Effect of Seatback Recline on Occupant Model Response in Frontal Crashes

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Abstract

The introduction of new highly automated vehicles will influence occupant seating behavior 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 currently 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 seating positions in frontal collisions.

Full vehicle crash test simulations were performed with the 2012 Toyota Camry finite element model (developed by the Center for Collusion Safety and Analysis), 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.

The occupant models were evaluated for usability (including ability to position in the reclined positions), stability, and general performance (kinematics, restraint interactions, etc.) during the collisions. Several issues were discovered for positioning the human body models. First, both GHBMC models were unable to fully recline under gravity, and it was necessary to force the torso into position through another pre-simulation. Secondly, the M50-OS tended to exhibit negative-volume errors in the abdominal region due to a large amount of compression during submarining in the reclined simulations (this was rectified through modifications of the model). Once these issues were fixed, 100% of the executed M50-OS models were stable and exhibited normal model termination. For the detailed M50-O model, only 20% of the simulated cases normally terminated. For completed simulations, differences in kinematics between the two occupant models were observed for the same impact case. M50-OS had larger neck flexion compared with M50-O, and both models had biofidelity issues within their thoracic cavities in the semi-reclined and reclined positions. The M50-OS also exhibited substantial bending in the lumbar spine, while M50-O displayed more bending in thoracic spine in all three positions. Additionally, both occupant models resulted in the lap belt sliding over the anterior superior iliac spine (ASIS) in the semi-reclined and reclined postures. However, M50-OS tended to display more severe submarining and larger forward excursion of the pelvis.

The occupant models haven't been validated so far in reclined case which is an extremely loading scenario because of the inclination for submarining. Continued development of these models is required to improve their response in these conditions like reasonable continuity definition between internal organs and flesh, connection between pelvis and pelvis flesh. Additionally, reclined PMHS tests will be necessary for validating the responses. At last, with the validated occupant models, injury risk evaluation and countermeasures are able to be conducted for occupants in automated vehicles.