

# An Investigation of Injury Factors Concerning Drivers in Vehicles Involved in Small-Overlap Frontal Crashes

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## ABSTRACT

The causes of injuries suffered by drivers in "small-overlap frontal crashes" (SOFC) were examined. These crashes were defined as ones in which vehicles are loaded outside their longitudinal side members. SOFC accident data sets stored in the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) database were investigated. Percentages of cases sustaining injury to each body region of drivers were calculated, and the differences between the percentages of injury by body region were examined. To investigate the injury mechanisms, SOFC tests with two types of rigid barrier were then conducted. Injury values in each body region were analyzed to validate the reproducibility of SOFC test as a relevant test.

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## INTRODUCTION

SOFC accident is defined as one in which a vehicle is loaded outside its longitudinal side members. Longitudinal side members would include frame rails or monocoque body rail structures. In such crashes, limited structural engagement may result in large intrusion; as a result, the occupants of the vehicle may be seriously injured [1]. SOFC accidents are 6.4% of all frontal crashes of post 1994 model year vehicles. The risk of AIS3+ injury in the SOFC accident is of similar magnitude relative to both the moderate offset and offset crashes [2]. Previous studies have proposed various crash-test configurations for evaluating crash safety performance of vehicles in SOFC. Eichberger et al. [3] investigated SOFC test conditions with finite element analysis as a laboratory test. Vehicle-to-vehicle simulations and four types of obstacle-to-vehicle simulations were compared. Aiming to develop a baseline understanding of vehicle interaction and occupant safety, Saunders et al. conducted SOFC tests (such as car to car, moving deformable barrier to car, and car to 10-inch-radius pole) [4]. Aiming to analyze thoracic loading kinematics and injuries, Hallman et al. [5] conducted small overlap tests with a 25-cm-diameter rigid pole. The purpose of the present study is to examine the injury mechanisms in a SOFC. To examine the causes of injuries suffered by drivers who had a maximum abbreviated injury scale of 3 or greater

(AIS3+), SOFC data sets stored in the NASS-CDS database were investigated. To examine the injury mechanisms, SOFC tests with two kinds of rigid barrier were then conducted.

## REAL WORLD CRASH DATA ANALYSIS

### SELECTION CRITERIA

Real-world SOFC cases were obtained from the NASS-CDS. The cases were selected according to the following criteria [1].

- NASS-CDS data years 2000 to 2007
- Passenger vehicle model years 2000 to 2008
- Driver injury: AIS3+ in near side crashes
- The principal direction of force: between  $-30^\circ$  and  $0^\circ$  from longitudinal direction
- Not involved in a rollover collisions and multiple crash
- Belt-restrained drivers only
- Drivers were between 19 to 69 years old

- Cases were excluded if the AIS3+ injuries were only to lower or upper extremities
- Cases with obvious longitudinal deformation of the bumper or longitudinal members were excluded

A total of 26 cases met all the inclusion criteria (non-weighted). The deployed curtain airbags and side airbags of four vehicles could be seen in the photographs. An example of a SOFC accident is shown in [Figure 1](#). In the crash shown in the photograph, there is clearly front partial contact outside the longitudinal side members.



**Figure 1. Example of vehicle in SOFC accident**

## ANALYSIS OF INJURY MECHANISMS IN SOFC ACCIDENT

### *Distribution of Percentage of AIS3+ Injury in Each Body Region*

The distribution of the percentage of AIS3+ injuries to each body region is shown in [Figure 2](#). Injury causes were classified into three groups according to the NASS-CDS description as follows: (1) injuries not directly related to intrusion, (2) injuries directly related to laterally intruded component, and (3) injuries directly related to longitudinally intruded component. The most-commonly injured body region is the chest (approximately 70% of drivers) in the 26 SOFC accidents studied. As for injuries directly related to intrusion (lateral or longitudinal), there is no significant difference between the percentages of injury by body region. As for the percentage of AIS3+ injury to the chest, over half of the cases are not directly related to intrusion. A similar result was not seen for the other body regions.

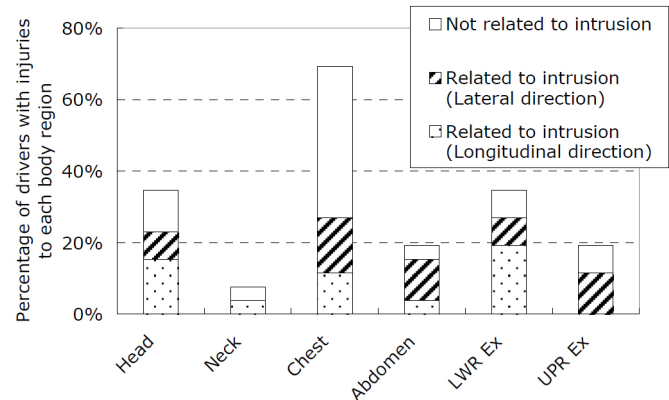


**Figure 2. Distribution of percentage of AIS3+ injury in each body region (non-weighted)**

### *Distribution of Percentage of Injury Source of AIS3+ Injury*

The distribution of the percentage of injury sources by which drivers suffered AIS3+ injuries is shown in [Figure 3](#). Left-side interior parts (such as armrest) stand out as the most prominent injury source (approximately 70%). As for injuries directly related to intrusion, left-side interior parts are again the most prominent injury source (approximately 45%).

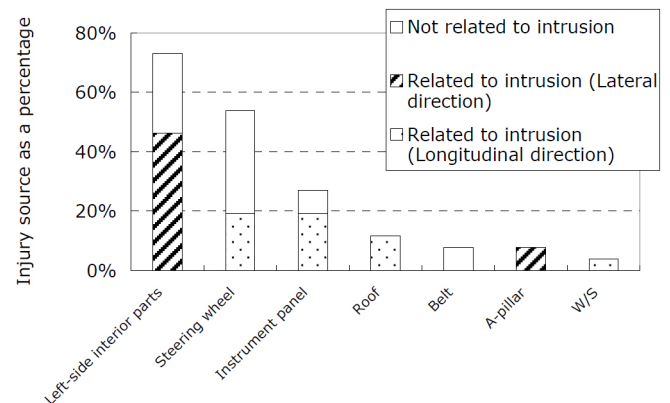


**Figure 3. Distribution of percentage of injury source of AIS3+ injury**

### *Estimation of Delta-V*

In NASS-CDS, the delta V is calculated with WinSmash. This program calculates delta-V based upon post-crash measurements. Frontal stiffness coefficients are derived from full frontal barrier crash tests. Because of this, delta-V estimation with WinSmash could be less accurate when the damage area is narrow. Niehoff P. et al [6] compared delta-V calculated with WinSmash and EDR measured delta-V. Using the slope of the best-fit line, NASS delta-V value decreases 0.71 for crashes when less than 50 percent of the vehicle is engaged. [Figure 4](#) shows the distribution of delta-V from NASS-CDS and adjusted delta-V of 17 SOFC accidents