PMHS-Based Validation of the HBM-Connect™ 50th Percentile Male in High-Speed Rearward-Facing Frontal Impacts on a Homogeneous Seat Bench.

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I. INTRODUCTION

Autonomous vehicles (SAE Levels four and five) may enable novel interior layouts in which first- and second-row occupants face each other, raising important safety concerns in high-speed rearward-facing frontal impacts (Δv = 56 km/h). NHTSA has identified several challenges in extending FMVSS 208 to this load case [1], including seat positioning, the lack of validated Anthropometric Test Devices (ATDs), and the absence of dedicated injury criteria. Kang *et al*. [2–3] conducted a series of high-speed post-mortem human subject (PMHS) sled tests. They demonstrated benefits of a simplified homogeneous rear-facing (HRF) seat in reducing injury artifacts associated with Original Equipment Manufacturer (OEM) seats, thereby providing a controlled loading environment suitable for Human Body Models (HBMs) validation. This study presents the first detailed finite element (FE) model of the HRF seat and evaluates the response of HBM Connect® 50M in high-speed frontal impact.

II. METHODS

Sled FE Modeling

The sled was modeled for ANSYS/LS-DYNA (R12.2.1 MPP single precision). The reinforced seat structure was modeled as rigid [2]. The seatback foam consisted of two layers: 50 mm PUR foam (48 g/l) and 40 mm PE foam (15 g/l). The seat pan, leg catcher, and headrest were modeled similarly. Seat load cells were instrumented with cross-sectional forces and accelerometers for inertial compensation calculations. The pressure mat was represented using *CONTACT_FORCE_TRANSDUCER with INTFOR output. The belt model with single pretensioner (activation time at 10 ms) was adopted from [4], with bending beams to ensure appropriate pelvis engagement. The applied pulse was derived from the PMHS tests. Foam material cards (*MAT_FU_CHANG_FOAM) were derived from [5] and calibrated to foam manufacturer specification sheet data.

HBM Positioning and Instrumentation

The HBM Connect® 50M v2.5 was used with additional outputs to match PMHS instrumentation. Special attention was paid to match the seating posture with the PMHS data [2], with a pelvis angle of 33° defined using the angle between the L5–S1 disc centre and the greater trochanter. Spinal curvature was adjusted to achieve 83 mm backset and appropriate support of the pelvic, lumbar, and lower thoracic regions to match the observed PMHS posture and initial seatback compression (Fig. 1, at 0 ms).

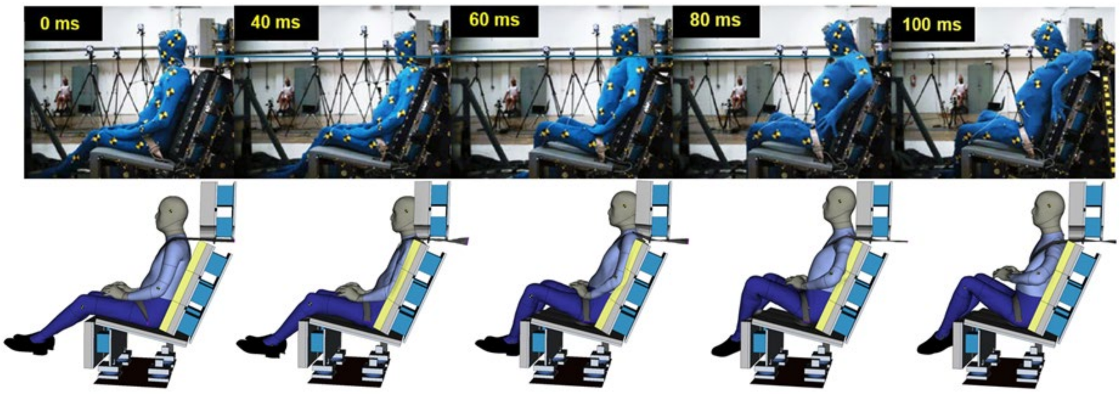

Fig. 1. Sled set-up and comparison PMHS3 to HBM kinematics.

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III. INITIAL FINDINGS

Seat–occupant coupling was assessed by cross-plotting load cell Fx against vertebral excursion. The simulation response remained within the ±1SD PMHS corridor (Fig. 2). HBM Connect® 50M captured T4, T8, and T12 rotational velocity trends, including peak values and reversal timing, indicating reasonable trend in spine straightening while interacting with the seatback (Fig. 3).

