MOVING TOWARD ZERO-PROTOTYPING FOR AUTOMOTIVE PASSIVE SAFETY

Automobile safety standards have become a moving target for manufacturers. As current and future requirements become increasingly stringent, automakers must perpetually stay a step ahead, designing and building accordingly. As a result, the latest car models are the safest ever and highway fatality rates are at an all-time low.

While meeting—and even exceeding—safety requirements is clearly a priority for automakers, the drive to improve vehicle safety is just one of several factors creating economic pressures on OEMs these days. Customer demands for a wider variety of car models and performance characteristics, tougher mileage standards that require reduced vehicle weight, and the development of more advanced materials—all these need to be factored into vehicle design without compromising crashworthiness. Staying cost-competitive under these conditions, while continuing to attract enthusiastic customers, is an ongoing priority for carmakers.

One tool that is increasingly proving its worth—from R&D department to factory floor to crash-test hall to auto showroom—is simulation software. Early adopters have grown their in-house design engineering expertise alongside advancements in computer modeling technology with extremely positive results.

Thought leaders across the automotive industry recognized years ago that the multiple challenges of vehicle development, underscored by the need to meet ever-updating safety standards, could only be addressed successfully with improved design simulation to help identify the most creative, robust, cost-effective route to success. An ambitious longer term goal: prove out and leverage the predictive worth of simulation to the point where prototypes could be eliminated for the passive safety design of a car model.

THE LIMITS OF PHYSICAL PROTOTYPING

While simulation has been employed in passive safety design for many years, physical prototypes are still commonly built and tested during the course of a vehicle development program. These pre-production vehicles are expensive and time-intensive to build and crash test, due in large part to the soft prototype tooling and hand fabrication required.

