Deq
principles, IRCs and thresholds

Informal Group on Frontal Impact
GRSP
November 23th, 2012
1. General principle

% risk

Hybrid III deflection

d localized

d distributed

evaluated separately

subtracting the localized deflection from the total deflection

combination (d localized, d distributed)
1. General principle

\[ d_{\text{distributed}}(t) = d_{\text{total}}(t) - d_{\text{localized}}(t) \]

- \( d_{\text{localized}}(t) = \frac{F_{\text{shoulder}}}{k_0} \)
- \( d_{\text{distributed}}(t) = \text{Drodpot} - \frac{F_{\text{shoulder}}}{k_0} \)

Belt-only tests
1. General principle

\[
d_{\text{equivalent}} = d_{\text{localized}} + f_n \times d_{\text{distributed}}
\]
1. General principle

\[ d_{\text{equivalent}} = \frac{F_{\text{shoulder}}}{k0} + f_n \times (D_{\text{dropot}} - \frac{F_{\text{shoulder}}}{k0}) \]
1. General principle

\[ D_{\text{equivalent}} = \alpha \times F_{\text{shoulder}} + \beta \times D_{\text{dropot}} \]
2. Adjustments

- Rodpot does not measure the maximum deflection
- Deq accounts for chest viscous component
2. Adjustments

**Belt contribution**

\[ D_{\text{belt}} = \frac{F_{\text{shoulder}}}{k_0} \]

![Diagram showing the comparison between belt and drop pot contributions over time.](image)
2. Adjustments

**AB contribution**

\[ \text{Dairbag} = D - \frac{F_{\text{shoulder}}}{k_0} \]

\[ D = D_{\text{droopot}} \]

\[ F_{\text{shoulder}}/k_0 \]

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**Airbag**

\[ \text{Time} \]

**Belt**

\[ \text{Time} \]

---

**F_{\text{shoulder}}**

\[ k_0 \]

**Belt-only tests**

\[ D_{\text{droopot}} \]
2. Adjustments
AB contribution

Dairbag = D – F/k0

Drodpot

Fshoulder/k0

Belt-only tests

Airbag <0

Airbag

Belt

Time

Time

Time
2. Adjustments

AB contribution

\[ F_{\text{shoulder}} = k_0 \cdot D \]

\[ D_{\text{airbag}} = D - \frac{F}{k_0} \]

\[ D_{\text{droppot}} = \text{Belt-only tests} \]

\[ F_{\text{shoulder}}/k_1 \]

\[ \text{Time} \]

\[ \text{Time} \]

\[ \text{Time} \]
2. Adjustments

Viscous component

- Exact DeqLin: 30.7 (4.1% risk @45y/o)
- Simplified DeqLin: 35.2 (7% risk @45y/o)
**DEQ LIN**

**DEQ LIN** = \[ \max ( \ d_{belt}(t) + \ Fn \cdot d_{airbag}(t) ) \]

**Belt contribution**
- \( k_1 = 136 - 0.0018 \cdot \text{USBF} \) (USFB= Upper shoulder belt Force in N)
- \( c_1 = 0.0185 \cdot k_1 - 0.2357 \) (c1 = effect of the viscous component)

**Airbag contribution**
- \( k_1 = 238 - 0.0023 \cdot \text{USBF} \) (USFB= Upper shoulder belt Force in N)
- \( c_1 = 0.0185 \cdot k_1 - 0.2357 \)

**Fn** = 0.84
Injury Risk Curves

**HIII 50th Male**

\[
Injury\ risk(50th) = 1 - \exp\left(-\exp\left(\frac{\ln(\text{deq}) - 4.99 + 0.0174 \times \text{age}}{0.246}\right)\right)
\]

