

A proposal for integrating pre-crash vehicle dynamics into occupant injury protection evaluation of small electric vehicles

Pronoy Ghosh, Marianne Andersson, Manuel Mendoza Vazquez, Mats Svensson, Christian Mayer, Jac Wismans

Abstract This research addresses integration of pre-crash dynamics into crash phase using two different human body models. The methodology discussed is a manual way of utilizing data from two different simulations and developing an interlinking chain of data to explore feasibility of integration.

The crash pulse was based on a collision scenario of 35 km/h (MPDB – 35 km/h - 30° - 50% offset configuration and a generic 1g braking pulse for the pre-crash phase was considered for Autonomous Emergency Braking events. Data transfer from the pre-crash to in-crash phase involved position, velocity, stress and strains for different body parts to introduce pre-crash dynamic effects. Two parameters, chest compression and contact force of Human Body Models with airbag, were chosen to assess risk of injuries to head and thorax. Simulations with different crash initiation times (650ms, 830 ms and 970 ms) were used to assess response of restraint systems to changing inertial loads of occupants.

The simulations results indicated that this method of data transfer is viable and can be used to assess injury risks for occupant. The coupling of two different simulations with different models could definitely yield accurate results, but, is sufficient to ensure realistic occupant kinematics and reasonable injury prediction capabilities.

Keywords active safety, electric vehicle, human body model, integrated safety, occupant safety

I. INTRODUCTION

In the next 20 years the number of Small Electric Vehicles (SEVs) is expected to increase and become a solution for urban mobility. It is likely that these vehicles will transport less than five occupants and will have short front and rear overhangs, leading to small crumple zones. To protect the occupants in these conditions, SEVs will require stiffer vehicle structures to minimize intrusions into the cabin. Resulting in aggressive crash pulses that will require advanced integrated restraint systems to protect the occupants. One of these advanced integrated systems is the autonomous emergency braking (AEB), that could avoid a crash or mitigate its severity. During an autonomous braking manoeuvre the occupants change their posture, position and velocity relative to the car interior and restraint systems [1]. The level of muscle contraction has been identified as a significant factor to determine the forward displacement of volunteers subjected to braking pulses [2-3]. It has been identified that an initial position close to the steering wheel increases the risk of injury for occupants [4-5] and that occupant kinematics during pre-crash influences the occupant interaction with restraint systems and the resulting injury measures [6]. Since the occupant position is influenced by its own muscular contraction, efforts are being made to include muscular contraction into numerical human body models (HBMs). References [7] and [8] have successfully simulated the occupant kinematic response during AEB events by implementing feedback control to regulate the muscle activation levels in HBMs.

In order to design restraint systems that enhance occupant protection, it is necessary to consider the kinematic response during the pre-crash phase, i.e. the AEB event, and integrate it to the protection evaluation during the in-crash phase. One approach using a finite element HBM would be to run one simulation covering the pre-crash and in-crash phases with an HBM with active muscles and the ability to predict injury. At this time, and to the best knowledge of the authors, there is no finite element HBM with these characteristics due to the different modelling techniques for the pre-crash and in-crash HBMs. An alternative approach would be to run

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two simulations separately, one for the pre-crash phase and with an active HBM, and then a second for the in-crash phase with an HBM that can estimate the risk of injury.

The objective of this paper is to present a method for integrating the results of pre-crash simulations with an active HBM into in-crash simulations with a HBM able to predict injury. This method is presented and applied to a simulation of an AEB event, 1 g of frontal deceleration, followed by a crash against a deformable barrier at 35 km/h. This collision scenario was identified based on the study prepared within the German collaborative research project, VisioM. The aim of the study was to compare current accident occurrence of general M1 vehicles and the accident occurrence expected for small urban vehicles, here represented by a subset of smaller M1 (VisioM-type) vehicles (average mass of 1150 kg). Accidents with VisioM-type vehicles were filtered out of the GIDAS accident database and compared with the regular M1 vehicle data. Only vehicles occupied by a maximum of two persons were considered. Vehicles with a payload capacity of more than 100 kg were excluded. The initial speed before the collision was maximum 100 km/h. Accidents that occurred more than 100 km from the origin or from the destination were excluded [9]. One of the recommended collision scenarios, used in the study, was derived from the findings that VisioM vehicles were more represented in intersection accidents (35% compared to 25%).

II. METHODS

FE Human Body Models

The current study utilizes two different FE Human Body Models: (1) Human Body model of Daimler (Active THUMS-D) and (2) Active Human Body Model of Chalmers University of Technology. A brief description of both the models is provided below.

Passive THUMS-D: Passive THUMS-D was developed previously after conducting significant modifications in the original THUMS. The modified model represents a mid-size adult male occupant FE model whose height and weight were 175 cm and 73.5 kg. The modifications conducted in the model involved mesh refinement in several body regions, connections in lower extremities and implementation of a new shoulder model. The modification and validation of the model is discussed in detail in our previous study [10-11].

AHBM of Chalmers University of Technology: The AHBM consists of musculature added to the THUMS Adult Male 50th percentile (AM50) version 3.0 (Toyota Motor Corporation, 2008). Figure 2 shows the added musculature; in total 326 Hill-type line muscle elements, which represents muscles in the neck, the lumbar spine, the abdomen and the upper extremities. These muscles are activated through a proportional-integral-derivative (PID) feedback control with the objective of maintaining a predefined posture of the model.

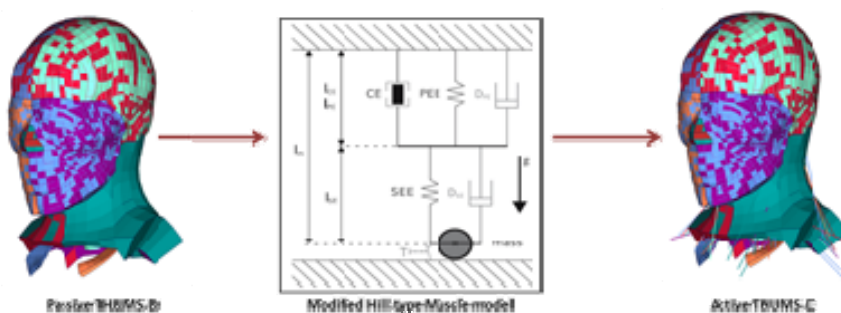


Fig. 1. Active THUMS-D model.



Fig. 2. AHBM with active muscles added by Chalmers are shown as red lines on the skeleton of the THUMS v3.

Apart from adding the aforementioned muscles, the AHBM includes some other modifications to the THUMS version 3.0, such as the reduction in elastic moduli and linear stiffness of the intervertebral discs, spine ligaments and skin, as well as the elimination of the constraints that fix nodes on the skin to the vertebrae. The hip joints were defined as ball joints, while the knee and ankle joints were defined as revolute joints. The full

description of the model is given in [12-14]. The AHBM in this study has been validated for longitudinal autonomous braking [12-13]. The first set of validation tests included autonomous braking of a sled. The sled tests were conducted on a rigid seat sled. Volunteer kinematics was measured. The peak deceleration was up to 10 m/s^2 , and the duration was 0.2 s [15]. Secondly, validation data was developed by conducting vehicle tests with autonomous braking. The vehicle tests (Volvo XC60) were conducted on roads. Autonomous braking was applied without prior notice to the observed volunteer. Volunteer kinematics was measured. The peak deceleration was 6.7 m/s^2 , with the duration of approximately 1.5 s [8][16].

Vehicle Environment and test conditions for integrated safety

The setup of the sled environment was derived based on a collision scenario of 35 km/h (MPDB – $35 \text{ km/h} - 30^\circ$ - 50% offset configuration). This collision scenario represents one of the predicted collision scenarios by 2025 [17] for SEVs equipped with AEB systems. Figure 3 below illustrates the collision scenario used for this study. The vehicle used for the evaluation was of gross vehicle weight of 740 kg (light SEV category). The vehicle under consideration was adapted from Smart fortwo FE model. Smart fortwo is bigger and heavier than an L7e class vehicle, which was the focus of the SafeEV project [18]. Since, for the tool chain development differences between M1 sub A and L7e model classes were not crucial, those differences were taken into consideration. However, to meet the mass requirements for this class the mass was modified virtually. The overall external dimensions of the new design are: Length: 2695 mm , Width: 1638 mm and Height: 1543 mm . Figure 4 depicts the sled model and full vehicle model used in the study. The current study was conducted with the occupant positioned in the driver's seat with a seat belt with pre-tensioner and airbag forming the required restraint systems.

