STRONG COMMITMENT TO INCREASING DRIVING SAFETY

In order to reflect the shift towards assisted and automated driving technologieswith respect to safety, Euro NCAP wants to adapt its assessment rules, which have been in force since 2009. In doing so, virtual tests are to be introduced and, in addition to dummies, human body models are to be permitted to analyze injury risks. In this area of tension, the conference 'Human Modeling and Simulation in Automotive Engineering' provided holistic substantive impulses on future innovations in the protection of occupants, pedestrians, and cyclists.

MARBURG/Germany, December 2024 (bv). In the spring of 1978, at a conference organized by the VDI (Association of German Engineers), the results of a simulation of the accidental crash of a fighter plane into a nuclear power plant were presented. This art of engineering work made German automotive OEMs aware of the possibility of making use of crash simulation methods. Then in the fall of 1985, at a user meeting held by supercomputer manufacturer Cray in Montreal, a comparison was presented between the simulation of a frontal crash of a VW Polo and photographs of a physical crash test from the previous year. Shortly afterwards, Peugeot used the first human body models in virtual crashes.

The discussion of results on human body modeling (HBM) can also look back on a long tradition. The symposium 'Human Modeling and Simulation in Automotive Engineering' took place for the tenth time. The two-day event has been organized every two years since 2007 by the global player carhs training GmbH from Alzenau/Germany. Special of this conference format is the clear focus on the automotive industry, because there are many areas of application for human body modeling. One of the main focus of this year's symposium was analyzing the risk of injury in the event of vehicle accidents (crashes).

Since the first event, the content has been coordinated with the Wayne State College of Engineering from Detroit/ US state Michigan. In fact, Wayne State University was the first institution to begin collecting scientific data on the effects of car accidents on the human body. "The goal is to bring researchers and developers of human body models together," said conference manager Dr Dirk Ulrich of carhs training in his opening speech. A total of 39 scientifically based presentations were offered in seven consecutive tracks. Sponsors were BETA CAE Systems, Applus+ IDIADA, DYNAmore, Elemance, GNS, and Oasys.

Keynote: Human body models must be part of the calculation

Michiel van Ratingen, Euro NCAP: 'Maximizing Safety — Why Human Models Must Be Part of the Equation'

The 'apéro' was hosted by Michiel van Ratingen, Secretary General of Euro NCAP. The organization, which represents European transport ministries, automobile clubs and insurance associations, is based in Leuven, Belgium, and is committed to the introduction of robust safety technologies for assisted and automated driving. This includes optimizing test scenarios to guarantee functionality in bad weather conditions and proactively providing information for effective emergency measures (for example in the event of a BEV crash) for first responders or the fire brigade.

According to Mr van Ratingen, improving accident protection for adults and children with a stronger focus on population diversity in the sense of greater equality is attracting political interest. The goal should be to ensure safety for everyone — regardless of gender, age, stature, weight, corpulence of adults and children — in all seating positions. "Our test methods must be adapted for this," he said, and brought virtual testing into play in order to be able to better evaluate the overall system performance. According to the secretary general, virtual testing makes it possible to use HBMs. In system performance studies, greater robustness can be achieved by taking additional load cases into account – not just crashes at an angle of incidence of, say, 90° (far side sled), but also at 95° or 100°.

Even though almost all eyes currently seem to be on HBMs, we must not ignore what has been achieved so far with anthropomorphic test devices (ATDs, better known as crash test dummies) to measure the human injury potential in vehicle accidents. There are also virtual prototypes of the ATDs.

Mr van Ratingen acknowledged this, but also mentioned that the costs of further developing ATDs are high and patience is required for the time required: The development of THOR began in 1982 at the US NHTSA (National Highway Traffic Safety Administration) as part of a research contract with the Highway Safety Research Institute at the University of Michigan. The THOR dummy is currently the most advanced dummy model for frontal impact testing. Compared to the previous standard frontal impact dummy (Hybrid III 50% man), it has improved biofidelity, i.e. the reproduction of human body behavior, as well as expanded instrumentation to better determine the relevant parameters in relation to injuries and injury mechanisms.

It wasn't that long ago that Euro NCAP relied entirely on ATDs: In 2020, the crash test organisation proposed using the male 50 % THOR dummy in some of its safety assessment tests. But times have changed and Mr van Ratingen stressed that the shorter development cycles for vehicles that were being sought did not match those of ATDs: "Dummies are very useful, but they are also very inflexible." But not everything that glitters is gold with HBMs either. The problem is that they are not yet standardized for productive use in crash scenarios. They are more tools for experts, not for the typical development engineer. Although the results are very promising, there are still many hurdles to overcome in the context of Euro NCAP's activities. "Use HBMs to gain deeper insights into your work rather than focusing on replacing ATDs," recommended the secretary general. If you like, he advocated the peaceful coexistence of both replica forms of human beings. The following is an excerpt from reports given at the symposium.

