Driver Injury Risk Variability in Finite Element Reconstructions of Crash Injury Research and Engineering Network (CIREN) Motor Vehicle Crashes

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Abstract

This study evaluated the sensitivity and uncertainty in the risk and severity of driver injuries in full frontal CIREN crash events as a function of occupant positioning using batch-processed finite element model (FEM) reconstructions.

Crash Injury Research and Engineering Network (CIREN) cases were reconstructed using FEM simulations in a three step process to assess the variability in injury risk and severity for common frontal crash injury patterns. Step 1: A simplified vehicle model (SVM) was developed and tuned to mimic the frontal crash response of each CIREN case vehicle. Frontal NCAP crash test vehicle kinematics for each case were implemented into crash test reconstructions with a Hybrid III anthropomorphic test device (ATD). Ten vehicle restraint parameters (e.g. airbag inflation rate, belt pretensioner force) were varied across 240 simulations using a Latin Hypercube Design (LHD) of experiments to find an optimal set of vehicle parameters to match simulated ATD responses to test data signals. Step 2: The THUMS v4.01 human body model (HBM) was implemented into the tuned SVM using CIREN-reported occupant positioning information, as well as a range of occupant positions by varying the seatback angle, longitudinal seat track position, D-ring height, and steering position/angle using a 120 simulation LHD. Step 3: The case vehicle's event data recorder (EDR) velocity pulse was applied to the tuned SVM in each of the 120 THUMS position simulations. Simulated THUMS instrumentation (i.e. accelerometers, load cells) was implemented to measure injury metrics correlated to common frontal crash injuries. AIS-based risks were estimated from the injury metrics using published injury risk curves.

The SVM was successfully tuned for all frontal CIREN reconstructions. Sprague and Geers magnitude (M) and phase (P) error factors validated the FEM against the crash test ATD head, chest and pelvis accelerations ($|M| < 0.23$, $P < 0.12$) and femur and belt force ($|M| < 0.12$, $P < 0.13$) signals. One reconstructed 2010 Camry occupant had no reported head injuries or knee-thigh-hip (KTH) injuries and injury risks calculated for the CIREN-reported occupant position versus the range of positions simulated were: AIS 1+, 2+, 3+ head (42%, 22-100%; 7.4%, 0-99%; 1.0%, 0-55%); AIS 2+, 3+ KTH (2.8%, 2-4%, 2.8%, 2-4%). In a 2006 Chevrolet Cobalt reconstruction, the occupant's AIS 3 lung contusion (49% of lung contused) was predicted since *over 49% of the THUMS lung elements exceeded a 34% first principal strain threshold and AIS 2 L1/L3 vertebral fractures were predicted from THUMS' L1/L3 cross-sectional force measurements.*

Head, chest, pelvis, and femur injury risks predicted with FEMs were well correlated with documented CIREN injuries. The reconstruction process allows for quantification of the sensitivity and uncertainty of injury risk predictions based on occupant position which is often uncertain in real-world crashes. THUMS injury metrics assessed include strain-based metrics for assessing organ injuries (i.e. lung) that are not easily assessed in postmortem human subjects (PMHS) or ATDs which could potentially be valuable to assess the effectiveness of restraint systems to further prevent or mitigate injuries.