Finite Element Analysis of Child Occupant Responses in Side Impact

Masatomo Yamaguchi, Koji Mizuno
Nagoya University

Yoshinori Tanaka
National Traffic and Environment Laboratory
Outline

• Background
  – Literature Study of Accident Analysis
  – Full-Car Side Impact Test
  – Oblique angle

• FE Analysis Condition

• Results

• Conclusions
Background
RF and FF CRS

Rear Facing (RF) CRS
Infant

Forward Facing (FF) CRS
Toddler
Accident Analysis of Child Occupants using Forward Facing CRS in Side Collisions

Principal direction of force (PDOF)

Injury body region

Reference: Arbogast, JSAE Congress 2009
# Injury Cause and Severity (AIS 2+) of Struck Side CRS Sitting Children

<table>
<thead>
<tr>
<th></th>
<th>Head</th>
<th>Cervical spine</th>
<th>Thorax</th>
<th>Abdomen</th>
<th>Pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A/B pillar</strong></td>
<td>AIS 5</td>
<td>AIS 5</td>
<td>AIS 5</td>
<td>AIS 5</td>
<td></td>
</tr>
<tr>
<td><strong>Door / Side interior</strong></td>
<td>AIS 5</td>
<td>AIS 5</td>
<td>AIS 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Glass / Side window</strong></td>
<td>AIS 2</td>
<td>AIS 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intruding object</strong></td>
<td>AIS 4</td>
<td>AIS 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Near by child interaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CRS buckle / shield</strong></td>
<td>AIS 3</td>
<td>AIS 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N=12

Reference: Langwider, SAE Paper 962439
Accident Analysis of Child Occupant in Side Impact (NHTSA)

Principal direction of force (PDOF)

Injury source (Forward facing CRS)

# Side Impact Test

## Test matrix

<table>
<thead>
<tr>
<th>Test No.</th>
<th>CRS type</th>
<th>Position</th>
<th>ATD</th>
<th>Target car (curb mass)</th>
<th>Striking vehicle (curb mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 01</td>
<td>Forward facing</td>
<td>Struck side</td>
<td>Q3s</td>
<td>Car A (1266 kg)</td>
<td>ECE R95 MDB (950 kg)</td>
</tr>
<tr>
<td>Test 02</td>
<td>Forward facing</td>
<td>Struck side</td>
<td>Q3s</td>
<td>Car B (1130 kg)</td>
<td>ECE R95 MDB (950 kg)</td>
</tr>
</tbody>
</table>

50 km/h

Target car

MDB

[Diagram showing the test setup with a target car and a striking vehicle.]
Kinematic Behavior

**Test 01**

- HIC 148
- Chest deflection 23.3 mm

**Test 02**

- HIC 182
- Chest deflection 20.5 mm
FMVSS214 Test Condition (NHTSA Study)

Reference: Sullivan, 21st ESV, 2009
In real-world accidents, the head is most frequently injury body region for the child seated in the FF CRS.

The head of the child dummy was contained in the CRS shell in ECE R95 test condition.

In angled impact (FMVSS 214), the head of the child dummy made contact with the door though the HIC was small.

It is difficult to reproduce the head injury of child occupant in contact with the door, which occur frequently in real-world accidents.
Purpose of the current study

- In order to examine the possibilities of the head injuries in contact with car interior, a series finite element (FE) simulation of car-to-car oblique collisions was carried out by using two occupant FE models.
Analysis Condition
Analysis Condition

- The impact angle of the striking car was 65 degrees.
- The CRS was installed on the struck side in the rear seat.
- Hybrid III 3YO FE model or the child FE model was seated in the CRS.
FE models

Hybrid III 3YO    Child FE    CRS FE model
## Analysis Matrix

<table>
<thead>
<tr>
<th>Analysis No.</th>
<th>CRS type</th>
<th>Position</th>
<th>Model</th>
<th>Shoulder harness slack (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Forward facing</td>
<td>Struck side</td>
<td>Hybrid III 3YO</td>
<td>0</td>
</tr>
<tr>
<td>02</td>
<td>Forward facing</td>
<td>Struck side</td>
<td>Child FE</td>
<td>0</td>
</tr>
<tr>
<td>03</td>
<td>Forward facing</td>
<td>Struck side</td>
<td>Child FE</td>
<td>70</td>
</tr>
</tbody>
</table>
Results
Kinematic Behavior of Hybrid III 3YO
Kinematic Behavior of Child FE

Child FE (no slack)
Child FE (No slack)
Kinematic Behavior of Child FE

Child FE (70mm harness slack)
Child FE (70 mm harness slack)
Head Excursion

Hybrid III 3YO

Child FE
No slack

Child FE
70mm harness slack

Head impact velocity
3.7 m/s

Head impact velocity
6.3 m/s

Slack +70 mm

The shoulder joint moved out of the CRS
Head Acceleration

![Graph showing head acceleration over time for different conditions: Hybrid III 3YO, Child FE, Child FE harness slack, and Contact.](image)
## Injury Measures

<table>
<thead>
<tr>
<th>Model</th>
<th>HIC C15</th>
<th>Chest deflection Dy (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IARV (3YO)</td>
<td>568</td>
<td>23.0</td>
</tr>
<tr>
<td>Hybrid III 3YO FE</td>
<td>90</td>
<td>8.2</td>
</tr>
<tr>
<td>Child FE (no slack)</td>
<td>185</td>
<td>10.6</td>
</tr>
<tr>
<td>Child FE (harness slack 70 mm)</td>
<td>481</td>
<td>11.0</td>
</tr>
</tbody>
</table>
Conclusions

- In the car-to-car oblique side collision, the head of the Hybrid III 3YO flexed but it did not make contact with the door.

- The head of child FE made contact with the stationary door. The head impact velocity and HIC was small (HIC 185)

- When the slack was added in the shoulder harness of the CRS, the head displacement of the child FE model was substantially large. The head made contact with the door beltline (HIC 481)

- It is probable that the misuse of the CRS could be one of the causes of the head contact with car interior in real world side collisions.
Thank you for your attention
Forward Facing CRS Misuse

The sitting misuse of child occupant

- Loose harness of the CRS: 60.3%
- Height adjustment of harnesses: 15.4%
- Physique nonconformity: 6.6%
- Harness twist: 16.2%
- Other: 1.5%
- Proper use: 47.2%
- Sitting misuse: 52.8%

Reference: Japan Automotive Federation (JAF) 2009