TUC Validation Repository

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Documentation
Validation Environment
VPS

Whole-Body Pedestrian Impact with a Generic Buck

Version:	V02
VPS version provided by:	ESI Germany GmbH
Last updated:	April, 2023
Experimental data published by:	Jason Forman, University of Virginia
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1. General

This document is part of the *validation kit* for the validation of a FE Human Body Model (HBM) against the loading condition specified under 1.1. The *validation kit* is composed of the following parts:

1. FE model of **validation environment**

   The following files contain the validation environment model and are provided as .pc- and .inc-files in VPS:

   a. *TUC_WB_PEDESTRIAN_SAE_MAIN_V02_FORMAN_MM_KG_MS.pc*
   b. *TUC_WB_PEDESTRIAN_SAE_Buck_FORMAN_V02*
   c. *TUC_WB_PEDESTRIAN_SAE_BCs_FORMAN_V02.inc*

2. Experimental corridors

   Experimental corridors will be provided in a later update of the validation kit.

3. Validation Protocol incl. a description of the load case

   The validation protocol describes the associated experiment briefly and shows how the human model to be validated needs to be integrated into the validation environment. It is provided separately for download.

1.1 Classification of validation load case

Body region	Whole-Body
Level	Global
Load case	Whole-Body Pedestrian Impact with a Generic Buck
References	Experiments published in: *J Forman, H Joodaki, A Forghani, P Riley, V Bollapragada, D Lessley, B Overby, S Heltzel, J Crandal (2015), Biofidelity corridors for whole-body pedestrian impact with a generic buck. IRCOBI Conf. Vol. 49.*
Unit system	kg - mm – ms – kN – GPa
Code	VPS

1.2 Disclaimer

The validation kit was developed in close cooperation within the THUMS USER COMMUNITY 2 (TUC2) research project. Any use of this validation environment shall be entirely at the user's own risk and responsibility. University of Munich (LMU), AUDI AG, Autoliv, BMW AG, Daimler AG, Porsche AG, Toyota Motor Corporation, Volkswagen AG and ZF TRW do not assume any responsibility for the validity, accuracy, or applicability of any results obtained from this research model and do not assume any liability or responsibility whatsoever for any damage, claims, injury or loss of any kind that may arise from or in connection with any use of, reference to and/or reliance upon this manual.

University of Munich (LMU), AUDI AG, Autoliv, BMW AG, Daimler AG, Porsche AG, Toyota Motor Corporation, Volkswagen AG and ZF TRW ask that the TUC project will be acknowledged under references for any use of this FE model resulting in papers and publications.

2. Short description of experimental setup and selection of configuration

In the experimental study of Forman et al. (1) three male post-mortem human surrogates (PMHS) were subjected to 40 km/h pedestrian impacts using a standard generic vehicle front (SAE J3093) (2-5). The PMHS were struck laterally in mid-gait stance. Pedestrian test methods described in detail by Kerrigan et al. (6) and Kam et al. (7) were used. Trajectories of the head centre of gravity (CoG), T1, T8 and the pelvis were recorded up to the time of head impact. The data were scaled to 50th percentile adult male and corridors developed.

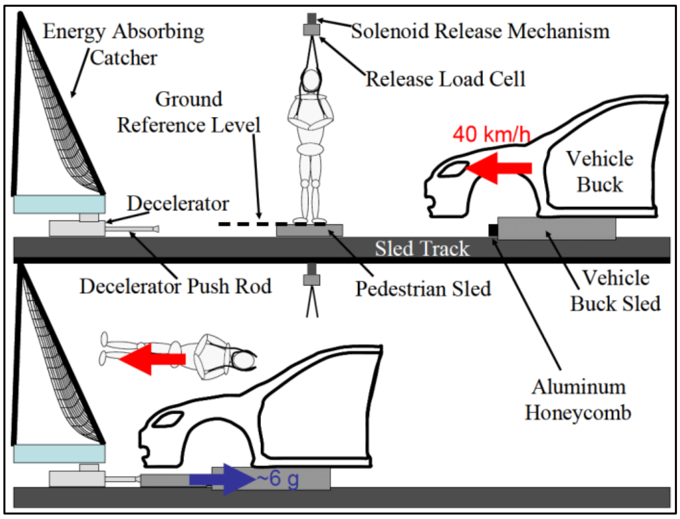


Figure 1 Experimental setup in Kerrigan et al. (7). Same test method was followed within experimental study of Forman et al. (1) using a standard generic vehicle front (SAE J3093)

Details of the Test Subjects with regard to age, gender and basic anthropometric measurements are given in the following table.