The entire simulation was bifurcated into two phases:

1. Pre-crash phase simulations
2. In-crash phase simulations

The same sled model was used in both the phases.

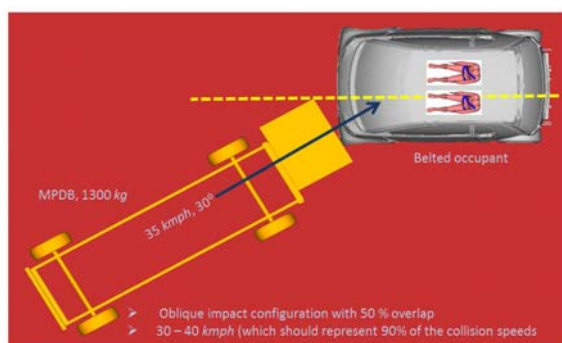


Fig. 3. 35 km/h collision scenario test.

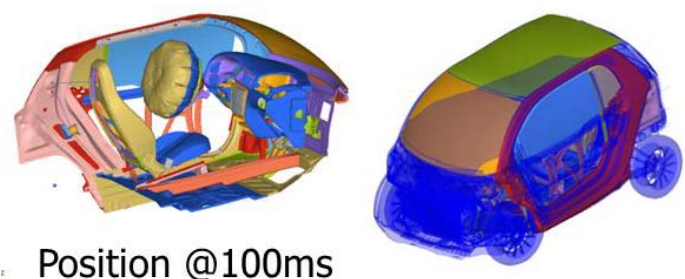


Fig. 4. Conversion of full vehicle crash to sled model.

Pre-crash Phase Test Conditions

A generic 1 DOF 1g braking pulse was used for conducting the pre-crash simulations. Figure 5 below illustrates the braking pulse used for the pre-crash phase. This braking pulse represents the following scenario where the vehicle under test was assumed to have an autonomous brake assistance system that decelerates the vehicle from 50 km/h to 35 km/h (the impact speed) in the vehicle longitudinal direction. The braking occurs just prior to t_0 (crash).

The simulation for this phase comprise of:

- 500 ms initialization run with gravity load only to reach muscle force equilibrium, followed by
- 467 ms braking (a generic brake pulse corresponding to a brake onset of 1 g per ms, up to a steady state braking of 1 g , and a total brake Δv of 15 km/h)

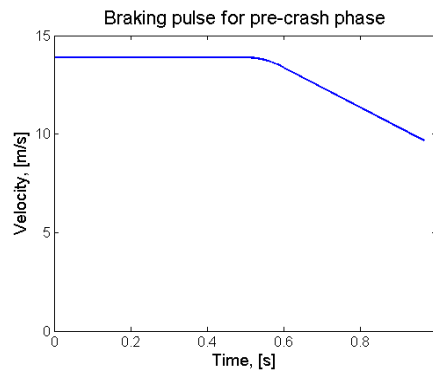


Fig. 5: Braking pulse for pre-crash phase.

Crash Phase Test Conditions

Figure 6 and 7 show the vehicle crash pulse derived from structural simulations for the considered collision scenario. Driver airbag and pre-tensioner are triggered 20 ms after t_0 .

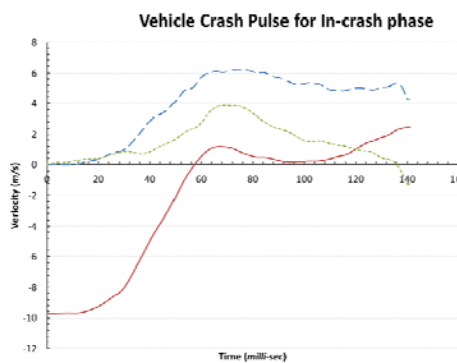


Fig. 6. Vehicle Crash Pulse (Translation).

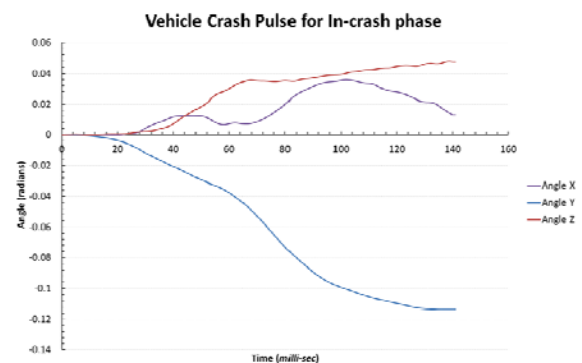


Fig. 7. Vehicle Crash Pulse (Rotational).

Pre-crash Braking Simulations

Figure 8 below shows plots of initial HBM position (0 ms), HBM position at start of braking (500 ms), HBM positions at certain intervals during the braking, and finally the position 17 ms prior to t_0 . The position at 800 ms (after 300 ms of braking) shows approximately the maximum forward and downward excursion of the head. The maximum forward and downward displacement was 208 mm (at 830 ms) and 91 mm (at 845 ms), respectively.



0 ms



600 ms



500 ms



700 ms



Fig. 8. Kinematics of the AHBM (view from right) during pre-crash phase.

Figure 9 and 10 illustrates forward and downward excursion of various tracking points on the AHBM. The tracking points are identified at head centre of gravity, T1, T12 and L5. It is observed that maximum excursion of the AHBM occurs before Δv of 15 km/h is achieved. This trend is observed both in forward and downward excursion. This suggests that AHBM starts to retreat after 830 ms much before Δv of 15 km/h is achieved. In actual crash conditions due to the existing uncertainty of the time of crash, the occupant can be at different excursion states based on t_0 .

Therefore, for further analysis 3 states are considered

1. ST650 : Time of pulse onset (650 ms)
2. ST830 : Time of maximum forward excursion (830 ms)
3. ST970 : Time of $\Delta v = 15$ km/h (970 ms)

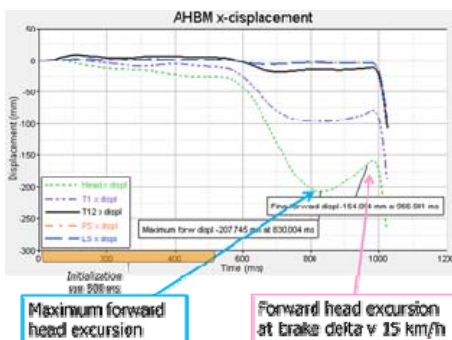


Fig. 9. Forward excursion of AHBM at 1g deceleration pulse.

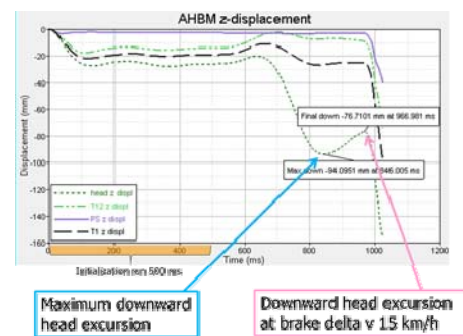


Fig. 10. Downward excursion of AHBM at 1g deceleration pulse.

Data transfer from pre-crash to in-crash phase

This method of data transfer was adopted due to lack of a single FE human body model capable of delivering the desired response in both phases. This forms an intermediate step, where to conduct integrated safety simulations; method was developed to interlink both phases. The subsequent section focuses on steps undertaken to ensure adequate data transfer. The data transfer from pre-crash to crash phase involves three parameters which are position, velocity and stresses in the model.

