Injection Molded Energy Absorber

(Ultramid® PA-GF30)

in the Front End of Mercedes-Benz S-Class MY2020

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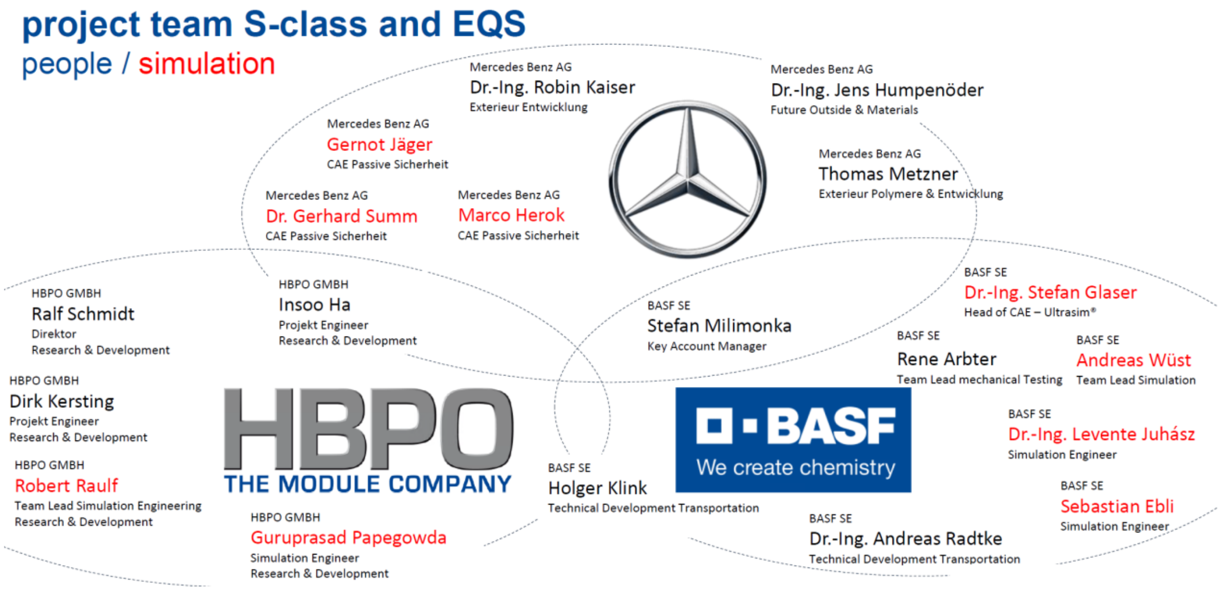
1 Motivation – Shortfiber reinforced plastics and Crash?

Energy management in passenger cars has traditionally been dominated by metal structures due to high energy demand and structural integrity. Due to changing legislation and increasing requirements, the trend in vehicle development is towards spatially distributed energy management concepts, leading to more and new load paths. Euro NCAP to frontal MPDB test is to be mentioned here. To serve these new load paths, new absorbers would actually be needed.

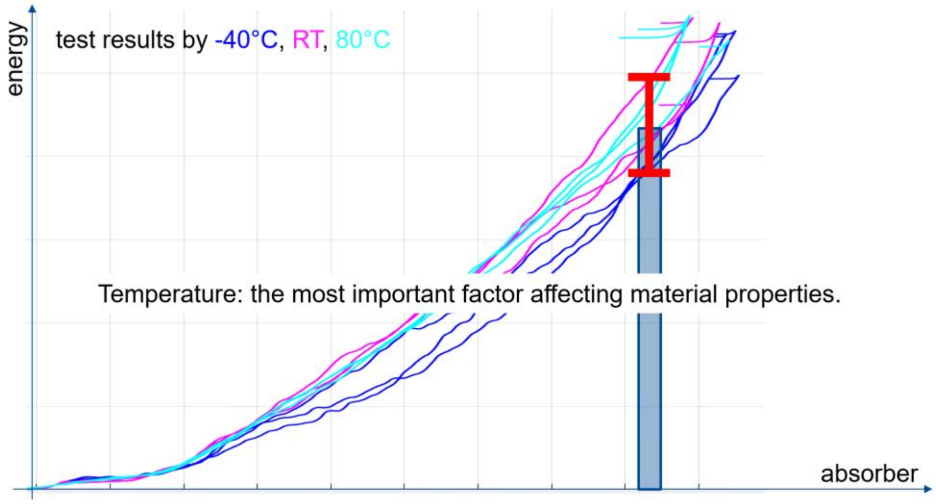
However, Mercedes-Benz has succeeded in integrating crash functions into existing components. This is done in a cost- and weight-neutral way instead of using a new absorber in the car. Existing short-fiber-reinforced plastic structures were upgraded for moderate energy absorption, designed for robust and controlled failure under variable environmental conditions. The new component concept was developed jointly by Mercedes-Benz AG, BASF SE and HBPO.

