

Advancing crashworthiness simulation

BMW uses ABAQUS, from SIMULIA, to conduct a wide range of crashworthiness simulations, such as this frontal offset impact simulation of a BMW 7 Series vehicle according to Euro NCAP requirements.

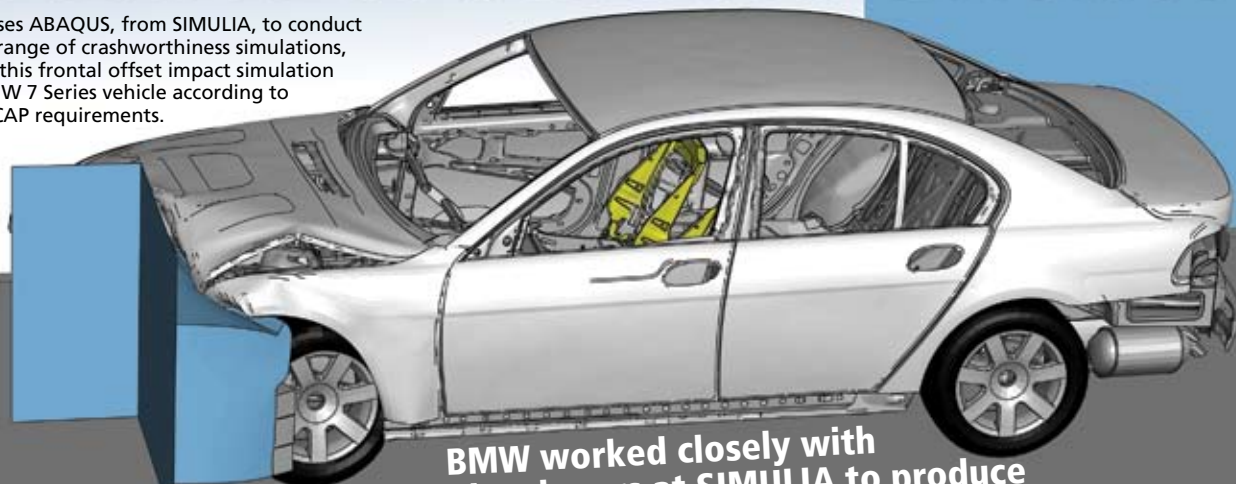


Image: BMW

BMW worked closely with software developers at SIMULIA to produce a customized solution for virtual product development.

Safer cars, lower costs, and shorter development cycles are familiar challenges for automotive OEMs. Vehicle crashworthiness is a demanding regulatory requirement for automotive companies, and knowledgeable consumers increasingly make buying decisions influenced by vehicle crash-safety ratings. To satisfy regulatory requirements and to address consumer safety concerns, leaders in the automotive market are seeking new technologies that can help them develop improved vehicle crashworthiness and occupant protection, while containing costs and accelerating time-to-market.

Turnaround time

The time and cost of physical crash testing is becoming prohibitive as the market demands faster delivery of new and more innovative vehicles. A crash test can be carried out only once per physical prototype. The ability of engineers to understand the system and component interaction from physical crash test results is limited by the small number of experiments that can be conducted.

In contrast, computer-based crash simulation enables multiple "what-if" studies to be performed that include a variety of structural designs, materials, and occupant and pedestrian interaction without destroying expensive physical prototypes and crash dummies. With

simulation, engineers can vary the conditions of analysis models and perform thousands of virtual crash tests to better understand and optimize vehicle crashworthiness.

Automotive OEMs such as **BMW** have demanding requirements for crash simulation. Vehicle structures involve a variety of materials and connections that undergo impact loading, with intricate contact interactions, severe deformations, and potential failure. Simulation of these vehicle structures must correlate with physical reality, and the time to model and run large and complex simulations has to be acceptable. The simulation tools and methods must integrate into an overall production environment consisting of multiple suppliers, contractors, and software vendors.

Collaboration pays off

Since 1986, BMW has been leveraging **ABAQUS** FEA software in the development of its vehicles. ABAQUS, now a product of SIMULIA a division of Dassault Systèmes, was initially used to determine thermo-mechanical creep effects on engine components and to carry out nonlinear static analysis of chassis components. Over the years, the software has demonstrated high fidelity in modeling and analyzing material behavior and in predicting realistic physical response

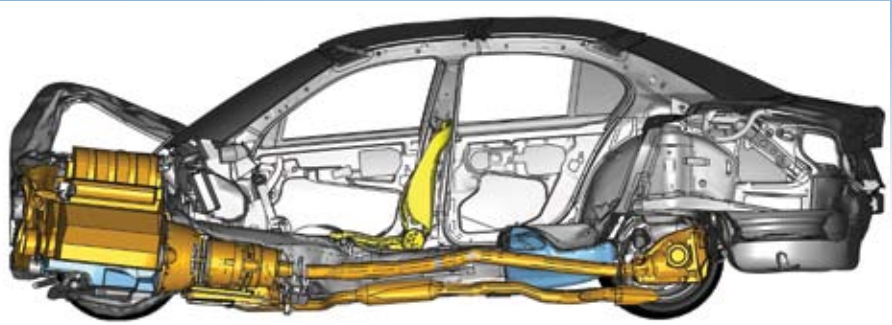
of automotive components and systems. This proven track record motivated BMW to further consider ABAQUS for crashworthiness simulation, to meet BMW's increasing needs for accuracy and robustness.

