Flex GT Testing of US Vehicles

NHTSA’s Vehicle Research and Test Center (VRTC)

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Goals

• Gain experience with Flex GT
• US vehicle performance with Flex GT
• Understand the effect of changing impact height as a substitute for added body mass
Tests Performed

2002 Mazda Miata

- Center

2005 Honda CR-V

- Center
- Outboard 347 mm from center

- Each location: 25 mm / 75 mm above ground reference level
- Two additional tests performed on Miata at 75 mm for repeatability
Method

- Flex GT (SN 06)
- GTR procedure (except test height*)
  - 11.1 m/s (+/- 0.2 m/s) by laser/video
  - All points within test zone
  - Orientation: ±5° axial rotation, ±2° pitch and roll by video
  - Test height: 25 mm & 75 mm* above ground reference level
- Flex GT certification following every test
Results

• Test Experience and Repeatability
• Injury Measurements for CR-V and Miata
  – Compared to proposed injury limits
  – Compared to prior test results with TRL
  – 25 mm and 75 mm results compared
• Damage to the Flex GT
Test Experience

• Orientation (±5° axial rotation)
  – Improvement over TRL and FlexPLI
  – Roller and flat knee area help reduce spin

• Orientation (±2° pitch and roll)
  – Roll tested in speed shots
  – Pitch confirmed for each test
    (affected by deformation of launch plate)
## Repeatability

3 tests: Mazda Miata, Center impact, 75 mm impact height

<table>
<thead>
<tr>
<th></th>
<th>Femur Bending Moment N-m</th>
<th>Tibia Bending Moment N-m</th>
<th>Knee ligament elongations mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A3</td>
<td>A2</td>
<td>A1</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>112</td>
<td>179</td>
<td>253</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>4.73</td>
<td>5.03</td>
<td>3.51</td>
</tr>
<tr>
<td><strong>Coefficient of Variation</strong></td>
<td>4.2%</td>
<td>2.8%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>
Injury Measures: CR-V and Miata
Results: Bending moments

- Femur 3
- Femur 2
- Femur 1
- Tibia 1
- Tibia 2
- Tibia 3
- Tibia 4

Bending Moment (N⋅m)

- Miata (25 mm)
- CR-V Outboard (25 mm)
- CR-V Center (25 mm)
Comparison to TRL: Fracture Measures

TRL Upper Tibia Acceleration (g)

Flex GT Bending Moment (N-m)

Upper tibia acceleration (g)

- Miata (25 mm)
- CR-V Outboard (25 mm)
- CR-V Center (25 mm)
Results: Ligament Elongation

- MCL: Miata (25 mm) > CR-V Outboard (25 mm) > CR-V Center (25 mm)
- PCL: Miata (25 mm) > CR-V Outboard (25 mm) > CR-V Center (25 mm)
- ACL: Miata (25 mm) > CR-V Outboard (25 mm) > CR-V Center (25 mm)
Comparison to TRL: Knee Bend Measures

- **Bending Angle (Degrees)**
- **Flex Ligament Elongation (mm)**

**TR**
- MCL

**FLEX GT**
- Miata (25 mm)
- CR-V Outboard (25 mm)
- CR-V Center (25 mm)
Comparison to TRL: Shear Measures

- **TRL**
  - Shear displacement (mm)
  - Miata (25 mm)
  - CR-V Outboard (25 mm)
  - CR-V Center (25 mm)

- **FLEX GT**
  - PCL
  - ACL

TRL Shear displacement (mm)

Elongation (mm)
Ligament Elongation
25mm vs. 75mm (Launch Height)
Bending moments
25 mm vs. 75 mm (Launch Height)
25 mm impact height (GTR)

Honda CR-V

Mazda Miata

75 mm impact height
Flex-GT Damage
Mechanical

- Knee Twist
- Bent Tabs
- Rubber Spacer
- Damaged Casings
- Seized Bolt/Sleeve
- Tibia Plate Damage/Rotation
Mechanical (cont.)

- Zippers need to be made more durable
  - Broken pull rings due to repeated high tension when assembling leg
- Slices and cuts were common
  - When does accumulated damage require replacement of flesh?
- Addition of threaded holes in standard location for accelerometer attachment at knee
  - Recommended for impact speed redundancy & comparison to TRL-measured tibia acceleration
Electrical

• We had 10 – 12 instances of a broken cable in our testing
• Improvements needed:
  – Better routing scheme
  – Dull sharp edges on knee structure
  – Stronger wire covers
  – Smaller bundle (can redundant gauges be coupled somehow to reduce the number of wires?)
  – Onboard DAS is a very good solution!
Summary

• Test experience and repeatability
  – Improved axial rotation with new roller support
  – Excellent repeatability

• Injury evaluation
  – Flex GT results ranked severity of impacts similarly to TRL testing but indicated higher injury severity
  – At least one Flex GT proposed injury limit exceeded for all three impact locations for 25 mm impact height
  – Effect of raising impact height to 75 mm varied

• Damage and durability
  – Several minor issues but no catastrophic damage
  – Need to test more aggressive vehicles to evaluate durability for US fleet