<table>
<thead>
<tr>
<th>DEQ values</th>
<th>HIII 50th</th>
<th>45 y/o</th>
<th>65 y/o</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>33</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>50</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>62</td>
<td>44</td>
<td></td>
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</tbody>
</table>
**HIII 5th Female**

\[
Injury\ risk(50th) = 1 - \exp\left(-\exp\left(\frac{\ln\left(\frac{deq}{0.83}\right) - 4.99 + 0.0174 \times age}{0.246}\right)\right)
\]

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<th>DEQ values</th>
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<th>65 y/o</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIII 5th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>25%</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td>50%</td>
<td>51</td>
<td>36</td>
</tr>
</tbody>
</table>
HIII 50th - 45 y/o

Deq LIN $\Leftrightarrow 6.6*USBF(kN) + 0.84*(Rodpot(mm) - 3.7*USBF(kN))$

Deq IRC has nothing to do with Rodpot IRC
Ex for belt-only: 5kN / 22mm Rodpot $\Leftrightarrow$ Deq=36 (4% AIS3+)

Deq = not a physical measurement
**Laituri - Injury Risk Curve**

**HIII 50th Male – NHTSA (Laituri 2005)**

\[
Injury\ risk(50th) = \frac{1}{1 + \exp^{-12.597 - 0.05861 \times \text{age} - 1.568 \times (\text{ChestDefl})^{0.4612}}
\]

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<th>65 y/o</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>26 mm</td>
<td>17 mm</td>
</tr>
<tr>
<td>25%</td>
<td>43 mm</td>
<td>32 mm</td>
</tr>
<tr>
<td>50%</td>
<td>55 mm</td>
<td>42 mm</td>
</tr>
</tbody>
</table>

**Graph of HIII 50th male**

- **Risk of AIS3+**
- **Chest deflection (mm)**
- **45 y/o**
- **65 y/o**
Test results

HIII 50\textsuperscript{th} - 45 y/o

Deq LIN $\Leftrightarrow 6.6 \ast \text{USBF}(\text{kN}) + 0.84 \ast (\text{Rodpot}(\text{mm}) - 3.7 \ast \text{USBF}(\text{kN}))$
Injury Risk Curve

Laituri IRC
- Data from Sled (Belt (19), Combined (29))
- Data from Table top tests (Belt (35), distributed (16), 2 diag (14), blunt (17))
- Data from Blunt (44)
- Data from OOP tests (12)

PMHS IRC

Transfert to HIII

\[
y = 386.81x^{2.0145} \\
R^2 = 0.9357
\]
Laituri IRC

- All configurations considered as a whole by Laituri
- Should split different configurations
- Blunt significantly different from Belt

Injury Risk Curve

- Injury Risk Curve for PMHS/HIII
- $y = 386.81x^{2.0145}$
- $R^2 = 0.9357$

- Injury Risk Curve for PMHS compression
- $y = 114.09x$
- $R^2 = 0.2064$

- Injury Risk Curve for linear relationship
- $y = 84.428x$
- $R^2 = 0.8725$
Laituri IRC

- All configurations considered as a whole by Laituri
- Should split different configurations
  - Blunt significantly different from Belt

Injury Risk Curve

With additional Blunt tests and Belt-only sled tests
Injury Risk Curve

Laituri IRC

HIII injury risk curves @ 45 y/o

Risk of chest AIS3+

HIII deflection (mm)

- Belt
- Blunt
- Dist
- Laituri2005
Thresholds

HIII 50th - 45 y/o

Deq LIN ⇔ 6.6*USBF + 0.84*(Rodpot-3.7*USBF)
Thresholds

HIll 5th Female - DEQ LIN 45 y/o

Deq allows more deflection than Rodpot
Proposal for ENCAP Upper limit: Deq @ 10% risk
@ 5kN, Rodpot should not overpass 18 mm
@ 2kN, Rodpot can reach 30 mm

Deq is more severe than Rodpot

HIll 5th - 45 y/o for ENCAP UPPER limit
Thresholds

HIII 50th - 45 y/o for ECE94 limit
and ENCAP LOWER limit