1. *Positioning of human body model:* The position of THUMS-D was aligned to that of the AHBM based on outer skin profile obtained from pre-crash 1g simulations. The positions of upper extremities, lower extremities, torso, head and neck, was achieved using THUMS positioning tool [19] and quasi-static loading of head and torso. Figure 11 below illustrates the position of THUMS-D (Blue) in driver position for in-crash phase and AHBM (Red) at the end of the pre-crash phase. The outer skin from AHBM was used to derive the posture of the THUMS in-crash phase. Figure 12 illustrates quasi-static loading setup. The same pulse used for conducting pre-crash simulations was applied to the beam elements. Three different points were identified in the mid-sagittal plane at the levels of mid-sternum, mid of abdomen and H-point. Beam elements were routed through these points to head, top and mid of sternum. Figure 13 shows final deformed thorax of THUMS-D after quasi-static loading. The deformed profile of the thorax shows fairly good correlation with the deformed profile of the AHBM thorax. Complete mapping of deformation patterns was difficult because the two models differed. Figure 14 shows the final positioned THUMS-D model used for crash simulations.

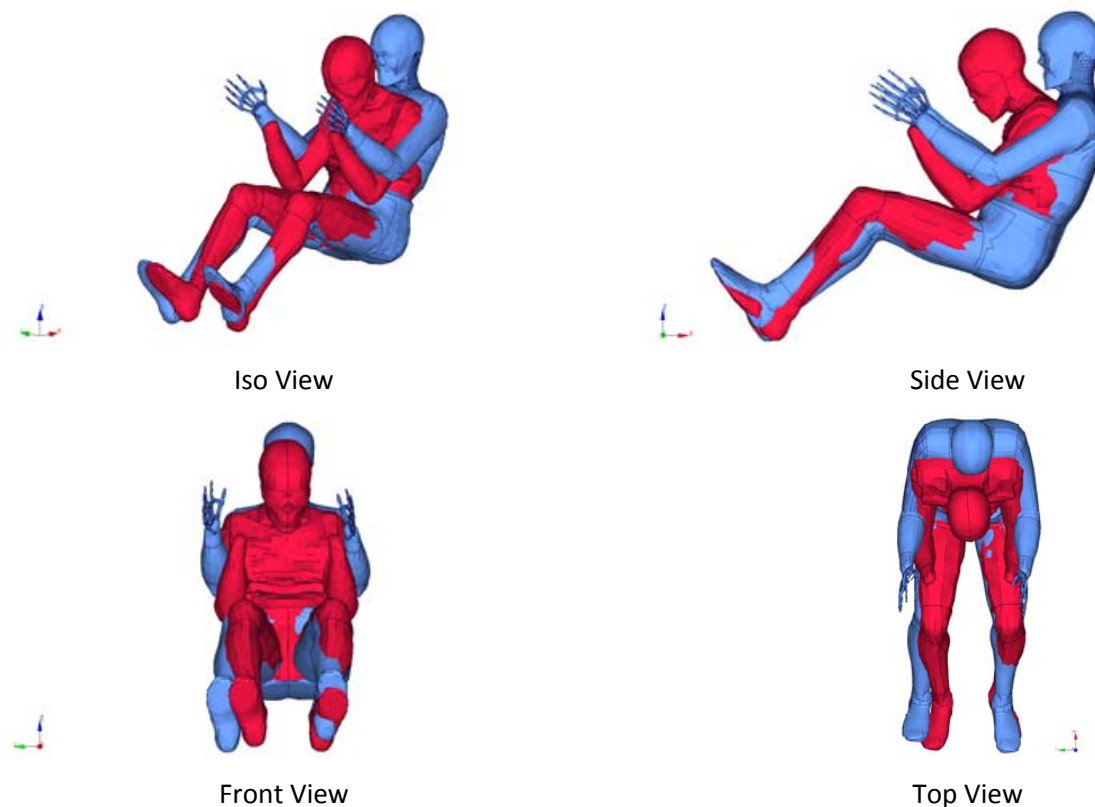


Fig. 11. Pre-crash and in-crash original positions of AHBM and THUMS-D (RED – AHBM and BLUE – THUMS-D).



Fig. 12. Quasi-static loading setup for positioning THUMS-D.

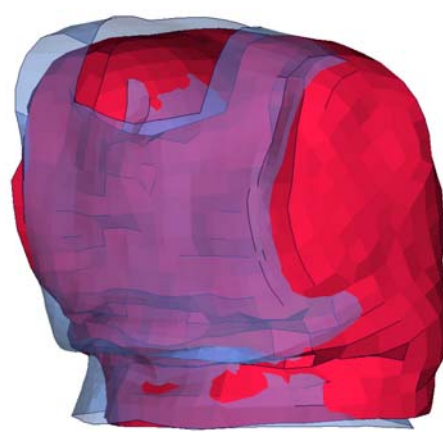


Fig. 13. Thorax deformation pattern after quasi-static loading (RED – AHBM and BLUE – THUMS-D).

2. Development of velocity profile for body region: The velocities of nodes on the surface of the outer skin were obtained from the AHBM. The velocity profile for the entire body was developed. This was done by dividing the entire body into 6 segments which are the head, neck, torso, pelvis, upper extremities and lower extremities. Figure 14 illustrates mean velocity, standard deviation and 95% Confidence Interval corridors for different body regions. The data analysis suggests that spatial distribution of velocity for entire skin surface lies between 11 and 11.1 m/s. The variation of velocities on the surface of the body is less than 1%. Average velocities based on data generated from those reported above were allocated to various body regions based on the approximation that standard deviation is not high. For instance, nodes on the head were grouped together and the average value of head velocity was allotted to this body region for in-crash phase.

	Head			Neck			Thorax		
	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel
Mean	-11.081	0.134	-0.096	-11.081	0.093	-0.041	-11.104	0.036	0.002
STDEV	0.036	0.025	0.030	0.020	0.018	0.024	0.104	0.060	0.061
Sample Size	1776	1776	1776	178	178	178	995	995	995
z($\alpha/2$) for 95% CI	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Confidence Interval	0.002	0.001	0.001	0.003	0.003	0.004	0.006	0.004	0.004
Error (Minimum Bound)	-11.083	0.133	-0.097	-11.084	0.090	-0.045	-11.111	0.032	-0.002
Error (Maximum Bound)	-11.045	0.159	-0.066	-11.078	0.095	-0.038	-11.098	0.040	0.006
	Pelvis			Femur			Knee		
	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel
Mean	-11.094	-0.017	-0.003	-11.088	-0.010	-0.001	-11.097	-0.010	-0.004
STDEV	0.370	0.309	0.342	0.023	0.024	0.028	0.010	0.024	0.018
Sample Size	831	831	831	479	479	479	364	364	364
z($\alpha/2$) for 95% CI	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Confidence Interval	0.025	0.021	0.023	0.002	0.002	0.002	0.001	0.002	0.002
Error (Minimum Bound)	-11.119	-0.038	-0.027	-11.090	-0.012	-0.004	-11.098	-0.012	-0.006
Error (Maximum Bound)	-11.069	0.004	0.020	-11.086	-0.007	0.001	-11.096	-0.007	-0.002

Fig. 14. Mean velocities, standard deviation and 95% CI computations for different body regions.

3. Stress initialization: Stresses and strains were computed for the quasi-static simulations conducted for positioning THUMS-D model in pre-crash position. These stresses and strains were then initialized in the crash phase of the simulations. This approach was adopted because the AHBM used for pre-crash simulations is a simplified model and is different from the THUMS-D model which was used in the crash phase. However, rib strains from the pre-crash phase were carried into the current model to ensure realistic assessment of fracture risk. Figure 15 illustrates rib strains obtained from pre-crash simulations which were used for the crash phase.

