Book of Abstracts: Workshop on Virtual Development in Passive Safety and Human Models for Future Mobility 2021

University of West Bohemia

Technische Hochschule Ingolstadt

September 21, 2021

**BOOK OF ABSTRACTS:
WORKSHOP ON VIRTUAL DEVELOPMENT IN PASSIVE SAFETY AND HUMAN MODELS FOR FUTURE MOBILITY 2021**

ISBN 978-80-261-1046-0

Published by
University of West Bohemia, Univerzitní 8, 301 00 Plzeň, Czech Republic, IC 49777513

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Learn and Get Inspired

The event addresses topics from virtual development in passive vehicle safety for the mobility of the future. It contains research work, reaching from biomechanics and human body modelling to crash and occupant simulations, as well as crash accident reconstruction. The main objective is to connect young Bavarian and Czech researchers in this field.

The workshop is planned as a one-day online event. It includes two keynote lectures from Czech and German recognised experts. Prof. Jan Kovanda from University of West Bohemia and Prof. Axel Schumacher from University of Wuppertal. There will be two sessions of young researchers' presentations following with a discussion forum on the presented topics.

This workshop, which was attended by over twenty-six participants from the Czech Republic, Germany and from abroad, was organised by the Department of Biomechanical Human Body Models New Technologies - Research Centre University of West Bohemia and CARISSMA - Center of Automotive Research on Integrated Safety Systems and Measurement Area, Technische Hochschule Ingolstadt under the auspices of

- The Bavarian-Czech Academic Agency,
- European Regional Development Fund-Project
  "Application of Modern Technologies in Medicine and Industry"
  (No. CZ.02.1.01/0.0/0.0/17_048/0007280),
- Czech Society for Mechanics.

Bayerisch-Tschechische Hochschulagentur
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EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

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Keynote Lecture's Extended Abstracts

Optimization methods for the development of crash structures.

21 Sep
09:30am

Prof. Dr.-Ing. Axel Schumacher, Chair for Optimization of Mechanical Structures
University of Wuppertal

Abstract

By using mathematical optimization methods, new structural designs are generated. Especially the topology optimization generate also new concepts. The topology optimization method are efficient in the field of structural design, taking into account linear structural properties and linear static loading conditions. E.g. the homogenization method introduced by M. Bendsøe and N. Kikuchi in 1988 (Comput. Methods Appl. Mech. Eng. 71:197–224) minimizes the mean compliance considering a mass constraint. Therefore, they divide the design space into small voxel and decide based on an analytical sensitivity for every voxel, is there material or not. After this optimization, the engineer has a good proposal and the possibility for the interpretation and the generation of a CAD model.

The consideration of the mean compliance is much too simple for the optimization of crash-loaded structures. When crash load cases have to be considered, the special characteristics of the highly non-linear dynamic crash problems have to be taken into account. Large deformations and rigid body displacements occur during a crash incident. The used material laws are mostly nonlinear because the kinetic energy is absorbed by plastic deformation. For the correct prediction of the material behavior, strain rate dependencies and complex failure criterions have to be considered. The majority of the forces is transmitted via contact. In additional to that, the crash simulation is much more complicate as the linear simulation of structures:

- non-smooth structural behavior
- not enough material data
- important scatterings of the material data
- mesh-dependent results
- physical bifurcations

- simulation bifurcations
- input deck optimized for a special design point

In the topology optimization we deal with all these problems. We have requirements like:

- Consideration of special acceleration values like the HIC value
- Energy absorption,
- Special force levels,
- Smooth force-displacement curve,
- Smooth acceleration-time curve,
- Special force paths for special loadcases.
- High stiffness of special parts, e.g. parts in a main force paths in the passenger area
- Low stiffness of special parts, e.g. at positions of the head contact of a pedestrian,
- Special safety criteria, e.g. no leakage of the petrol system.

One of the first works in the area of topology optimization for crashworthiness was the work of R.R. Mayer, N. Kikuchi and R.A. Scott in 1996 (Int. J. Numer. Methods Eng. 39:1383–1403). Their optimization method is based on the voxel method and an optimality criterion is used to maximize the energy absorption at specific weighted times. A resizing algorithm is utilized for the alteration of the design variables and a threshold algorithm is used to delete finite elements from the structure.

