EXPLORATIONS IN CAE (COMPUTER-AIDED ENGINEERING) FOR VEHICLE CRASH SAFETY DESIGN

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Ensuring crashworthiness and occupant safety is an important consideration in vehicle design. For automobiles, especially for ones with GVWR (Gross Vehicle Weight Rating) not exceeding 10000 lb (4536 kg), a plethora of regulatory standards exist in a country such as the USA in areas encompassing front, side, rear, and head impact safety, roof crush resistance and roll over safety, etc. CAE (Computer-Aided Engineering) has been occupying a center-stage in driving vehicle crash safety design in contemporary times. However, the perception of CAE, in the context of collision safety design of automobiles, has been primarily limited to detailed engineering assessment using techniques such as nonlinear explicit Finite Element Analysis (FEA) for which a fairly matured CAD (Computer-Aided Design) model of a complete vehicle is a pre-requisite. A primary challenge in design is the conception of a vehicle's complex body structures in the early phase when a CAD model is still evolving and CAE-based simulation in its conventional form is not feasible. Alternative approaches are therefore necessary in the concept phase of vehicle design for arriving at rational decisions on body architecture, sectional geometric details, material selection, etc. such that a robust and optimal design can be achieved in an efficient manner using conventional CAE at a later stage with minimum changes to the initial body design. It is here that empirical data-driven techniques such as Regression-Based Modeling (RBM) and simplified mechanics-based approaches such as Lumped Parameter Modeling (LPM) become relevant. Additionally, as detailed Finite Element Modeling (FEM) for contact-impact analysis is often time-consuming and skill-intensive, quick predictions of effects on safety performance due to changes in selected design parameters in a vehicle using AI (Artificial Intelligence) and ML (Machine Learning) techniques can be attractive. The latter tools can also be useful for design optimization and supporting the inverse nature of a design problem.

In the backdrop of vehicle crash safety design as discussed, a strong need is felt for expanding the scope of CAE to include, apart from traditional FEM, other techniques such as RBM, LPM and AI/ML. The current talk attempts to provide insights into the implementations of the diverse CAE approaches mentioned covering topics such as material and geometric nonlinearities, viscoplasticity, behavior of lightweight materials, etc. for prediction of responses under impact loading. In this context, a possible common thread behind the seemingly disparate empirical and physics-based algorithms for crash safety assessment is pointed out. The relevance of commercial tools for implementation of CAE methodologies supplemented with selective testing is highlighted. Illustrations are provided on the power of CAE as an enabling technology in various areas of designing vehicles for crashworthiness and occupant/pedestrian safety. An exposure is also given on the dependence of occupant injury parameters on structural crashworthiness. It is shown that CAE can be a potent platform not only for assessment of crash safety performance of a vehicle for design according to laboratory regulated and customer-rating tests, but also for simulating real-world crashes and devising improved test procedures for addressing issues such as incompatible vehicle collisions.

Bio: Dr. Anindya Deb is currently a Professor (Higher Administrative Grade) at the Centre for Product Design and Manufacturing (CPDM), Indian Institute of Science (IISc), Bangalore. He is also an Associate Faculty Member at the Interdisciplinary Centre for Energy Research, IISc. He served as a Chairman of CPDM during the period 2009-2014. He previously obtained his (a) PhD from the State University of New York at Buffalo, Amherst, NY, USA, (b) ME from the Memorial University of Newfoundland, St. John's , Canada, and (c) BE from Jadavpur University, Kolkata, India. In CPDM, IISc, he established CAR (Creative Automotive Research) and Impact Safety Engineering Laboratory (CARISEL). Prior to joining IISc, he had worked with Ford Motor Company (Dearborn, Michigan), SDRC (Milford, Ohio), Caddtech Productivity (Liverpool, New York) and Tata Motors (Jamshedpur, Jharkhand, India). He also held a part-time position of Adjunct Lecturer with the University of Michigan at Dearborn, MI, USA. In IISc, he has supervised a total of around 50 PhD, MTech and MDes students in their theses and projects. He has published substantively (about 200 papers) in international journals and conference proceedings, and obtained 5 patents and a design registration. He has received several awards in industry and academia, and is a Fellow of the Indian National Academy of Engineering (INAE) as well as SAE (Society of Automotive Engineers, USA). He has also been the Principal Investigator for a number of government- and industry-funded research projects. His areas of research include: CAE (Computer-Aided Engineering) in design, design of automotive systems, vehicle crash safety design, impact testing and simulation, design and prototyping of lightweight electric vehicles, fiber-reinforced composites, MDO (Multi-Disciplinary Design Optimization), AI/ML in design, human body modeling, and biomechanical assessment of medical implants/fixations.

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