History of Development of the Flexible Pedestrian Legform Impactor (Flex-PLI)

November 3rd, 2011
Japan
Contents

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1. Background
# 1. Background

## - Pedestrian Injured Body Regions -

(USA, Germany, Japan, and Australia: All Age Groups: AIS 2-6)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>32.7%</td>
<td>29.9%</td>
<td>28.9%</td>
<td>39.3%</td>
<td>31.4%</td>
</tr>
<tr>
<td>Face</td>
<td>3.7%</td>
<td>5.2%</td>
<td>2.2%</td>
<td>3.7%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Neck</td>
<td>0.0%</td>
<td>1.7%</td>
<td>4.7%</td>
<td>3.1%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Chest</td>
<td>9.4%</td>
<td>11.7%</td>
<td>8.6%</td>
<td>10.4%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Abdomen</td>
<td>7.7%</td>
<td>3.4%</td>
<td>4.7%</td>
<td>4.9%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Pelvis</td>
<td>5.3%</td>
<td>7.9%</td>
<td>4.4%</td>
<td>4.9%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Arms</td>
<td>7.9%</td>
<td>8.2%</td>
<td>9.2%</td>
<td>8.0%</td>
<td>8.2%</td>
</tr>
<tr>
<td><strong>Lower Limbs</strong></td>
<td><strong>33.3%</strong></td>
<td><strong>31.6%</strong></td>
<td><strong>37.2%</strong></td>
<td><strong>25.8%</strong></td>
<td><strong>32.6%</strong></td>
</tr>
<tr>
<td>Unknown</td>
<td>0.0%</td>
<td>0.4%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: IHRA/PS WG 2001 report

- Head Protection Tests
- Lower Limb Protection Test
1. Background, contd.

- Lower Limb Injured Parts and Contact Locations -
  (USA, Germany, Japan, and Australia : Pedestrian Lower Limb : AIS 2-6)

**AIS 2-6**
USA, Japan, Europe, and Australia

<table>
<thead>
<tr>
<th>Contact Location</th>
<th>Overall</th>
<th>Thigh</th>
<th>Knee</th>
<th>Leg</th>
<th>Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Front Bumper</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top surface of bonnet/wing</td>
<td>2.1%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Leading edge of bonnet/ wing</td>
<td>4.7%</td>
<td>3.3%</td>
<td>0.5%</td>
<td>2.4%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Windscreen glass</td>
<td>0.1%</td>
<td></td>
<td>0.1%</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Windscreen frame/ A pillars</td>
<td>0.5%</td>
<td>0.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Panel</td>
<td>0.9%</td>
<td>0.9%</td>
<td>1.0%</td>
<td>3.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Others</td>
<td>0.6%</td>
<td>0.4%</td>
<td>0.5%</td>
<td>2.6%</td>
<td>1.3%</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>10.5%</td>
<td>8.0%</td>
<td>9.1%</td>
<td>52.0%</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

**AIS 2-6**
USA, Japan, Europe, and Australia

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<td></td>
<td>0.1%</td>
<td></td>
<td>0.2%</td>
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<td>0.7%</td>
<td>0.1%</td>
<td>0.6%</td>
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<td></td>
<td>0.1%</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
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<td>0.5%</td>
<td>0.1%</td>
<td>1.3%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Others</td>
<td>0.9%</td>
<td>0.5%</td>
<td>0.9%</td>
<td>7.0%</td>
<td>0.7%</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>1.9%</td>
<td>4.8%</td>
<td>0.9%</td>
<td>7.0%</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

source: IHRA/PS WG 2001 report
1. Background, contd.

- EEVC Pedestrian Lower Legform Impactor -

Main Concerns: (1) **Low biofidelity** and (2) **Insufficient Measurement Items**

**Structure**

- **Main unit**
  - Femur (Rigid)
  - **Low Biofidelity**

- **Exterior**
  - **Flesh**
    - Disposable Flesh Foam
    - Sensitive to Temperature and Humidity

**Instrumentation**

- **Tibia**
  - **Middle/Lower**
  - **No measurement Items**

- **Knee**
  - **Hard**
  - Low Biofidelity

- **Knee Ligaments** (Steel plate)

Real-world Accident Analysis
Otte et al, 2007

- Knee Shearing Displacement
- Knee Bending Angle
- Upper Tibia Acceleration

Knee center

64 mm
2. History of Flex-PLI Development (Overview)
• The Japan Automobile Research Institute (JARI) and the Japan Automobile Manufacturers Association, Inc. (JAMA) initiated the development regarding a biofidelic flexible pedestrian legform impactor (Flex-PLI) from 2001.
• In 2002, its first version, Flex-PLI 2002, was made.
• The impactor has Flexible Long bones (Femur/Tibia) and knee ligament restraint system like human ones.
• Besides, the impactor has an capability to measure bending moment at multiple locations at Tibia and Femur.

**Measurement cables:**
To measure bending moment at multiple locations at tibia and femur.
2. History of Flex-PLI Development (Overview), contd.

- After the Flex-PLI 2002 development, several improvements were applied.
- GRSP/Pedestrian Safety Informal Working Group (IG-PS WG) interested in the capability of Flex-PLI, then, Flex-PLI technical Evaluation Group (Flex-TEG) were settled in 2005 under the GRSP/IG-PS WG to evaluate the Flex-PLI capabilities as a regulatory tool from Flex-G.
- Finally, the prototype of final version of Flex-PLI (Flex-GTR) were developed in 2009.
- Flex-TEG members were evaluated Flex-GTR capabilities, then they approved the Flex-GTR capabilities in 2010.
- After that, Flex-TEG chair country, Japan, submitted amendments regarding gtr and ECE to the GRSP using the Flex-GTR specifications, etc..
Specifications of Flex-GTR-prototype

Main Achievements: (1) **High biofidelity** and (2) **Multiple Measurement Items**

**Structure**
- **Femur (Flexible)**
  - High Biofidelity

**Exterior**
- **Flesh**
  - Reusable
  - Low Sensitive to Temperature and Humidity

**Main unit**
- **Knee (Ligaments restraint system)**
  - High Biofidelity

**Instrumentation**
- **Injury Assessment Items**

**Tibia (Flexible)**
- High Biofidelity

**Specifications of Flex-GTR-prototype**

**Main Achievements**:
1. **High biofidelity**
2. **Multiple Measurement Items**

**Real-world Accident Analysis**
Otte et al, 2007

**Synthetic Rubber**
- BM: Bending Moment
- Upper end of tibia

**Dimensions**
- Femur-3 BM: 297 mm
- Femur-2 BM: 217 mm
- Femur-3 BM: 137 mm
- Knee-ACL Elongation: 134 mm
- Knee-PCL Elongation: 214 mm
- Knee-MCL Elongation: 294 mm
- BM: Bending Moment

**Materials**
- Flesh
  - Reusable
  - Low Sensitive to Temperature and Humidity

**Ligaments**
- MCL: Medial Collateral Ligament
- ACL: Anterior Cruciate Ligament
- PCL: Posterior Cruciate Ligament
- LCL: Lateral Collateral Ligament

**Reusable**
- Low Sensitive to Temperature and Humidity
• The Flex-GTR had been developed based on the discussions with the Flex-TEG members.
• Detailed information on discussions and achievements of the Flex-TEG regarding
  • Biofidelity
  • Performance/Injury Criteria
  • Benefit
  • Durability
  • Reproducibility and Repeatability
  • Vehicle Countermeasures
  of Flex-PLI are provided by another document.
Thank you for your attention!