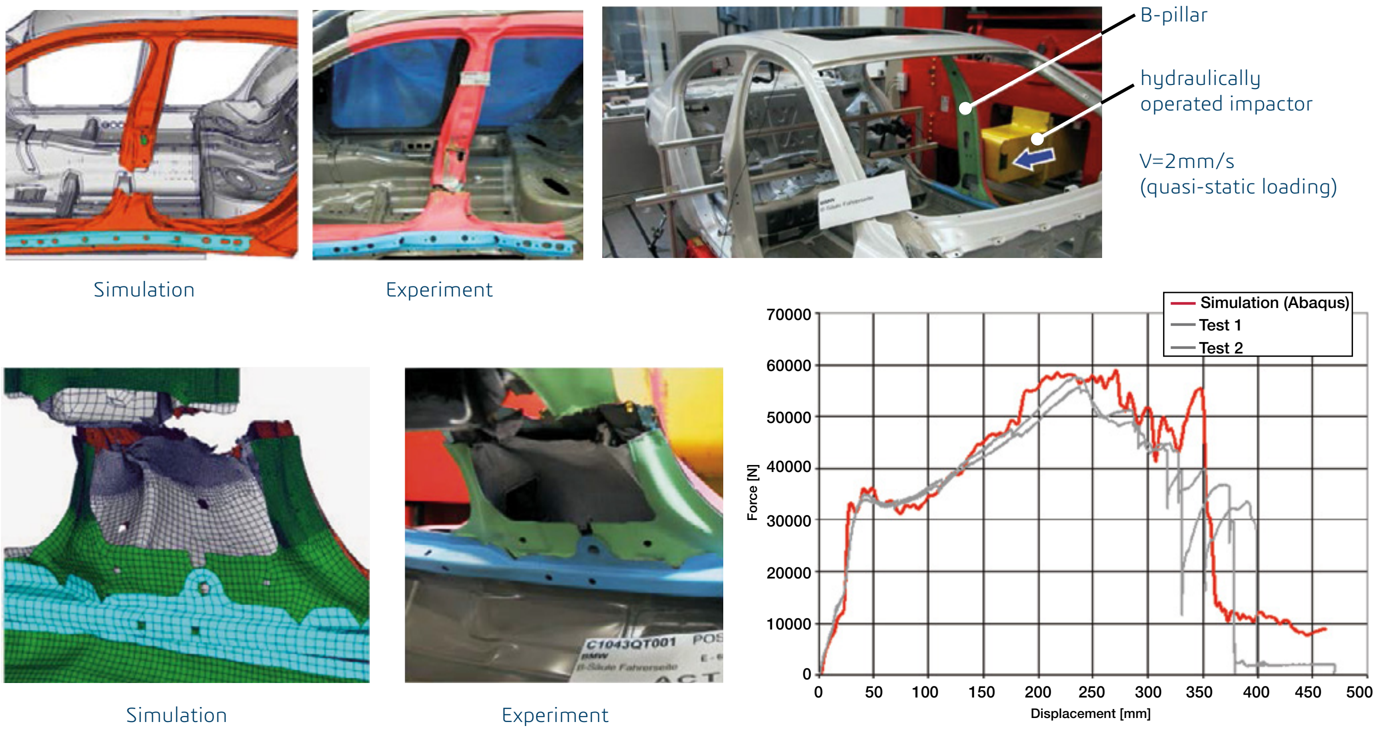


Figure 1. Abaqus simulations of material failure behavior in B-pillar intrusion experiment. The test is deliberately carried out to complete failure, and so the corresponding forces are higher than typically occur in a crash event. Predicted crack initiation and propagation correlated highly with test data, validating the material modeling approach for deployment in production design simulation. Leveraging realistic simulation to achieve such accurate local predictions within global design models early in the vehicle program increases vehicle design development efficiency by avoiding problems later, when changes are more costly to correct and can impact vehicle launch timelines.

This type of hardware proofing has other limitations, all of which either constrain or influence results: it's impossible to test for all load cases in this way, and test results are not fully transferable to cars that roll off the production line since these prototype vehicles are hand-assembled approximations of series production vehicles.

AN AMBITIOUS GOAL: REDUCE PROTOTYPING THROUGH SIMULATION

Premium automaker BMW Group and Dassault Systèmes SIMULIA, provider of the Abaqus FEA software suite, have partnered for more than ten years in passive safety design simulation in pursuit of this product development evolution. For computer-aided design (CAD), the automaker uses CATIA V5 (also from Dassault Systèmes).

While earlier simulations had accurately demonstrated global vehicle behavior during a collision, the team recognized that detailed local behaviors of materials and connections that could lead to damage and failure needed to be considered as well (see sidebar on page 8). For instance, it would be critical to accurately simulate the potential localized damage to the sheet metal and spot welds in the B-pillar for a side crash test, in order to accurately predict the passive safety performance of the vehicle for that load case. This level of predictiveness would be key to enabling truly virtual design iterations where important design decisions are made based on realistic simulation results.

Throughout the virtualization partnership, SIMULIA experts worked closely with BMW Group engineers to implement and test new capabilities in Abaqus, often in response to specific requirements from the automaker. New features were validated through increasingly close correlation between simulation results and real-world test data.

The BMW 6 Series Gran Coupé was then chosen as the first BMW Group car model where a zero prototype approach to vehicle development would be undertaken.

MOVING DIRECTLY FROM DESIGN TO HARD TOOLING

A number of virtual passive safety design iterations were carried out during the BMW 6 Series Gran Coupé development utilizing the accumulated simulation results to make subsequent design modifications. The final design was predicted to meet all passive safety performance targets.

