Validation of THUMS Human Body Model in Far Side Impact

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I. INTRODUCTION

Car crash safety has been constantly enhanced thanks to an increased number of component and full-vehicle crash tests. However, it would not be feasible to expand the number of laboratory tests to replicate the large variety of accident types, nor to develop crash test dummies to represent the wide range of occupants and road users. Recently, the computer simulations in crash safety have shown remarkable progress, which will help to better account for real-world scenario variations.

Since 2019, the European New Car Assessment Programme has been developing a Virtual Testing procedure as announced in its 2025 Roadmap [1] and selected far side as a pilot case to start with. It is foreseen that human body models will also be used in future. The Total Human Model for Safety (THUMS) Version 4 was validated at component and full body level under different load cases [2]. In particular, THUMS kinematics was evaluated in far side loading with a 3-point seatbelt only [3]. In this study, THUMS validation in far side loading was continued using results from [4] in order to consider the interaction with a car centre console.

II. METHODS

The far side sled experiments using Post-Mortem Human Subjects (PMHSs) were simulated under LS-DYNA mpp971R7 FEM code using the environment model consisted of a rigid seat, footrest, centre console, 3-point seatbelt and retractor. The console was covered by a 50 mm thick Ethafoam sheet and modelled using MAT 57 (Low Density Foam) card including stress-compression curves of tests [4]. The seatbelt was modelled using MAT 24 (Piecewise Linear Plasticity). A static pretension force of 200N was applied at the retractor. The sled model was accelerated up 8 m/s along the laboratory Y-axis angled by 75° with the sled longitudinal X-axis. THUMS Version 4.1 was used to simulate the PMHSs. THUMS height and weight (178.6 cm, 77.6 kg) were larger than the PMHSs' average height and weight (172 cm, 69 kg). However, THUMS seated height (89 cm) was close to the average PMHSs' (91 cm) and in both cases, the height of their 10th right rib was aligned with the center console top surface. THUMS geometry and bone properties were considered representative of a 35 year old male [2], i.e., 48 years younger than the average age of the PMHSs (83 years old). A modified version of THUMS was thus proposed in this study to represent the PMHSs' average age. Yield stress of rib, sternum and clavicle cortical bone was decreased from 80 MPa to 71 MPa, failure plastic strain from 2.04 % to 0.83 % [5-6] (Figure 1a) and the thorax cortical bone thickness was decreased by 34% [7] (Figure 1b) from THUMS V4.1. Additionally, the neck muscle tension characteristics was stiffened for large neck bending motion (Figure 2). Simulations were performed using THUMS V4.1 and its modified version. THUMS initial position and belt routing were adjusted to match the measurements taken on the PMHSs prior to the tests. The Y and Z displacements in the laboratory coordinate system of THUMS head centre of gravity were compared to the envelope corridors of the PMHSs' responses. The rib fracture prediction of both THUMS models was compared with the PMHS autopsies.

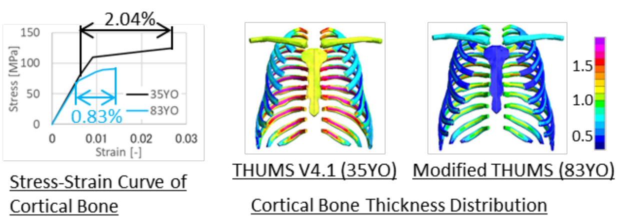

Fig. 1. Rib sternum and clavicle age related modification.

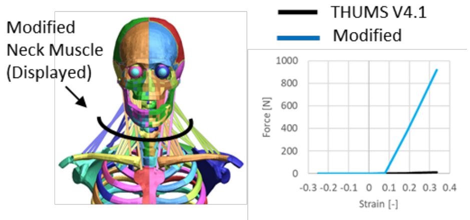

Fig. 2. Neck muscle modification.

