Exploring Occupant Injury with Finite Element Reconstructions of Crash Injury Research and Engineering Network (CIREN) Motor Vehicle Crashes

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Introduction

This study sought to develop a methodology for case-specific finite element model (FEM) reconstructions of full frontal Crash Injury Research and Engineering Network (CIREN) crashes, and then utilize the FEM-predicted occupant kinematics and injury metrics to study injury causation. In CIREN case reviews, occupant kinematics and injury metrics are predicted using available evidence, but imagination is still required. Reconstructions can serve as a tool to inform injury causation determination through the visualization of occupant kinematics and contacts within the vehicle interior.

Methodology

Two CIREN cases (2014 Nissan Murano; 2013 Lexus ES350) were reconstructed using a three-step process. Step 1: Using a Faro Freestyle 3D scanner, the interior of an exemplar vehicle was scanned for each case. Individual parts of a FE simplified vehicle model (SVM) were transformed to align with the geometry of the exemplar interior scan, thus representing the CIREN case vehicle interior. Step 2: The simplified 50th percentile male Global Human Body Models Consortium (GHBMC) v1.8.4.1 human body model was scaled to approximate the mass and height of the case occupant. The GHBMC model was then settled and belted in the transformed SVM using occupant positioning information obtained from the crash investigation. Step 3: The SVM was subjected to the velocity pulse from the CIREN vehicle's event data recorder (EDR) and the belt pretensioner and airbag were set to trigger based on the EDR information. The occupant's injuries were compared with the occupant kinematics and injury metrics from each simulation and used to determine injury causation.

Results and Conclusions

The Murano case occupant sustained right 8th and 9th rib fractures and a sternal fracture. The Lexus case occupant sustained fractures of left ribs 3-5, 8, and 9 and a sternal fracture. Both reconstructions generated elevated strains in the local rib and sternum regions where fracture occurred in the CIREN occupants, especially for ribs 8-9 and the sternum in the Lexus reconstruction. Strains in the local regions where fracture occurred were 36.2%, 89.7%, and 39.8% higher in ribs 8-9 and the sternum (Murano occupant) and 81.8%, 34.2%, 65.2%, 113.3%, 347.1%, and 357.8% higher in ribs 3-5, 8-9, and the sternum (Lexus occupant), compared to non-fractured regions. Both reconstructions illustrated elevated strains in the ribs and sternum underneath the path of the belt restraint. Only strains in rib 9 and the sternum for the Lexus reconstruction surpassed fracture thresholds defined by Kent, et al. (2005), with values of 2.1% and 3.3%, respectively.

The reconstructions provide greater insight into crash kinematics for specific CIREN cases. Rib and sternum injuries in case occupants were correlated with regions of strain in reconstructions, caused by belt and airbag loading. Reconstructions were able to discern times of maximum belt restraint and airbag engagement, thereby allowing for greatly improved determination of injury causation in frontal collisions. With continued improvement, these reconstructions can become an extremely valuable tool for CIREN case reviews and be adapted to multiple collision types.