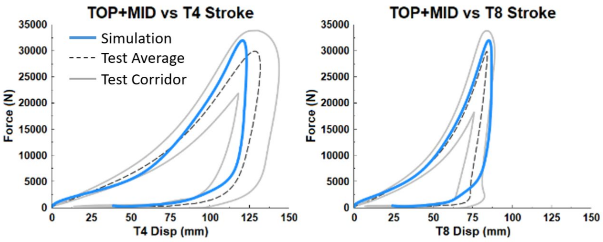

Fig. 2. Seatback load cell force vs thoracic stroke.

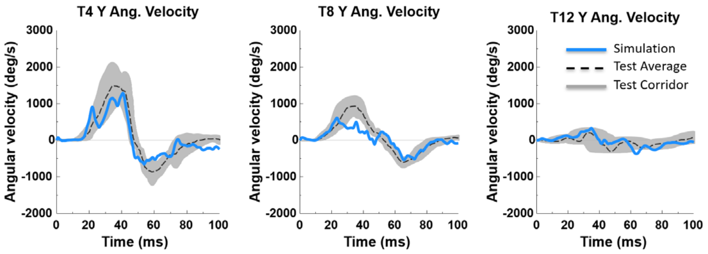

Fig. 3. Thoracic spine Y-rotational velocities.

The locations of peak maximum principal strain in the HBM Connect® 50M cortical bone corresponded well with the lateral rib fracture locations observed in the tests (Fig. 4). No element deletion based on failure criteria was applied. The simulated seatback pressure distributions were consistent with the pressure mat measurements (Fig. 5). Pelvic cross-sectional forces and the increased separation of the iliac wings in the simulation were indicative of the superior pubic ramus fracture timing and the open-book kinematics observed in the tests (Fig. 6 and Fig. 7).

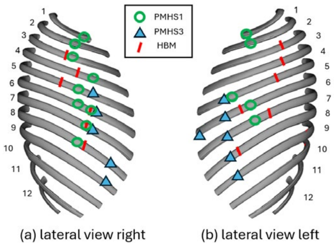

Fig. 4. Lateral rib fracture location.

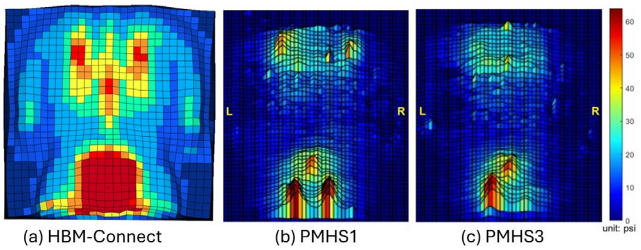

Fig. 5. Pressure mat reading at 42ms (maximum torso compression).

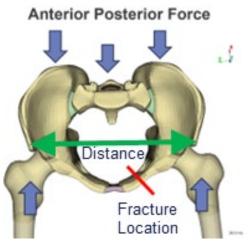

Fig. 6. Pelvis instrumentation (red) and load path analysis.

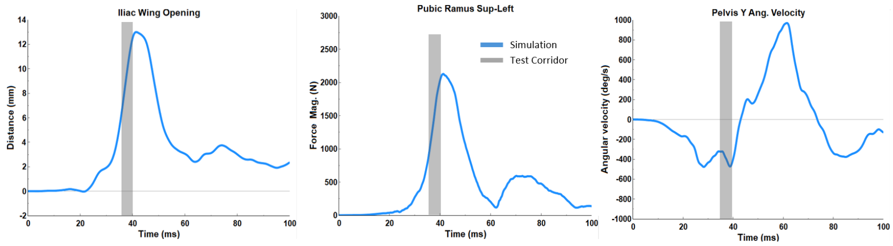

Fig. 7. PMHS superior left pubic ramus fracture timing (gray) and pelvic signals.

IV. DISCUSSION AND CONCLUSION

Overall, the HBM Connect® 50M response matched well with the PMHS responses, not only kinematics but also the localised ribcage and pelvis deformation. This suggests that HBM Connect® 50M has potential for high-speed rear-facing frontal impact application. Additional investigation is needed to better understand the rib fracture mechanism as postulated by [2] and calculate risks [6]. Foam modeling was found to be important to explain peak foam pressure deviations, and future improvements will help in better predicting the spine-to-backrest coupling and pelvis load transfer. Sensitivity studies on posture, ribcage geometry, BMI, gender, and seat energy management need to be carried out. Establishing injury assessment and evaluating whole body HBM and ATD biofidelity remains an open challenge and may require further investigation.

V. REFERENCES

[1] NHTSA DOT HS 813 716 & DOT 813 755, 2025. [2] Kang *et al.,* Ann. Biomed. Eng., 2025. [3] Kang *et al.,* RCCADS Public Workshop, 2023. [4] Dönmez *et al.*, ICVES, 2025. [5] Trummer *et al.*, Project VIRTUAL, 2020. [6] Forman et al., IRCOBI, 2022.