In the "Hybrid Cellular Automaton (HCA)" method of N.M. Patel et al. published in 2009 (J. Mech. Des. 131:061013.1–061013.12) an optimality criterion is used which is based on a homogenous distribution of the inner energy density. The design space is divided into cells in which the finite elements have an artificial density. These artificial densities have influence on the mechanical properties of the finite elements and are used as design variables for the optimization. The inner energy density distribution is homogenized with a material distribution rule, which changes the design variables. Neighbourhood relationships can be taken into account by the "Cellular Automaton Lattice". Displacement, mass and force constraints can be used in the optimization.

The "Equivalent Static Loads Method (ESLM)" of G.J. Park published in 2011 (Struct. Multidisc. Optim. 43:319–337) uses a nonlinear dynamic analysis domain and a linear static optimization domain. An iteration of this optimization method consists of a nonlinear dynamic simulationand a linear static optimization. Equivalent static loads are calculated for discrete times of the nonlinear dynamic simulation. They are calculated such, that they cause the same displacement field in the initial design of the linear static optimization as the structure has in the non-linear dynamic simulation at the specific time. The linear static optimization is performed with a multiple loading condition using the equivalent static loads. Due to the nonlinearities, other structural responses like strains and stresses are not identical in the analysis and the optimization domain.

The "Graph and heuristic based topology optimization (GHT)" of C. Ortmann and A. Schumacher published in 2013 (Struct. Multidisc. Optim. 47:839–854) was developed because of the limitations of the voxel-based methods. The approach combines topology, shape and sizing optimization and use established finite element shell models for the crash simulation. The optimization task is divided into an outer optimization loop which performs the topology optimization and an inner optimization loop which performs the shape and sizing optimization (Figure 1).

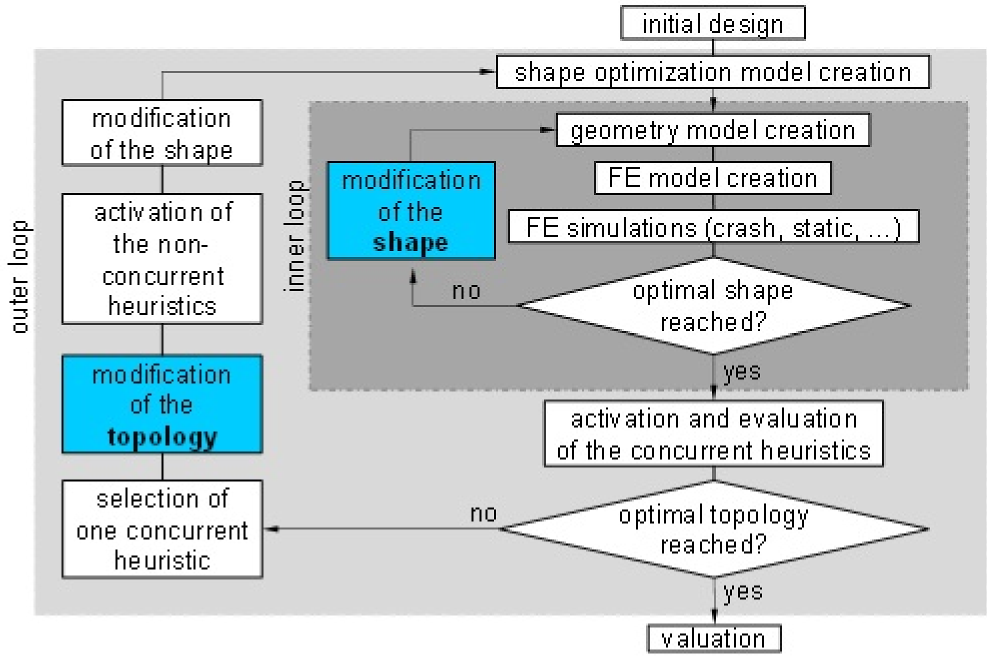

Figure 1: Optimization scheme of the graph and heuristic based topology optimization (GHT)

The inner loop is carried out with mathematical optimization algorithms while the outer loop uses in addition to mathematic tools heuristics (rules), which are derived from expert knowledge. E.g.:

- delete unnecessary walls,
- support fast deforming walls in order to avoid buckling,
- remove small chambers to simplify structures,
- balance energy density,

- use deformation space,
- smooth structure to simplify structures.

