Proposal for a Dynamic full assembly certification test procedure (inverse certification test)

6th Meeting of the GRSP Flex PLI Technical Evaluation Group
Bergisch Gladbach, March 31st, 2008

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Current certification test

- The full calibration test procedures for the Flex-GTR (TEG-056) include a dynamic certification test
- The legform impactor is suspended upside down without flesh and skin over a pin joint from a fixed calibration rig with support arm and release magnet
- The impactor is lifted up to a (not yet) defined height and then released
- A stopper with several layers of neoprene and rubber sheets, mounted on a cross beam, is hit by the knee joint of the released impactor
- Measurement items / pass - fail parameters: string potentiometers (ACL, PCL, MCL and LCL), strain gauges (femur and tibia), tibia top accelerometer

Current certification test

- Certification of the impactor without flesh and skin
- Certification test is just replacing a functional test of the strain gauges and string potentiometers could be replaced by a manual impactor bending
- Test results are far out of a critical range and don't mirror the real accident / injury scenario:

\[ \text{Flex-GT tentative thresholds: } 299-337 \text{ Nm} \]
\[ \text{Flex-GT tentative threshold: } 11.2 \text{ mm} \]
### Current certification test

- Hard impact: neoprene / rubber sheets on steel beam are used as substitute for legform flesh → test represents legform impact against rigid object
- Influence of stopper and neoprene / rubber sheets on test results disproportionately high (independent from stopper material control)
- Consistency test of stopper needed (see TEG-056)
- Certification does not necessarily reveal existing defects / malfunctions
- Certification does not ensure proper functionality of impactor
- Certification after each test necessary → high effort needed

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**Inverse certification test**

- Flex PLI is impacted by the upper edge of a linearly guided Al honeycomb impactor at a previously defined impact speed
- Impact location: upper edge of the honeycomb in line with the center of the knee
- Measurement items / pass - fail parameters: three string potentiometers (ACL, PCL, MCL), four strain gauges (tibia)

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**Test parameters:**

- Impact speed = 40 km/h
- Mass of honeycomb impactor = 8.1 kg
- Impact height: upper honeycomb edge in line with center of knee

**Aluminium honeycomb specifications:**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell size</td>
<td>3/16</td>
</tr>
<tr>
<td>Alloy</td>
<td>5052</td>
</tr>
<tr>
<td>Foil gauge</td>
<td>.001</td>
</tr>
<tr>
<td>Density</td>
<td>3.1</td>
</tr>
<tr>
<td>Crush strength</td>
<td>75 PSI</td>
</tr>
<tr>
<td>Dimensions</td>
<td>250 * 160 * 60 mm</td>
</tr>
</tbody>
</table>
Inverse certification test

- Certification of the fully assembled impactor with flesh and skin
- Certification test checks the impactor functionality under real impact conditions
- Test results are within a more critical range and mirror the real accident / injury scenario:

- **Flex-GT tentative thresholds:** 299-337 Nm
- **α tentative threshold:** 11.2 mm
- **Flex-GT tentative thresholds:** 18 mm, 20 mm

March 31st, 2008

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Inverse certification test

- No consistency test of stopper needed
- No fixation of legform end needed
- „Soft“ impact due to deformable honeycomb material
- Certification after every 20 tests or each year → lower effort needed
- Inverse certification test reveals existing defects / malfunctions better than previous procedure:

Inverse certification test results - Traces taken from TEG-051

Current certification test results
Inverse certification test

• Inverse certification test shows a higher scatter within test results
• Again, possible defects / malfunctions could become more obvious with inverse certification test:

Repeatability of previous certification test results - CV [%]:
Repeatability of inverse certification test results - CV [%]:

Assessment of the standard deviation (CV) according to the requirements for dummies (best practice):

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### Summary

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Current certification test</th>
<th>Inverse certification test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impactor assembly</td>
<td>w/o neoprene and rubber sheets (-)</td>
<td>full assembly with neoprene and rubber sheets (+)</td>
</tr>
<tr>
<td>Suspension</td>
<td>upside down; fixation of tibia end (-)</td>
<td>no fixation of legform end; in line with real car test (+)</td>
</tr>
<tr>
<td>Significance</td>
<td>functional test of strain gauges and string potentiometers only (-)</td>
<td>impactor functionality check under real impact conditions (+)</td>
</tr>
<tr>
<td>Certification results</td>
<td>not in the critical / injury relevant range (-)</td>
<td>within a more critical range reflecting the real injury scenario (+)</td>
</tr>
<tr>
<td>Additional tests</td>
<td>consistency test of stopper needed (-)</td>
<td>no additional test needed (+)</td>
</tr>
<tr>
<td>Efforts for single certification test</td>
<td>comparatively low (+)</td>
<td>comparatively high (-)</td>
</tr>
<tr>
<td>Frequency</td>
<td>after each test (-)</td>
<td>after 20 tests / each year (+)</td>
</tr>
<tr>
<td>Impact</td>
<td>„hard“ - legform impact against rigid object (neoprene / rubber sheets on steel beam are used as substitute for legform flesh) (-)</td>
<td>„soft“ due to honeycomb material (+)</td>
</tr>
<tr>
<td>Influence of flesh simulation on test results</td>
<td>too high weighting of stopper and neoprene / rubber sheets – high impact material used (-)</td>
<td>balanced weighting - deformable impact material used(*)</td>
</tr>
<tr>
<td>Defects</td>
<td>not necessarily revealed (-)</td>
<td>revealed better because test conditions are reflecting better the real impact scenario (+)</td>
</tr>
<tr>
<td>Expendables</td>
<td>neoprene / rubber sheets for stopper</td>
<td>honeycombs</td>
</tr>
<tr>
<td>Others</td>
<td>measuring channels to assess the impactor functionality are partly not used for injury assessment</td>
<td>tendencies of current certification test can be stressed by inverse test</td>
</tr>
</tbody>
</table>

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**Content**

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Next steps

- Inverse certification test results should mirror the critical values w.r.t. the Flex PLI injury criteria

- Definition of aluminium honeycomb specifications:
  - Cell size
  - Alloy
  - Foil gauge
  - Density
  - Crush strength
  - Honeycomb dimensions

- Definition of test parameters:
  - Impact speed
  - Mass of honeycomb impactor
  - Impact height

- Development of a certification test protocol (including specs, corridors etc.)

- Round robin evaluation tests (repeatability, reproducibility, applicability)

Thank you!

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Oliver Zander  March 31st, 2008  Slide No. 15

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