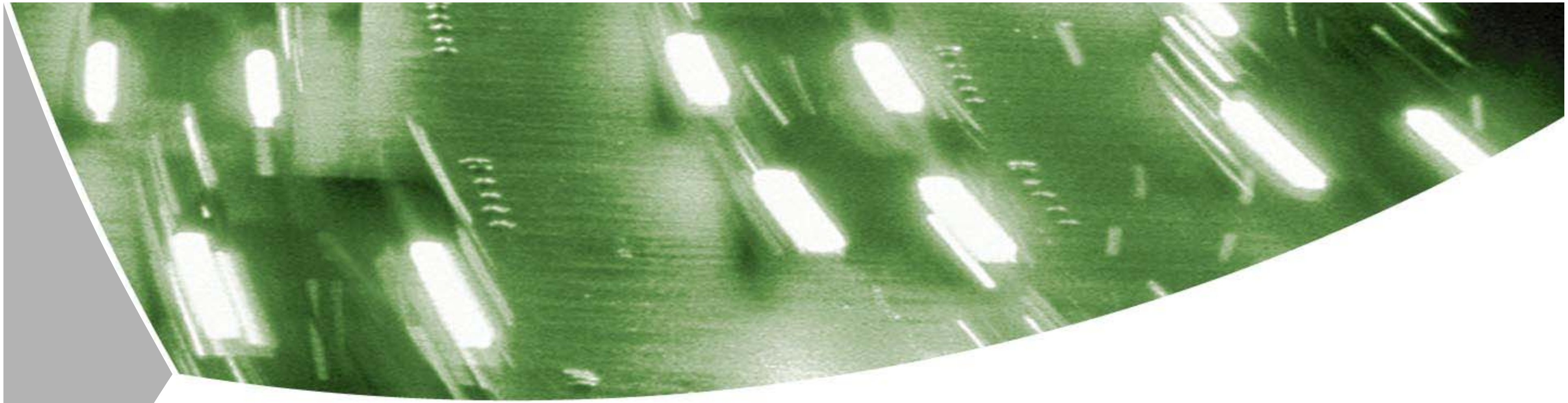


Metal-hybrid structures for an improved crash behaviour of car body structures

Michael Kriescher, Walid Salameh, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), DE

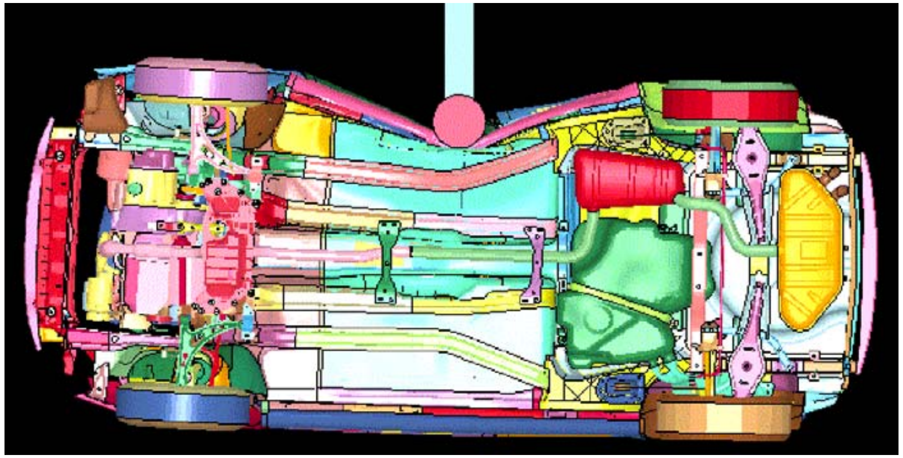
Dr. Alexander Droste, Jan Röttger, DOW Automotive Systems

18. Mai 2010 **»Materialien des Karosseriebaus«**

Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Automotive Systems

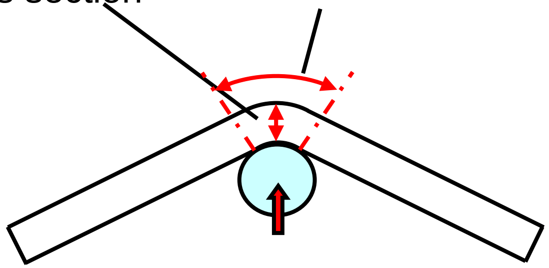
Motivation



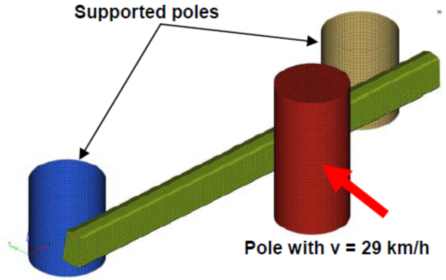
floor structure developed by DLR during SLC-project

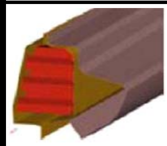
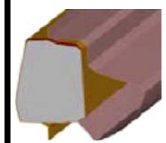
- collapse of the rocker‘s and side piece‘s cross-section during pole-crash -> energy must be absorbed by various other components
- a stabilisation of the cross-section during bending should lead to a much higher weight specific energy-absorption of the rocker -> higher freedom of design and choice of materials for the surrounding structures, like the floor panels -> possibility of an overall weight reduction
- the storage of critical components like Li-Ion batteries in the underbody requires a low intrusion
- demand for a simple, lightweight concept made of relatively cheap materials, adaptable to different kinds of vehicle concepts

