Computational Simulation of Experimental Frontal Sled Tests with the GHBMC M50 Model.

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I. INTRODUCTION

Human Body Models (HBMs) are a powerful tool for predicting the occurrence of injuries during a vehicle crash. These models also support the development of vehicles in order to improve the safety of occupants involved in an accident. To achieve this, model-specific Injury Risk Functions (IRFs) or injury thresholds need to be defined. A common method for developing IRFs is to use impact experiments on Post-Mortem Human Subjects (PMHS) with clearly defined boundary conditions and documented injury outcomes for the subjects. One of the challenges is that most experiments available in the literature were conducted on old subjects, and the amount of available data per test configuration is often limited. The aim of this work is to replicate a historical series of frontal sled tests performed on a large number of PMHS spanning a wide age range, using the male 50th percentile GHBMC detailed model. In the future, these simulations are intended to be used to assess the validity of existing thoracic IRFs or to develop new model-specific IRFs. The work described was carried out as part of the EU project ProtAct-Us (Grant No. 101147445).

II. METHODS

The experimental frontal sled tests reproduced in this study were performed end of the 1970s (15 configurations, 200 tests) and a reanalysis was provided by the authors to the HUMOS2 European project [1]. In the current study, to validate the sled environment with the GHBMC model (M50 detailed model v6.0), the subsample from [1] was used (four configurations, 44 tests). Table I briefly presents the experiment features used for the validation of the environment. The deceleration pulses had a trapezoidal shape, and the PMHS sample included male and female subjects ranging from 20 to 69 years of age.

TABLE I
EXPERIMENTAL TESTS DESCRIPTION

	Impact velocity/deceleration	Number of subjects	Mean Age (SD)	Mean Weight (SD)
Group 1	30km/h/20g	11	48 yrs. (17 yrs)	70 kg (15 kg)
Group 2	40km/h/20g	10	46 yrs. (15 yrs.)	73 kg (11 kg)
Group 3	50km/h/20g	11	34 yrs. (15 yrs.)	65 kg (12 kg)
Group 4	60km/h/15g	12	39 yrs. (14yrs.)	73.5 kg (9 kg)

To reproduce the experiments, the GHBMC model was seated in a generic seat model extracted from the full generic vehicle model presented in [2]. The anchorage points of the three-point seat belt, as well as the simplified sled environment, were defined to match the experimental conditions. As in the experiments, no load limiter and no pretensioner was used. A total of four simulations was run using the pulse from each group [1] with LS-DYNA R12.2. The model response was compared to the PMHS response in terms of belt forces (B3 and B6) over time, as well as maximal head and pelvis X-displacements.

III. INITIAL FINDINGS

Lap-belt and shoulder-belt forces from the simulations, compared to the experimental corridors, are presented in Figs. 1 and 2, respectively. Maximal head and pelvis X-displacements are presented in Fig. 3 for each configuration.

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For all configurations except one, (the 50 km/h configuration) the peak head X-displacement predicted by the model is consistent with the experimental response. During the simulations, the HBM did not submarine which is consistent with the experimental findings.

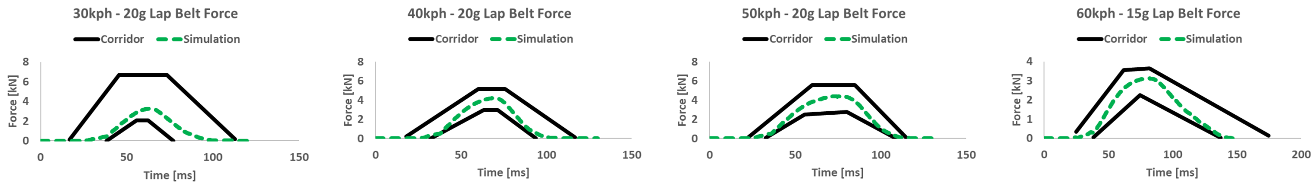

Fig. 1. Lap belt forces

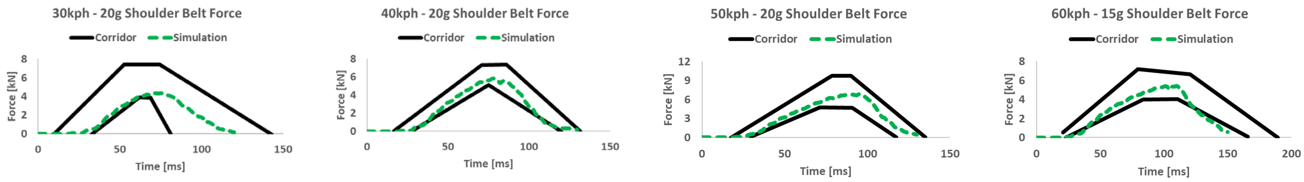

Fig. 2. Shoulder belt forces

Fig. 3. Maximal pelvis (left) and head (right) X-displacements (HBM response is in green)

IV. DISCUSSION

In this study, a simplified sled environment was developed and validated using the GHBMC model to represent the experimental setup described in [1]. Despite the limited measurements available - restricted to belt-force time histories response corridors and peak head and pelvis displacements - and the uncertainties related to PMHS positioning and actual seat material properties, the model was nevertheless able to reproduce the principal response characteristics of the PMHS across the four loading pulses. The belt forces predicted by the simulations are in accordance with the experimental corridors. However, the model underestimates the pelvis X-displacement compared to the PMHS response. This discrepancy may be due to uncertainties in the seat and belt material properties. The reason why the 50 km/h simulation exhibits a higher head displacement than the PMHS is not entirely clear, although a more accurate description of the boundary conditions could help improve the model's performance.

This newly developed environment will be employed in future studies to develop a model-specific sternal AIS2+ IRF, as well as to assess existing IRFs, as those related to rib fractures. A major strength of the original experimental dataset lies in the detailed documentation of the injuries sustained by the PMHS under loading, based on nearly 200 tests with a mean age of 42 years old.

This generic sled environment will also be used to perform simulations with the small female and large male GHBMC models in order to evaluate the influence of size and sex on the biomechanical response.

V. REFERENCES

[1] D15, HUMOS2 Project GRD2-2001-50053.
[2] Iraeus J *et al.* , Accid Anal Prev, 2016.