Energy absorption is based on controlled destruction of these components. In order to meet the digital vehicle development, numerical material models are essential, which allow an accurate description of the failure process, force level and the absorbed energy. In the project, the material model Ultrasim® from BASF was used for this purpose. Properly designed, the parts allow a high degree of functional integration through injection molding, reducing system costs.

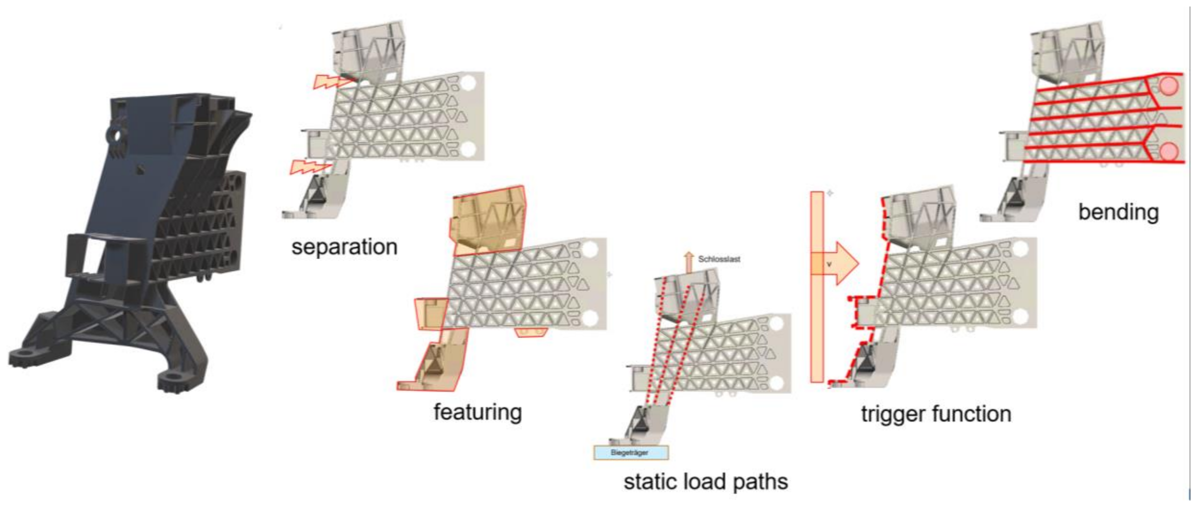


2 Main challenge – Robust behavior

The greatest challenge in the development of a crash component for vehicles is the requirement for robust behavior, i.e. the energy absorption performance must be ensured under changing boundary conditions. In the front end, this primarily includes varying impact angles and a temperature range between -40°C and 80°C.
BASF has developed a basic structure [1], which has now been further developed for larger installation spaces and higher energy and force levels. This new triangle structure is patented with Mercedes-Benz [3, 5] and enables high energy absorption and mainly temperature-independent absorber behavior. Furthermore, a high lateral force absorption is achieved by this suitable rib structure.



The functional principle of the part under consideration is based on crushing at room temperature instead of folding. The design of a crushing behavior is an additional challenge but allows higher functional integration through predetermined breaking points and local adjustments. Crushing allows also unprecedented design freedom, because parts of the component can be selectively separated in a crash, thus avoiding unwanted side effects. Energy absorption thus becomes successive execution of scheduled actions.



