TUC Validation Repository

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Load Case Description

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Validation Protocol

Whole-Body Pedestrian Impact with a Generic Buck

Version: V01dev01 (beta)

LS-Dyna version provided by: Autoliv

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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 LS-Dyna files contain the validation environment model and are provided as .k-files in LS-Dyna:

   a. *TUC_WB_PEDESTRIAN_SAE_MAIN.key*
   b. *TUC_WB_PEDESTRIAN_SAE_OUTPUT.key*
   c. *TUC_WB_PEDESTRIAN_SAE_CONSTRAINTS.key*
   d. *TUC_WB_PEDESTRIAN_SAE_BCs.key*
   e. *TUC_WB_PEDESTRIAN_SAE_GEOMETRY.key*
   f. *TUC_WB_PEDESTRIAN_SAE_MATERIAL.key*

   The HBM to be validated needs to be prepared and integrated into the validation environment according to the validation protocol in section 4.

2. Experimental corridors

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

3. Documentation incl. a detailed description of the load case and a validation protocol

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	LS-Dyna

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.

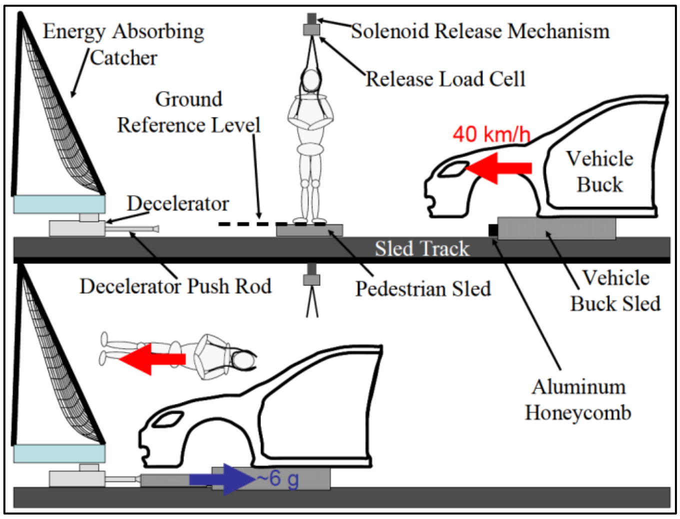


Figure 1 Experimental setup in Kerrigan et al. (7). Same test method was followed within experimental study of Forman et al. (1) using a standard generic vehicle front (SAE J3093)