The basis for the modification of the geometry by the optimization software and for the automatic creation of input decks for the crash simulation is a flexible description of the geometry using mathematical graphs. The first approach is the optimization of profile cross-section of the structure abstracted by a planar graph, which reduces the geometric optimization problem to the second dimension, although the structure itself and all performed simulations are three dimensional.

Application examples

The shown application examples are optimized with the GHT. The first example is an academic application (figure 2): A simple frame structure clamped on the left side. A sphere with a mass of 1.757 kg hit the structure with an initial vertical velocity of 6.25 m/s. Two optimization tasks are considered:

1. minimize the maximum intrusion with a constraint of the mass $\leq$ 0.027 kg
2. minimize the maximum acceleration with a constraint of the intrusion $\leq$ 49 mm

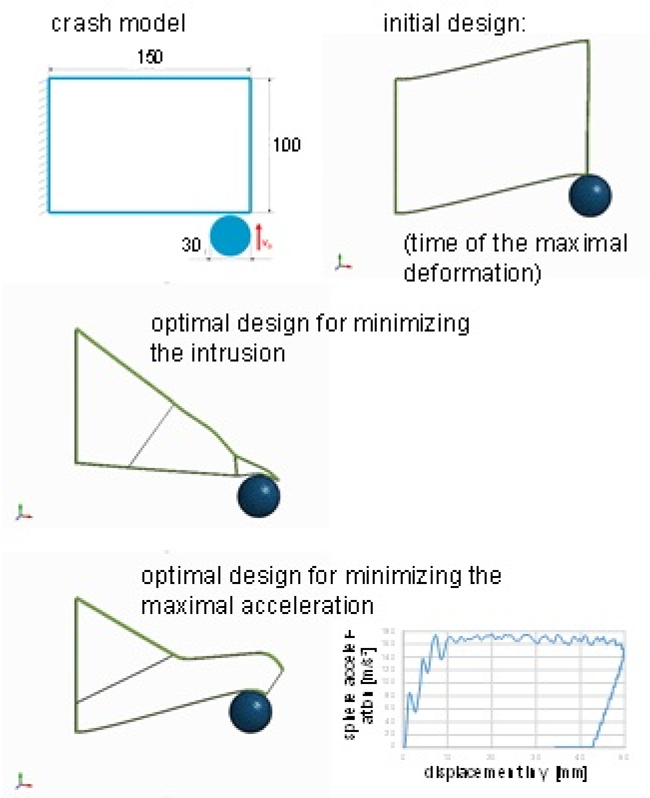

Figure 2: Topology optimization of a frame.

The second example is submodel of an automotive rocker again a pole (Figure 3). The optimization tasks is to find the optimal topology and shape of the cross section of the rocker profile. The goal is the minimization of the maximal force at a moved rigid wall, so that some stiffness constraints and the manufacturing constraints are fulfilled.

