Effect of Seatback Recline on Occupant Model Response in Frontal Crashes

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INTRODUCTION

The introduction of new highly automated vehicles holds the promise to influence occupant seated behaviour and seat design. Different seat orientation with respect to the vehicle, and increased seatback recline angles are some novel factors that may challenge occupant restraint systems currently available in the vehicle fleet. It is unknown, however, if current occupant injury assessment tools (dummies, human body models) are capable of simulating these novel postures and predicting the resulting occupant responses and restraint interactions in a realistic manner. As a first step, this study examined the usability and performance of the Global Human Body Model Consortium (GHBMC) owned 50th percentile male occupant models (detailed: M50-O, and simplified: M50-OS) in various reclined seated positions in frontal collisions.

METHODS

Computational Modelling

Full vehicle crash test simulations were performed with the 2012 Toyota Camry finite element model (developed by the Center for Collision Safety and Analysis—George Mason University), impacted by the National Highway Traffic Safety Administration Research Moving Deformable Barrier (RMDB) model. Models of contemporary restraints (3-point belt with pre-tensioner and force-limiter, passenger frontal airbag, side curtain airbag, side torso airbag) were integrated into the vehicle model. Two types of seatbelt mounting schemes were evaluated – standard d-ring, and seat-integrated d-ring (with a reinforced seat structure). The occupant models were seated in the right front passenger position, and were evaluated in three recline positions - nominal-upright (25˚), semi-reclined (45˚) and fully reclined (60˚). Impacts were simulated with an RMDB in frontal crash closing speed of 56 km/h. In order to accommodate the variations in seat reclined positions, both occupants were positioned using a pre-simulation method. Under gravity load, M50-OS settled into the seat and reclined back into the seatback. However, due to the high stiffness of the spine in the model, an additional simulation to position the upper torso of the occupant into the seatback for semi-reclined and reclined postures was necessary with applied external force (Fig. 1). Taking positioned M50-OS models as golden standard, M50-O were postured to match them respectively. At first, three-point transform in LS-Prepost was utilised to transform pelvis of M50-O to match that of M50-OS. Then pre-simulations were required to match upper body (head, clavicle, spine), femur, arms, tibia and feet step by step (Fig. 1). The discrete beam cables were defined to pull the head, clavicle, spine and lower extremity to the target positions.

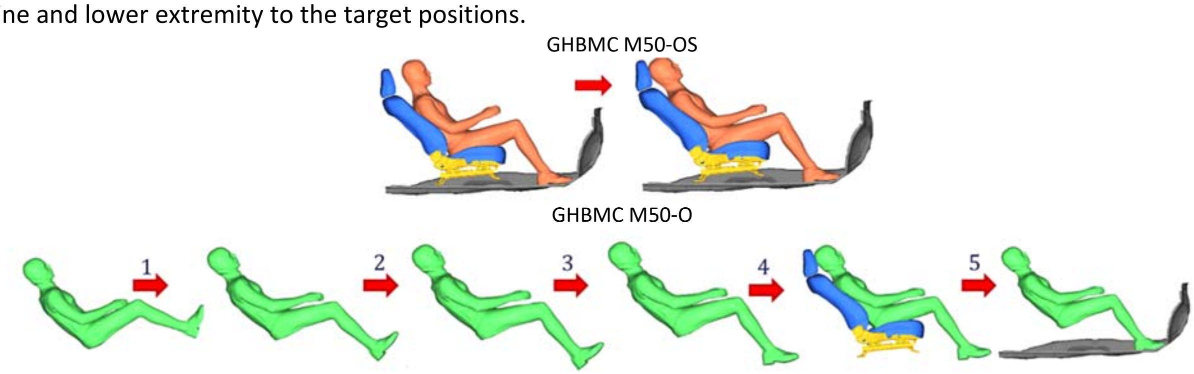

Fig. 1. Schematic overview of the positioning procedures for GHBMC M50-OS and GHBMC M50-O

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INITIAL FINDINGS

Occupant kinematics varied with recline angle, and pelvis motion was a primary indication of the occupant response and restraint effectiveness. Fig. 2 displays the pelvis rotations about Y axis of simplified M50-O in three postures with standard d-ring and seat integrated mounting d-ring seat belts. With the standard d-ring seat belt, reclined M50-O has the largest posterior rotation while the results of upright and semi-reclined M50-OS are pretty close. However, as the recline angle increases, the posterior pelvis rotation of M50-OS also increases.

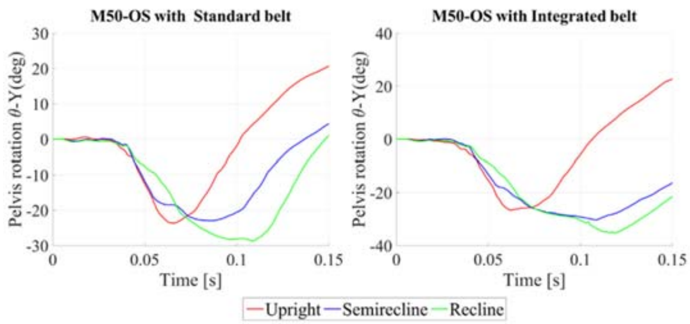

Fig. 2. Pelvis rotation about Y axis of GHBMC M50-OS.

DISCUSSION

Both occupant models submarined with the lap belt sliding over the anterior superior iliac spine of the pelvis in the semi-reclined and reclined postures. Submarining resulted in pronounced posterior rotation and forward excursion of the pelvis, and substantial lap belt intrusion into the abdomen. Reclining the seatback exacerbated this issue. With the standard d-ring shoulder belt, the delay in torso engagement resulted in more forward excursion of pelvis. This was partially mitigated through the use of the integrated shoulder belt, but it did not eliminate submarining. Compared with M50-O in the same posture constrained by the same type of seat belt, M50-OS sustatined more severe submarining coming with more forward excursion and posterior rotation. The kinematic difference might result from different boundary conditions between pelvis bones and surrounding flesh in two occupant models (Fig. 3). For M50-O, there is almost no relative rotation between the pelvic bone and pelvis flesh since the pelvic bone got wrapped by the pelvis flesh. While for M50-OS, there is plenty of room left between the pelvic bone and the pelvic flesh which allows the pelvic bone to slide off the pelvis flesh a lot with substantial shear force.

This work highlights the injury prediction, modelling, and restraint challenges for reclined occupants. In this environment, both occupant models encountered numerous challenges in maintaining numerical stability. New experimental data is needed to provide data for validating these models in reclined seated postures.

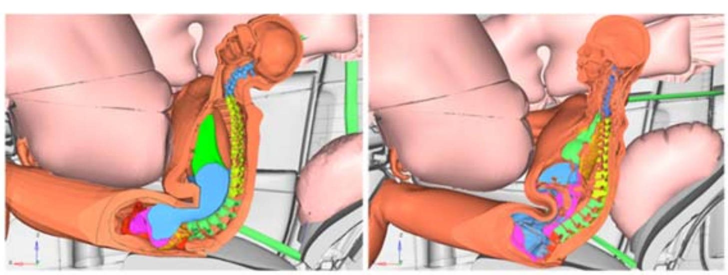

Fig. 3. Unrealistic internal organ's connections for GHBMC M50-OS and GHBMC M50-O

V. REFERENCES

[1] Saunders J et al. SAE,2011
[2] Reichert R et al. SAE 2016
[3] GHBMC M50-O v4.4 User's Manual. Global Human Body Model Consortium, 2015
[3] GHBMC M50-OS v1.8.4.1 User's manual. Global Human Body Model Consortium, 2015