Comparison of 5th Percentile Female THOR ATD, THOR FE Model, and Human Body Model Chest Deflection in Frontal Crash

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I. INTRODUCTION

Numerical modelling is becoming an increasingly important tool to understand how different occupant surrogates including anthropometric test devices (ATDs), both physical and numerical, and human body models (HBMs) compare to one another in crash loading. Furthermore, in frontal crash tests the need for thoracic deflection measurements across several locations to assess occupant loading has been identified as critical for safety assessment [1]. The current study compares experimental testing and computational models of 5th percentile female occupants (THOR 5F physical ATD, THOR 5F computational model and GHBMC F05 HBM) in a frontal crash environment using a rigid bench [2] with high and low severity sled pulses. The responses were assessed by comparing the chest deflection at the four measurement locations typically used for evaluation of the THOR ATD.

II. METHODS

Experimental Testing

Experimental sled testing was carried out with a THOR 5F ATD (Humanetics, Standard Build Level B, Farmington Hills, MI, USA) on a servo-driven reverse acceleration sled (Seattle Safety, 2.0 MN ServoSled Catapult Sled System, Seattle, WA, USA) using acceleration pulses taken from vehicle mounted accelerometers in a pair of crash tests, with peak values of 15g (24 kph ΔV) and 24g (45 kph ΔV). The ATD was placed on a rigid steel bench based on the seat used for FMVSS 213 testing, with a raised platform for the ATD to sit on. The lower belt anchor locations were mounted in such a way as to prevent buckle-to-ATD and belts-to-platform contact (Fig. 1a, left). The ATD was belted using standard belt webbing (Shield Restraint Systems, Elkhart, IN, USA) and a simplified, generic retractor with no pretensioner [3] mounted on the left side of the ATD. Shoulder and lap belt load cells were used to measure belt forces during the tests, and the ATD was instrumented with 78 data channels in the head, neck, thorax and pelvis. Prior to testing, 24 FARO arm measurements and 3D scans (Creaform, MetraSCAN 3D, Lévis, QC, CA) were performed to provide positioning data for the model and to ensure test-to-test consistency (H-point within 13 mm; head CG within 10 mm). For each sled pulse, three repeats were performed.

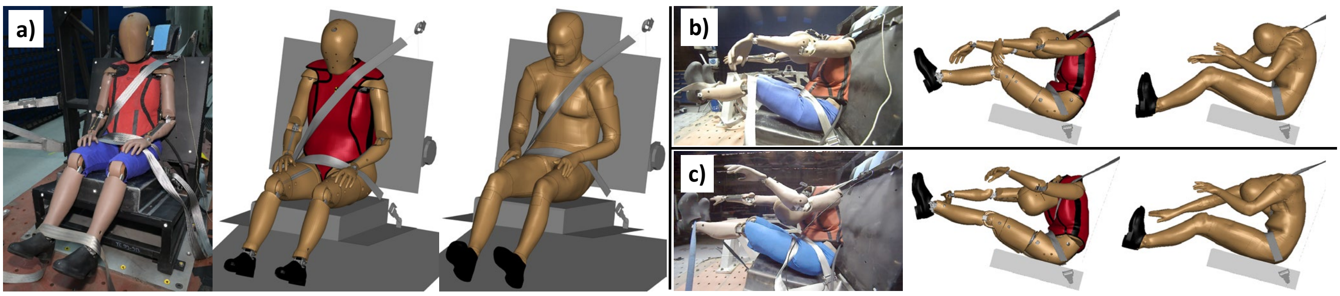

Fig. 1. Isometric view (a) and side view of occupant response for 15g peak pulse (b) and 24g peak pulse (c) at 125 ms of THOR 5F ATD in physical test setup (left, all), THOR 5F model (middle), and GHBMC F05 model (right).

Computational Modeling

Finite element models of the sled tests were solved using a commercial explicit finite element solver (LS-DYNA R12.2.2 single precision, IntelMPI, Ansys, Canonsburg, PA, USA) with a THOR ATD model (Humanetics, Standard Build Level B, V1.3.1, Farmington Hills, MI, USA) and the Global Human Body Models Consortium 5th percentile female HBM (GHBMC F05, V5.1). The GHBMC model was updated to include zero-stiffness measurement springs at locations that matched the mounting locations of the chest sensors (IR-TRACCs) in the THOR ATD. This meant

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that the measurements springs were connected between the posterior of ribs 7 and 11 and the intercostal tissue connecting ribs 4 and 7 with the sternum. The sled base and bench seat were modeled using a rigid material definition and the belt and retractor properties were based on properties from tension tests carried out on the retractor and webbing from the same spool as that used for sled testing. 2D seat belt elements were used to define the portions of the belt in contact with the occupant and 1D elements were used to model the portions of the belt near the anchor, sliprings and retractor. The THOR model was positioned (H-point within 0.1 mm of test average, head CG within 8 mm) and belt geometry was generated to match the test scans and the GHBMC model was positioned to match the H-point, head CG, and arm and leg positions of THOR model as closely as possible, given the subject specific geometry of the HBM. To load the occupants, a prescribed acceleration pulse matching that used for the experimental tests was applied to the sled and bench seat.