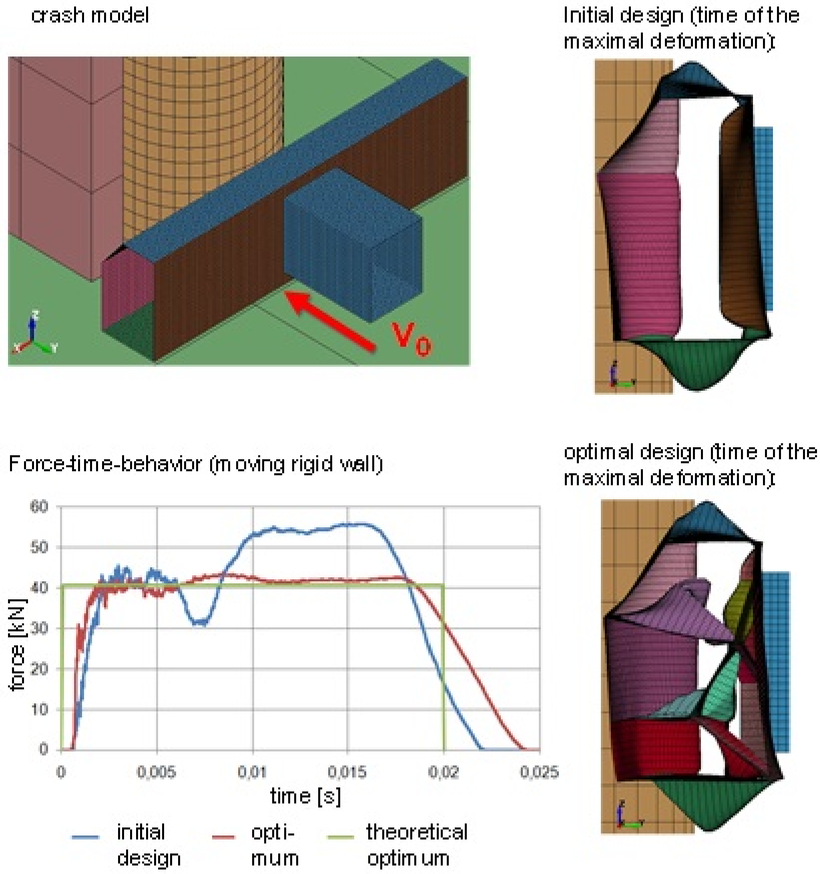

Figure 3: Topology optimization of a rocker.

Especially the force-time curve and the acceleration-time curve of the optimal results are impressively, because there are nearby the theoretical optimum (constant level during the crash time).

Note: This abstract text is similar to the text in the automotive safety Companion:
https://www.carhs.de/de/companion-poster/product/automotive-caecompanion-20212022-digital-pdf.html

21 Sep
10:00am

Safety of Future Mobility

Prof. Jan Kovanda
University of West Bohemia, Faculty of Mechanical Engineering, Regional Technological Institute, CZ

Abstract

The global road safety problems in relation to the Vision Zero [5] and current statistics

