

## Occupant response in frontal crash, after alterations of the standard driving position

Cyrille Grébonval, Xavier Trosseille, Philippe Petit, Xugang Wang, Philippe Beillas

### I. INTRODUCTION

The development of highly autonomous vehicles (HAVs) may relieve drivers from driving tasks and allow new activities while in transit, such as relaxation or conversation with passengers. Such activities would benefit from new seating configurations. Design concepts of HAVs include swivelling and reclining seats, and such arrangements were found desirable in volunteer studies (e.g. [1]). Even in current vehicles, similar positions were already observed in numerous out-of-position cases (NASS-CDS analysis by [2]), confirming the interest of the road users in varied seating configurations.

Several studies have already used human body models (HBMs) to study the possible effect of these new postures on the occupant kinematics and on the efficacy of restraint systems. They used real environments (e.g. vehicle cabin interior in [3]), however, making them difficult to reproduce. In addition, new biofidelity data may be required to validate HBMs in these configurations, and a semi-rigid seat from LAB [4] is considered by some future studies to help with the reproducibility of the testing while providing a reasonable environment to study submarining. In this context, the present study investigates the occupant response in a frontal crash before and after alterations of posture using the semi-rigid seat and a HBM. Two types of alteration were studied: seat swivelling; and reclining seat.

### II. METHODS

Occupant and loading environment were simulated using a 50<sup>th</sup> percentile HBM (GHBM, M50-O, Version 4.5) and finite element (FE) model of the semi-rigid seat, respectively. Simulations were run using LS-DYNA (Version 7.1.3). The semi-rigid seat is completed with a pre-inflated airbag, a three-point seatbelt with lap and shoulder pretensioners, and a 6 kN force limiter. Two pulse severities were used: **P1** (used in [4]), represented a 56 km/h full width crash scaled down by 20%; **P2**, more severe, corresponded to a 56 km/h 50% offset barrier test. The Baseline configuration represented a standard driving position, with a seatback angle (SB) of 22° and a seat pan angle (SP) of 15°.

#### Case 1: Swivelled seat

A seat swivelled from -10° to -30° about the vertical axis Z was used to mimic a driver in a working or conversation configuration. In addition to the baseline airbag position (AB Baseline), a configuration where the airbag was moved to follow the head Y position and was centred on it (AB Moved) was simulated. Simulations were run with the original seat pan width (38 cm) or with a wider seat pan (50 cm), with or without lateral supports for the pelvis. Only **P1** was used.

#### Case 2: Reclined seat

Three reclined configurations with a fixed SB of 40° were defined corresponding to three SP values (5°, 15° and 25°). This range of SP was selected based on the variability of comfortable positions for SB of 40°, as observed on volunteers by [5]. The airbag was moved with the seat back. The PIPER software ([www.piper-project.org](http://www.piper-project.org)) was used to reposition the GHBM by changing the hip angle to fit with the different SP angles.

### III. INITIAL FINDINGS

#### Test Case 1: Swivelled seat configurations

None of simulations led to submarining. With the original seat pan width, the pelvis fell off the seat for an angle of 30°. For the wider flat seat pan, a pelvic fracture was observed in the left iliac crest for a seat rotation of 30°. The lateral support prevented that fracture. The seat rotation or airbag position had limited effect on other injury criteria (e.g.  $HIC15_{Baseline} = 142$ ,  $HIC15_{AB\ Moved} = 158 \pm 15$ ,  $HIC15_{AB\ Baseline} = 147 \pm 7$ ). However, the airbag position in line with the head limited the head excursion, which was otherwise on the edge of the airbag for 30°.

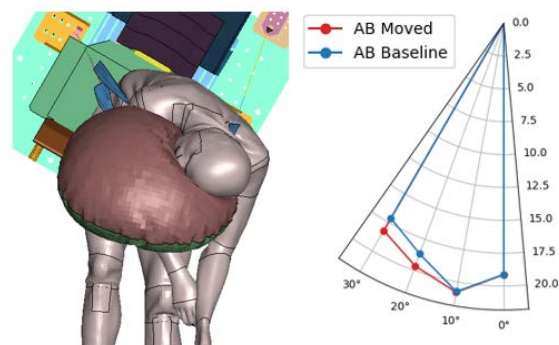


Fig. 1. Seat rotation of 30°, AB Baseline (*left*) and Anteroposterior thoracic compression vs. seat angle (*right*, on percentage of the initial thoracic depth).

