SAFETY ENHANCED INNOVATIONS FOR OLDER ROAD USERS

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Deliverable Title	Updated Human Body Models representing elderly occupants and pedestrians (incl. overweight/obese)		
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Written by	Eggers, Andre Wisch, Marcus	BASt	
	Wagner, Anja Mühlbauer, Julia Fuchs, Therese Peldschus, Steffen	LMU	
	Pipkorn, Bengt Mroz, Krystoffer Jaber, Leila	Autoliv	
	Fiorentino, Anita	FCA	
Checked by	Hynd, David	TRL	27/11/2017
Approved by	Wisch, Marcus	BASt	26/02/2018
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EXECUTIVE SUMMARY

Updated improved Human Body Models (HBMs) were developed to be used in subsequent tasks and work packagesof this project and beyond. In particular human models were developed with an updated thoracic rib cage taking into account relevant changes due to aging, HBMs with active muscles representing elderly car occupants and improved pedestrian human models. Furthermore some studies were carried out to investigate the relevance of age and overweight/obesity related to occupant safety.

The work on updating an HBM in terms of eldery rib cage was implemeted in the THUMS TUC occupant model. This model was updated regarding age-related material changes and rib cage geometry. The two most relevant material parameters (costal cartilage stiffness and cortical bone thickness) were implemented in THUMS TUC and also in a second occupant model the GHBM model.

The geometry modification of the rib cage were done based on data from medical imaging (CT scans) of almost 1,000 subjects. The data was parameterised according to geometrical two- and three-dimensional rib parameters. Based on this data a geometry was chosen that best fitted an elderly (65+ years) person in most parameters. This geometry was implemented in the HBM.

Table-top and sled simulations with the aged model taking into account geometry and material changes indicated that age-related modifications show low effect on stiffness response, but have an effect on rib peak strain, which is the most important predictor for rib fractures. Based on this finding it was decided to use the aged HBM including the proposed material and geometric changes for further investigations related to rib fracture risk within the subsequent tasks of the SENIORS project.

Volunteer tests were carried out to investigate the active muscles response in a real controlled and a virtual environment. The data collected during the experiments simulating hazard and sudden braking situations include information about muscle activations, forces applied and e.g., movements of certain body regions. Hereby, major differences between elderly and young, as well as male and female, were reported.

Based on volunteer test data an elderly active human body model was developed to predict the response of elderly occupants during braking events as current primary consequence of the potential activation of an Automatic Emergency Braking system. Simulations were performed with the elderly active human body model in emergency braking events for two individual volunteers, one average and one outlying volunteer. The correlation of the model output against experiments looks promising, but still shows room for improvement. The updated elderly active human body model can be used in further studies of pre-crash events.

An updated improved pedestrian HBM was developed focusing on the enhancement of biofidelity as well as stability and robustness. The biofidelity improvement was focused on head kinematics and bumper forces. The predicted head velocities of the updated model showed improved biofidelity and bumper contact forces were well predicted by the updated model.

To investigate the relevance of overweight/obesity a literature study and a simulation-based study were performed. The literature study pointed out various particularities related to overweight for example lower rib angle. It is recommended to consider all these factors in an occupant model representing an overweight person.

The simulation study was conducted in a frontal impact sled load case comparing a standard small female occupant model with a modified obese small female occupant. It showed that for the small female obese in the middle seat position only a small distance was left between the head and the instrument panel indicating increased risk of bottoming-out the airbag, which would greatly increase the risk of head injury. Also neck forces and moments were higher compared to the average male dummy in some seating positions. Based on this it can be recommended to use an occupant surrogate geometrically representing an obese person to further investigate this issue.

APPENDIX A.3 - LIST OF MODIFICATIONS TO THE THUMS TUC V2.0 PEDESTRIAN MODEL.

Keyword	Entity Name (Part, Contact etc)	Issue	Modification
***MAT** ***SECTION_ SHELL**	right and left tibial_collateral_ligament (MCL) right and left fibular_collateral_ligament (LCL)	Negative volume	New material with MAT_ADD_EROSION card included. New section with name "FIBULAR_LIGAMENT (fabric)"
***MAT**	Glenohumeral_ligaments_1_1	Negative volume	Scaled E, es1, es2 and es3 by factor 10
***SECTION**	Acromioclavicular_ligament Acromioclavicular_ligament_1_1	Negative volume	Switched to SOLID element type 1
***HOURGLASS**	left_thigh_soft_tissues	Negative volume	Switched to HOURGLASS type 3 (viscous form)
***HOURGLASS**	right_buttock left_buttock	Negative volume	Switched to HOURGLASS type 3 (viscous form)
***HOURGLASS**	skin_neck_right skin_neck_left	Negative volume	Switched to HOURGLASS type 5 (stiffness form)
***PART**	right_humerus_distal_cort right_clavicle_spon right_scapula_spon left_clavicle_spon left_scapula_spon	Negative volume	Added HOURGLASS type 5 (stiffness form)
***PART**	nucleus_pulposus(L5-S1) annulus_out(L5-S1) vertebral_endplate_upper(L5-S1) vertebral_endplate_lower(L5-S1) cartilaginous_endplate_upper(L5-S1) cartilaginous_endplate_lower(L5-S1) annulus_in(L5-S1) nucleus_pulposus(L4-L5) annulus_out(L4-L5) vertebral_endplate_upper(L4-L5) vertebral_endplate_lower(L4-L5) cartilaginous_endplate_upper(L4-L5) cartilaginous_endplate_lower(L4-L5) annulus_in(L4-L5) nucleus_pulposus(L3-L4) annulus_out(L3-L4) vertebral_endplate_upper(L3-L4) vertebral_endplate_lower(L3-L4) cartilaginous_endplate_upper(L3-L4) cartilaginous_endplate_lower(L3-L4) annulus_in(L3-L4) nucleus_pulposus(L2-L3)	Negative volume	Added HOURGLASS type 3 (viscous form)