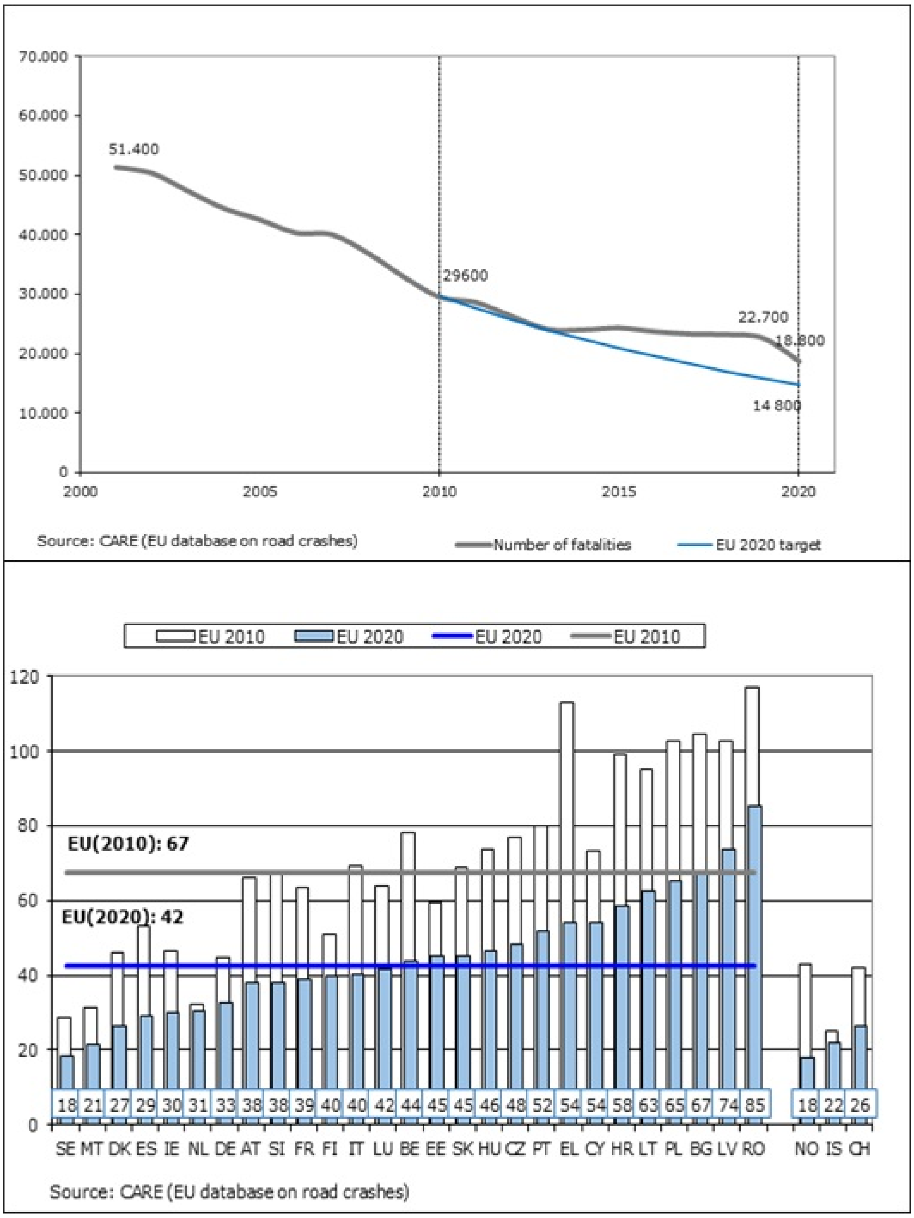

Figure 4: EU Road Statistics, source CARE (EU database on road crashes)

Fatalities are just the tip of the Iceberg according to the WHO 2013/2015 and Worldbank/IHME 2014. Important is The 2030 Agenda for Sustainable Development, adopted by all UN Member States in 2015.

Future Outlook

Global Societal Trends 2030+:
Strong increase in population, particularly in Asia and Africa, aging population, increasing urbanization and congested megacities, increase of motorization in low and middle income countries, climate change: urgent need to reduce CO2 and emissions due to transportation, many new technology developments including automation, policy focus on liveable cities and smart cities. Solution: lightweight vehicles, autonomous driving, roadway management, electrification, virtual testing and its growing role:

