Assessing SAFER HBM Kinematic Response Sensitivity in Frontal Impacts with Various Reclined Seating Postures

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I. INTRODUCTION

Automated driving vehicles will allow the possibility of non-conventional occupant positions, such as various seat-pan and seat-back angles [1-2]. Several experimental and computational studies have analysed the kinematics of occupants and possible new injuries in frontal impacts, with the seat-back angle as low as 32° to the horizontal plane [3-4]. To our knowledge, there is only one experimental study, still ongoing, that has tested various seat-back reclination angles in combination with varied seat-pan angles [5]. Due to limited experimental data, it is still uncertain whether conventional occupant surrogates, such as anthropomorphic test devices (ATDs) or human body models (HBMs), are sensitive to seat-back and/or seat-pan angle changes. Thus, the aim of this work was to assess the sensitivity of pelvic and spinal kinematics of the SAFER HBM v11 to the new loading conditions imposed by reclined seating positions (SPs).

II. METHODS

Four frontal impact simulations at 40 km/h and 50 km/h with two seat-back and seat-pan angles were performed utilising LS-DYNA MPP R12.2.1 (Ansys). The chosen impact pulses are comparable to those used in other experimental studies of occupants in reclined seating postures. The occupant, SAFER HBM v11, was a 50th percentile male [6]. The duration of impact simulations was 150 ms, which allowed full observation of forward excursion regardless of the applied pulse velocity.

A semi-rigid seat was utilised, and the following pairs of seat-back and seat-pan angles (to the horizontal plane) were studied: 68° and 14° (SP1), 45° and 14° (SP2), 30° and 25° (SP4), 30° and 40° (SP5) [7]. Anterior to the seat pan, an anti-submarining (ASM) ramp was present, rotated at 32° (SP1/2), 43° (SP4) and 58° (SP5). No back rest was utilised.

SAFER HBM v11 was positioned using the marionette method, generating the associated keywords in PRIMER FE pre-processor (Oasys). Occupant pelvis, lower extremity angle and spine curvature selection in each posture were based on available volunteer and PMHS occupant studies [2-4][8]. Gravity was not utilised in positioning; thus, the vertical position selection was justified by verifying that contact forces between the HBM and seat pan show realistic values in respect to occupant weight. Pelvis and femur soft tissue strains and stresses were exported from pre-positioning simulation results and applied to the occupant for impact simulations. The HBM was restrained with FE model of a 3-point seat belt, where all anchor points were equipped with 2 kN pretensioners and 4–5 kN load limiters. The feet of the occupant were not restrained. Positioned and seat belt-fitted HBMs in all studied SPs are shown in Fig. 1.

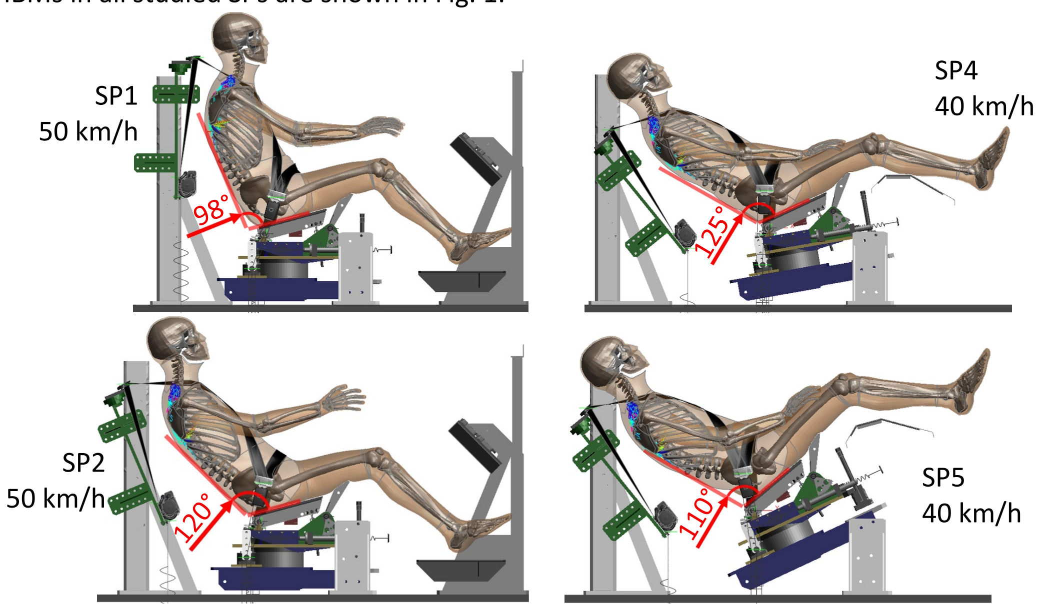

Fig. 1. Positioned SAFER HBM and the applied seat impact pulse in all SPs.