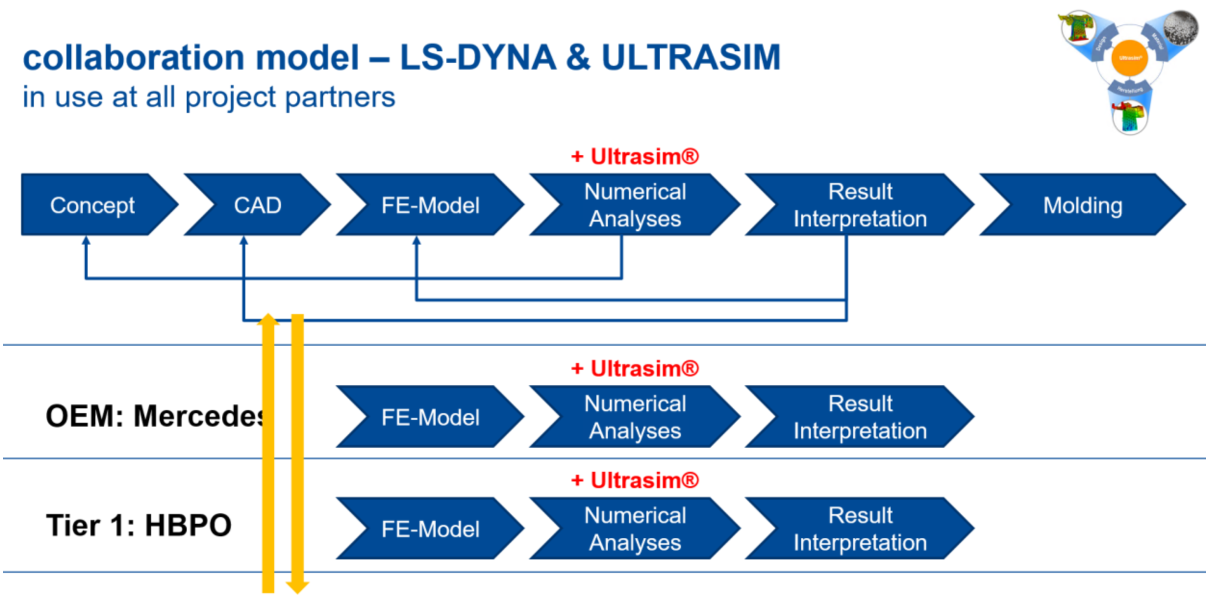
However, this makes accurate simulation an essential part of the process. Appropriate contact and failure modeling are critical to success. FEM modeling was performed using LS-DYNA with Ultrasim, a material modeling suite developed in-house by BASF. LS-DYNA and Ultrasim were used throughout by all project partners, ensuring comparability and sharability of results.

3 Collaboration model LS-DYNA & Ultrasim

3.1 Collaboration model

For an efficient development of a complex component group like front end it is necessary to share simulation tasks with the supplier. Development goals are defined by specifications and have a critical impact on development costs and success. Mercedes-Benz was able to derive clear targets for the absorber and for the front end and thus significantly speed up the development process. This approach leads to the need to share the specific part results and transfer them to increasingly complex models.

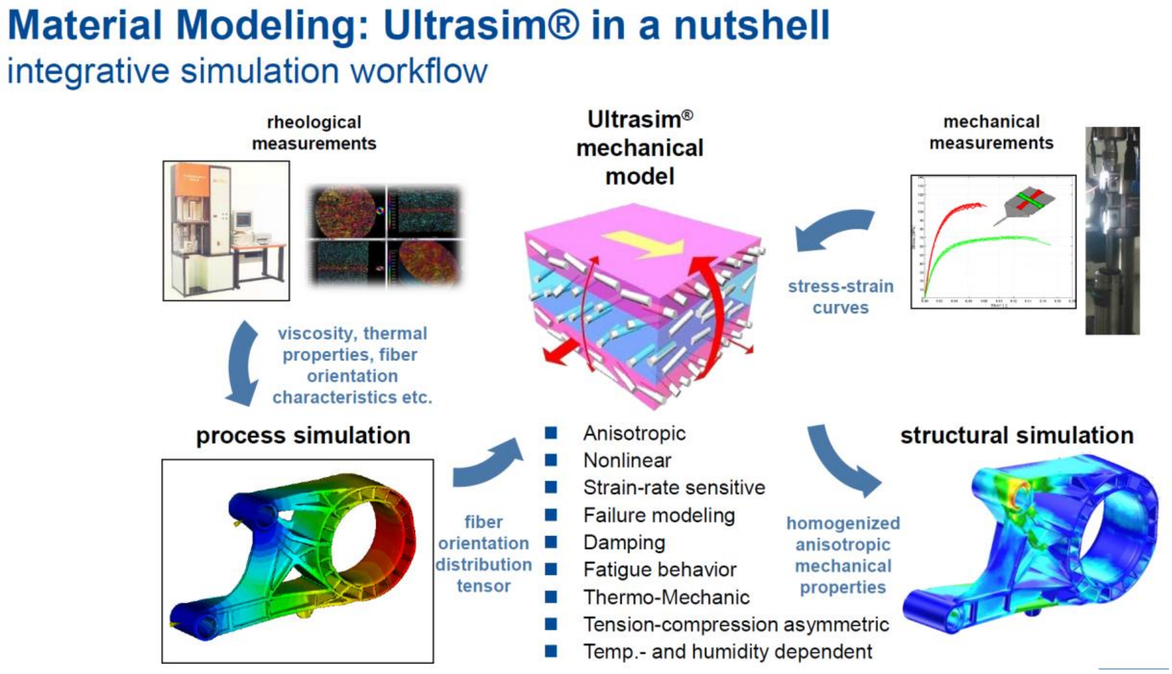
In crash analyses, it is especially important that the results of simple component calculations can be transferred to more complex calculations without loss. The use of the same simulation tools creates significant synergy effects. FEM solver is determined by OEM, in the case of Mercedes-Benz it is LS-DYNA for crash topics. For the numerical description in crash analyses LS-DYNA was used by all partners in the project.
For simulation of plastic parts in crash LS-DYNA was extended by Ultrasim as material modeler for the anisotropic short fiber reinforced plastics [literature reference].