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.key,

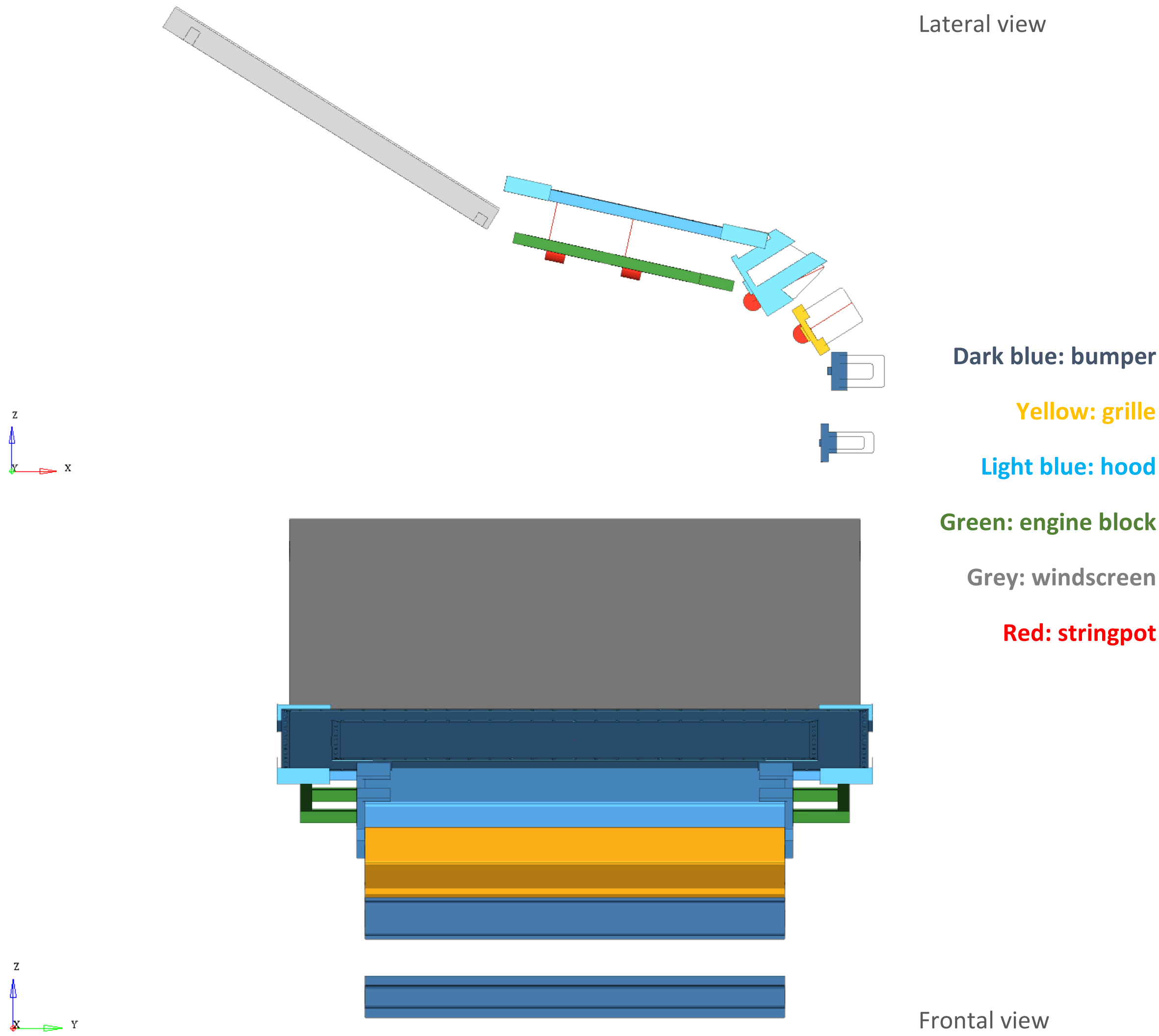
TUC_WB_PEDESTRIAN_SAE_GEOMETRY.key,

TUC_WB_PEDESTRIAN_SAE_MATERIAL.key,

TUC_WB_PEDESTRIAN_SAE_CONSTRAINTS.key and

TUC_WB_PEDESTRIAN_SAE_OUTPUT.key.

The protocol of section 4 (coming soon) describes how a human body model needs to be processed to be integrated in and validated with this environment FE model.



3.1 *TUC_WB_PEDESTRIAN_SAE_MAIN.key* - main file

Keyword	Explanation	
*INCLUDE	**Included files are:** • *TUC_WB_PEDESTRIAN_SAE_GEOMETRY.key,* • *TUC_WB_PEDESTRIAN_SAE_MATERIAL.key,* • *TUC_WB_PEDESTRIAN_SAE_CONSTRAINTS.key* • *TUC_WB_PEDESTRIAN_SAE_OUTPUT.key.* • *[HBM.key]*	**Include files**
*CONTROL_TERMINATION	ENDTIM = 120 ms	**Control Cards**
*CONTROL_TIMESTEP	DT2MS = -6.0e-4 ms LC (ID 2) for limiting timestep size vs time	
*CONTROL_SHELL *CONTROL_SOLID *CONTROL_HOURGLASS *CONTROL_BULK_VISCOCITY *CONTROL_CONTACT *CONTROL_OUTPUT *CONTROL_ENERGY	Defined global control cards	