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III. INITIAL FINDINGS

Overall kinematics of the PMHSs and both models were comparable (Figure 3). Pelvis and lower right chest contacted the console inducing torso and neck bending similarly to PMHSs' kinematics. The modified THUMS maximum head rotation was lower by 5° compared to the original model (129° vs 134°) due to the stiffer neck muscle characteristics and better mimicking the PMHSs' head rotation, on average by 119° with a standard deviation of 13°. Relative head X displacement of the original and the modified THUMS were within the PMHS corridors until their maximum value. Head Z displacement of both THUMS models increased faster than PMHSs between 100 to 175 ms. The maximum Z displacement of the modified THUMS remained in the PMHS corridor while the one of the original THUMS was slightly above of the corridor (Figure 4). Figure 5 shows the overlay of the bone fractures of all PMHSs and the prediction of the original and modified THUMS. In the PMHS tests, fractures were observed mainly at the right lower ribs entering in contact with the centre console during the impact (four PMHSs out of six had three or more rib fractures on the right chest). Four rib fractures on the right chest observed in the modified THUMS were closer to the PMHSs'. Cervical spine fractures were additionally observed in the tests (one PMHS out of six) and also predicted by THUMS.

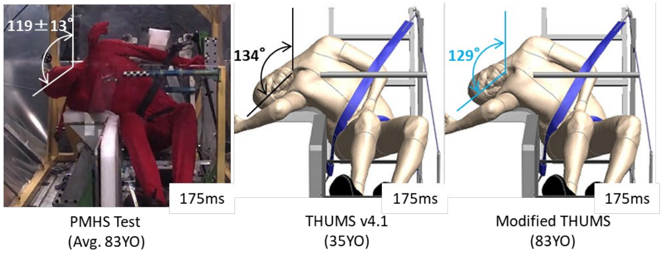

Fig. 3. Comparison of kinematics.

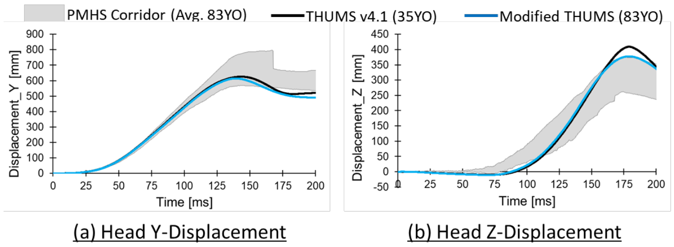

Fig. 4. Comparison of head COG displacements.

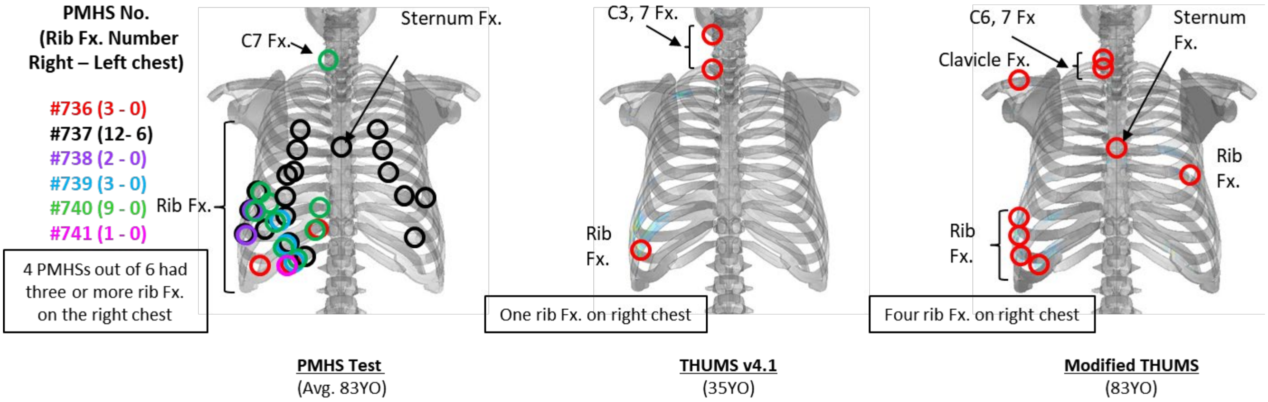

Fig. 5. Comparison of bone fractures.

IV. DISCUSSION

This study compared the impact response of the original THUMS v4.1 and its modified version with PMHSs' average response in far-side loading with a centre console. Both THUMS models' kinematics resembled the PMHSs' overall kinematics, however for rib fracture prediction, the modified THUMS gave a prediction more in line with the PMHSs' rib fracture number due to age influence. The overall anthropometry of THUMS was matching the PMHSs' and therefore no adjustment of the THUMS dimensions was performed. However, the authors acknowledge that geometrical differences between THUMS and the PMHSs, especially in ribcage shape, changes with age [8] may also affect the injury prediction.

V. REFERENCES

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