TUC Validation Repository

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Documentation
Validation Environment
LS-Dyna

Whole-Body Pedestrian Impact with a Generic Buck

Version:	V02
LS-Dyna version provided by:	Autoliv
Last updated:	September 15th, 2022
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_V02.dyn*
   b. *TUC_WB_PEDESTRIAN_SAE_BCs_V02.k*
   c. *TUC_WB_PEDESTRIAN_SAE_BUCK_V02.k*

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	LS-Dyna

1.2 Disclaimer

The validation kit was developed in close cooperation within the THUMS USER COMMUNITY 3 (TUC3) 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, Mazda Motor Corporation, Mercedes-Benz AG, Porsche AG, Toyota Motor Corporation, Volkswagen AG and ZF Automotive Germany GmbH 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 anyuse of, reference to and/or reliance upon this manual.

University of Munich (LMU), AUDI AG, Autoliv, BMW AG, Mazda Motor Corporation, Mercedes-Benz AG, Porsche AG, Toyota Motor Corporation, Volkswagen AG and ZF Automotive Germany GmbH ask that the TUC3 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.

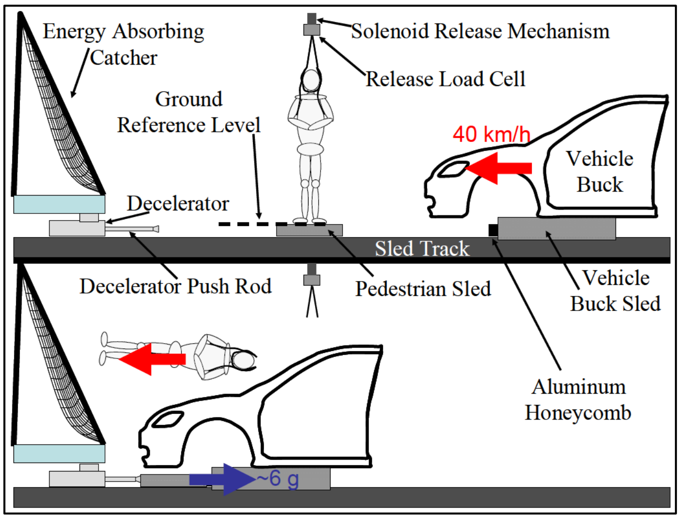


Figure 1 Experimental setup in Kerrigan et al. (7). Same test method was followed within experimental study of Forman et al. (1) using a standard generic vehicle front (SAE J3093)

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

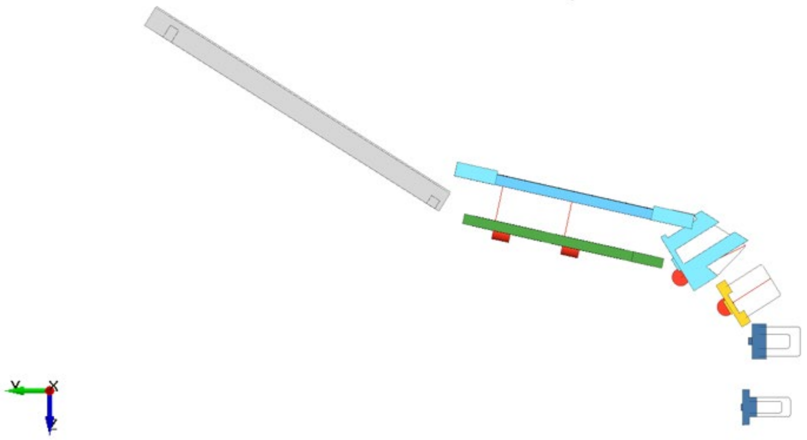
In this section the validation environment, i.e. the numerical model of the experimental setup excluding the HBM to be validated, is described by providing an overview of the keywords used in the above mentioned input decks:

TUC_WB_PEDESTRIAN_SAE_MAIN_V02.k,

TUC_WB_PEDESTRIAN_SAE_BCs_V02.k,

TUC_WB_PEDESTRIAN_SAE_BUCK_V02.k

Lateral view



Dark blue: bumper

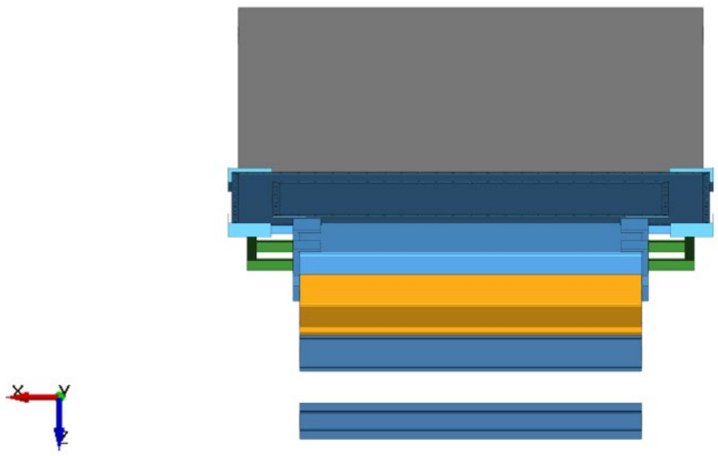
Yellow: grille

Light blue: hood

Green: engine block

Grey: windscreen

Red: stringpot



Frontal view

3.1 *TUC_WB_PEDESTRIAN_SAE_MAIN_V02.k* Main file

Keyword	Explanation
*TITLE	TUC_WB_PEDESTRIAN_SAE_MAIN_V02
*INCLUDE	**Included files are:** • TUC_WB_PEDESTRIAN_SAE_BUCK_V02.k • TUC_WB_PEDESTRIAN_SAE_BCs_V02.k • [HBM.k]

