Flex-GTR Testing

Transportation Research Center
NHTSA Vehicle Research & Test Center

Flex-TEG Meeting
Dec. 1-2, 2009
Overview

- History of VRTC Testing with Flex-PLI
- Objectives
- Test Setup & Procedure
- Test Matrix
- Results
  - Repeatability
  - Durability
  - SLICE
History of VRTC Testing with Flex

- **Flex-G tests**
  - ESV 2005
  - Durability issues identified

- **Flex-GT tests**
  - Presented at Flex-TEG (March 2008) & SAE Govt.-Industry Meeting (May 2008)
  - Less durability problems but still some issues
    - Still haven’t tested any very stiff cars

- **Flex-GTR tests (2009)**
  - This presentation
Objectives: Flex-GTR Tests (2009)

- Provide Flex-TEG with feedback on
  - Repeatability
  - Durability
  - SLICE onboard data acquisition
Test Procedure

- GTR conditions (40 km/h, 75 mm height)
  - Laser speed-traps to measure impact velocity
- Center impacts
- Overhead and lateral video
  - Monitor alignment during flight
- DTS Onboard SLICE Nano DAS
## Test Matrix

### Selection Criteria
- Vehicle location did reasonably well in TRL tests (Mallory, ESV 2009 & more recent testing)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Tibia Acceleration (GTR: 170 g)</th>
<th>Bending Angle (GTR: 19 deg)</th>
<th>Shear Displacement (GTR: 6 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Honda CR-V</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2002 Mazda Miata</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2006 Infiniti M35 (with Nissan Fuga bumper)</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2006 Volkswagen Passat</td>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>2001 Honda Civic</td>
<td>Fail (marginal)</td>
<td>Fail (marginal)</td>
<td>Fail (marginal)</td>
</tr>
</tbody>
</table>
Repeatability
Honda CR-V

Graph showing femur moment (N-m) over time (sec) for Heavy – Test 1 and Light – Test 2.

Legend:
- Femur 3
- Femur 3
- Femur 2
- Femur 2
- Femur 1
- Femur 1
Repeatability
Honda CR-V

Repeatability
Honda CR-V

Time (sec)

Heavy – Test 1
Light – Test 2

Flex-TEG Recommended Limit = 340 N-m

Tibia Momen (N-m)
Repeatability
Honda CR-V

Flex-TEG MCL Limit = 22 mm
Flex-TEG ACL/PCL Limit = 13 mm

Ligament Elongation (mm)

Time (sec)

Heavy – Test 1
Light – Test 2
Repeatability
Honda CR-V

Heavy – Test 1
Light – Test 2
Repeatability
Mazda Miata

![Graph showing femur moment vs time for heavy and light tests.](image-url)
Repeatability
Mazda Miata

Flex-TEG Recommended Limit

Heavy – Test 1
Light – Test 2
Repeatability
Mazda Miata

![Graph showing ligament elongation over time for Heavy - Test 1 and Light - Test 2 with Flex-TEG MCL and ACL/PCL limits.]
Repeatability
Mazda Miata

![Graph showing time (sec) vs. tibia acceleration for 'Heavy – Test 1' and 'Light – Test 2' with Flex GTR Acceleration lines.](image-url)
Repeatability
Nissan Fuga

Graph showing the femur moment (N·m) over time (sec) for Heavy – Test 1 and Light – Test 2.
Repeatability
Nissan Fuga

Time (sec)

Flex-TEG Recommended Limit

Tibia 1
Tibia 1
Tibia 2
Tibia 2
Tibia 3
Tibia 3
Tibia 4
Tibia 4

Heavy – Test 1
Light – Test 2
Repeatability
Nissan Fuga

Software glitch (MCL reached 25 mm in a 3rd test)
Repeatability
Nissan Fuga

Graph showing the performance of Nissan Fuga with two tests:
- Heavy – Test 1
- Light – Test 2

Lines on the graph indicate Flex GTR Acceleration.
Repeatability
Volkswagen Passat

Time (sec)

Heavy – Test 1
Light – Test 2

Femur Moment (N-m)
Repeatability
Volkswagen Passat

Time (sec)

