Use of FE Simulations to Parametrically Evaluate and Compare Seat Belt Restraint Systems and Related Injury Risk in Heavy Truck Frontal Crash Conditions

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2015 Traffic Safety Conference
Corpus Christi, Texas

June 09, 2015
Order of Presentation

- Background
- Objective
- Methodology
- FE Computer Models (Vehicle, ATD, Passive Restraint Systems)
- FE Computer Frontal Impact Simulations
- Results
- Future Research
Background

- Approximately 340,000 medium/heavy trucks involved in traffic crashes per year in U.S.
- 600 fatalities; 20,000 injuries to truck drivers
- Aggregate cost of crashes to society is $3.1 billion

- No existing standards for truck cab crashworthiness or occupant protection in heavy truck crashes (although being discussed)
- Need of additional characterization of crash-injury, current heavy truck crashworthiness, potential benefits of crashworthy structures in heavy truck cabs
Objectives

TTI and UMTRI proposed jointly effort devoted to collect & develop required information by:

- analyzing crash & travel datasets available at UMTRI and TTI;
- identify frequencies & costs of types of heavy truck crashes;
- estimate benefits of crashworthy structures in heavy trucks to reduce death, injury, & societal costs of heavy truck crashes
Methodology
FE Computer Models

- Heavy Truck
- ATD
- Seatbelt
- Airbag

FE Computer Simulations

- Frontal Impact (Wall)
- Parametric Variation Seatbelt Properties
- ATD Injury Criteria
Simplified Methodology

Crash pulse applied to cab mounts

Frontal Impact (Wall)

ATD
Seatbelt
Airbag
Step 1

Develop Heavy Truck Cabin Model
Computer Model – Heavy Truck

Current FE Computer Model

Need for Occupant Compartment Interior
Heavy Truck Cabin Model

FE Model of Cab-Over-Engine Cabin*

* Developed by TTI under project funded by Department of State

Morphed Conventional Cab*

* As of Peterbilt 387
Step 2

Develop Heavy Truck Interior Compartment
Cloud Point Scans*
* Developed by UMTRI for Peterbilt 387
Heavy Truck Interior Compartment

Models developed applying mesh grid over cloud points
Step 3

Inclusion of ATD
ATD Inclusion and Pre-Positioning

Existing LSTC Hybrid III 50% Male ATD
Step 4

Addition of Passive Restraint Systems
Seatbelt Model

Original
*Developed by LSTC for Passenger Car

Modified
*To fit Heavy Truck Geometry

Original

Modified
Seatbelt Model

Modified

*To fit Heavy Truck Geometry

![Diagram of seatbelt model]

<table>
<thead>
<tr>
<th>Event</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ms</td>
<td>Retractor sensor fires – enters locked mode</td>
</tr>
<tr>
<td>10 ms</td>
<td>Pretensioner sensor fires – enters locked mode</td>
</tr>
<tr>
<td>1.8 kN tension reached</td>
<td>Pretensioner disengages – retractor active</td>
</tr>
<tr>
<td>4 kN tension reached</td>
<td>Load limiter 1 engages (load limit case 1 only)</td>
</tr>
<tr>
<td>8 kN tension reached</td>
<td>Load limiter 2 engages (load limit case 2 only)</td>
</tr>
</tbody>
</table>
Airbag Model

Airbag - *Developed by NCAC

Folded

Deployed

NCAC

Heavy Truck
Step 5

Crash Pulse
Crash Pulse – 35 mph Frontal
Step 6

FE Parametric Simulations of Frontal Impacts
Frontal Impacts - 35 mph

- Baseline
- No Pretensioner
- 4 kN Load Limiter
- 8 kN Load Limiter
- Lowered D-Ring
Step 7

ATD Injury Criteria Evaluation
ATD Modeled Instrumentation

- Head Accelerometer
- Chest Accelerometer
- Right Upper Leg (Femur)
- Pelvis Accelerometer
- Left Upper Leg (Femur)
- Left Lower leg (Tibia)
- Right Lower leg (Tibia)
Head Injury Criteria (HIC)