Controls

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

Keyword	Explanation
*CONTROL_TERMINATION	ENDTIM = 120 ms (see validation protocol)
*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

Database Definitions

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

Additional Definitions

Keyword	Explanation
*CONTACT_AUTOMATIC_SURFACE_SURFACE	Contact definitions for integration of HBM with ID 330, 331 and 332
*SET_PART_LIST	**HBM Outer Surface** • ID 330 • Outer shell parts of HBM to be selected **HBM Head Outer Surface** • ID 331 • Outer shell parts of HBM Head to be selected **HBM Body Outer Surface** • ID 332 • Outer shell parts of HBM Body to be selected **Buck Contact Surface** • ID 329 Parts: 10, 20, 30, 40, 50, 60
*LOAD_BODY_Z *DEFINE_CURVE_TITLE	• To apply gravity in local z-direction Uses local CS: ID 9

3.2 *TUC_WB_PEDESTRIAN_SAE_BUCK_V02.key* SAE buck model

Parts and Mesh

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 Ground (to be adapted to HBM according to protocol) • 1 part with ID 102
*PART_CONTACT	**Hood** • 5 parts with ID 50, 52, 53, 54, 55, 56 **Windscreen** • 1 part with ID 62
FE mesh, elements and nodes	**Hood** • *ELEMENT_BEAM: ID range 1-42 • *ELEMENT_DISCRETE: ID range 43-46 • *ELEMENT_MASS: ID 47 • *ELEMENT_SHELL: ID range 77-257024 • *ELEMENT_SOLID: ID range 125873-156190 • *NODE: ID range 1 - 311782

Sections

Keyword	• Explanation
*SECTION_BEAM	• Parts: HOOD_EDGE_COVER_BEAM, HOOD_EDGE_BEAM_TOWER_BEAM_INSIDE • SECIDs 12, 22
*SECTION_DISCRETE	• Part: STRINGPOT • SECID 23
*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, GROUND_RIGID • SECIDs 9, 10, 30, 40, 50, 60, 70, 80, 102
*SECTION_SOLID	• Parts: BPR_LOWER_BEAM, BPR_UPPER_BEAM, GRILLE_BEAM, HOOD_EDGE_BEAM, HOOD_SPOTWELD • SECIDs 11, 21
*HOURGLASS	Defined hourglass control

Materials

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, ENGINE_BLOCK, HOOD_SUPPORT, WINDSCREEN_FRAM_RIGID • density: ρ = 7.81 e-006 kg/mm3 • Young's modulus: E = 206 GPa • Poisson's ratio: ν = 0.3 • All DOFs constrained except X translation in local CS (ID 9) **GROUND_RIGID** • MID 102 • GROUND_RIGID • density: ρ = 1e-005 kg/mm3 • Young's modulus: E = 210 GPa • Poisson's ratio: ν = 0.4 All DOFs constrained in global CS
*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

*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
*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)

Constraints

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
*CONSTRAINED_JOINT_LOCKING *CONSTRAINED_JOINT_TRANSLATIONAL	• IDs 48, 49, 50, 51, 52, 53, 54, 55
*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

Contacts

Keyword	Explanation
*CONTACT_TIED_SURFACE_TO_SURFACE *SET_PART_LIST	• CID 5 • SIDs 327, 328
*CONTACT_AUTOMATIC_SINGLE_SURFACE_ID_MPP *SET_PART_LIST	**Vehicle** • Buck Self Contact • CID 11111111 • SID 1
*CONTACT_AUTOMATIC_GENERAL_ID_MPP *SET_PART_LIST	**HE_TOWER_to_GE_COVER_BEAMS** • Front Hood Clamping Self Edge Contact • CID 200002 • SID 4

Local Coordinate System

Keyword	Explanation
*DEFINE_COORDINATE_NODES_TITLE	• ID 9 Used in definitions of SPCs (rigid materials), initial velocity and gravity

3.3 *TUC_WB_PEDESTRIAN_SAE_BCs_V02.k* Specifications for the Validation Environment

Keyword	Explanation	
*INITIAL_VELOCITY_GENERATION *SET_PART_LIST	• Initial velocity of 40 km/h (11.11m/s) for the buck in local x-direction • Uses local CS: ID 9 • SID 222	**Velocity**

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.