Sensitivity of the Q-Series Abdominal Pressure Twin Sensors to loading type and position in dynamic restraint system loading tests

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I. INTRODUCTION

The Abdominal Pressure Twin Sensors (APTS) were developed to measure restraint system loading to the abdomen of the Q-Series dummies in front impact tests. The sensors were found not to influence the response of the abdomen in moderate-rate belt compression tests using a material testing machine [1]. In the same tests, the APTS were also found to be sensitive to restraint loading type and position [1-2]. Appropriate sensitivity is likely to be desirable in discriminating differences in protection between child restraint systems.

A material testing machine provides a very controlled means of loading the abdomen in order to characterise its response. However, it may not replicate the effects of jerk loading typical of a dynamic collision event. This short communication describes a series of restraint loading tests in which the test device provided a high-rate dynamic, yet controlled, restraint system input to the abdomen. The aim was to bridge the gap between the previously reported moderate-rate tests and full sled tests in order to understand the sensitivity of the APTS to loading type and position.

II. METHODS

A series of table-top tests was carried out using a set-up similar to that described by Kent [3]. The test fixture provided two-point belt loading on the anterior abdomen of the Q3 dummy using a 5 cm wide belt. The dummy was placed supine on the table and the belt was positioned across the anterior abdomen, either directly or via an impact shield. The two ends of the seatbelt passed through the table over low friction supports and were attached to a horizontal loading bar. The movement of the loading bar was activated by a miniature bungee-powered sled. The sled was given an initial velocity of 3.0 m/s, which produced approximately 50 mm of abdomen compression in 40 ms, with an instantaneous peak velocity of approximately 3 m/s. The force at each end of the belt passing over the dummy was measured with a load cell before connection to the loading bar. Movement of the belt or impact shield was measured with linear variable differential transformers (LVDTs) mounted to a frame above the dummy. The force measurements from three load cells under the table supporting the dummy were combined to provide a total reaction force.

Three loading positions were investigated. In the lowest position, the belt or shield engaged fully with the pelvis. In the middle position, the belt or shield was aligned with the middle of the abdomen. In the highest position, the belt or shield was aligned with the top of the abdomen and partially engaged the ribs (particularly in the case of the shield). The production version of the Q3 APTS was used in this study.

III. INITIAL FINDINGS

The Q3 dummy displayed a stiffer response with an abdomen that was equipped with APTS (Fig. 1). These findings were consistent between the seatbelt force and the reaction force. Belt loading was applied to the middle of the abdomen in these tests.

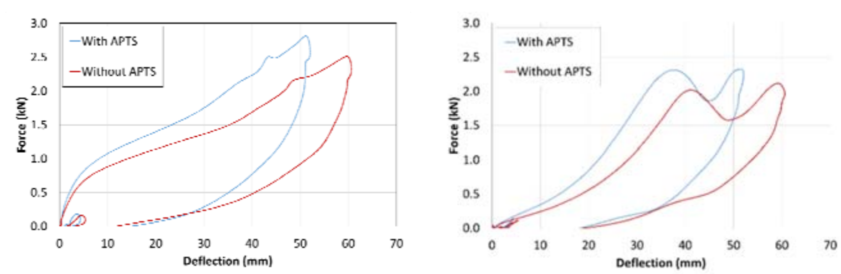

Fig. 1. Belt (*left*) and reaction (*right*) force vs. deflection with and without APTS installed in the Q3.

When belt loads were applied to different segments of the abdomen (i.e. low, middle and high), the stiffest response was observed in the lowest position (Fig. 2, *left*). In this position, the belt engaged with the pelvis. The middle and high loading positions were

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relatively similar to each other in stiffness, but the high position displayed a slightly higher force at peak deflection, possibly because part of the belt was starting to engage with the ribs. Negligible abdomen pressure was measured with the belt in the lowest position (Fig. 2, *right*). As noted above, the belt engaged with the pelvis in this test; nevertheless, nearly 40 mm of deflection was observed from the LVDT.