3.2 Ultrasim in a nutshell

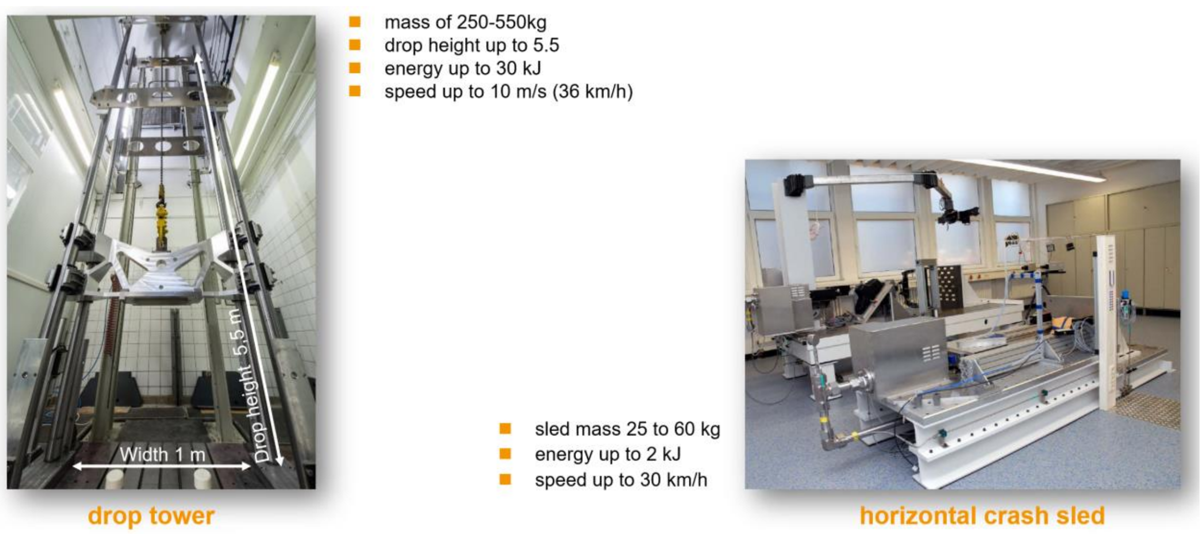
Ultrasim is a CAE tool which was developed at BASF which is able to model the relevant characteristics of plastic materials in a high level of accuracy. The Ultrasim workflow starts with the material models and parameters used in Rheology (Filling simulation) to ensure a good prediction of the fiber orientation in the part. The orientation tensor based on a filling simulation is mapped onto every integration point in the mechanical LS-DYNA FE-mesh. [2, 4, 6]

The Ultrasim material model accounts for all plastic relevant characteristic, as shown below. Especially the enhanced failure models used ensure a reasonable prediction for force and energy levels together with an efficient handling of self contact in LS-DYNA.