C. Grébonval (e-mail: [cyrille.grebonval@ifsttar.fr](mailto:cyrille.grebonval@ifsttar.fr); tel: +33 4 72 14 26 68) is a PhD student in Biomechanics and X. Wang, PhD and P. Beillas, PhD are researchers at the LBMC, UMR\_T9406, Université Claude Bernard Lyon 1 - Ifsttar in Lyon, France. X. Trosseille, PhD and P. Petit, PhD are Research Engineers at the LAB PSA Groupe - Renault in Nanterre, France.

### Test Case 2: Reclined seat configurations

Sacrum and iliac crest fractures occurred in all reclined configurations, which prevented running the simulations without error until the submarining status could be determined. Fractures occurred for lap-belt forces from 8.5 kN to 11.5 kN. In the Baseline configuration, lap-belt forces reached 12 kN and did not cause any fracture. Disabling pelvis fracture led to submarining for some combinations of the seating configurations and pulse (SP05 for P1 and P2, SP15 for P2). It did not occur for all other test conditions. In the SP25-P1 configuration, shoulder-belt forces reached 4.2 kN, lap-belt forces 8.5 kN and lumbar spine forces 3 kN, whereas in the SP05-P1 configuration they reached 4.7 kN, 11.5 kN and 2.2 kN, respectively.

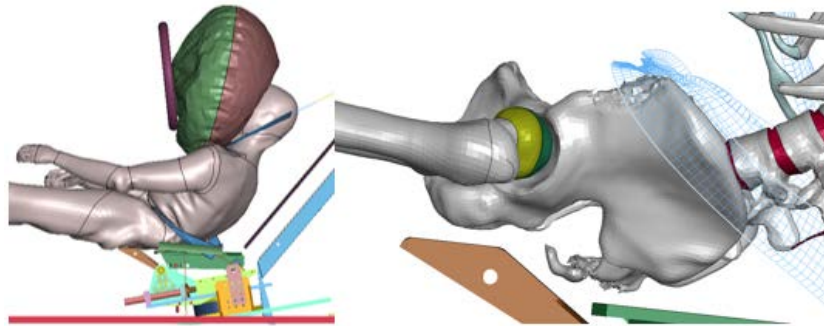


Fig. 2. Reclined seat submarining (*left*, P1, SP05 configuration, pelvic fracture disabled) and pelvic fracture (*right*).

## IV. DISCUSSION

Simulation results demonstrate a sensitivity of the model response to the seating configuration and highlight the importance of the boundary conditions and restraint location.

For the swivelling case, the change of airbag position helped to limit the head excursion, especially at 30°. This case should be simulated with more severe pulse as it may affect the head and the pelvis kinematics and may lead to pelvic fractures at less than 30°. As could be expected, the seat pan geometry affected the pelvis restraint.

For the reclined case, submarining was observed for some combinations of pulse and seat pan angle. The seat pan angle affected both vertical load transmitted through the spine and initial seatbelt position. It was found that as the lap-belt anchorage position affected the submarining [6], the effect of the anchorage position should be studied independently from the seat pan angle. The SB40-SP15 configuration was near the submarining limit, i.e. submarining at P2 but not at P1. A seat pan of 15° is close to the middle of the comfortable angles observed in [5] for a seat-back angle of 40°, suggesting that this posture might be ergonomically realistic and should be analysed more precisely. In terms of limitations, these results were obtained with pelvis fracture disabled. This should be further investigated to clarify whether these fractures are realistic. Also, the pelvis angle was kept from the baseline GHBM, which may be questionable for a relaxed reclined posture. This may affect submarining. Additional simulations will be performed with other pelvis angles.

This study also highlights the importance of the pulse selection – given that submarining might occur only above a given severity – and of the geometrical parameters of the restraint. Such parameters should be selected carefully for future PMHS tests in new seating configurations, to ensure their relevance for restraint design.

## V. ACKNOWLEDGEMENT

This study received funding from the SURCA French project.

## VI. REFERENCES

- [1] Jorlöv, S., *et al.*, IRCOBI, 2018.
- [1] McMurry, T. L., *et al.*, *Traf Inj Prev*, 2017.
- [3] Kitagawa, Y., *et al.*, *Stapp Car Crash J*, 2017.
- [4] Uriot, J., *et al.*, *Stapp Car Crash J*, 2015.
- [5] Theodorakos, I., *et al.*, *Proceedings IEA Congress*, 2018.
- [6] Luet, C., *et al.*, *Stapp Car Crash J*, 2012.