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

3.2 *TUC_WB_PEDESTRIAN_SAE_GEOMETRY.key* – 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** • 5 parts with ID 40, 41, 42, 44, 56 **Engine** • 1 part with ID 51 **Windscreen** • 2 parts with ID 60, 61 **Stringpot** • 3 parts with ID 96, 97, 99	**SAE Buck model**
*PART_CONTACT	**Hood** • 5 parts with ID 50, 52, 53, 54, 55, 56 **Windscreen** • 1 part with ID 62	
FE Mesh *ELEMENT *NODE	**Hood** • *ELEMENT_BEAM: ID range 1-42 • *ELEMENT_DISCRETE: ID range 43-46 • *ELEMENT_MASS: ID 47 • *ELEMENT_SHELL: 77-125872 • *ELEMENT_SOLID: 125873-156190 • Node ID range: 1 - 210187	
*RIGID_WALL_PLANAR	**Buck reference plane** • to be adapted to HBM	

3.3 *TUC_WB_PEDESTRIAN_SAE_MATERIAL.key*

Keyword	**Explanation**	
*SECTION_BEAM	• Parts: HOOD_EDGE_COVER_BEAM, HOOD_EDGE_BEAM_TOWER_BEAM_INSIDE • SECIDs 12, 22 • Element ID range: 243012-243055, 246787-246814	**Section cards**
*SECTION_DISCRETE	• Part: STRINGPOT • SECID 23 • Element ID range: 1-4	
*SECTION_SHELL	• Parts: BPR_LOWER_COVER, BPR_LOWER_COVER_INNER, BPR_UPPER_COVER, BPR_UPPER_COVER_INNER, GRILL_COVER, HOOD_EDGE_COVER, HOOD_SKIN, HOOD_FLANGE, WINDSCREEN, WINDSCREEN_FRAME, RIGID • SECIDs 10, 30, 40, 50, 60, 70, 80 • Element ID range: 46008- 153131	
*SECTION_SOLID	• Parts: BPR_LOWER_BEAM, BPR_UPPER_BEAM, GRILLE_BEAM, HOOD_EDGE_BEAM, HOOD_SPOTWELD • SECIDs 11, 21	
*HOURGLASS	Defined hourglass control	

Keyword	**Explanation**	
*MAT_PIECEWISE_LINEAR_PLASTICITY	**BUMPER BEAM** • MID 9 • BPR_LOWER_BEAM, BPR_UPPER_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 • 8 data points for stress-strain behaviour **ALUMINIUM** • MID 10 • GRILLE_BEAM, 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 **OTHER** • MID 200 • WINDSCREEN_FRAME, HOOD_FLANGE_WELD_PLATE, HOOD_FLANGE_30mm, HOOD_FLANGE, HOOD_SKIN, HOOD_EDGE_COVER • density: ρ = 7.8e-006 kg/mm3 • Young’s modulus: E = 210 GPa • Poisson’s ratio: ν = 0.3 • LCSS 200 **PE300** • MID 1300 • BPR_LOWER_COVER, BPR_LOWER_COVER_INNER, BPR_UPPER_COVER, BPR_UPPER_COVER_INNER, GRILLE_COVER, WINDSCREEN • density: ρ = 9.6e-007 kg/mm3 • Young’s modulus: E = 0.9 GPa • Poisson’s ratio: ν = 0.4 • *DEFINE TABLE • LCID 1310, 1311, 1312, 1313, 1314	
*MAT_NULL	• MID 42 • HOOD_EDGE_COVER_BEAM • density: ρ = 7.85e-006 kg/mm3 • Young’s modulus: E = 210 GPa • Poisson’s ratio: ν = 0.3	

