Influence of Belt Path on Rotation of Rearward-Facing Infant Child Restraint Systems

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I. INTRODUCTION

The correct use of a child restraint system (CRS) had been associated with substantial reductions of injury and mortality risks in motor vehicle crashes [1-4]. The safety benefits of rearward-facing CRS for paediatric occupants in actual crashes have also been demonstrated [5-6]. Many rearward-facing infant CRS models in the US can be used with or without a base [7], with the latter being a more convenient option for travel or rideshare. When a rearward-facing infant CRS is installed without the base, there are typically two belt path options (i.e., European or US) [8]. A review of the user manuals of 58 rearward-facing infant CRS models currently available in the US revealed that 36 (62%) depicted installation using the European belt path.

In a recent study, sled tests of a 12-month-old Child Restraint/Air Bag Interaction (CRABI-12) anthropomorphic test device (ATD) seated in rearward-facing CRS models positioned directly behind a centre console during frontal impacts were performed [9]. The European belt path tests resulted in CRS models experiencing yaw motion toward the seat belt post, roll motion toward the seatbelt buckle, minimal forward translation and no contact with the centre console, which were attributed to the asymmetrical belt routing across the rear shell of the CRS. In contrast, the tests using the symmetrical US belt path mainly resulted in substantial forward translation due to the lack of seatbelt routing across the rear shell of the CRS. Although sled testing has the advantage of being a controlled test environment with high repeatability [10], it lacks some of the dynamic conditions of full-vehicle tests. Therefore, the aim of the current study was to investigate the influence of belt path on the rotation of rearward-facing infant CRS models during full-frontal rigid barrier vehicle tests.

II. METHODS

Full-Frontal Rigid Barrier Vehicle Tests

As part of a comprehensive research programme aimed at evaluating crashworthiness protection for child occupants, Transport Canada has performed in-vehicle crash testing of rearward-facing CRS [11-12]. Transport Canada provided access to this dataset, from which two 56 km/h full-frontal rigid barrier tests involving sport utility vehicle (SUV) models were analysed. In the second-row outboard seat of each vehicle, a CRABI-12 ATD was seated either in a rearward-facing infant CRS model without the base attached via the European belt path or a baseless rearward-facing infant CRS model via the US belt path (Fig. 1). A high-speed video camera captured the side view of the CRS during the test. Video footage was corrected for distortion and the motion of quad markers on the CRS were tracked using video analysis software (META v25, BETA CAE Systems). The rotation of the CRS in the lateral plane was quantified.

Fig. 1. CRS without a base attached to a vehicle seat using the European (left) and US (right) belt path.

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III. INITIAL FINDINGS

The rearward-facing infant CRS without a base attached using the European belt path rotated rearwards (Fig. 2) with the head of the CRABI-12 ATD moving towards the second-row seatback (i.e., the seatback of the seat to which the CRS was attached). In contrast, the baseless rearward-facing infant CRS attached using the US belt path rotated forwards with the head of the CRABI-12 ATD moving towards the floor of the vehicle. Neither rearward-facing infant CRS model nor the CRABI-12 ATD was observed to contact the front-row seatback of the vehicle at any point during the impact. The CRS-seatback distance for the US belt path test was 346 mm. The CRS-seatback distance was not available for the European belt path test but was qualitatively observed to be substantially less compared to the US belt path test.

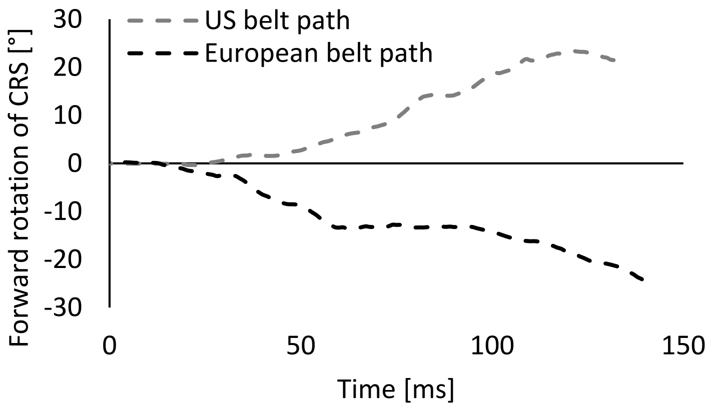

Fig. 2. Forward rotation of rearward-facing infant CRS in frontal impacts.

Qualitatively, the rearward-facing CRS without the base attached using the European belt path was observed to undergo outboard yaw motion, inboard roll motion and minimal forward translation similar to previous sled test results [9]. In contrast, the baseless rearward-facing CRS attached using the US belt path underwent substantial forward translation.

IV. DISCUSSION

The rearward-facing CRS without the base attached using the European belt path rotated rearwards, whereas the baseless rearward-facing CRS attached using the US belt path rotated forwards. This difference is likely due to the European belt path involving the shoulder portion of the belt wrapping around the rear shell of the CRS, which then acts similarly to a support leg or Australian tether, resisting forward rotation of the CRS towards the front-row seatback and floor of the vehicle [9] [13]. Limiting the forward rotation of a rearward-facing CRS has the benefit of preventing or minimising contact with front row structures, such as the front-row seatback or centre console, which has been previously found to reduce head injury metrics in sled tests [9] [14].

The main limitation of this study was that the two full-frontal rigid barrier tests involved different vehicles and rearward-facing infant CRS models. Specifically, the baseless rearward-facing infant CRS had a different design to typical rearward-facing infant CRS models without a base due to the option for attachment using lower anchors.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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