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

November 3rd, 2011
Japan
Contents

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1. Back ground
# 1. Background

## Pedestrian Injured Body Regions

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</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>TOTAL</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*

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**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)

<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

*Source: IHRA/PS WG 2001 report*

<table>
<thead>
<tr>
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<th>Overall</th>
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<th>Knee</th>
<th>Leg</th>
<th>Foot</th>
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<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>0.2%</td>
<td>0.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading edge of bonnet/ wing</td>
<td>0.4%</td>
<td>0.7%</td>
<td>0.1%</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>Windscreen glass</td>
<td>0.1%</td>
<td></td>
<td></td>
<td></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>0.5%</td>
<td>0.1%</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>0.9%</td>
<td>0.5%</td>
<td>1.3%</td>
<td>0.5%</td>
<td></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
  - Tibia (Rigid)
    - Low Biofidelity
- Knee (Hard)
  - Low Biofidelity

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

**Instrumentation**
- Real-world Accident Analysis
  - Otte et al, 2007
  - Knee center
    - Knee Shearing Displacement
    - Knee Bending Angle
    - Upper Tibia Acceleration

- Injury Assessment Items
- Tibia Middle/Lower
  - No measurement Items
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.
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
- **Tibia (Flexible)**
  - High Biofidelity

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

**Instrumentation**
- Injury Assessment Items

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

**Synthetic Rubber**

**Main unit**
- Femur-1 BM
- Femur-2 BM
- Femur-3 BM
- Femiur-4 BM
- Tibia-1 BM
- Tibia-2 BM
- Tibia-3 BM
- Tibia-4 BM

**BM: Bending Moment**

**Knee (Ligaments restraint system)**
- **MCL**
- **ACL**
- **PCL**
- **LCL**

**Specifications of Flex-GTR-prototype**

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

- **Tibia** (Flexible)
  - High Biofidelity

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

- **BM: Bending Moment**

- **Injury Assessment Items**

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

- **Main Achievements**
  - (1) **High biofidelity**
  - (2) **Multiple Measurement Items**
2. History of Flex-PLI Development (Overview), contd.

• 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!