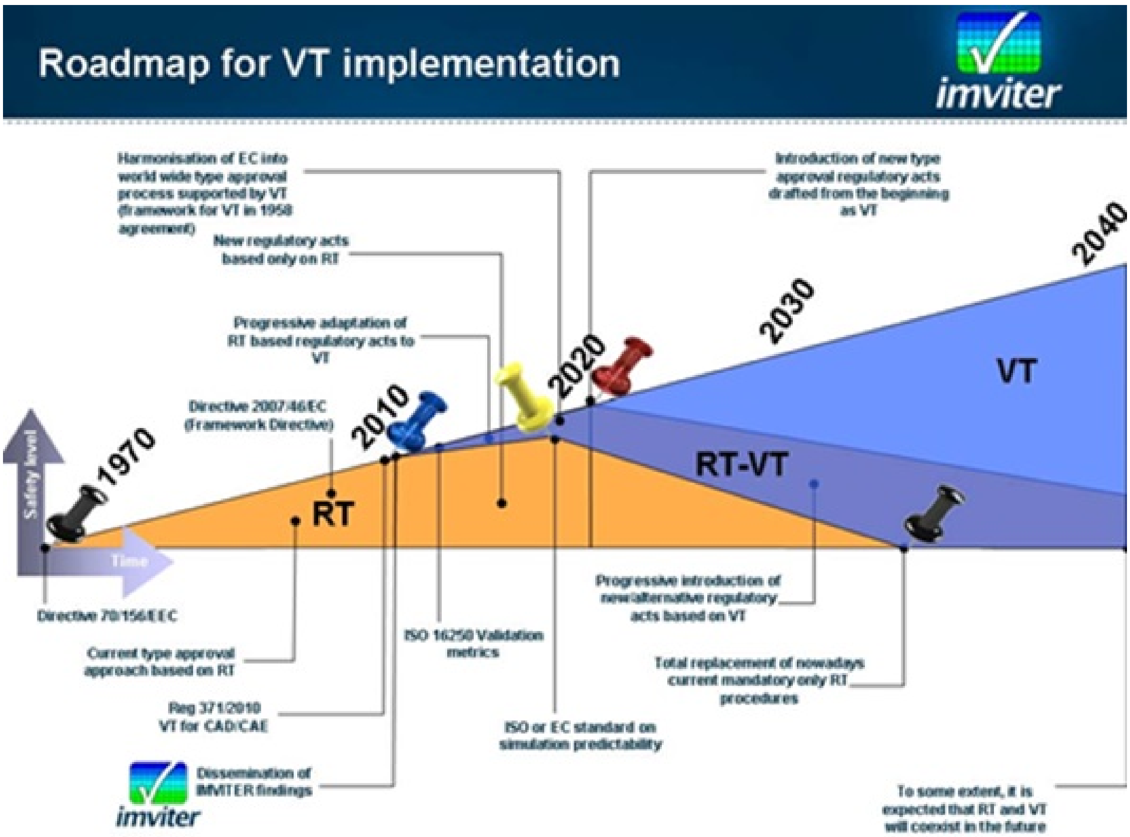

Figure 5: Roadmap for VT, source Imviter project [1], [2], [3]

Example of Safety project on UWB – The Safe Tram Front End:

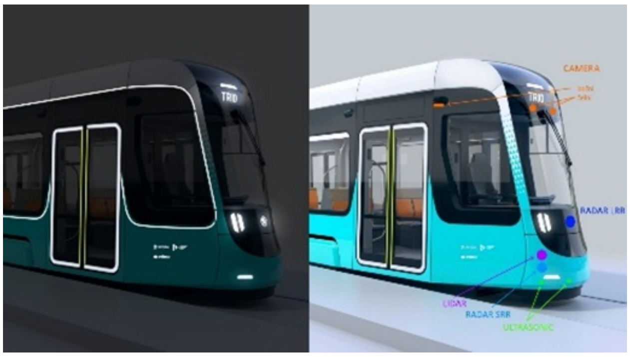

Figure 6: Skoda Transportation safe front end, source Project Final Report [4]

Conclusion:

- Next to further improvements in vehicle safety (incl. autonomous driving), prioritization should be given to vulnerable road users like separate lanes for Non-Motorized Traffic (NMT), helmet usage for pedal bikes and in particular e-bikes,
- Also very important is better and safer public transport especially for the elderly. Note that public transport is ¿ 10 times safer than cars per km travelled,
- Measures to improve motorcycle safety like ABS, helmets, protective clothing, visibility and most importantly Intelligent Speed Adaption (ISA),
- Measures for trucks include blind spots, compatibility with other road users, EA fronts, ISA etc.

References:

[1] Wismans, J.: Global Challenges for Road Safety till 2030. The 2nd International Symposium on Future Mobility Safety Science and Technology. 2019, Pilsen, CZ

[2] Wismans, J.: Reflection on 50 Years of Human Body Modelling and Future Challenges from a Global Perspective. 8th International Symposium Human Modeling and Simulation in Automotive Engineering, 2020, Wiesbaden, Germany

[3] Corgero, R.: Imviter Final Report, Cidaut 2007, Spain

[4] Rajdl, P. et all: Final Report of Safe Tram Front End Project. Skoda Pilsen 2021, CZ

[5] Commision Document: EU Road Safety Policy Framework 2021-2030, 2019, Brussels

Abstracts

Does Virthuman suggest non-standard seating for families in highly automated vehicles?

21 Sep
10:40am

Abbas Talimian, Ph.D.
University of West Bohemia

Highly automated vehicles (HAVs) will be the main part of future mobility. The usage of automated driving systems (ADS) in HAVs can remarkably decrease car accidents. But it takes a long time to equip all vehicles with fully automated systems. Since then, considering passenger safety in car crashes is a must. On the other hand, a vehicle's interior faces fundamental changes by increasing the share of machines in controlling a vehicle. For instance, cars no longer need a steering wheel. It gives a chance to HAVs' occupants to rotate their seats and be in non-standard seating configurations. The present study's simulations were done by the application of Virthuman model - two genders and different ages (Boy, Girl, Female and Male) - showed these non-standard seating configurations can be safe for a family. But current passive safety tools are not efficient to be used in non-standard seating configurations hence some modifications are needed to be done on the vehicle's seat. More specifically a seat's headrest and seatbelts.

