Abdominal Pressure Twin Sensors (APTS) for Q dummies

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Background: Abdominal Pressure Twin Sensors (APTS)

Developed during CHILD by INRETS = Two cylindrical PU bladders filled with gel and equipped with pressure sensors; located in the abdominal block of Q3/Q6 (free to slide)
- If belt remains on the pelvis then pressure is low…
- If belt/other loads the abdomen: pressure increases with force
  - The higher the load, the higher the pressure
- Provides some localization info (left/right/side) for loading
Overview of past tests (Child and other activities)

• Dummy tests included:
  – static bar compression,
  – belt frontal and side compression
• Sled tests (parametric)

• 9 accident reconstructions found in report
  – selection?
  – Too few for reliable injury risk curve but trend is visible
Example of sled results (Q3, R44 type, Child+Casper)

- Belt on upper thigh, booster, no misuse: Peaks: 0.3-0.5 bar
- Belt on lower abdo, no booster: Peaks: 0.6 to 0.7 bar
- Anchor raised, misuse (belt path), med patches: about 1 bar
- + Anchor raised more + relaxed position: 1.7 to 1.9 bar

Note:
For more on patches: Dummy dev. Session (Wednesday)
For more on APTS/Q6/misuse: Applications Casper Session
Objectives and approach for Casper

- Objectives: further develop a solution to assess abdominal injuries (here: APTS) towards an evaluated industrial solution applicable to Q dummies
- Approach / Work performed:
  - Evaluate sensor response in compression & dummy flexion
  - Design and implement and evaluate new sensor version based on observed limitations/shortcomings
  - Use the sensors in accident reconstructions in order to build/consolidate an injury risk curve
- Perspective: application to other dummies…
Evaluation of sensitivity to flexion

Why? abdomen vertical compression could affect reading…
  – especially considering the Q abdomen design

Tests: dummy torso flexion
  – **Static:** HIII torso flexion type test (simplified)
  – **Dynamic:** horizontal pull at shoulder (>1m/s)

Results: Effect on response

![Graph showing moments at lumbar level vs. angle (degrees)]
Evaluation of sensitivity to flexion

- Effect small (max=0.17bar << level in injurious accident reco)
- Good repeatability/symmetry
  - Connector of one of the sensor damaged in last test
- Pressure time history is well correlated with moment

Results of 4 static tests

Results of 4 dynamic tests

Aligned on peaks
Evaluation of the sensor compressive response

1) Isolated: why? facilitate sensor modelling and modifications;
   • Instron and drop tower, 0.001 to 3m/s
   • Good repeatability (force, pressure)
   • Force vs. pressure linear and speed independent up to 1m/s

Up to 50% compression (5s plateau)
2) In dummy. Why? evaluate the effect of sensor on dummy response (w.r.t. biomechanical corridors)

- 67 to 76 mm stroke from 0.001 to 1m/s
- Rigid cylinders and belts (25, 50mm)
- Response symmetric and repeatable

![Graph showing pressure vs. displacement for different speeds and sensor types.](image)
Q3 response: standard or with APTS

• APTS less rate sensitive than standard block
  – Stiffening at low speed but response is similar at 1m/s

Stiffness seems ok (at 1m/s) → same target will be kept for new design
Sensor shortcomings and design objectives

Sensor identified shortcomings:
- Cable output is fragile in testing
- Cap tends to open when subjected to extreme loading
- Pressure sensor sensitive to tightening torque
- Manufacturing constraint: unmolding is very difficult…
- Sensors can migrate upwards during testing

Design objectives:
- Same response targeted
- Solve shortcomings
- Make modular system so that it can be adapted to other dummies (Q10, Q1.5?)

Approach: changes first evaluated using FE modeling
APTS v2

Design target: similar response but solving shortcomings

- Subminiature pressure cell
- Larger lips & collar
- Horizontal cable output
- Single cap
- Modular mold (length: 82 to 217mm in 5mm steps)
  - Adaptation to other dummies
- Filled under pressure column

Unexpected change: material
- more rigid
APTS v2 testing

- Main objectives:
  - Compare their response to v1 to determine a scaling factor between the output of the two sensors (if needed)
  - Characterize the new sensors and their variability (manufacturing)

Test program

- Compression (still ongoing)
  - Standalone and in Q3 dummy (started)

- Sled testing (still ongoing)
  - Standard and misuse position Q3
  - Different seats (3 point belt + boosters, harness, shield)

- Accident reconstructions (used in 5 dummies, both Q3 and Q6)
APTS v2 testing tests

- E.g. Sled with shield (R44 like)
  - HIC36: 700, Head 3ms: 73g, Neck Fz 2.2kN, Chest 3ms: 36g
APTS v2 testing tests

- E.g. reco. 2032 (LAB-Fiat):
  3 children with abdo injuries
  - 2 pairs of APTS v2, 1 pair of v1

![Graph showing abdominal pressure over time for Case 2032]

- 6YO (MAIS4)
- 8YO (MAIS3)
- 4YO (MAIS4)
Accident reconstruction: summary v1+v2

- 30 points considered for injury curve (about half Q3, half Q6)
- Each case will be reviewed to check the loading mechanism, misuse, thorax injury, etc… to determine if point will be used in the end
- Different metrics will be considered (currently: max(peak pressures))
Perspectives: application to other dummies

- **Currently**: Q3 and Q6; sensors with same diameter can be easily manufactured
- **Q10**: Interest for abdominal injury assessment → new Casper Task: sensor implantation
  - Selection of sensor length and location after iterations with Humanetics; Manufacturing ongoing
  - Compressive tests planned 2\textsuperscript{nd} part of March
  - Sled testing planned in April at Dorel
  - If results ok: testing may continue with Q10
- **Q1.5**: implantation considered

Sensor looks small in Q10 block and huge in Q1.5
Perspectives: application to other dummies

• More work is needed to determine how to scale between dummies
  – Sensor size vs. pressure vs. tolerance etc…
  – Using FE modeling (both dummy and human) to scale?

• Two recent studies may help:
  • Ifsttar-Toyota collaborative project on Thor abdo. (Masuda and Compigne, 2012): Tests performed in configurations for which PMHS data is available
  • NHTSA funded study on the use of pressure based injury predictor (Kremer et al., 2011), 10 PMHS lower ribcage impacts
Conclusion and perspectives

• During Casper, Abdominal Pressure Twin Sensors for Q3 and Q6 were further developed towards an industrial application:
  – Better characterization, New version (v2) designed and build…
• Sensors (v1 or v2) were used in numerous tests
  – Isolated tests, Q3, Q6, sleds with/without misuse, Accident reconstructions
• Overall: seem to be able to detect abdominal loading with regard to misuse, submarining etc…
  – Work will continue to develop injury risk curve
  – Promising tool for the assessment of abdominal injuries!
• Perspectives:
  – the implantation of the sensors in the Q10 (and other dummies)
  – Work on scaling between sensors/dummy/etc…
  – Calibration procedures
Questions? Comments?