Track: Biomechanics

Cynthia Bir, Cameron (Dale) Bass, Wayne State University: 'Undamped Tribulations – Soft Tissue and Validation in Human Body Models'

Cynthia Bir took on the role of experimental scientist and pointed out that there are mutual dependencies between experiment and numerical modeling. She emphasized that there is a large selection of test methods at the tissue level, for example to determine stress-strain curves and elastic modulus, Poisson's number or viscoelastic coefficients. This requires a great deal of sensitivity.

Cameron Bass then discussed the modeling of tissue properties using the example of the brain, which has

very different properties under different loads: non-linear under volumetric load and shear load; also viscoelastic, anisotropic or inhomogeneous; almost incompressible; demonstrable Poynting effect; stress-pressure asymmetry and strong temperature dependence. This is reflected in a large number of models that are justified for specific applications. It must always be clarified what resolution the models represent, he said.
For example, the Lagrangian finite element method with 100 000 or more hexahedral elements at an average resolution of 2.5 mm is used to predict injuries. “The problem, of course, is that the moment the resolution is increased, the computing time increases significantly, especially when it comes to imaging shear phenomena. And almost all deformations occur in shear mode, so we have to reproduce shear phenomena correctly!“, said Mr Bass emphatically. Shear shocks can be the cause of mild to severe neurotrauma in the brain above a certain intensity.

At Wayne State University, a complex approach based on finite volume element methods was developed to reproduce shock waves in tissue. This went well beyond the current state of science, said the scholar. It followed deep insights into the complexity of biomechanical processes. These had to be reproduced very precisely, as to hear, in order being able of sharing the results with a wider range of experts than before.

Özgür Cebeci, IAT: ‘Parametrized Statistical Shape and Appearance – Modelling Strategy to Predict Proximal and Diaphyseal Femur Fractures’

In the distal femur fracture, the bone is broken in the area of the knee joint. The topic is highly controversial because the mortality rate in older people in the first year after this type of femur fracture is over 20 percent. The goal of the study presented by Özgür Cebeci was to develop and evaluate a parametric modeling method that takes into account the influence of changed anthropometry and age in fracture prediction.
A parametric representation was generated from a so-called baseline femur model. The femur bones modeled in this way were examined with regard to three-point bending, axial torsion, and lateral fall load. The results were evaluated with regard to the correlation with height, body mass index (BMI), and age. As a result of the study, Mr Cebeci said that parametric femoral models enable meaningful investigation of the influence of anthropometry at reduced costs.

Frank Meyer, Strasbourg University: ‘First validation and bone fracture reproduction under multidirectional loadings with an advanced Neck FEM’

Autonomous driving leads to unusual seating positions for the occupants in a vehicle. Frank Meyer’s first studies on the subject date back to 2004. At that time, the head and cervical vertebrae were only networked with shell elements and there was no coupling with HBMs. This was followed by a systematic further development of the approach until it was coupled to the Toyota HBM THUMS V4 in 2020 — the UNISTRA-Head-Neck-2020 model was created. It was dynamically validated with regard to the kinematics of the head in situations with impact from behind, front, side, and oblique (NBDL tests). Two types of injury were examined in particular in the approach: skull fracture and diffuse axonal injury. Diffuse axonal injury describes a pathophysiological feature that can occur in the context of a traumatic brain injury. The goal was to determine the lateral bending tolerance of the head-cervical spine system in an initially twisted head posture using loads on the occipital condyles. Calibration was carried out using a human who died at the age of 63. The experimental setup included a motion capture system with six cameras that measured the kinematics at 1 kHz. The approach is convincing because in the event of injury, UNISTRA-Head-Neck-2020 predicts the same type of fracture in the first cervical vertebra C1 as observed experimentally.

Passive human models

Xiaofan Wu et al., China Automotive Engineering Research Institute: 'Development and validation of AC-HUM'

Is the human body model approach based on European and North American humans suitable for representing Chinese people? A good question, as Xiaofan Wu made clear, because there are indeed differences in geometry and anatomy between people from the West and Asia that lead to differences in kinematics and injury responses. For example, the length, bone thickness and cross-sectional area of the Chinese femur are smaller than those of the US femur. Under the same loading conditions, the local high-stress area of the Chinese femur is larger than that of the US femur, says Mr Wu.
Immense effort was put into systematically recording the differences. The study collected more than 40 000 bone cross-sectional measurements. And over 3 000 biomechanical tests were carried out on human tissue to determine material data. A HBM series for men has been developed, and one for women is due to be released next year. These models will be gradually used in virtual crash simulations as part of a roadmap.