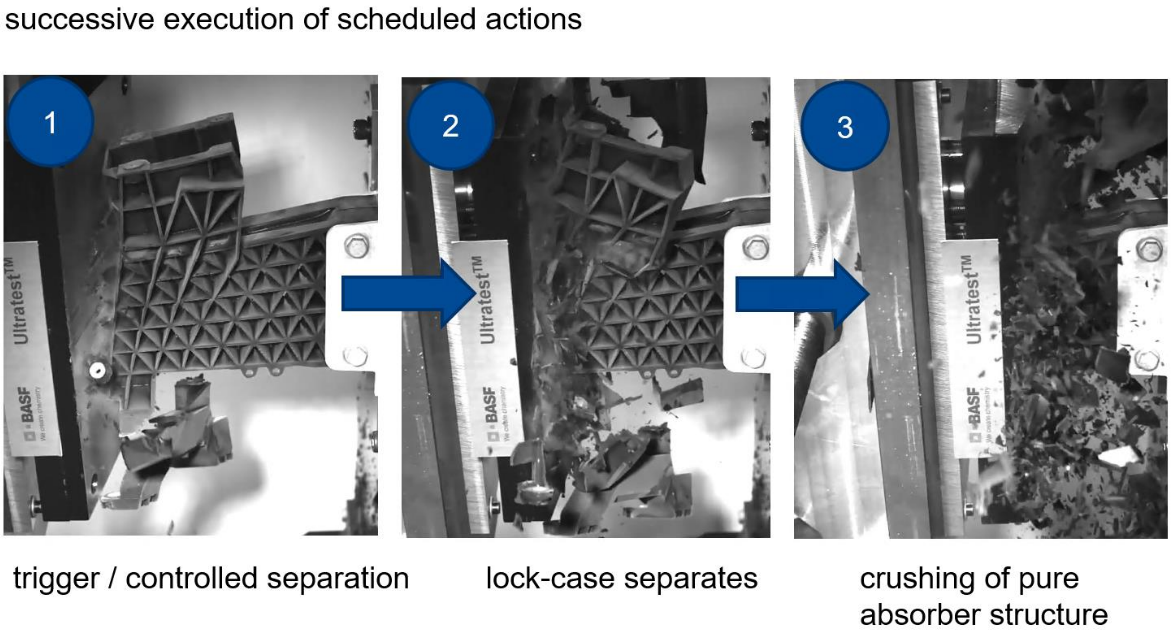
4 Testing support

In addition to Ultrasim, BASF also provided test equipment for crash testing at component level (Ultratest™). The absorber development was flanked by selected component tests that demonstrated the performance and stability of the part in different development phases. Various drop towers and crash test devices were used to analyze the behavior of the component. The calculation method (Ultrasim with LS-DYNA) was tested in parallel throughout. The aim is to optimize the design in the future purely based on simulation.