Keyword	**Explanation**	
*MAT_RIGID	**RIGID_BEAM** • MID 43 • HOOD_EDGE_BEAM_TOWER_BEAM_INSIDE • density: ρ = 7.81 e-006 kg/mm3 • Young's modulus: E = 206 GPa • Poisson's ratio: ν = 0.3 **RIGID** • MID 99 • STRINGPOT_RIGID, RIGID • density: ρ = 7.81 e-006 kg/mm3 • Young's modulus: E = 206 GPa • Poisson's ratio: ν = 0.3 • Constrained in all translational and rotational DoFs	
*MAT_SPOTWELD	**HOOD_SPOTWELD** • MID 56 • HOOD_SPOTWELD • density: ρ = 1.95 e-005 kg/mm3 • Young's modulus: E = 20 GPa • Poisson's ratio: ν = 0.3	
*MAT_SPRING_GENERAL_NONLINEAR	• MID 96 • SPRINGPOT • LCID 96	

3.4 *TUC_WB_PEDESTRIAN_SAE_CONSTRAINTS.key* – Constrained cards and contacts

The following contacts and constraints are defined in the validation environment.

Keyword	Explanation	
*CONSTRAINED_EXTRA_NODES_NODE *CONSTRAINED_RIGID_BODIES *CONSTRAINED_NODAL_RIGID_BODY	• PIDs 5, 6, 7, 11, 12, 13, 343, 344, 345, 346, 347, 350, 351, 354, 355, 356, 357, 358, 359, 360, 361	**Constraint**
*CONSTRAINED_JOINT_LOCKING *CONSTRAINED_JOINT_TRANSLATIONAL	• IDs 48, 49, 50, 51, 52, 53, 54, 55	**Joints**
*SET_NODE_LIST	• SID 326: referenced in *CONSTRAINED_EXTRA_NODES_NODE • SIDs 5, 6, 7, 11, 12, 13, 343, 344, 345, 346, 347, 350, 351, 354, 355, 356, 357, 358, 359, 360, 361 referenced in *CONSTRAINED_NODAL_RIGID_BODY	**Node sets**
*CONTACT_TIED_SURFACE_TO_SURFACE *SET_PART_LIST	• CID 5 • SIDs 327, 328	**Contact**
*CONTACT_AUTOMATIC_SINGLE_SURFACE_ID_MPP *SET_PART_LIST	• CID 11111111 • SID 1	
*CONTACT_AUTOMATIC_GENERAL_ID_MPP *SET_PART_LIST	• CID 200002 • SID 4	

3.5 *TUC_WB_PEDESTRIAN_SAE_BCs.key* – Boundary Conditions

The following boundary conditions are defined in the validation environment.

Keyword	Explanation	
*INITIAL_VELOCITY_GENERATION *BOUNDARY_SPC_SET *SET_NODE_GENERAL *SET_PART_LIST	• To apply an initial velocity of 40 km/h (11.11m/s) to the buck in x-direction • SIDs 11111, 222	**Velocity**

3.6 *TUC_WB_PEDESTRIAN_SAE_OUTPUT.key* – output definitions

The following output parameters are defined in the validation environment.

Keyword	**Explanation**	
*DATABASE_BINARY_D3PLOT	time step = 1.0 ms	**Binary**
*DATABASE_BINARY_D3THDT		
*DATABASE_EXTENT_BINARY		
*DATABASE_DEFORC *DATABASE_JNTFORC *DATABASE_NODOUT *DATABASE_RCFORC	Time step = 0.05 ms	**Time-history**
*DATABASE_SECFORC *DATABASE_RBDOUT *DATABASE_ELOUT *DATABASE_GLSTAT *DATABASE_MATSUM *DATABASE_SLEOUT	Time step = 0.1 ms	
*DATABASE_HISTORY_NODE_ID	BUCK CoG	

4. Validation Protocol

The following validation protocol is a step-by-step procedure to safeguard a credible validation of any HBM this validation environment is used for. The protocol is composed of three parts containing the following information:

1. **Pre-processing**
   Coming soon
2. **Solution**
   Coming soon
3. **Post-processing**
   Coming soon

It is envisaged that the following protocol can be applied to any HBM which is to be validated against the above mentioned loading condition.

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.