Akira Yamaoka et al., Toyota Motor Corporation: 'Development of a 50th percentile female human body model: THUMS AF50 Version 7.1 Occupant Model'

The Total Human Model for Safety (THUMS) is an HBM that has been actively developed by Toyota Motor Corporation and Toyota Central R&D Labs since 2000, so model updates and upgrades are regularly available. The commercial version of THUMS can be purchased in Germany from DYNAmore. In addition, a non-commercial version is available, but it is restricted for use by universities and research institutions. There is a so-called 50th percentile male occupant model (AM50) and a 50th percentile male pedestrian model (AM50). The three representative body sizes (05F, 50M and 95M) are often used to assess injuries in both ATDs and HBMs.

According to accident research, female occupants suffered more chest and lower limb injuries (especially ankles) in vehicle collisions than male occupants. Akira Yamaoka stressed that there is therefore a need for a '50F' model to take into account the promoted research on gender equity in occupant protection.
The new version 7.1 of the THUMS AF50 model was developed by scaling from AF05 model, but with some specific improvements: The rib cage was scaled taking into account the fact that it is not as voluminous in women as in men. The modeling of the ankle ligaments was also revised, correcting the origin and insertion points and adding missing ligaments. Validations in cases with anterior and lateral thorax loading and in the case of ankle inversion showed that the mechanical response curves calculated by the THUMS AF50 7.1 occupant model are within the PMHS test corridors (cadaver tests).

Active human body models

Niclas Trube et al., Fraunhofer EMI: 'Artificial Intelligence for real-time injury prediction — Development and Plausibility Assessment of an Active Human Body Model in Numerical Cyclist to Vehicle Collision Simulations based on Real-life Accident Data'

First, let us look at some aspects that characterize so-called active human body models (AHBMs). AHBMs take the movement and joint stiffness of the human musculoskeletal system into account via active muscle beam elements in a dynamic FEM. In modern HBMs, almost all human muscle groups are modeled in the form of 1D beam elements that connect each joint. While a lot of work has been put into improving the active and passive behavior of this 1D muscle system in the past, the volumetric muscle system of THUMS was modeled in a simplified way based on post-mortem test data on human subjects (PMHS). The stiffness-changing effect of isometric contraction, however, has so far hardly been taken into account for the volumetric muscle system of whole-body models.

Niclas Trube's presentation therefore focused on applying an AHBM developed by Fraunhofer EMI to the study of bicycle accidents with cars in order to reproduce the stabilizing influence of muscles in living people. The results should reproduce accident data from the GIDAS database better than before. GIDAS is the German study for in-depth traffic accident data collection. The project is sponsored by the Federal Highway Research Institute (BASt) and the Automotive Technology Research Association (FAT).

Background: The number of bicycle accidents in the EU has not decreased since 2010 and is even increasing in Germany. 53 percent of cyclists who died in accidents between 2015 and 2017 were due to collisions with cars. 81 percent of all cyclists killed in accidents in the EU between 2010 and 2019 are male. And they were not wearing a helmet. In the very well-founded study presented by Niclas Trube and colleagues, the results of the AHBM approach were compared with a PHBM-based (PHBM: Passive Human Body Model). A typical collision scenario between a vehicle and a bicycle was used for this purpose. "The data used on frontal collisions between a vehicle and a cyclist with a high number of injuries show that the dimensions of the front of the vehicle are similar to those of the Toyota Camry model and the height and weight of the injured cyclists can be described with those of THUMS V4.02 AM50," said Mr Trube. He then presented a whole catalog of details on the methods used. For example, a trekking bike model, also developed by Fraunhofer EMI, was used, which corresponded to the most common type of bikes in the filtered GIDAS data.

THUMS was positioned based on an average cyclist's posture. The corresponding data was extracted from video-documented car-cyclist collisions. It was slightly adjusted to correspond to the pedal positions, handlebars, and saddle of the bicycle FE model.

Mr Trube finally presented quite surprising results: PHBM and AHBM perform equally well in terms of kinematics, collision points, and injury-causing contact pairs. However, PHBM performs better on average than AHBM in terms of injury assessment. The comparison between simulation and GIDAS data showed that the stabilizing effect of muscle contraction during the accident influences injury prediction. However, the spokesperson did not specify in which form.

Conference day two: Pre- and Postprocessing of HBMs

Leyre Benito Cia, GNS mbH: 'Hans meets the GNS software – Handling of Human Body Models with Generator4 and Animator4'

As already evident from Niclas Trube's presentation, positioning a human body model in a vehicle or bicycle model is a challenging task. Support is therefore very welcome. Leyre Benito Cia demonstrated this using the example of 'Hans', the preprocessor Generator4 and the postprocessor Animator4.