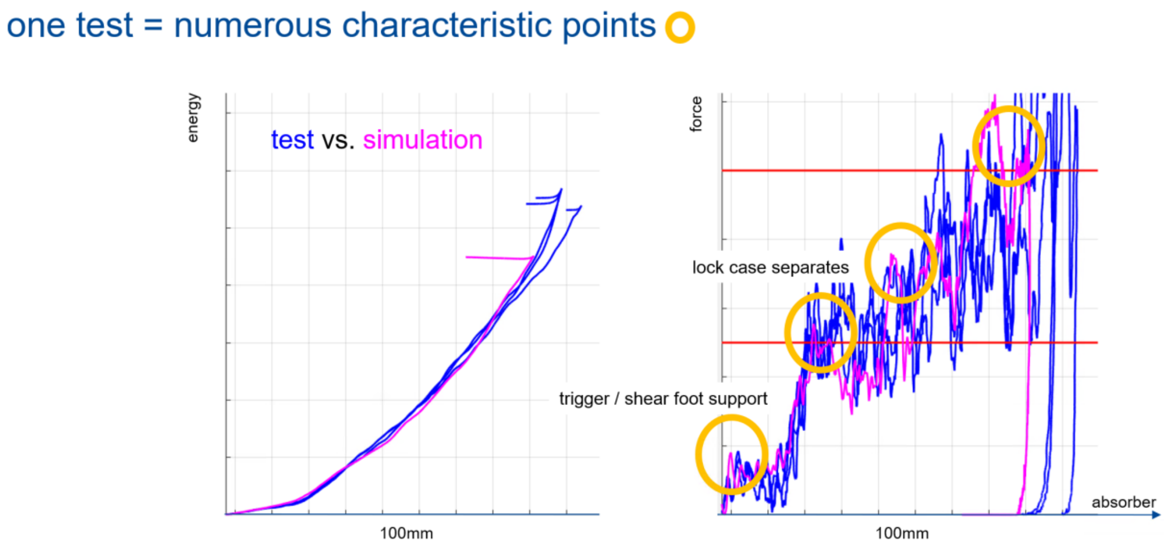


4.1 Part testing and simulation comparison

In each case, the test was carried out at 3 temperatures with 3 different impact angles. Because several characteristic events follow each other during the energy absorption, the test simulation adjustment can be performed several times for each test.



Through this procedure and through different prototype phases, numerous experiences could be accumulated. The results show an overall good agreement between simulation and test, which proves the applicability of the described simulation approach.

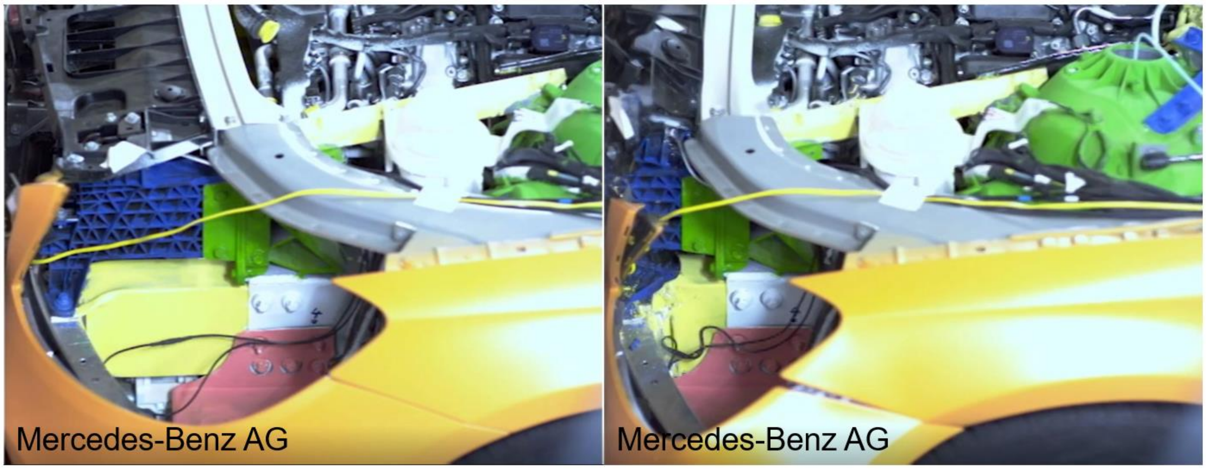


The test with the final part was passed at all required impact angles and temperatures as predicted by the simulation. The observed variations in performance are acceptable in terms of temperature, impact angle and moisture and no longer have any influence on the overall vehicle performance.

4.2 Full car test by Mercedes-Benz

In order to test the concept in detail, the absorber was tested in a specialized full vehicle test in a hardware phase of the project: To observe the behavior of the absorber during impact, the headlight in the car was removed and the absorber and some other parts of the front car were highlighted [see picture bellow].

Again, the desired mode of failure and energy absorption was demonstrated, and the interaction of multiple components proceeded as planned.



5 Summary and Conclusion

A shortfiber reinforced, injection molded energy absorber for the Mercedes-Benz S-Class Model Year 2020, made of Ultramid B3WG6 (PA-GF30) has been jointly developed by Mercedes-Benz, HBPO and BASF. The successful development was only possible by establishing a tight collaboration between the involved partners in the field of numerical methods and part testing.

The functional principle through crushing and predetermined breaking points allows a high degree of featuring and design freedom of the absorber. Submodeling, distributed development and focused component optimization accelerate the development process and bring cost savings, but only work well with the same simulation tools. LS-DYNA® with Ultrasim® are established as a collaboration model.

S-Class / EQS absorbers are the first applications of this front-end concept with crash-relevant plastic parts - other applications will follow soon. Furthermore, controlled energy absorption is possible in many components that were not originally intended for this purpose. New, innovative plastic applications can be developed in this way because the idea can be applied in injection molded components in general.

6 Literature

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