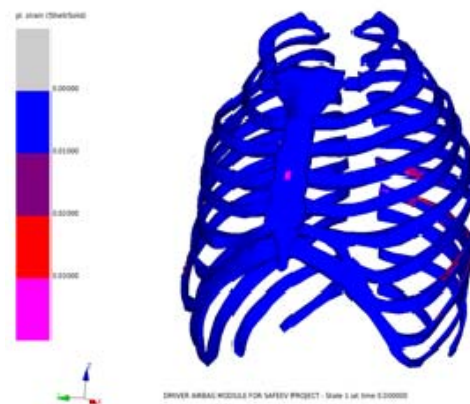
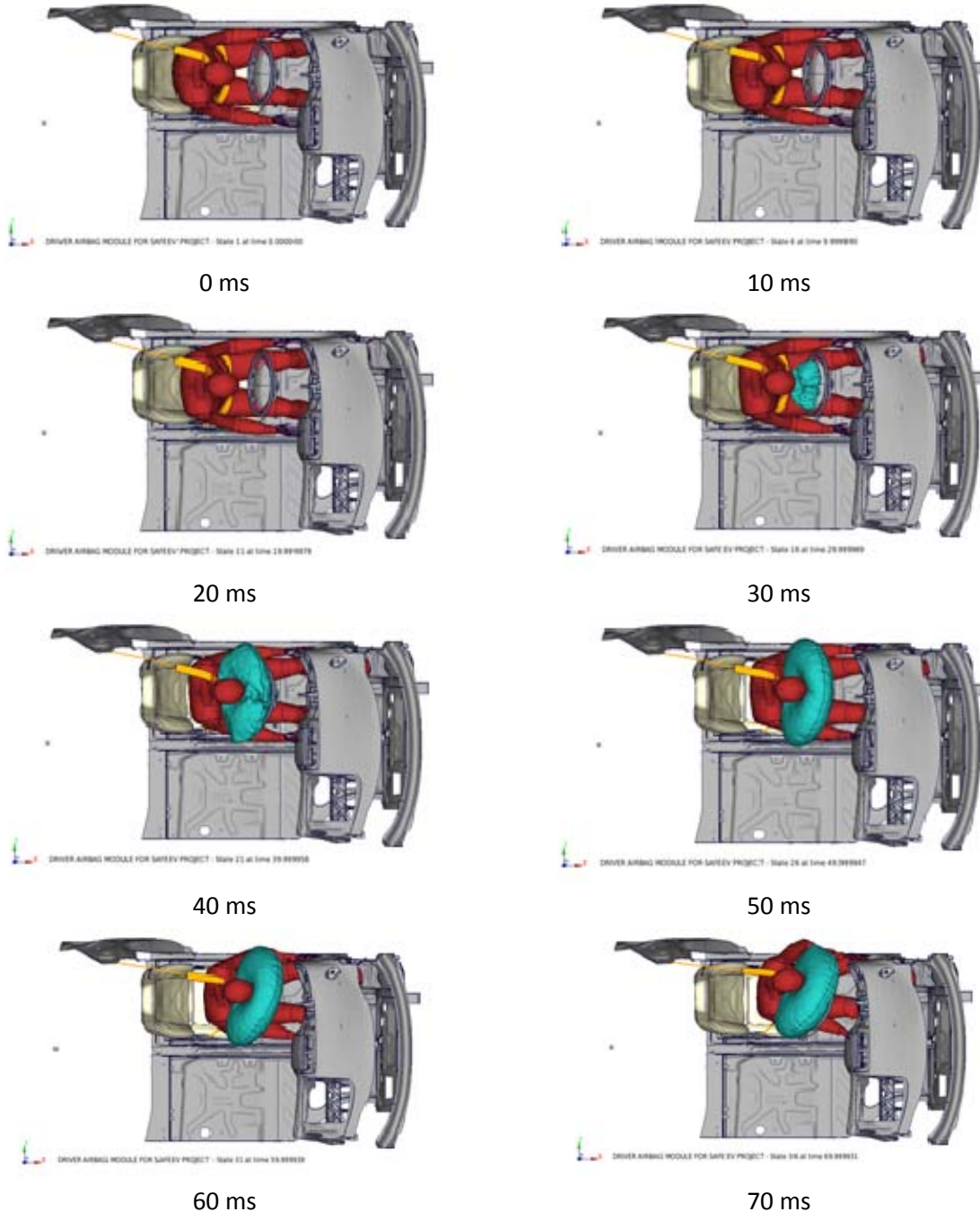


Fig. 15. Rib strains for AHBM in pre-crash phase simulations.

Crash Simulations

The crash phase of occupant safety simulations were conducted with the THUMS-D FE model with pre-crash positions, velocities and stress initialized with pulse as illustrated in Figure 6 and 7. The belt used for the simulations was a generic seat belt with a pre-tensioner and load-limiting feature enabled. The belt for the crash phase was re-routed based on a profile obtained from the pre-crash phase. The belt loads experienced during braking and deformed seat profile from the pre-crash phase was also obtained (no stress initialization was done for the seat foam) and this was used for the crash phase. The trigger time for the airbag and pre-tensioner were 25 and 20 ms respectively. These trigger times for the crash phase was based on parametric studies conducted during the vehicle design and results are available in our project work disseminations [20]. Figure 16 below illustrates the occupant kinematics for the considered collision scenario.



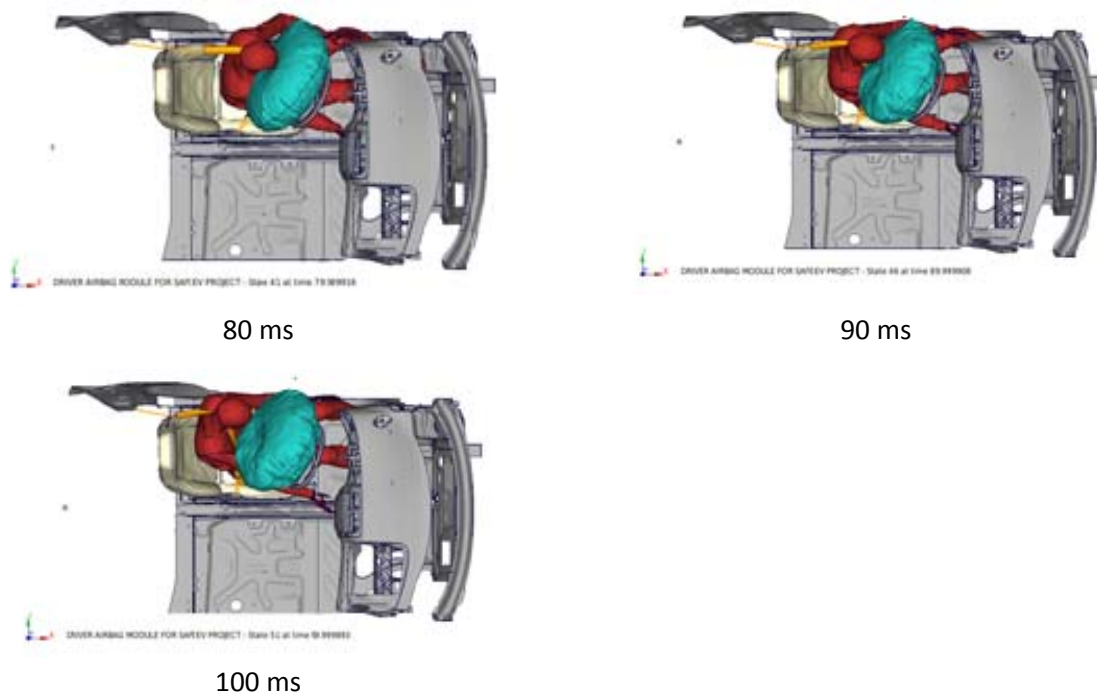


Fig. 16. Occupant kinematics using THUMS-D 50th Percentile Male Occupant Model.

III. RESULTS

Comparison of occupant kinematics and injury risk with and without pre-crash braking

In the current section, state 970 ms (ST970) represents the time when the vehicle speed reduces to 35 km/h from an initial velocity of 50 km/h after pre-crash braking. Impact kinematics is compared between ST970 and the load case where no effects (position and inertia) due to braking were introduced. Figure 17 below illustrates occupant kinematics with and without pre-crash braking. It is observed that position & inertial differences exist with the application of pre-crash braking. The occupant is positioned closer to the steering wheel for braking. This position poses greater risk to occupant in case of crash phase onset (discussed later).