Test #	Age	Gender	Stature (cm)	Body Mass (kg)
V2370	73	Male	208	94.5
V2371	54	Male	194	92.8
V2374*	67	Male	216	99.1

Further design and performance specifications of the standard vehicle buck can be read in SAE J3093 (2).

This validation kit will provide the FE model of the validation environment (available), experimental corridors (coming soon) as well as a detailed protocol (partly available) for the validation of any FE pedestrian Human Body Model (HBM).

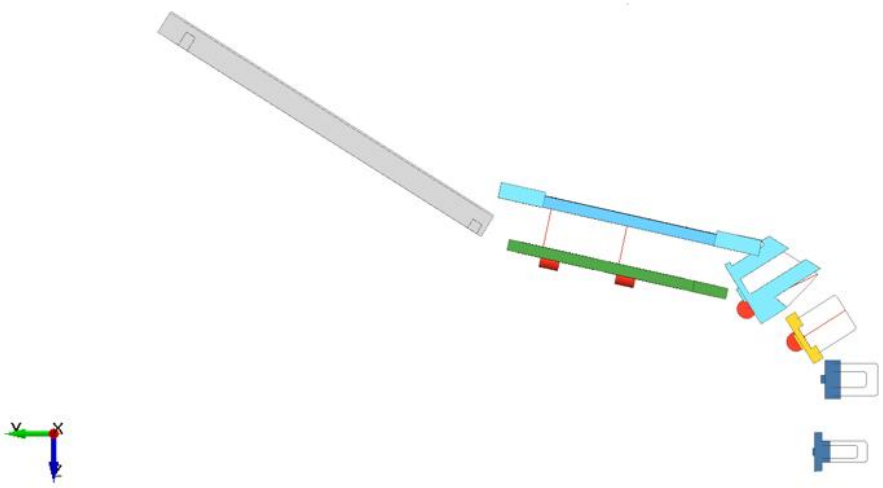
3. Description of the Validation Environment

In this section the validation environment, i.e. the numerical model of the experimental setup excluding the HBM to be validated, is described by providing an overview of the keywords used in the above mentioned input decks:

TUC_WB_PEDESTRIAN_SAE_MAIN_V02_FORMAN_MM_KG_MS.pc

TUC_WB_PEDESTRIAN_SAE_Buck_FORMAN_V02

TUC_WB_PEDESTRIAN_SAE_BCs_FORMAN_V02.inc



Lateral view

Dark blue: bumper

Yellow: grille

Light blue: hood

Green: engine block

Grey: windscreen

Red: stringpot

Frontal view

3.1 *TUC_WB_PEDESTRIAN_SAE_MAIN_V02_FORMAN_MM_KG_MS.pc* Main file

Keyword	**Explanation**	
INCLU_/_	**Included files are:** • *TUC_WB_PEDESTRIAN_SAE_GEOMETRY_V02.inc,* • *TUC_WB_PEDESTRIAN_SAE_MATERIAL_V02.inc,* • *TUC_WB_PEDESTRIAN_SAE_CONSTRAINTS_V02.inc* • *TUC_WB_PEDESTRIAN_SAE_OUTPUT_V02.inc.* • *[HBM.inc]*	**Include files**
RUNEND/_	TIME 120. -> simulation run end time in ms	**Control Cards**
TCTRL_/_	PREFER 0.0005 INIT_MASS_SCALE 0.0005 DYNA_MASS_SCALE 0.0005 20. NODAL YES SHELL_TIMESTEP SMALL NOBEND NU -> global control card to prevent the simulation time step from falling below 0.5 µsec using recommended control schemes	
ECTRL_/_ OCTRL_/_	Other defined global control cards for elements and output	
CNTAC_/_, type 33	• Contact ID 1 • Integration contact HBM-Body-Rest against vehicle Slave: optional GROUP 'GROUP_HBM_OUTER_SURFACE_BODY', Master: Part ID 10, 20, 30, 40, 50	
CNTAC_/_, type 33	• Contact ID 2 • Integration contact HBM-Head against vehicle • Slave: optional GROUP 'GROUP_HBM_OUTER_SURFACE_HEAD', Master: Part ID 10, 20, 30, 40, 50	
CNTAC_/_, type 34	• Contact ID 3 • Integration contact HBM against ground Slave: optional GROUP 'GROUP_HBM_OUTER_SURFACE', Master: Part ID 102 (Ground)	
ACFLD_/_	Gravity defined in local directions for vehicle and for HBM	
TRSFM _/_	Transforms the model and the BCs to the desired orientation	

Control cards might need to be adapted to control cards delivered with the HBM itself.

