Requested reliability of dynamic mechanical measurement in mobility, from automobile to service robot

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Japan Automobile Research Institute

- JARI: Independent lab. for automotive research & test in Japan

- Research and testing on automotive safety and environment

- Expanding our research and testing field to safety of robotics in terms of interactions with human

- In this presentation, dynamic measurement methods for collision of cars and robots will be reported and discussed.
Contents

• Collision tests of personal care robots
• Car crush criteria
• Car crush dummy
• Calibration of sensors
• Required dynamic response (Examples of data)
• Dynamic measurement in our studies
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Collision tests of personal care robots

Project for practical applications of service robots by New Energy and Industrial Technology Development Organization
Collision tests of personal care robots
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# Car crush criteria

## Example 1: Rigid barrier / in-position / FMVSS 208

<table>
<thead>
<tr>
<th></th>
<th>50 % male</th>
<th>5% female</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head</strong></td>
<td>HIC(_{15} = 700)</td>
<td>HIC(_{15} = 700)</td>
</tr>
<tr>
<td><strong>Neck</strong></td>
<td>N(_{ij} = 1.0)</td>
<td>N(_{ij} = 1.0)</td>
</tr>
<tr>
<td>Tension: F(<em>{z</em>{\text{max}}} = 4.17) kN</td>
<td>Tension: F(<em>{z</em>{\text{max}}} = 2.62) kN</td>
<td></td>
</tr>
<tr>
<td>Compression: F(<em>{z</em>{\text{max}}} = 4.0) kN</td>
<td>Compression: F(<em>{z</em>{\text{max}}} = 2.52) kN</td>
<td></td>
</tr>
<tr>
<td><strong>Chest</strong></td>
<td>a(_{3ms} = 60) G</td>
<td>a(_{3ms} = 60) G</td>
</tr>
<tr>
<td>s(_{\text{max}} = 63) mm</td>
<td>s(_{\text{max}} = 52) mm</td>
<td></td>
</tr>
<tr>
<td><strong>Femur</strong></td>
<td>F(_{\text{max}} = 10) kN</td>
<td>F(_{\text{max}} = 6.805) kN</td>
</tr>
</tbody>
</table>

\[
HIC_{15} = \left( \frac{1}{t_2-t_1} \int_{t_1}^{t_2} a \, dt \right)^{2.5} (t_2-t_1)
\]
### Car crush criteria

#### Example 2: Deformable barrier / in-position / EC

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>HPC\textsubscript{36} = 1000</td>
</tr>
<tr>
<td>Neck</td>
<td>My = 57 Nm</td>
</tr>
<tr>
<td>Chest</td>
<td>VC = 1 m/s</td>
</tr>
<tr>
<td>Femur</td>
<td>FFC (F\textsubscript{max})</td>
</tr>
<tr>
<td>Knee</td>
<td>s\textsubscript{max} = 15 mm</td>
</tr>
<tr>
<td>Tibia</td>
<td>TCFC(F\textsubscript{max}) = 8.0 kN</td>
</tr>
</tbody>
</table>

![Graph showing Axial Femur Force (kN) vs. Duration (ms)](image)

- FFC (F\textsubscript{max})
  - 9.07 kN
  - 10 ms
  - 7.58 kN

- 50% male

HPC\textsubscript{36} = 1000

a\textsubscript{3ms} = 80 G

My = 57 Nm

VC = 1 m/s

ThCC(s\textsubscript{max}) = 50 mm

FFC (F\textsubscript{max})

s\textsubscript{max} = 15 mm

TCFC(F\textsubscript{max}) = 8.0 kN

TI = 1.3
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## Calibration of sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Static Calibration of sensors</th>
<th>Dynamic Calibration of sensors</th>
<th>Response verification of dummy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>✓</td>
<td>improving</td>
<td>✓</td>
</tr>
<tr>
<td>Displacement</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Force</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Torque</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Note:** Dynamic calibration of sensors is currently under improvement.
Calibration of accelerometer

~ 1000 G

Static
Calibration of accelerometer

Dynamic (up to 2000 Hz)

<10 G
Calibration of accelerometer
Calibration of force/torque transducer

Static
Verification of dummy head response

Resultant Acceleration Hybrid-III 50th

Time (ms)
Verification of dummy chest response
Verification of dummy chest response

Knee Impact Force Hybrid-III 50th

Time (ms)

kN

- 規格
- JARIコリドー
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Examples of car crash data

35mph Frontal Impact

\[ HIC_{15} = \left[ \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} (t_2 - t_1) \]

\[ HIC_{15} = 518 \]
Examples of car crash data

35mph Frontal Impact
Examples of car crash data

35mph Frontal Impact
Example of robot crash data.

Moving object:
- 200 kg
- Steel Structure
- 6 km/h

Dummy:
- 6-Y-O
- Standing in front of wall

HIC<sub>15</sub> = 323

REF: NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Example of robot crash data

Moving object:
- 200 kg
- Steel Structure
- 6 km/h

Dummy: 6-Y-O
- Standing in front of wall

$S_{\text{max}} = 10$ mm

Displacement (mm)

Chest Injury Probability (%)

Chest Deflection (mm)

S$\max = 10$ mm

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Dynamic measurement
Tire dynamic force /1987
Dynamic measurement
Tire contact force /1989

Tire tread

Road surface

Transducer
Dynamic measurement
Tire contact force / 1989
Dynamic measurement
Tire temperature in actual contact area /1990
Dynamic measurement
Tire temperature in actual contact area /1990

- 2 µm Deposited Chromel Coating
- Alumel Wire
- Ceramic Insulation
- Chromel Tube

Graph: Temperature Rise vs. Distance into Patch (mm)

- Measured
- Computed
Dynamic measurement
Tire tread vibration /1999

Transducer

Acceleration

Transducer

Transfer function (m/s/N)

Frequency (Hz)

Real

Imaginary

Time (s)

0 0.02 0.04 0.06 0.08 0.1

0 500 1000 1500 2000

0.016

0.014

0.012

0.01

0.008

0.006

0.004

0.002

0 1000 1500 2000

200 m/s²

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Dynamic measurement
Tire tread vibration /1999
Dynamic measurement

Crash barrier force / 20XX

Transducers