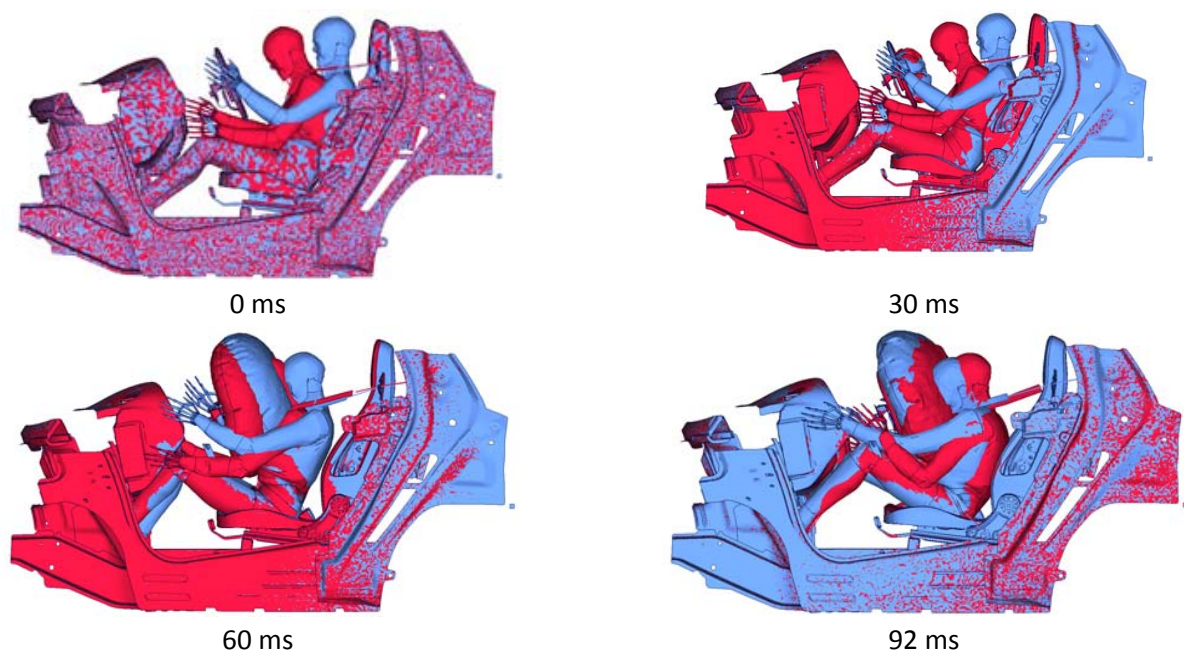


Fig 17. Occupant kinematics using THUMS-D 50th Percentile Male Occupant Model for standard position (without pre-crash braking in BLUE) and with pre-crash braking (ST970 in RED).

Figure 18 below shows comparison of contact forces between airbag and occupant for with pre-crash braking

(ST970) and without pre-crash braking. Contact forces with pre-crash braking (3.25 kN) are higher than that without pre-crash braking (1.55 kN). This difference is due to greater forward excursion of the occupant during braking and inertial forces (velocity of occupant at crash initiation is 9.35 m/s). This is evident from airbag pressure distribution (Figure 19a) for the without pre-crash braking scenario with a peak pressure of 0.125 MPa which is lower than in the pre-crash braking scenario (0.1425 MPa).

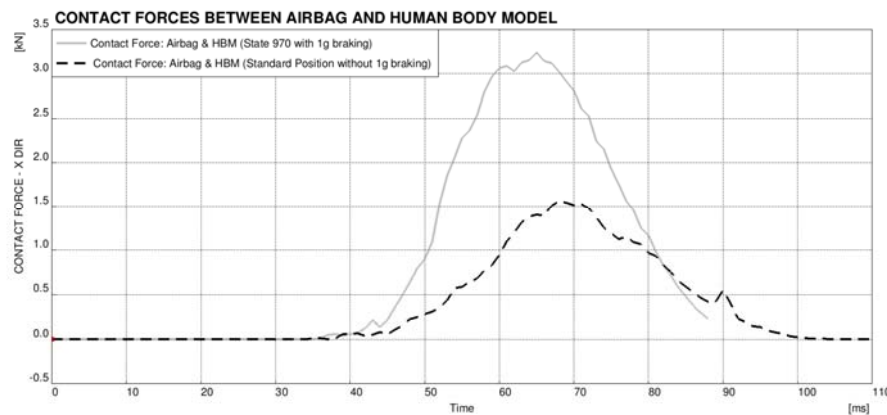


Fig. 18. Contact forces between the THUMS-D FE model and airbag without and with pre-crash braking.

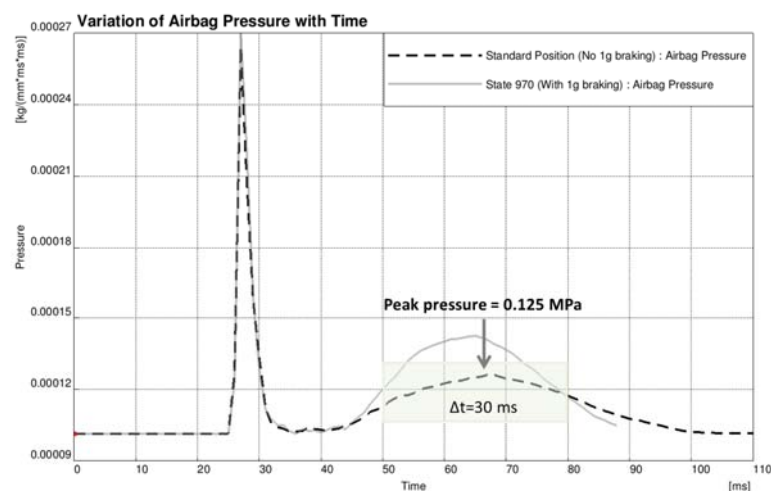


Fig. 19a. Contact forces between the THUMS-D FE model and airbag without and with pre-crash braking.

Chest deflection with and without pre-crash braking are depicted in Figure 20. The chest deflections were measured at mid sternum and at four additional points. The additional points were derived based on Hybrid III Thorax Multi-Point and high Rate measurement device (THMPR) points [21] as illustrated in Figure 19b below. However, for comparison, mid sternum deflection has been considered. The chest deflections at mid sternum are approximately the same for both, with and without pre-crash braking load case. However, differences are observed for measurements at ribs 4 and ribs 6, which are lesser for without pre-crash braking.