21 Sep
11:00am

Status of the Assessment of the Influence of Human Body Diversity on Passive Safety Systems.

Franz Plaschkies

Technische Hochschule Ingolstadt

For assessing the vehicle's interaction with its occupants, few anthropometric configurations – technical surrogate models, so-called crash test dummies, are being used during a car´s development. This state-of-the-art overview presents approaches to broaden the testing during the system development to increase its robustness. Current occupant safety development methods are summarized and available databases for the human body listed. Relevant studies on expanding the informative value utilizing machine learning methods are presented, and approaches to overcome the requirements of the vast amount of data for machine learning are mentioned.

Methodologies for crash reconstruction and data comparison.

21 Sep
11:40am

Shahabaz Afraj

Technische Hochschule Ingolstadt

In the automobile industry, the development of passive safety system is a very crucial domain of engineering. The effectiveness of this system has to be achieved by continuous testing and validation. Hence, data models that can mathematically represent the various responses of vehicle crash behavior are fundamental necessities for the analysis. Within the scope of our presentation we explore different methodologies to arrive at the required parameters in the analysis of a crash scenario, mainly crash tests in controlled environment and on-road vehicle crashes using different approaches.

21 Sep
01:30am

Testing and identification of the LLDPE material for impact applications.

Jan Špička
University of West Bohemia

Current industrial trends bring new challenges in energy absorbing systems. Polymer materials as the traditional packaging materials seem to be promising due to their low weight, structure, and production price. Based on the review, the linear low-density polyethylene (LLDPE) material was identified as the most promising material for absorbing impact energy. The current paper addresses the identification of the material parameters and the development of a constitutive material model to be used in future designs by virtual prototyping. The paper deals with the experimental measurement of the stress-strain relations of linear low-density polyethylene under static and dynamic loading. The quasi-static measurement was realized in two perpendicular principal directions and was supplemented by a test measurement in the 45∘ direction, i.e., exactly between the principal directions. The quasi-static stress-strain curves were analyzed as an initial step for dynamic strain rate-dependent material behavior. The dynamic response was tested in a drop tower using a spherical impactor hitting a flat material multi-layered specimen at two different energy levels. The strain rate-dependent material model was identified by optimizing the static material response obtained in the dynamic experiments. The material model was validated by the virtual reconstruction of the experiments and by comparing the numerical results to the experimental ones.

Problematic of materials for personal protective equipment - ecology and 3D printing.

21 Sep
01:50pm

Sandra Kaňáková

University of West Bohemia

The quality of personal protective equipment is constantly improving. However, its frequent replacement raises questions about the ecology of used materials. Both the production and, above all, the disposal of protectors with regard to the environment is important. Unfortunately, this is a problem that is not so obvious to most end customers. This work focuses on the recyclable materials which can be used as energy-absorbers in personal protective equipment. A series of impact tests were carried out to demonstrate the energy-absorbing ability of these materials. Furthermore, a bicycle helmet was designed using outstanding material.

21 Sep
02:10pm

Development of innovative active head restraint system in a car using virtual tools.

Jan Vychytil
University of West Bohemia

We present the idea of an innovative active headrest system for head and neck protection of an occupant. Its FE model is created and embedded in a model of a small car. The occupant is represented with the virtual human body model Virthuman. Consideration of different side impact scenarios based on EuroNCAP testing protocols, standard and out-of-positions seating leads to more than 100 simulations. The results in terms of injury risk helps to improve the design of the headrest system step-by-step in the process of virtual development.

Structure concept with the addition carbon fiber layers and filling forms for crashworthiness increase.

21 Sep
02:30pm

Stanislav Špirk, Ph.D.
University of West Bohemia

The contribution describes bus construction with the addition carbon fibre layers and filling foams, used as local reinforcement of the structure. Here the composite materials and manufacturing technologies reduce the weight of the bus vehicle. This paper is more focused in the crash field (especially rollover Ro.66). The main work is connected with simple beam model, but the general results will be applied in bus construction.

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