and “Y”. The highest risk ratio of AIS 3+ injuries for head, chest, pelvis, upper extremity and lower extremity was respectively about 28.5%, 33.5%, 22.6%, 32% and 35.5% associated with the damage zone “Y”.

The results from horizontal damage location suggest that the primary crushed location of impacted vehicle is forward of c-pillar in real world side impact collisions, and it is less possibility to impact the rearward of c-pillar for target vehicle. Therefore, for design researches it is useful to maintain the side rigidity of vehicle specially accounted for structure rigidity of side doors, A-pillar, B-pillar and rocker rail.

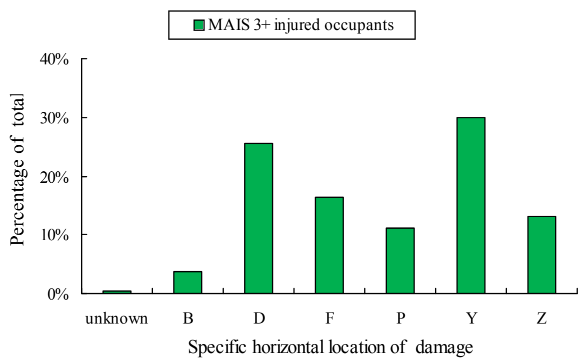

Figure 7. Distribution of MAIS 3+ injuries by horizontal location of damage

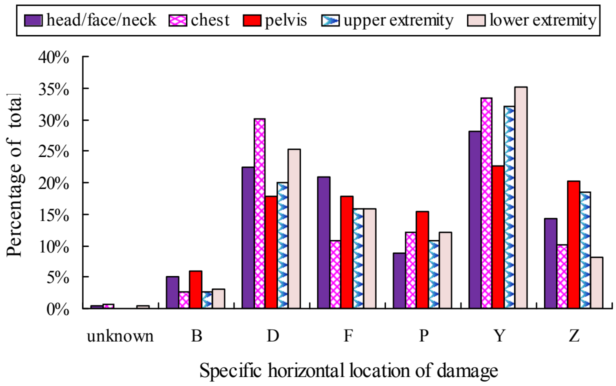

Figure 8. gwu Distribution of MAIS 3+ injuries by body regions of occupant and horizontal location of damage

4.3. Specific Vertical Location of Damage

Figure 9 shows the distribution of MAIS 3+ injuries by specific vertical location of damage in side impact collision. Approximately 64.8% of MAIS 3+ injuries were resulted from the damage location "E"; zone "G+M" was comprised of only 0.09% of MAIS 3+ injuries.

Figure 10 demonstrates the distribution of AIS 3+ injuries for each body region by specific vertical location of damage. As it can be seen, the majority of all AIS 3+ injuries were contribute to the damage location "E", the risk ratio of AIS 3+ injuries for head, chest, pelvis, upper extremity and lower extremity is about 62.5%, 55.5%, 64.5%, 77% and 69%, respectively.

Consequently the results suggest that the primary crushed location of impacted vehicle is located in upward of rocker rail and downward of windowsill in real world side impact collisions, and it is less possibility to impact the upward of windowsill for target vehicle. Considering improving the level of side protection particularly should enhance the rigidity of side doors and rocker rail from perspective of vertical anti-crushed location of vehicle.

5. Conclusions

This paper has evaluated the risk of injury from two vehicle front-to-side impact crashes. Our analysis was based upon an examination of approximately 1,362,000 weighted cases of passenger cars and light truck vehicles which were extracted from the NASS/CDS 2007 crash investigations database. The findings of the research were used to establish priorities for occupant protection and injury reduction.

Specific conclusions are as follows:

Over half of crash types in real world traffic accidents were attributed to vehicle-to-vehicle crashes.

The specific location of damage accounted for MAIS 3+ injured occupants and 50% injury risk was extent zone 3, zone "Y" and "E" respectively from lateral, horizontal and vertical direction of struck vehicle.

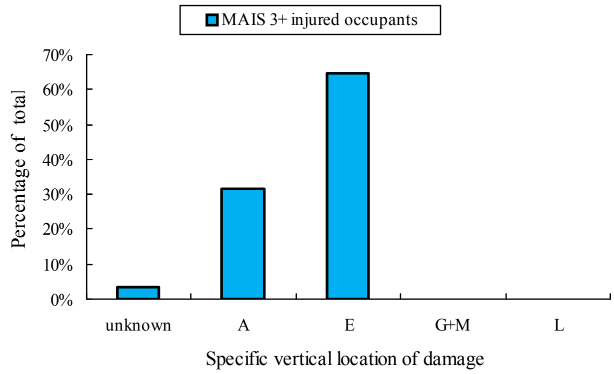

Figure 9. Distribution of MAIS 3+ injuries by vertical location of damage

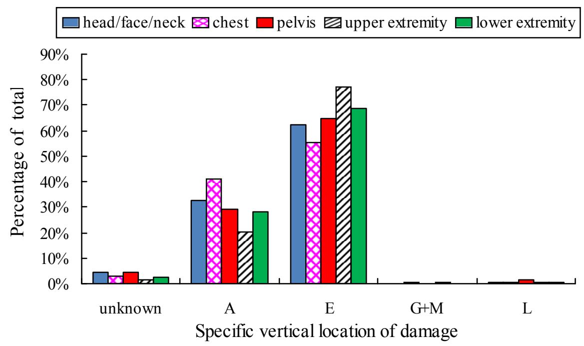

Figure 10. Distribution of MAIS 3+ injuries by body regions and vertical location of damage

Rigidity of side doors, A-pillar, B-pillar and rocker rail are priorities for improving the safety level of side impact.

Protection of head, chest and pelvis are priorities for injury countermeasure development. These three body regions accounted for over half of AIS 3+ injuries suffered from vertical crush zone "E" in CAR-to-LTV side impact collision.

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References

[1] CDS (Crashworthiness Data System) 2007 coding and editing manual [M]. Washington D.C: United States Department of Transportation National Highway Traffic Safety Administration.

[2] S. Acierno, R. Kaufman, F. P. Rivara at al. Vehicle mismatch: injury patterns and severity [J]. Accident Analysis and Prevention. 2004, (36): p761-772.

[3] Youming Tang, Libo Cao. Statistics analysis for passenger vehicle in front-to-side impact collision [J]. Automobile Parts. 2010, (4), p47-49. (Ch)

[4] SAE Standard J224: Collision Deformation Classification [S]. Warrendale: Society of Automotive Engineering, Inc. 1980