Mid-Sternum and Multi-Point Chest Deflection Measurements

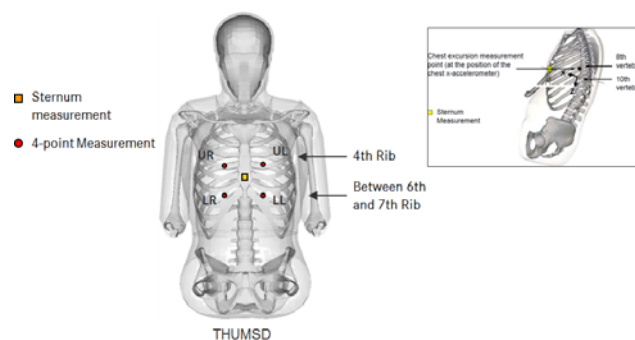
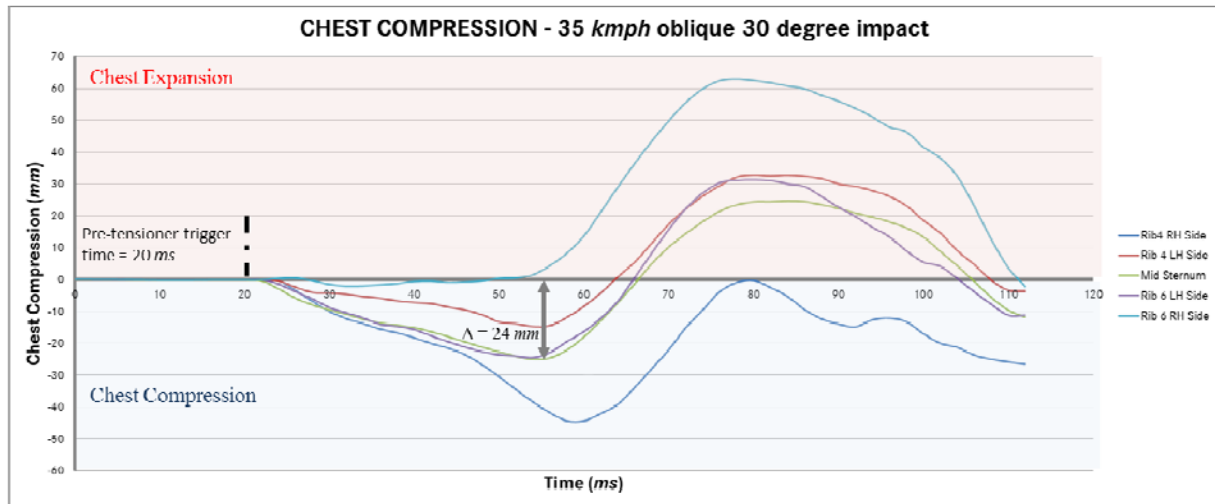
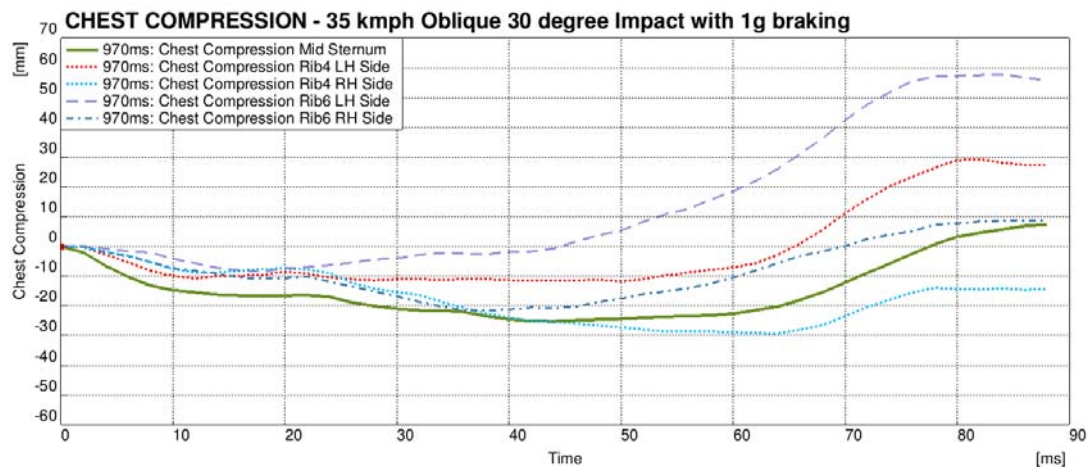


Fig. 19b. Chest deflection measurement points on THUMS-D FE human body model.



(a) Without pre-crash braking



(b) With pre-crash braking (ST970)

Fig. 20. Chest deflection measurement on THUMS-D FE human body model.

Influence of pre-crash braking on occupant kinematics and injury risk at different time instants of crash initiation

Impact kinematics of three different crash initiation states (ST650, ST830 and ST970) highlight that adaptive restraint systems that are suitable for the requirements need to be designed for such cases. Figure 21 below illustrates contact forces between the airbag and the THUMS-D FE human body model for the three different states (ST650, ST830 and ST970). The contact forces for the 3 different states suggest highest forces are experienced by occupants for the 830 ms, followed by 650 ms and 970 ms states.

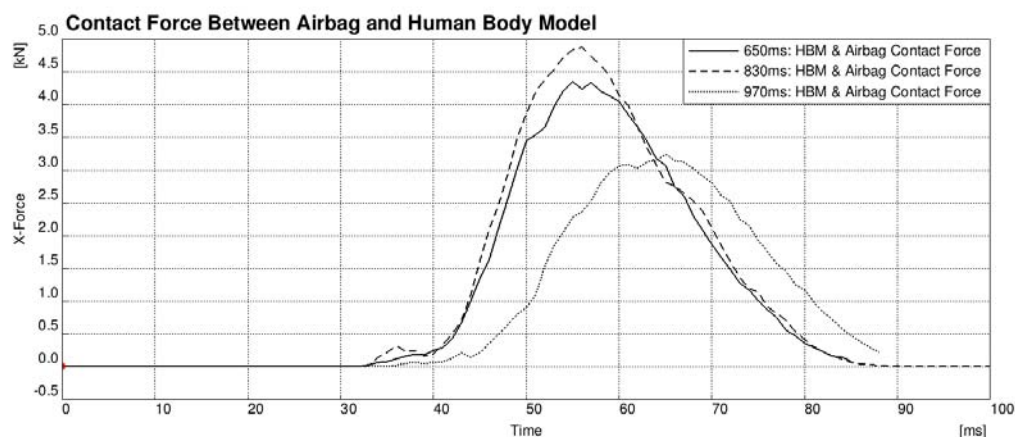


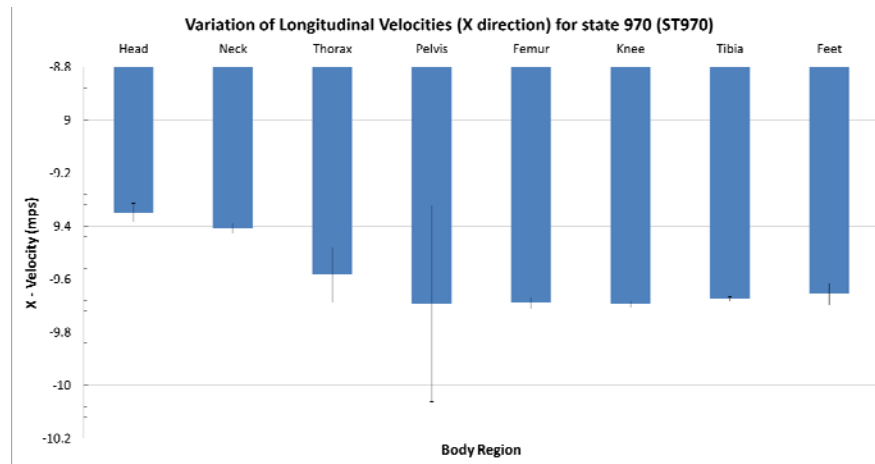
Fig. 21. Contact forces between the THUMS-D FE model and airbag for different states.

The differences are due to the position (ST830 closest to steering wheel) and velocity of the occupant (11.4 m/s

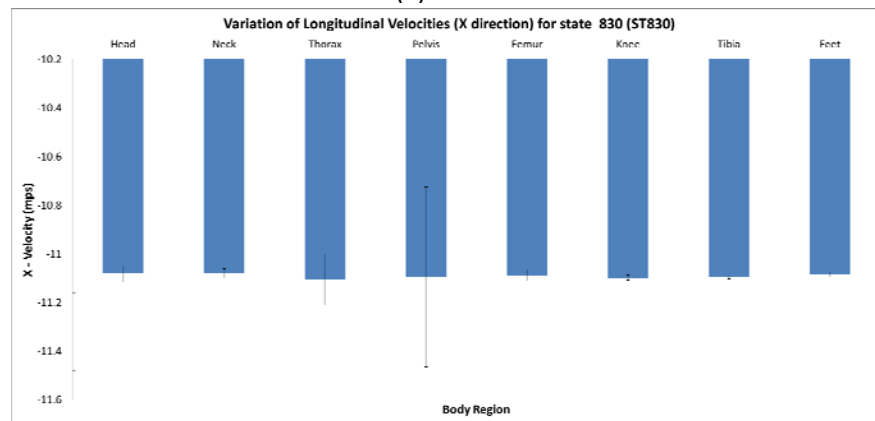
> vehicle velocity = 9.72 m/s) at the beginning of the crash phase results in a more critical risk for head injuries. Table 1 below shows distance and velocity of head c.o.g from the center of the steering wheel. The velocity distribution for other body regions is illustrated in Figure 22 below.