3.2 *TUC_WB_PEDESTRIAN_SAE_Buck_FORMAN_V02*

SAE buck model

Keyword	Explanation	
PART__/_	**Bumper** • 6 parts with ID 10, 11, 12, 20, 21, 22 **Grille** • 2 parts with ID 30, 31 **Hood** • 11 parts with ID 40, 41, 42, 44, 50, 52, 53, 54, 55, 56, 100 **Engine** • 1 part with ID 51 **Windscreen** • 3 parts with ID 60, 61, 62 **Stringpot** • 2 parts with ID 96, 97 **Ground** • 1 part with ID 102, **reference plane to be adapted to HBM** **Constrained Joints** • 1 part with ID 101 for constraining Rbodies, partly with translational degree of freedom	**SAE Buck model**
MASS__/_	• Total number: 1	
FE mesh, elements and nodes	• BEAM_/_: ID range 1-42 • BAR___/_: ID range 43-46 • SHELL_/_: ID range 77-125872, 156375-257024 • SOLID_/_: ID range 125873-156014 • PLINK_/_: ID range 156191-156366 • NODE__/_: ID range: ID range 1 – 311683 (with gaps, some nodes belong to SAE_CONSTRAINTS-include)	

Constraint cards and contacts

Keyword	Explanation	
RBODY_/_	• Vehicle connections, rigid vehicle parts and ground • Total number: 24	**Constraint**
KJOINT/_, type GENERAL with all DOFs constrained	• Element IDs 156367, 156369, 156371, 156373 • RBODY-connections, no unconstrained DOFs	**Joints**
KJOINT/_, type TRANSLAT	• Element IDs 156368, 156370, 156372, 156374 • RBODY-connections with free translational DOFs in global y-direction	
CNTAC_/_, type 33	• Contact ID 1 • Integration contact HBM against vehicle • Slave: optional GROUP 'GROUP_HBM_OUTER_SURFACE', Master: Part ID 10, 20, 30, 40, 50	**Contact**
CNTAC_/_, type 46	• Contact ID 200002 • Front Hood Clamping Self Edge Contact • GROUP '4_*SET_PART_LIST'	

Material Cards

Keyword	Explanation	
MATER_/_, type 103, elastic-plastic isotropic thin shell material	**HOOD** • MID 200 • Shell integration rule ISINT 3 for fully integrated Belytschko-Wong-Chiang • Part 40 HOOD_EDGE_COVER, Part 50 HOOD_SKIN, Part 53 HOOD_FLANGE, Part 54 HOOD_FLANGE_30mm, Part 55 HOOD_FLANGE_WELD_PLATE • density: ρ = 7.8e-006 kg/mm3 • Young’s modulus: E = 210 GPa • Poisson’s ratio: ν = 0.3 • LCSS 200 **PE300** • MID 1300 • Shell integration rule ISINT 3 for fully integrated Belytschko-Wong-Chiang • Part 10 BPR_LOWER_COVER, Part 12 BPR_LOWER_COVER_INNER, Part 20 BPR_UPPER_COVER, Part 22 BPR_UPPER_COVER_INNER, Part 30 GRILLE_COVER • density: ρ = 9.6e-007 kg/mm3 • Young’s modulus: E = 0.9 GPa • Poisson’s ratio: ν = 0.4 • Plasticity defined by stress-strain curves, LCID 1310, 1311, 1312, 1313, 1314 **WINDSCREEN FRAME** • MID 1311 • Shell integration rule ISINT 0 for Belytschko-Tsai Uniform Reduced Integration • Shell elements hourglass prevention flag 4 stiffness method using the plastic modoulus • Part 62 WINDSCREEN_FRAME • density: ρ = 7.8e-006 kg/mm3 • Young’s modulus: E = 210 GPa • Poisson’s ratio: ν = 0.3 • LCSS 200 **WINDSCREEN** • MID 1316 • Shell integration rule ISINT 0 for Belytschko-Tsai Uniform Reduced Integration • Shell elements hourglass prevention flag 4 stiffness method using the plastic modoulus • Part 60 WINDSCREEN • density: ρ = 9.6e-007 kg/mm3 • Young’s modulus: E = 0.9 GPa • Poisson’s ratio: ν = 0.4 • Plasticity defined by stress-strain curves, LCID 1310, 1311, 1312, 1313, 1314	

