Finite Element Modeling of the Seat Evaluation Tools (SETs)

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I. INTRODUCTION

New safety systems have reduced the number of automotive neck injuries [1]. However, this has benefited the male population more than the female population, with a reduction of injuries for males up to 65% greater than for females [1]. This is possibly due to the predominant use of the average-sized male dummy in both product development and legislation testing [2]. Several projects have been initiated to close the gap in protection between males and females.

The EU project ADSEAT developed a prototype of an average-sized female dummy, the BioRID P50F [3]. In 2017, a Finite Element (FE) human body model (HBM) representing an average female was presented, the ViVA [4]. It was further developed, in the EU project VIRTUAL, into models of both average females and males, the VIVA+ models [5], which served as the basis for the design concepts of two Seat Evaluation Tools (SET 50F and SET 50M) [6].

The SETs were designed to form a bridge between physical testing and virtual testing in rear impact safety assessment. They serve as a tool to validate vehicle seat models for virtual testing. The FE models of the SETs were developed to create a virtual representation of the hardware SETs. An important focus of the development of the SETs was the kinematics of the spine, as well as the body surface contour, to ensure a biofidelic interaction with vehicle seats. An additional ambition with the SETs is to provide biofidelic head relative to torso responses, addressing soft tissue neck injury protection evaluation of vehicle seats in low velocity rear impacts.

II. METHODS

Development of the first version of the SET 50F and 50M models was done for the FE code LS-DYNA (ANSYS Inc.). The key features of the SETs are; an articulated spine, flexible shoulders and a biofidelic body surface contour that closely matches that of the corresponding HBM, VIVA+. The lumbar and thoracic spine designs have three types of vertebral joint, with alternating direction of rotation to allow for an omnidirectional spinal bending, while the cervical spine joints were designed for sagittal plane rotations. Neck stiffness is governed by a combination of pre-tensioned springs and a damper placed in the head. Surrounding the thoracic and lumbar spine is a molded torso and abdomen of soft polyurethane (PUR) foam, with outer geometry representing the body shape of the respective HBMs [5]. The torso and abdomen PUR foam was coupled to the spine at six levels with metal rods, which are attached to the spine and project laterally into the foam [6].

FE SET models

FE mesh with tetrahedral elements was generated on the CAD geometry of the SETs [7] using the preprocessor in ANSYS Mechanical (ANSYS Inc.). Only the main metal parts of the skeleton and the surrounding foam were incorporated in the mesh, with minor geometric details removed prior to meshing. All metal parts were modeled as rigid bodies, hence no effort was made to ensure element size or quality. Inertial properties were taken from the original CAD, i.e. including mass of screws, bolts, etc.

The foam parts were meshed with tetrahedral elements of varying size (3–20 mm). The smaller elements were needed to model details, e.g. close to the spinal rods. The foam of the arms, head, femur and pelvis was meshed continuously from the metal to the surface, to avoid unnecessary contact definitions. An element formulation with 1-point constant stress and nodal pressure averaging was used (ELFORM=13), as it has been shown to avoid volumetric locking [8]. The PUR foam was represented using a non-linear material law.

The spinal joints were simplified as revolute joints, with stiffness calculated from detailed simulations of the individual joints with the metal springs and rubber blocks (Fig. 1). The neck model is described in Fig. 2.

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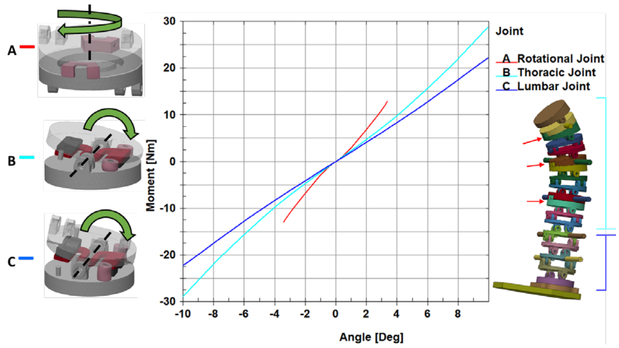

Fig. 1. Simulation results for moment versus rotational angle for the three types of joint in the spine (SET 50F).

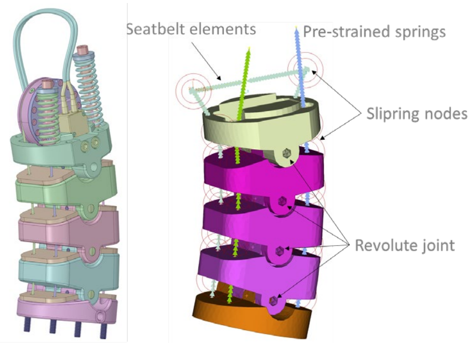

Fig. 2. Neck design in CAD (left) and FE SET (right).

III. INITIAL FINDINGS

For SET 50F, the spinal stiffness compared to quasistatic tests showed good correlation up to 30 mm displacements (Fig. 3). More material and subsystem-level physical testing are currently being performed to further validate the FE SETs. The FE SETs were used in a simulated sled test (Fig. 4) where seat properties were modified. Neck kinematics changed in response to seat modifications, demonstrating the potential for the intended future use.

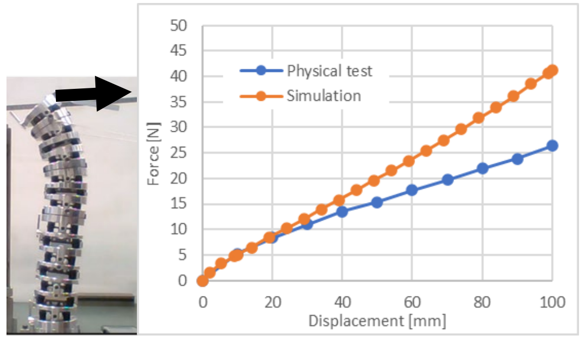

Fig. 3. Quasistatic spine loading at T1 level in test (blue) and simulation (orange) for SET 50F.

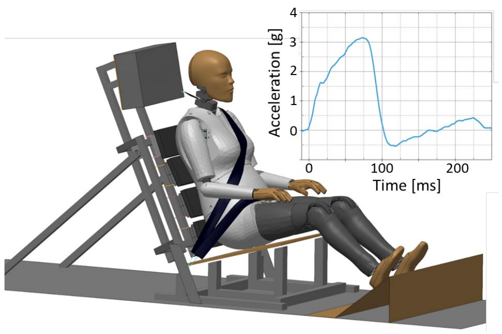

Fig. 4. Sled test simulation set-up and acceleration pulse.

IV. DISCUSSION

The FE SET models are being developed to obtain a close fidelity of virtual response to the hardware SET responses. Especially important is the ability to interact with and deform the vehicle seat in the same way, as well as to predict accelerations, velocities and displacements measured in the hardware SETs. Comparing the responses of the FE SETs and the hardware SETs is ongoing work. Together, the hardware and FE SETs are being developed for validation of vehicle seat FE models as part of a possible future certification in virtual assessment of safety performance.

Further, the FE SETs can contribute to an evaluation of how design changes in the SET could influence the dynamic response and biofidelity. Also, a comparison of the responses of various HBMs and the FE SETs in the same simulation conditions could be of interest to investigate. The FE SETs are freely available on the OpenVT platform [7].

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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