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III. INITIAL FINDINGS

Figure 2 shows the time-history curves of forward (X axis) and vertical (Z axis) displacements of SAFER HBM spine and pelvis, as well as the rotation angle (around Y axis) of the latter.

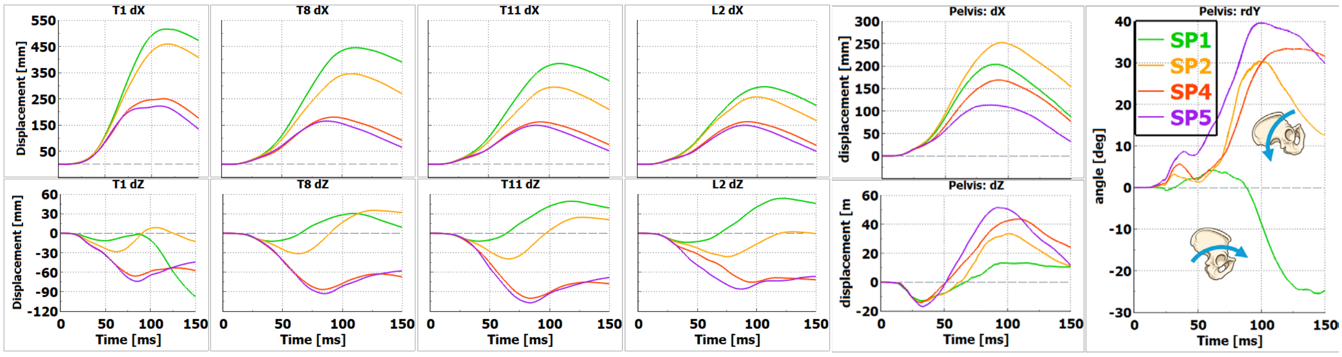

Fig. 2. Spine (1st, 8th, 11th thoracic and 2nd lumbar vertebrae) and pelvis kinematics of SAFER HBM in all SPs.

As seat-back angle increased, the forward displacement of vertebrae decreased in both magnitude and peak reaching time. In SP1, T1 exhibited a downwards displacement following its peak forward excursion (consistent with head kinematics). Moving caudally towards the pelvis, every vertebra initially showed slight negative vertical displacement, followed by positive upward motion. SP2 demonstrated larger initial negative displacements and progressively reduced upward displacements along the spinal column. Vertical displacement patterns were completely different for SP4 and SP5 – all vertebrae displaced downward throughout their entire forward excursion. Between these two seating postures, in SP5 slightly smaller forward displacements were observed, but also slightly greater negative vertical displacements than in SP4.

Forward pelvis excursion was largest in SP2, followed by SP1 and SP4; SP5, characterised by the largest seat-pan inclination, resulted in lowest pelvis forward displacement. Only minimal differences were observed for forward displacement peak timings. In all SPs, the occupant pelvis initially displaced downward with similar magnitude; however, subsequent positive vertical displacement increased with seat-pan inclination angle. Because seat-pan angle was identical in SP1 and SP2, the increased pelvis vertical displacement in SP2 was attributed solely to the seat-back angle. Pelvic rotation occurred in the posterior direction in all reclined seating positions, with rotation magnitude increasing with seat-pan inclination.

IV. DISCUSSION

SAFER HBM showed distinct spine and pelvis kinematic responses in all studied SPs. The response was also sensitive to isolated changes in seat-back angle (distinctions between SP1 and SP2), as well as seat-pan angle (distinctions between SP4 and SP5). Larger seat-pan inclination increased support of the pelvis, resulting in its reduced excursion and increased posterior rotation. Increased seat-back recline altered the load transfer through the spinal column, producing the observed differences in vertebral displacement patterns. However, it must be considered that simulations with the deep-reclined SPs were run at a lower impact pulse, which likely contributed to the lower forward displacements of the HBM there. The observed kinematics are also influenced by changes in occupant-restraint interaction. Different occupant positions in all SPs created unique belt-routing combinations (although the lap belt was always kept below ASIS), which may contribute to differences in pelvis rotation and forward excursion.

Generally, the observed posture-dependent kinematics indicate changes in load transfer through the spine. In more reclined configurations, reduced pelvis forward excursion and downward vertebral motion suggest a shift toward more compressive spinal loading. Assessment of HBMs in reclined SPs should be further investigated, to evaluate their injury prediction capabilities.

V. REFERENCES

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