Keyword	Explanation	
MATER_/_, type 1, elastic-plastic solid with isotropic and/or kinematic hardening	**BUMPER BEAM** • MID 9 • Solid integration rule ISINT 0 for uniform reduced integration • Solid elements hourglass prevention flag 2 stiffness method using hourglass shape vectors • Part 11 BPR_LOWER_BEAM, Part 12 BPR_UPPPER_BEAM • density: ρ = 7.81e-006 kg/mm3 • Young's modulus: E = 206 GPa • Poisson's ratio: ν = 0.3 • Yield stress = 0.23 GPa • 9 data points for stress-strain behaviour **ALUMINIUM** • MID 10 • Solid integration rule ISINT 0 for uniform reduced integration • Solid elements hourglass prevention flag 2 stiffness method using hourglass shape vectors • Part 31 GRILLE_BEAM, 41 HOOD_EDGE_BEAM • density: ρ = 2.7e-006 kg/mm3 • Young's modulus: E = 71 GPa • Poisson's ratio: ν = 0.33 • Yield stress = 0.22 GPa • LCID 10	
MATER_/_, type 100, null material for shell elements	**RIGID** • MID 99 • Part 51 ENGINE_BLOCK Part 52 HOOD_SUPPORT Part 61 WINDSCREEN_FRAME_RIGID Part 97 STRINGPOT_RIGID • density: ρ = 7.81 e-006 kg/mm3 • Young's modulus: E = 206 GPa • Poisson's ratio: ν = 0.3 **GROUND** • MID 102 • Part 102 RIGIDWALL_1_GROUND • density: ρ = 1. e-005 kg/mm3 • Young's modulus: E = 210 GPa • Poisson's ratio: ν = 0.4	
MATER_/_, type 200, null material for beam and bar elements	**NULL_MATERIAL** • MID 42 • Part 42 HOOD_EDGE_COVER_BEAM • density: ρ = 7.85e-006 kg/mm3 • Young's modulus: E = 210 GPa **RIGID_BEAM** • MID 43 • Part 44 HOOD_EDGE_BEAM_TOWER_BEAM_INSIDE • density: ρ = 7.81 e-006 kg/mm3 • Young's modulus: E = 206 GPa	

Keyword	Explanation	
MATER_/_, type 302, material for plink elements	**HOOD_SPOTWELD** • MID 56	
MATER_/_, type 204, non-linear bar/dashpot element material	**SPRING_GENERAL_NONLINEAR (1-D)** • MID 96 • Spring mass 1E-6 kg • LCID 96	

Output definitions

Keyword	Explanation	
OCTRL_/_ > CONTOUR_PLOT INTERVAL	Constant output interval 1.0 ms for contour data like plastic strains etc.	
OCTRL_/_ > TIME_HISTORY INTERVAL	Constant output interval 0.05 ms for all time history data like energies, parts, time history elements and nodes etc	**Time-history**
THELE_/_	Time history output for string pot elements, names STRING_POT_43, STRING_POT_44, STRING_POT_45, STRING_POT_46	
THNOD_/_	BUCK Center of Gravity COG	

3.3 *TUC_WB_PEDESTRIAN_SAE_BCs_FORMAN_V02.inc* Boundary Conditions

The following loading and boundary conditions are defined in the validation environment.

Keyword	Explanation	
INVEL_/_	• Initial velocity of 40 km/h (11.11m/s) for the buck in local x-direction	**Velocity**
BOUNC_/_, DOF Code 011111	• Free translation in local x-direction for all rigid vehicle nodes	**Boundary SPC**
BOUNC_/_, DOF Code 111111	• Ground fully constrained	

References

1. J Forman, et al. (2015), Biofidelity corridors for whole-body pedestrian impact with a generic buck. IRCOBI Conf. Vol. 49.
2. SAE J3093, Design and Performance Specifications for a Generic Buck used in the Assessment of Pedestrian Dummy Whole Body Impact Response.
3. Pipkorn, et al. (2012), Development and validation of a generic universal vehicle front buck and a demonstration of its use to evaluate a hood leading edge bag for pedestrian protection. Proceedings IRCOBI conference.
4. Pipkorn, et al. (2014), Development and Component Validation of a Generic Vehicle Front Buck for Pedestrian Impact Evaluation. Proceedings of IRCOBI Conference.
5. Takahashi, et al. (2014), Full-scale validation of a generic buck for pedestrian impact simulation." Proceedings of IRCOBI Conference.
6. Kerrigan et al. (2005), Kinematic corridors for PMHS tested in full-scale pedestrian impact tests. Experimental Safety Vehicles Conference.
7. Kam et al. (2005), Design of a full-scale impact system for analysis of vehicle pedestrian collisions. Paper 2005-01-1875, Society of Automotive Engineers, Warrendale, PA.