Evaluation of the RibEye™ Multipoint Deflection Measurement System installed in the WorldSID-50M Dummy

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Motivation

• Measure deflection of a single point

• IRTRACCs
  – WorldSID-50M
  – WorldSID-5F

• Linear potentiometers
  – ES-2re
  – SID-Ils
Motivation

- Measure deflection of a single point
RibEye™ Multipoint Optical Measurement System

- WorldSID-50M
  - x, y, z positions of 18 points
  - 2 sets of 3 sensors & 9 LEDs
    - Top set ~ red filters & LEDs
    - Bottom set ~ blue filters & LEDs
    - Origin is at center of lens of middle sensor
  - 9 LEDs can be anywhere
  - All 3 sensors must sense light from an LED to measure its position
Objectives

1. Assess the accuracy of RibEye™ measurement
2. Assess ability of RibEye™ to capture max deflection
3. Determine optimal anterior and posterior LED locations
4. Evaluate RibEye™ in crash tests
Is RibEye™ Accurate?

- Quasi-static tests w/9 LEDs on each rib
- Single ribs loaded at $0^\circ$, $\pm 10^\circ$, $\pm 20^\circ$, $\pm 30^\circ$, $\pm 40^\circ$
- Loaded in 10 mm increments to 30, 40 or 50 mm
- LED positions measured with FARO and RibEye™
Is RibEye™ Accurate?

- Quasi-static tests w/9 LEDs on each rib
- Single ribs loaded at 0°, ±10°, ±20°, ±30°, +40°
- Loaded in 10 mm increments to 30, 40 or 50 mm
- LED positions measured with FARO and RibEye™
Can RibEye™ Capture Max Deflection?

• Single rib dynamic impacts
• Thorax ribs 1-3 tested, each with 9 LEDs
• Impact speeds 2.0-4.3 m/s
• Impact angles 0°, +/-10°, +/-20°, +/-30°
• Impactor mass 23 kg
• Impactor face 152 mm dia.
• HS video - track targets
Can RibEye™ Capture Max Deflection?

30° posterior impact

Lateral-most point of rib (location of single-point deflection measurement systems)

Max deflection

Deflection (mm)

Impact Angle (deg)

-40 -20 0 20 40

TEMA Max
RibEye Max
RibEye Middle LED
Where Are Optimal LED Locations?

- 3 LEDs per rib
- 1 LED at lateral-most rib location
- What locations are optimal for anterior & posterior LEDs?
  - Trio of LEDs that would give the estimate of deflection closest to the truth at every time point in every test
    - Average error among all data
    - Maximum error among all data

Max deflection
### Best Combinations of 3 LED Locations
(Sorted by Maximum Error, from least to most)

<table>
<thead>
<tr>
<th>Trio</th>
<th>Mean Error (mm)</th>
<th>Max Error (mm)</th>
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<tbody>
<tr>
<td>A4 0 P5</td>
<td>0.85</td>
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<tr>
<td>A5 0 P5</td>
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**Best Trio:**
- average error = 0.85-0.92 mm; max error = 7.2 mm
### Best Combinations of 3 LED Locations
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**Best Trio:** avg error = 0.85-0.92 mm; max error = 7.2 mm

**Final Trio:** avg error = 1.1-1.4 mm; max error = 9 mm

**Middle LED only:** avg error = 5.1 mm; max error = 30 mm
Evaluation of RibEye™

- Side NCAP crash tests
  - 6 Pole tests
  - 6 MDB tests
  - WorldSID-50M w/RibEye driver
  - Chest band on Thorax rib 1

Front left view of chest band on Thorax rib 1
Evaluation of RibEye™

Chest band contours with RibEye™ LEDs

- Chest band
- Inner rib
- Outer rib

Load direction:
- Left lateral
- Right lateral
- Anterior
- Posterior

Graph showing Anterior-Posterior Position (mm) vs. Lateral-Medial Position (mm) with various markers indicating initial, max deflection, Ribeye v3 performances.
Evaluation of RibEye™ - Pole test results

Frnt=10  Mid=22  Rear=21
Frnt=37  Mid=33  Rear=18
Frnt=61  Mid=40  Rear=13
Frnt=39  Mid=41  Rear=23
Frnt=42  Mid=40  Rear=22
Frnt=61  Mid=44  Rear=18
Evaluation of RibEye™ - Pole test results

Front LED:  Risk AIS 3+ = 64%

Middle LED: Risk AIS 3+ = 8%
RibEye™ Idiosyncrasies

- Finite sensor measurement range
- Error codes
  - Exceed sensor range

Error code replaced with null data
RibEye™ Idiosyncrasies

- Finite sensor measurement range
- Error codes
  - Exceed sensor range
  - One or more sensors are blocked or see too much ambient light

Error codes replaced with null data
Conclusions

- **RibEye™** is sufficiently accurate
- In oblique single-rib dynamic loading conditions, **RibEye™** successfully captured the maximum deflection of the rib (with 9 LEDs)
- Several crash tests demonstrated oblique loading to the thorax
- In all crash tests, **RibEye™** LEDs followed the shape of the chest similar to the chest band
- In several crash tests, the front **RibEye™** LED measured the maximum deflection of the rib, illustrating its advantage of measuring multiple points on a rib
- In a few crash tests, the front **RibEye™** LED measured ~20 mm more than the middle LED, resulting in an injury risk difference of 56%, demonstrating the value of measuring multiple deflection points
EVALUATION OF THE RIBEYE™ MULTIPoint DEFLECTION MEASUREMENT SYSTEM INSTALLED IN THE WORLDSID-50M DUMMY