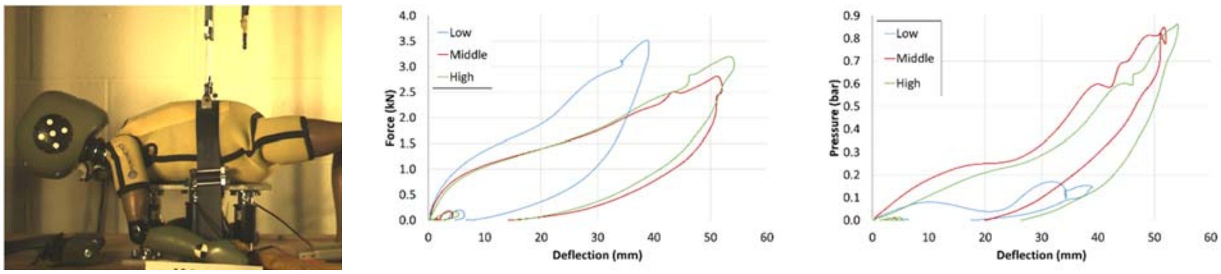

Fig. 2. Effect of belt position: belt force vs deflection (*left*); abdomen pressure vs deflection (*right*).

When loads were applied with an impact shield, there was some evidence for a stiffer response in the lower part of the abdomen (Fig. 3, *left*). However, this was less pronounced than in the seatbelt loading tests. Markedly greater deflection (for a given force) was observed when the shield was in the high position. Although the rib cage was likely to have been engaged in this position, the shield was further from the pelvis. The pressure was relatively low, compared with the belt loading tests, despite there being similar levels of deflection (Fig. 3, *right*). It is possible that the shield was tilting or rocking during the tests and therefore compressing the ribs, rather than the abdomen. The oscillatory nature of the response may support this hypothesis, but further analysis is needed.

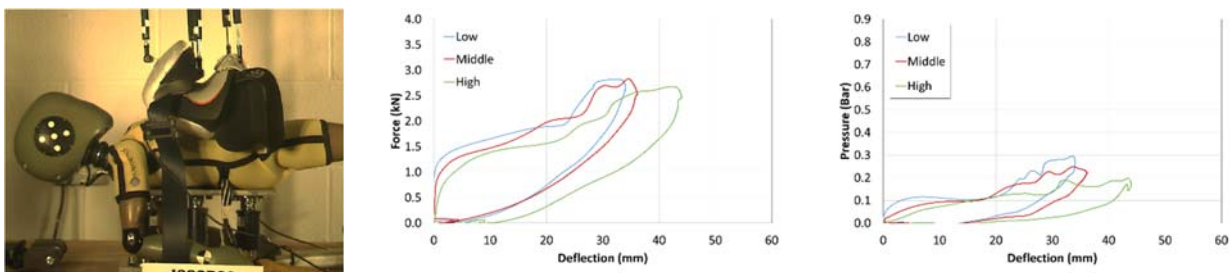

Fig. 3. Effect of shield position: belt force vs deflection (*left*); abdomen pressure vs deflection (*right*).

IV. DISCUSSION

The APTS increased the stiffness of the Q3 abdomen in these table-top tests with dynamic restraint loading. Further testing is needed to establish whether the differences were within reasonable variation expected between different Q3 dummy abdomens. The Q3 abdomen and the APTS were sensitive to the type and location of the restraint loads. Engaging the pelvis of the dummy is likely to reduce deflection and pressure for a given force for any restraint type. However, the APTS do not descend fully into the pelvis and hence it may be possible to load the abdomen in front of the pelvis in a region not covered by the sensors. The risk of abdomen injury may be less when the restraint engages with the pelvis; nevertheless, relatively high deflection was observed with negligible pressure in the belt loading tests in the lowest loading position.

These tests generated a great deal of data. Further analysis is planned to complete our understanding of the APTS and their sensitivities. This will include additional measurement parameters, as well as additional tests at a higher loading speed. Our findings apply to APTS installed in the Q3 dummy. Further testing is needed to validate our findings for other dummies in the Q-Series family.

V. REFERENCES

[1] Beillas *et al.*, *Stapp Car Crash J*, 2012.
[2] Beillas *et al*., 12th International Conference Protection of Children in Cars, 2014.
[3] Kent *et al.*, *Stapp Car Crash J*, 2006.