***PART**	annulus_out(L2-L3) vertebral_endplate_upper(L2-L3) vertebral_endplate_lower(L2-L3) cartilaginous_endplate_upper(L2-L3) cartilaginous_endplate_lower(L2-L3) annulus_in(L2-L3) nucleus_pulposus(L1-L2) annulus_out(L1-L2) vertebral_endplate_upper(L1-L2) vertebral_endplate_lower(L1-L2) cartilaginous_endplate_upper(L1-L2) cartilaginous_endplate_lower(L1-L2) annulus_in(L1-L2) nucleus_pulposus(T12-L1) annulus_out(T12-L1) vertebral_endplate_upper(T12-L1) vertebral_endplate_lower(T12-L1) cartilaginous_endplate_upper(T12-L1) cartilaginous_endplate_lower(T12-L1) annulus_in(T12-L1) nucleus_pulposus(T11-T12) annulus_out(T11-T12) vertebral_endplate_upper(T11-T12) vertebral_endplate_lower(T11-T12)	Negative volume	Added HOURGLASS type 3 (viscous form)
***PART**	cartilaginous_endplate_upper(T11-T12) cartilaginous_endplate_lower(T11-T12) annulus_in(T11-T12) nucleus_pulposus(T10-T11) annulus_out(T10-T11) vertebral_endplate_upper(T10-T11) vertebral_endplate_lower(T10-T11) cartilaginous_endplate_upper(T10-T11) cartilaginous_endplate_lower(T10-T11) annulus_in(T10-T11) right_hipbone_spon left_hipbone_spon	Negative volume	Added HOURGLASS type 3 (viscous form)
***PART**	abdomen_lower_right abdomen_lower_left	Negative volume	Added HOURGLASS type 5 (stiffness form)
***PART**	right and left tibial_collateral_ligament (MCL) right and left fibular_collateral_ligament (LCL)	Negative volume	Added HOURGLASS type 2 (viscous form)
***DAMPING_ PART_ STIFFNESS**	Neck ELEMENT_SOLID parts	Negative volume	Added damping = 0.25
***CONTACT**	arm-surface_skin_out	Large element deformations due to penetrating nodes	New contact settings: SOFT=2, SBOPT=3.0, DEPTH=5, BSORT=5
***CONTACT**	arm-buttock_outer arms-thigh arm_contact_to_chest	Simplification of contact definition	Contacts definitions removed and the parts added to contact “arm-surface_skin_out”
***CONTACT**	sacrum-buttock right_hipbone-buttock left_hipbone-buttock	Large element deformations due to	New contact settings: MAXPAR=0.0, DTSTIF=1.0E-3

	buttock_in-buttock buttock_in-abdomen_lower cervical_spine-surface_neck_inner surface_neck_inner- surface_neck_outer diaphragm-abdomen_upper_top abdomen_upper_bottom- abdomen_lower	penetrating nodes	
***CONTACT**	buttock_each_element_self_contact	Large element deformations due to penetrating nodes	New contact settings: SOFT=2, SBOPT=3.0, DEPTH=5, BSORT=1, SST=4.0
***CONTACT**	Contacts skin right self contact and skin left self contact	Missing contact	Contacts added
***CONTACT_ INTERIOR**	*CONTACT_INTERIOR	Negative volume	Added soft tissue parts of legs, arms and shoulder (ELEMENT_SOLID). Added lumbar spine vertebral disc parts (ELEMENT_SOLID). Added scapulae and clavicles. Added ligament parts connected to clavicles and scapulae (ELEMENT_SOLID).
***CONTACT_ INTERIOR**	skin_right skin_left right_buttock left_buttock	Negative volume	Parts removed from CONTACT_INTERIOR. Separate contacts were defined for these parts.
***CONTROL_ MPP_DECOMP OSITION_ PARTSET_ DISTRIBUTE**		Large model run time	Added for two sets: THUMS TUC and BUCK parts for improved run time efficiency
***CONTROL_ SOLID**		Negative volume	Element deletion specification PSFAIL defined for a part set containing whole-body surrounding soft tissue parts (ELEMENT_SOLID) and the cervical spine parts right_cart, left_cart and annulus_out (ELEMENT_SOLID).