Head acceleration recorded during impact event employed to calculate HIC representing probability of head injury

\[ HIC = \max \left[ \left( \frac{\int_{t_2}^{t_1} a(t) \, dt}{(t_2 - t_1)} \right)^{2.5} (t_2 - t_1) \right] \]
## Comparison to IARV

### Injury Assessment Reference Values (IARVs)

*Injury event termed “unlikely” if associated injury value does not exceed IARVs*

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Parameter</th>
<th>IARV</th>
<th>Injury Criteria</th>
<th>% of Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>HIC</td>
<td>700</td>
<td>104</td>
<td>0.15</td>
</tr>
<tr>
<td>Neck</td>
<td>Nij</td>
<td>1</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>Neck axial tension (kN)</td>
<td>4.17</td>
<td>2.8</td>
<td>0.68</td>
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<tr>
<td>Chest</td>
<td>Deflection (mm)</td>
<td>63</td>
<td>85</td>
<td>1.36</td>
</tr>
<tr>
<td><strong>Lower Extremity</strong></td>
<td>Femur axial force (kN)</td>
<td>-10</td>
<td>-4.7</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>Tibia Index</td>
<td>1</td>
<td>2.3</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>Tibia axial force (kN)</td>
<td>-8</td>
<td>-9.3</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Comparison to IARV
Examples of Computer Simulations
Frontal Simulations – No Airbag

No Airbag - Baseline

No Airbag – No Pretensioner

UMTRI
University of Michigan
Transportation Research Institute

ATLAS CENTER
Advancing Transportation, Leadership and Safety

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Frontal Simulations – No Airbag

No Airbag – 4 kN Limit Load

No Airbag – Lowered D-Ring
No Airbag – Injury Probability

Head

- Baseline
- No Pretensioner
- 4 kN Load Limiter
- 8 kN Load Limiter
- Lowered D Ring

Neck

- Baseline
- No Pretensioner
- 4 kN Load Limiter
- 8 kN Load Limiter
- Lowered D Ring

Chest

- Baseline
- No Pretensioner
- 4 kN Load Limiter
- 8 kN Load Limiter
- Lowered D Ring
When Adding Airbag...
Head Injury Probability

No Airbag

Airbag
Neck Injury Probability

No Airbag

<table>
<thead>
<tr>
<th>Condition</th>
<th>Probability</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.3</td>
</tr>
<tr>
<td>No Pretensioner</td>
<td>0.4</td>
</tr>
<tr>
<td>4 kN Load Limiter</td>
<td>0.4</td>
</tr>
<tr>
<td>8 kN Load Limiter</td>
<td>0.5</td>
</tr>
<tr>
<td>Lowered D Ring</td>
<td>0.6</td>
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</table>

Airbag

<table>
<thead>
<tr>
<th>Condition</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.1</td>
</tr>
<tr>
<td>No Pretensioner</td>
<td>0.1</td>
</tr>
<tr>
<td>4 kN Load Limiter</td>
<td>0.1</td>
</tr>
<tr>
<td>8 kN Load Limiter</td>
<td>0.1</td>
</tr>
<tr>
<td>Lowered D Ring</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Conclusions

- 35 mph w/OUT airbag and 8 kN load limiter produced lowest injury criteria results for ATD.
- 35 mph w/airbag and 4 kN load limiter produced lowest injury criteria results for ATD.
- Inclusion of airbag resulted in significant reduction in probability of neck injury.
Future Research

- Validation of interior component material modelling (for accurate deformation response of truck cabin interior)
- Realistic seat characteristics (suspensions)
- Development and analysis of additional restraint systems
  - side curtain airbag system
  - five point seatbelt
  - ...

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Texas A&M Transportation Institute
Acknowledgements

- Robert Wunderlich (Associate Director, ATLAS Center, TTI) for sponsoring the project through ATLAS Center Program.
- DOS for use of COE truck cabin FE model developed by TTI.
- Jingwen Hu (Associate Research Scientist, UMTRI) for seatbelt model and assistance with FE computer simulations.
- Akram Abu-Odeh (Research Scientist, TTI) and Kimberley Ryan (Former Graduate Student Worker, TTI) for assistance with TruckSim.
- Abhinav Mohanakrishnan (Former Graduate Student Worker, TTI) for compilation of injury criteria results.
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Questions?