Heavy – Test 1
Light – Test 2

Flex-TEG Recommended Limit

Tibia 1
Tibia 1
Tibia 2
Tibia 2
Tibia 3
Tibia 3
Tibia 4
Tibia 4

www.nhtsa.gov
Repeatability
Volkswagen Passat

Heavy – Test 1
Light – Test 2

Flex-TEG MCL Limit
Flex-TEG ACL/PCL Limit

Ligament Elongation (mm)

Time (sec)
Repeatability
Volkswagen Passat

Heavy – Test 1
Light – Test 2
Repeatability
Honda Civic

Time (sec)

Heavy – Test 1
Light – Test 2

Femur Moment (N-m)

NHTSA

www.nhtsa.gov
Repeatability
Honda Civic

Heavy – Test 1
Light – Test 2

Flex-TEG MCL Limit
Flex-TEG ACL/PCL Limit
Repeatability
Honda Civic

![Graph showing Repeatability of Honda Civic](image)

- Heavy – Test 1
- Light – Test 2

Time (sec)

Flex GTR Acceleration

Tibia Acceleration
## Summary

<table>
<thead>
<tr>
<th></th>
<th>TRL Legform</th>
<th>Flex-GTR Legform</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tibia Acceleration</td>
<td>Bending Angle</td>
</tr>
<tr>
<td>Limit (GTR value for TRL or 9th Flex-TEG recommendation for Flex-GTR)</td>
<td>170 g</td>
<td>19 deg</td>
</tr>
<tr>
<td>2002 Mazda Miata</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2006 Infiniti M35 with Nissan Fuga bumper</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2006 Volkswagen Passat</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>2001 Honda Civic</td>
<td>Fail (marginal)</td>
<td>Fail (marginal)</td>
</tr>
</tbody>
</table>
Durability
Flex-GT (2008)

Knee Twist  Bent Tabs  Rubber Spacer

Damaged Casings  Seized Bolt/Sleeve  Face Plate Rotation
Durability
Flex-GTR (2009)

Scuffing but no deformation

Blue segment face detached - easily re-attached

Longitudinal lines looked like material lamination not cracks

Separated cable casing - no data loss

No Functional Damage
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Twist (Needed Manual Fix)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bent Tabs</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rubber Spacer Fell Out</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Damaged Cable Casings</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Seized Bolt Sleeves</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Broken Zipper Ring</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cut/Pulled Instrumentation Cables</td>
<td>X (sensors)</td>
<td>X (SLICE)</td>
</tr>
<tr>
<td>Scuffing of Support Piece</td>
<td>X (easily replaced)</td>
<td>X (easily replaced)</td>
</tr>
<tr>
<td>Blue Cap Came Off</td>
<td>X (easily replaced)</td>
<td>X (easily replaced)</td>
</tr>
<tr>
<td>Longitudinal Lamination Lines on Bone?</td>
<td>Not considered damage (?)</td>
<td></td>
</tr>
</tbody>
</table>
Advantages

- Wire-free system improved flight alignment
- Sensor ID streamlined setup
- Contact switch *concept* good
Functional Issue

*However*, contact switch only functional when legform still connected to system

Double-tape contact switch

System connection
SLICE

Usability Issues (Communicated to FTSS/DTS)

- **Software bugs**
  - Ligament full scale: 20 mm limit (workaround: no offset removal)
  - Viewer: Multiple channels plotted to different scales
  - Export: Cannot export to DIADEM channels with single character units (g)
  - Collection: If connection status monitored up to release, errors occur when disconnected.
  - Software freezes: Needed frequent re-start of software/computer if left without activity for several minutes prior to testing.

- **Ligament polarity inconsistent**
  - LCL, MCL \(\rightarrow\) Elongation (+)
  - ACL, PCL \(\rightarrow\) Elongation (-)
Summary

- Very good repeatability
  - In two repeat tests, center impact, 5 vehicles

- Improved durability
  - But we have not tested vehicles that were poor performers in TRL legform tests

- SLICE is functional & improvement over conventional DAS
  - But does have some bugs that need to be worked out
Future Work

NHTSA still needs to evaluate:

– Biofidelity
– Reproducibility (do multiple Flex-GTR legforms produce similar results?)
– Poorly performing vehicles
– Larger vehicles (for example, pickup trucks)