TABLE 1
Resultant distance and velocity between head c.o.g and steering wheel

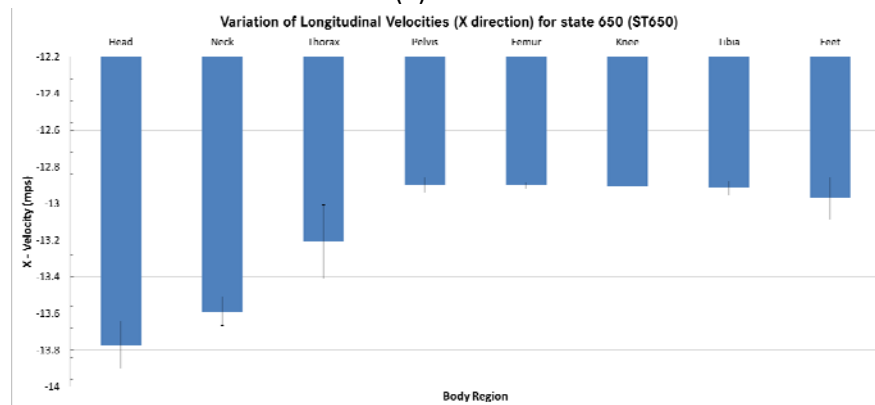
State	Distance (mm)	Velocity (mm/ms)	Time (ms)
650	415	13.75	0
830	277	11.4	0
970	329	9.3	0



(a) ST970



(b) ST830



(c) ST650

Fig. 22. Velocity distribution for different body regions for ST650, ST830 and ST970.

However, it was observed that the airbag deployment is less severe for ST970 compared to the other 2 states.

The reduced contact forces are due to lower initial velocity of the occupant (occupant velocity = 9.3 m/s and vehicle velocity = 9.72 m/s) and venting characteristics of the airbag (which were optimised to no pre-crash braking scenario and in this case favorable for this crash initiation state). The sluggish response of the occupant for ST970 towards forward movement (Figure 24 and 25) is assisted by onset of venting which ensures that airbag pressure is lower than ST830 and ST650. Figure 23 illustrates the variation of airbag pressure with time for states 650, 830 and 970.

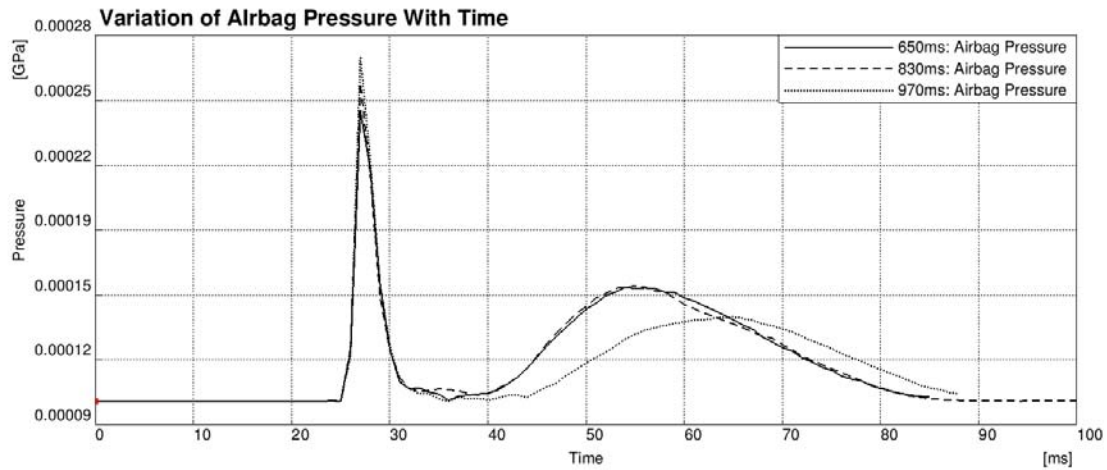


Fig. 23. Airbag pressure variation with time for different states.

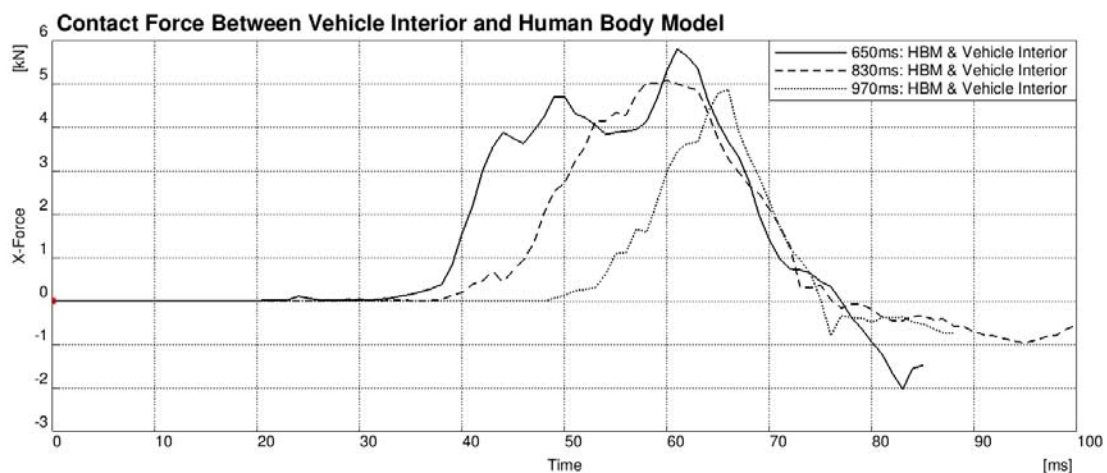


Fig. 24. Contact force variation between vehicle interior and occupant for different states.

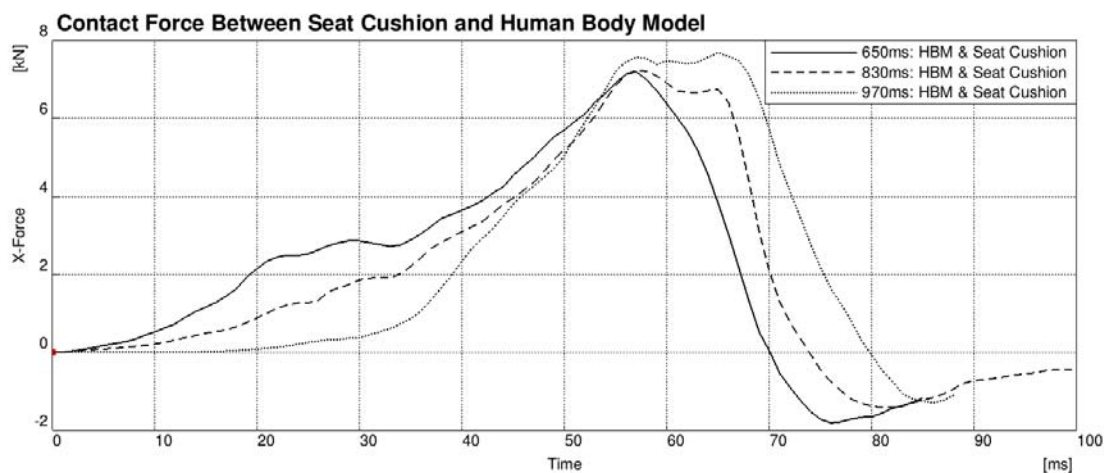


Fig. 25. Contact force variation between seat cushion and occupant for different states.

Figure 26 shows occupant kinematics for 3 different states identified in the pre-crash frontal braking maneuver. The effect of inertia is demonstrated at 30 ms, during the crash phase, where the ST650 occupant is closer to

ST970.

