Assessment of Occupant Response in Frontal Bus Crash Sled Scenarios to Investigate Public Transportation Safety

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Background

Public transit provides an affordable and environmentally friendly form of transportation for millions of commuters every year. While a relatively safe form of transportation, passengers can still sustain injuries during a bus crash event. Research into passenger safety of public transit has been modest, and Canadian motor vehicle regulations do not include crashworthiness standards for mass transit buses. Transport Canada (TC) has undertaken sled tests with bus seating to investigate frontal impact kinematics using a Hybrid III (HIII) 50^{th} percentile ATD. The tests demonstrated the potential for occupant impact with surrounding structures, including focal impact on the neck and head. Finite Element (FE) models can enhance experimental research by assessing a range of occupant positions and impact conditions. However, these models first require validation with experimental data.

Problem Statement

Seating design in public transit buses is focused on passenger convenience, with low seat backs for visibility and handrails for ease of access. As a result, current bus interior designs may present an injury risk due to interaction with the occupants during a crash.

Objective

The objective of this study was to validate a FE model of the sled test with a HIII occupant, and then assess impact scenarios using the HIII and a contemporary Human Body Model (HBM) (GHBMC M50v5.1). Both models were assessed based on kinematics and relevant injury metrics for varying impact severities and occupant seating positions.

Methodology

A FE model of the sled test was created with an applied deceleration curve matching that of the experimental tests. The HIII and HBM were seated prior to the acceleration pulse being applied using a pre-simulation to match the initial posture as reported in the experiments. The HIII kinematics were compared to the experimental data. Injury criteria (HIC, chest deflection, femur load) were evaluated using the HIII and HBM for varying seated postures and impact severities. Kinematics and injury metrics for the experimental HIII, computational HIII and HBM.

Results

The head, thorax, and pelvis accelerations of the HIII model showed good correlation to the experimental data, assessed using cross-correlation. Kinematic results show a tendency for the HIII knees to impact the forward seatback, followed by impact of the neck on the handrail. In this case, the HIC, chest deflection, and femur load predicted a low probability of severe injury. However, changes to the occupant posture led to the head impacting the handrail, resulting in a HIC value increase of 150 (75%). The HBM kinematics and injury criteria predictions were in agreement with the computational HIII in that both models indicated the potential for injury due to focal impact on the neck.

Conclusions

Bus passenger kinematics in a frontal sled impact were consistent between experimental results and simulations. There was a tendency for focal loading on the neck from the forward seat handrail, potentially leading to injury. Future research will investigate alternate passenger configurations and will also investigate improved interior design to mitigate injuries with a focus on interaction with the interior components.