III. INITIAL FINDINGS

When comparing the THOR model to the physical test, considering the belt forces, the head, thorax and pelvis resultant accelerations and the four chest deflection signals, the THOR model average ISO 18571 [4] rating was 0.8 for both the 15g and 24g sled pulse cases, which is considered ‘good’. Qualitatively, the kinematics of the models and tests were also in good agreement (Fig. 1b, c). The THOR peak IR-TRACC deflections occurred at the lower right sensor (55.2 mm and 57.2 mm average for the 15g and 24g pulse tests, respectively, and 51.3 mm and 56.8 mm for the model, Fig. 2). In contrast, the GHBMC model predicted highest chest deflection at the upper right chest location (31.2 mm for 15g and 50.9 mm for 24g). In general, the THOR model right side chest deflection, which provided the maximum chest deflection and was thus the focus of the study, fit the test data better than the left (average ISO rating of 0.87 vs. 0.56).

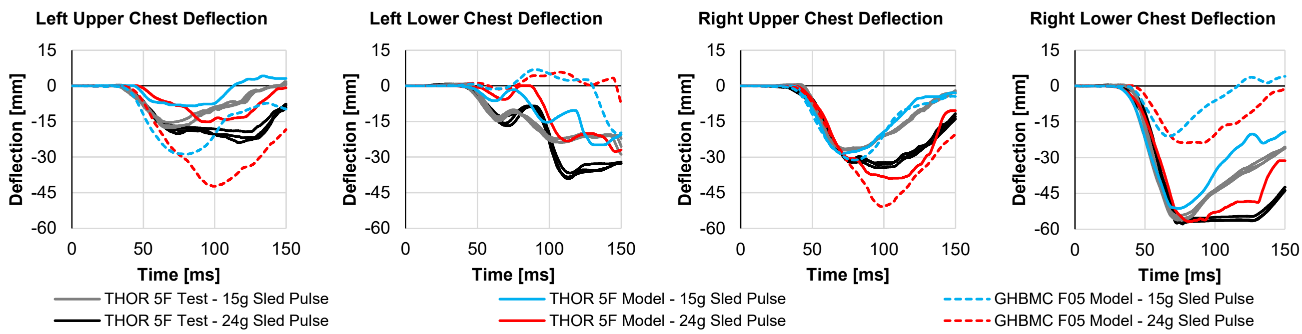

Fig. 2. Chest deflection-time response at each of the 4 thoracic measurement locations

IV. DISCUSSION

While the peak THOR chest deflection value for both acceleration pulses were of similar magnitude, the right lower deflection-time responses were substantially different, with the 24g pulse response showing an extended plateau at maximum deflection (between 60 ms and 130 ms for the test and somewhat less for the model), as the IR-TRACC sensor had reached the maximum deflection. The response of the 15g pulse, on the other hand, reached maximum deflection at roughly the same time as the 24g pulse, but began to unload almost immediately, similar to the behavior of the GHBMC model (albeit at a different measurement location for the HBM). The chest deflection of the GHBMC model was also affected by fracture of the ribs and clavicle. No fractures (based on critical effective plastic strain) were predicted by the GHBMC with 15g loading, while eight total rib fractures and a clavicle fracture were predicted by the GHBMC when loaded using the 24g peak acceleration pulse. The THOR exhibited similar, high levels of chest deflection for both acceleration pulse levels while the GHBMC model exhibited more differentiation between pulses, particularly for the upper portion of the chest. This point may have important consequences if maximum chest deflection is the primary focus of evaluation. Future work will focus on further understanding the cause of high chest deflections seen in this study and the differences noted between the THOR and HBM.

V. REFERENCES

[1] Schneider, *et al.,* SAE 922520.
[2] Watson, *et al.,* ESV, 2026.
[3]Tang, *et al.,* Con. Pro. Child., 2019.
[4] ISO/TS Standard 18571:2024.