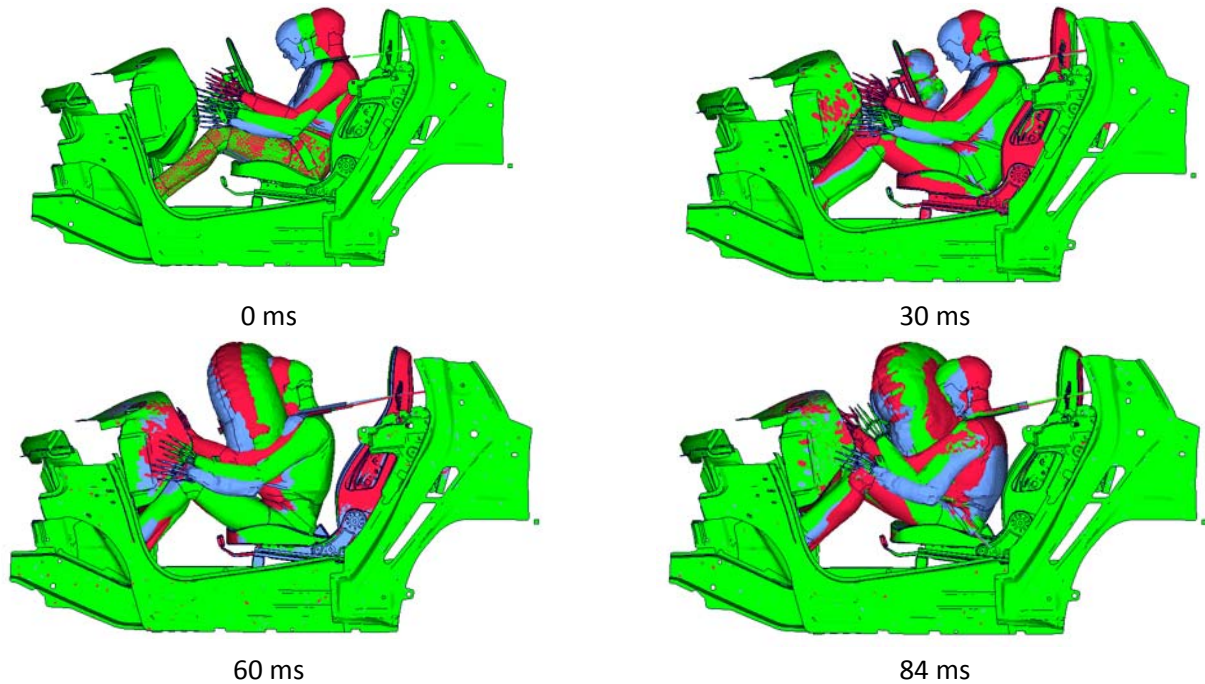


Fig. 26. Occupant kinematics using THUMS-D 50th Percentile Male Occupant Model for ST650 (RED), ST830 (BLUE) and ST970 (GREEN)

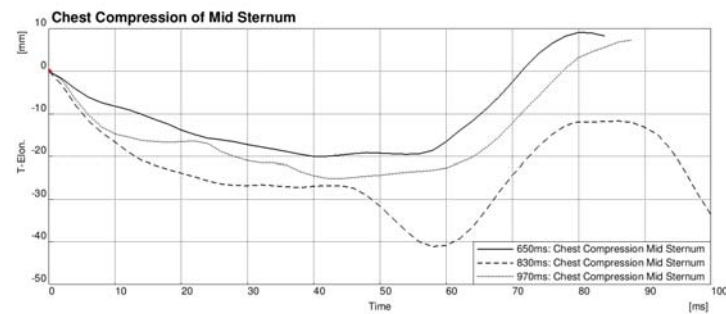
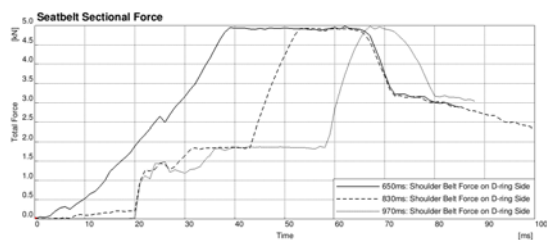
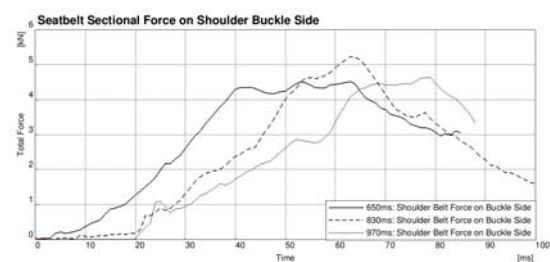


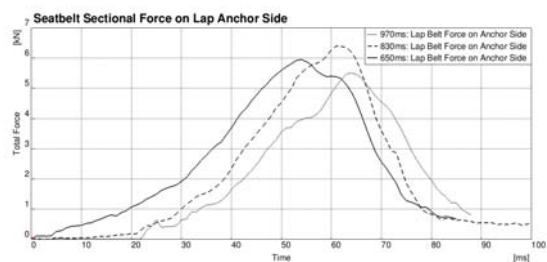
Fig. 27. Mid sternum chest compression for THUMS-D 50th Percentile Male Occupant Model.



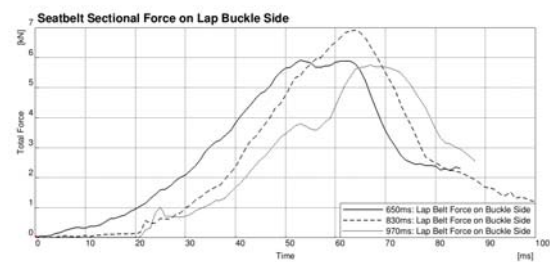
(a) Shoulder belt sectional forces on D-ring side



(b) Shoulder belt sectional forces on buckle side



(c) Lap belt sectional forces on anchor side



(d) Lap belt sectional forces on buckle side

Fig. 28. Seatbelt sectional forces for various occupant states in crash.

Figure 27 depicts chest compression at mid sternum for various states. The chest compression is highest for the ST830 occupant position. The seatbelt sectional force, shown in Figure 28, shows that the overlap between 43

to 52 ms rise in shoulder seatbelt force on D-ring side was observed for ST830. The increase in seatbelt force is coupled by loading from the airbag (Figure 23) which leads to an increase in mid sternum chest compressions. The lower values of chest compression, for other 2 states (ST650 and ST970), occur because airbag deployment happen either prior or post the time seat belt sectional forces become constant.

IV. DISCUSSION

Currently, HBMs have stability issues during long runtimes. To overcome this shortcoming, current Pre and In – Crash simulations were carried out separately. The challenge in such split simulations is, the carry-over of model behavior – position, dynamic parameters and any existing deformation, associated strains/stresses – from one phase to another; in this case from Pre-Crash to In-Crash. The study demonstrates that this intermediate solution to link Pre-Crash to In-Crash simulations provides a feasible approach to ensure data transfer between two phases. The method presently deals in transfer of positions, velocities and strains (for ribs only) due to differences in pre-crash and in-crash HBM models.

The feasibility of the study is demonstrated by comparing the response of a HBM in the crash phase due to inertial and positional effects of the pre-crash phase. The comparison of the HBM response, with and without pre-crash braking, suggests that with inception of inertial effects increase contact forces of airbag deployment with that of HBM for 1g pre-crash braking. The chest compressions are, however, found to be closer for this generic restraint system and vehicle configuration. Higher forces are experienced by occupant on interaction with airbag where 1g pre-crash braking is introduced.

Further confidence in the method was assessed by comparing data for 3 different states of pre-crash (time of onset of braking pulse, time of maximum forward head excursion and forward head excursion at brake delta v of 15 km/h). The results suggest that the state of occupant at time of maximum forward head excursion could be critical for occupant safety with respect to chest compression and head injuries. Chest compression (42 mm) and head contact forces (4.8kN) for ST830 are higher than the ST650 & ST970. This suggests that, in addition to, 1g braking pulse the influence of occupant response to braking plays an important role in occupant protection. The chest compression of occupant for different states is also influenced by response of seat belt system these varying positions & inertial effects. The seat belt loads on the shoulder region showed a delayed onset for ST830 & ST650.

The study has the following limitations. The vehicle and restraint models considered are generic and might not necessarily represent trends of injury scenarios in actual car crashes for this category of vehicle. The use of different HBM models restrict complete transfer of data for all body regions and differences in material models between the two can have influence on fracture prediction.

V. CONCLUSIONS

The study conducted oblique collisions simulations for SEV's using AHBM (Active THUMS) of Chalmers University of Technology and THUMS-D 50th percentile male occupant model to examine the feasibility of data transfer from pre-crash to in-crash phase within the course of the EU project SafeEV. The simulations results indicated that method of data transfer is viable and can be used to assess injury risks for occupants. The coupling of two different simulations with different models could definitely yield accurate results, but, is sufficient to ensure realistic occupant kinematics and reasonable injury prediction capabilities. The method utilised an oblique collision scenario, to identify potential occupant position during pre-crash (occupant position at time of maximum forward head excursion) as a critical one in terms of occupant safety (head injuries and chest compression). This method will now allow the assessment and optimization of pre-crash adaptive systems. This will be further demonstrated in the next project phase.

VI. ACKNOWLEDGEMENT

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