Hans is an HBM that is suitable for various applications such as ergonomics, biomechanics, comfort and more. The model covers structural aspects and includes detailed representations of the human body, including its anatomy, physiology and mechanical properties. Hans impresses with its high accuracy of the musculoskeletal system and therefore enables realistic model kinematics and biofidelity.

Hans can be positioned in a driver's seat and the seat belt fastened using Generator4. In doing so, the user is guided through a dialog in four steps that organize his workflow and allow the simultaneous positioning of several dummies and HBMs.

A crash with Hans can then be evaluated using Animator4. This includes the documentation of head acceleration curves, brain damage, injuries to the chest cavities, ribs, cervical, thoracic, and lumbar spine. In addition, there are examinations of the intervertebral discs and organ damage.

Jens Bauer, Arup: 'Emergency brace positioning and injury risk prediction of aircraft occupants under impact loading'

The US Federal Aviation Administration (FAA) requires two different load cases (so-called 0° pitch, 16g; 60° pitch, 19g) with ATDs strapped in via two-point belts for the certification of aircraft seats. For this purpose, Jens Bauer presented a validated simulation method for the crash of civil aircraft using v-ATDs and HBMs alike. The method is used to investigate the kinematics and injury risks of aircraft occupants in a variety of simulated impact scenarios. The Oasys LS-DYNA simulation environment and the Ansys LS-DYNA solver were used for the entire CAE workflow. Oasys PRIMER came into play as a preprocessor for positioning the human models, with the target markings extracted from test data from the US National Institute of Aviation Research (NIAR).

Mr Bauer concluded that this study represents the first phase of application and evaluation of v-ATDs and HBMs for aerospace applications. The speaker expected that the study will contribute to the wider application of HBMs in the aviation industry and promote biomechanical research on aircraft occupant safety. The rigid seat test data provided by NIAR served as a valuable baseline assessment for validating modeling methods.

Pablo Lozano, Applus+ IDIADA: 'Exploring Gender Disparities in Heavy Quadricycle Crash Tests: Assessing Male and Female Human Body Models'

L7e vehicles, also called heavy quadricycles (HQCs), are four-wheeled cars with a mass of less than 450 kg (without batteries) and an output of less than 15 kW. The goal of the study was to develop L7e with typical car safety features. By the way, the small vehicles are just right for smaller cities or those with narrow streets. Applus+ IDIADA developed safety requirements and gave them a four-star rating according to Euro NCAP. "However, we asked ourselves whether this Euro NCAP assessment procedure was sufficient to adequately cover accident protection for adults," said Pablo Lozano, motivating his presentation. This is because the phenomenon of submerging (slipping on the seat below the seat belt) was observed in the case of AF50, which leads to an increased risk of abdominal injury. Another result: Increased risk of thorax injury for female test subjects, also presumably caused by the submerging movement. This submarining correlates with the positioning of the seat belts.

Current protocols are limited by the exclusive use of the Hybrid III male dummy. Mr Lozano suggested more anthropometrics in the evaluation of safety investigations. Finally, there are significant differences in injury risk profiles between male and female subjects. Potential improvements can be expected through adaptive restraint systems and the integration of the seat belt into the seat structure.

Marius Rees, BMW AG, Ludwig-Maximilians-Universität München: 'Comparison of Hardware- and Virtual-ATDs to HBMs in a Generic BMW Far Side Sled Environment including a Far Side Airbag'

First, Dr Marius Rees recapitulated the status of the presentation at the previous symposium, which essentially corresponded to the content of his dissertation. The presentation was entitled: 'How is the maximum lateral movement of different HBMs influenced by a variation of the friction coefficient between the shoulder belt and the HBM skin in a side crash environment?'

The question now was whether the same results could be reproduced if a realistic environment were integrated into the scenario. This is a BMW sedan environment with a seat. The test setup was accelerated to 32 km/h by a sled impulse according to the CNCAP far-side protocol. The integration of the three HBMs THUMS v4.1-50P, -05P, 95P was taken into account.

Regarding the results, Dr Rees said that in a commercial seat environment, the overall deflection is reduced due to active contact with the center console, but friction sensitivity can still be detected, albeit to a lesser extent. When the side airbag is active, the load on the ribs in ATDs tends to be less favorable than in HBMs.

King-Hay Yang Young Scientist Award

At the end of the event, Rainer Hoffmann, one of the managing directors of carhs training, announced the winner of the King-Hay Yang Young Scientist Award: Dr Marius Rees was able to convince the independent jury and was therefore announced as this year's winner. "This recognition is particularly meaningful to us as we had the privilege of getting to know King-Hay Yang personally during his time at Wayne State University. His contributions to biomechanics and his vision for safety innovations have left a lasting legacy that inspires all of us in this field," emphasized Mr Hoffmann. The renowned researcher King-Hay Yang taught biomechanics and was director of the Bioengineering Center at Wayne State University. He died in 2023.

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