At BMW Group, crashworthiness simulation focuses on two primary areas: the behavior and response of the vehicle during a crash event, and the behavior of occupant and pedestrian safety systems. BMW began its evaluation of ABAQUS software for application to crash and safety with a trial project initiated in 1999. The project focused on simulating headform impact to meet FMVSS 201 regulatory requirements for protecting occupants from serious head injuries during crash events. Strong collaboration between BMW and ABAQUS engineers resulted in a new crushable foam material model that could be used to simulate energy-absorbing components in automotive interiors. This achievement prompted BMW to adopt ABAQUS software for headform impact simulation across a number of vehicle programs.

Based on the success of the initial trial project, BMW and ABAQUS established a formal process to proceed with specifying and developing full crash simulation capabilities in ABAQUS software. ABAQUS committed a team of project leaders, software developers, and support



Image: BMW



BMW uses ABAQUS software to conduct a wide range of crashworthiness simulations, such as this full frontal impact simulation of a BMW 5 Series vehicle according to U.S. NCAP requirements.

BMW works closely with SIMULIA and with other industry and research partners to develop advanced failure-prediction capabilities for materials, spot welds and rivets, structural adhesives, and so on. The top images show the effect of quasi-static axial compression, and the bottom images show the effect of dynamic compression. The ABAQUS simulation results show good correlation with experimental results for both scenarios.

engineers to the project. BMW also dedicated staff resources to the effort, including all departments that use crash simulation software. Target milestones, such as successful completion of a set of crash loadcases, were established to monitor and evaluate development progress. The current 5 Series sedan was selected as the target vehicle for many milestones, as it represented the most current modeling practices used at BMW.

Accurate modeling of material damage and failure is important for crashworthiness simulation, since these phenomena can substantially alter the load paths and response of the vehicle in a crash event. The joint engineering team developed a number of new capabilities in ABAQUS software for accurately representing progressive damage and potential failure that can occur in sheet metal and other materials, spot welds, rivets, and structural adhesives.

Pilot program

By 2004, the success of all these new developments gave BMW the confidence to put ABAQUS software through the rigors of a pilot production project—a new vehicle development program in which ABAQUS

would be used exclusively for all crashworthiness simulations. The objective of this pilot project was to further validate the accuracy and robustness of ABAQUS, as well as to establish how the software would integrate into a production environment that includes pre- and post-processing tools from other providers. BMW presently uses software from **Altair Engineering, GNS, Science + Computing**, and other vendors. As part of the project, **First Technology Safety Systems** developed FEA-based crash dummy models for ABAQUS, to support crash simulation.

In the first year of the pilot production project, more than 1500 separate simulations were successfully completed for all relevant loadcases, each providing insight into the crashworthiness design aspects of the new vehicle, and BMW concluded that it could meet its production requirements for accuracy and robustness. In fall 2005, BMW announced its decision to implement ABAQUS software for all future crashworthiness simulation requirements.

Meeting future requirements

Crashworthiness simulation is certainly more sophisticated and accurate today than it was several years ago, but there

are always opportunities to integrate it more thoroughly within the vehicle design process. Performance is one key area. As vehicle models grow in size and complexity, the need to obtain simulation results in a timely manner will not diminish. Continuing gains in model size and complexity require the effective use of parallel computers, employing 8, 16, 32, or more CPUs simultaneously in a single simulation to reduce turnaround time.

Ongoing improvements in simulation fidelity and the integration of multi-physics are also important. In airbag deployment, for example, the gas dynamics that occur with the structure during inflation are quite complex. Integrating realistic gas dynamics provides for a more accurate representation of airbag deployment and hence a more accurate prediction of crash-dummy response. The ongoing commitment to advance crash simulation capabilities by companies such as BMW and SIMULIA ensures that simulation technology will continue to evolve to meet regulatory and consumer demands for vehicle safety.

This article was written for *AEI* by **Marc Schrank**, Director of Product Management for SIMULIA, with reference to a BMW paper titled "Migration of Crash Simulation Software at BMW," presented at the 2005 ABAQUS Users' Conference in Stockholm, Sweden.



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