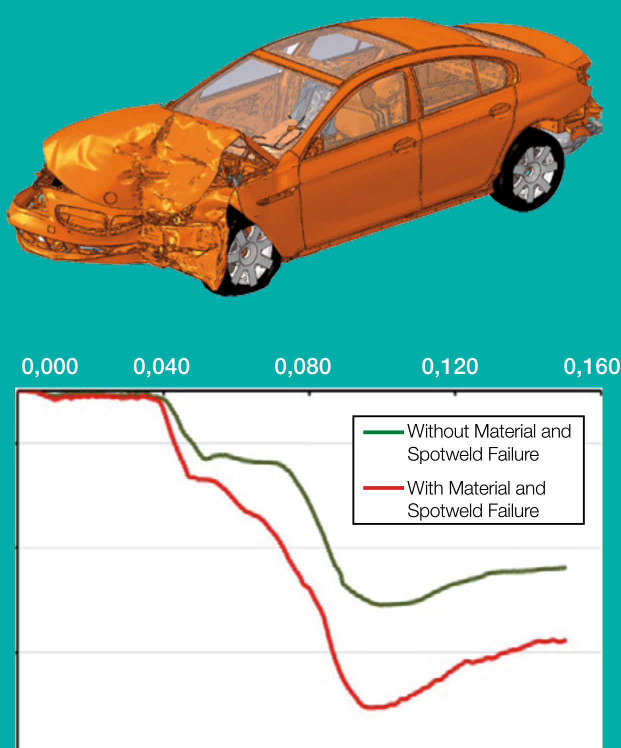
Confidence in this final design eliminated the usual soft tooling stage for prototyping, so that BMW Group could proceed directly to series production with hardened production tooling. Physical crash test results from these early series production vehicles closely matched the simulation predictions and the BMW 6 Series Gran Coupé was launched.

THINK GLOBAL, BUT SIMULATE LOCAL AS WELL

Accurate prediction of crashworthiness depends on simulation of all phenomena that might affect the performance of a vehicle in a crash event. This includes global distortions of the car body and chassis, as well as 'local' failure mechanisms of materials such as sheet metal and internal joining techniques like spot welds and adhesives. Developing and deploying accurate simulation capabilities for these local failure mechanisms has been a key factor in BMW Group's zero-prototype achievement.

The graph shows the difference in simulation results for the firewall intrusion into the passenger compartment for an offset frontal crash test, comparing the earlier (green line) modeling technique and the newer (red line) modeling technique.

The virtual vehicle model without local failure mechanisms predicted an intrusion of the firewall that was 30% stiffer than the more complete model that included all important failure mechanisms. In other words, the less complete model led to the non-conservative prediction that there was less intrusion into the passenger compartment than would actually occur. The newer, more comprehensive approach is employed as standard practice in all crash simulations.



Frontal offset crash test simulation in Abaqus FEA (top) and corresponding firewall intrusion results with and without local failure mechanisms incorporated in the model (bottom).

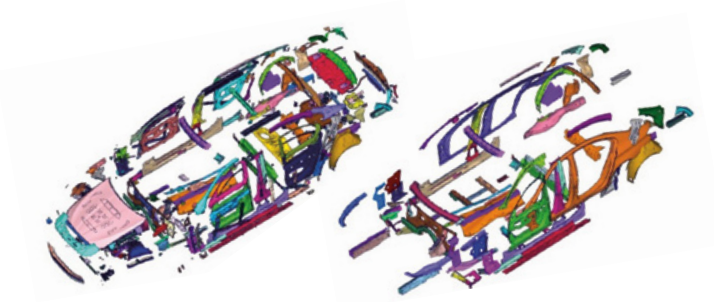


Figure 2. Modeling potential sheet metal failure during a crash test simulation is standard practice at BMW Group. The figure on the left shows the typical body components where this is considered. The effects of prior forming processes, such as stamping, can have an influence on failure, and the figure on the right shows the typical components where results from earlier forming simulations are mapped onto their crash model counterparts.

Figure 3. Side impact load cases are often the most difficult from a crashworthiness perspective. The figures above show actual BMW 6 Series Gran Coupé results for two standard side crash tests: IIHS side impact with moving deformable barrier (left); and FMVSS 214 side pole impact (right). For each, the corresponding design simulation results are also shown which accurately predicted the passive safety performance and led to the zero-prototype success.

THE JOURNEY CONTINUES

The high level of predictiveness of the simulations gives engineers greater insight into how to improve and optimize future car designs. As vehicle platforms continue to evolve—to multi-material construction—simulation will be an instrumental tool for designers and engineers. SIMULIA will continue to collaborate closely with BMW Group to ensure that passive safety simulation capabilities in Abaqus are enhanced to accommodate fresh platforms and ever-more stringent safety requirements.

Of course real-world crash tests are always the final proof for assessing the ultimate value of simulation. While creating and following a roadmap towards zero-prototyping takes time and commitment, accurate and robust simulation capabilities can and should play a central role, enabling automakers to reach new passive safety milestones throughout the product development journey.

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