Basic principle

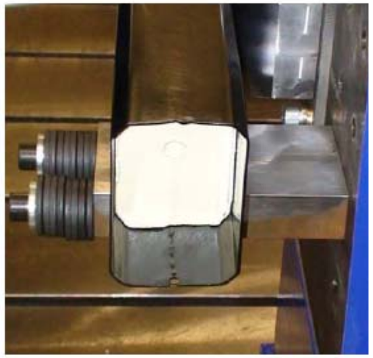


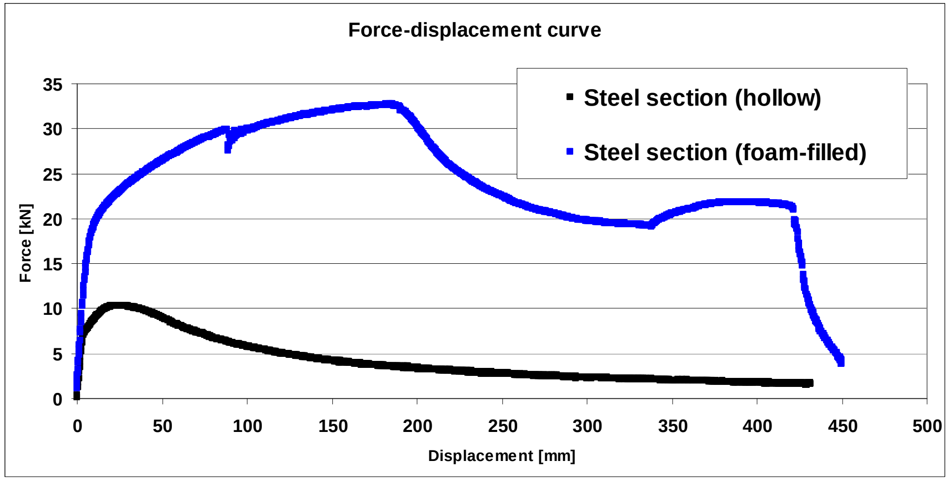
- stabilisation of the beam by a core structure
- the core must stay intact, throughout the entire bending process, in order to increase weight specific energy absorption
- simplified LS-Dyna-calculations showed an increase in weight specific energy absorption by a factor of about 2,5



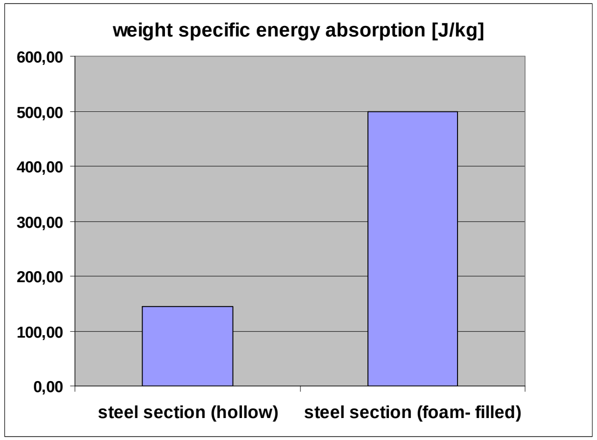
Variant	Drawing	Total mass [kg]	Material	Energy absorption [kJ]	kJ/kg
Reference		22,39	Various types of steel	4,5	0,2
Al honeycomb		15,15	Core: 1 mm Al; shell: 1 mm TRIPLEX	5,8	0,38
Foam		28,1	Core: foam 400 kg/m³ shell: 1 mm TRIPLEX	14	0,5

Testing performed in cooperation with DOW





DC 04 - beam filled with foam by the DOW chemical company
density 400 kg/m³ -> weight increase by a factor of 1,72 compared to hollow beam



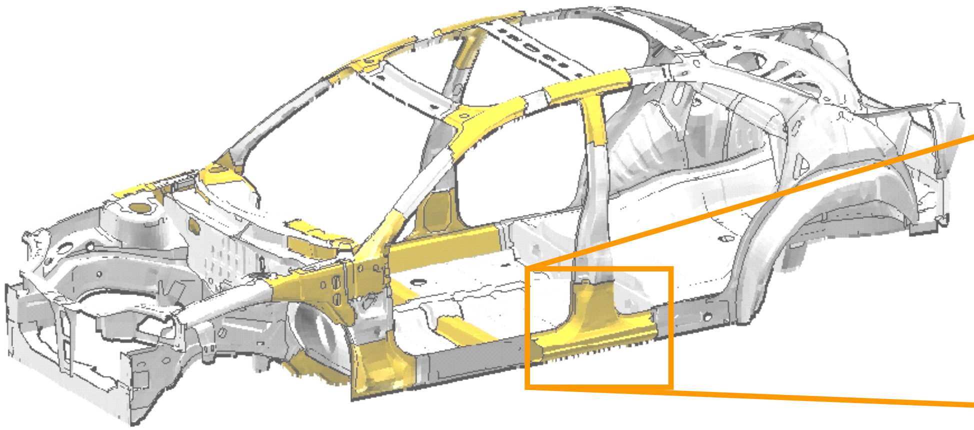
hollow beam, 12,35 kg

foam filled beam 21,15 kg

Summary structural foams

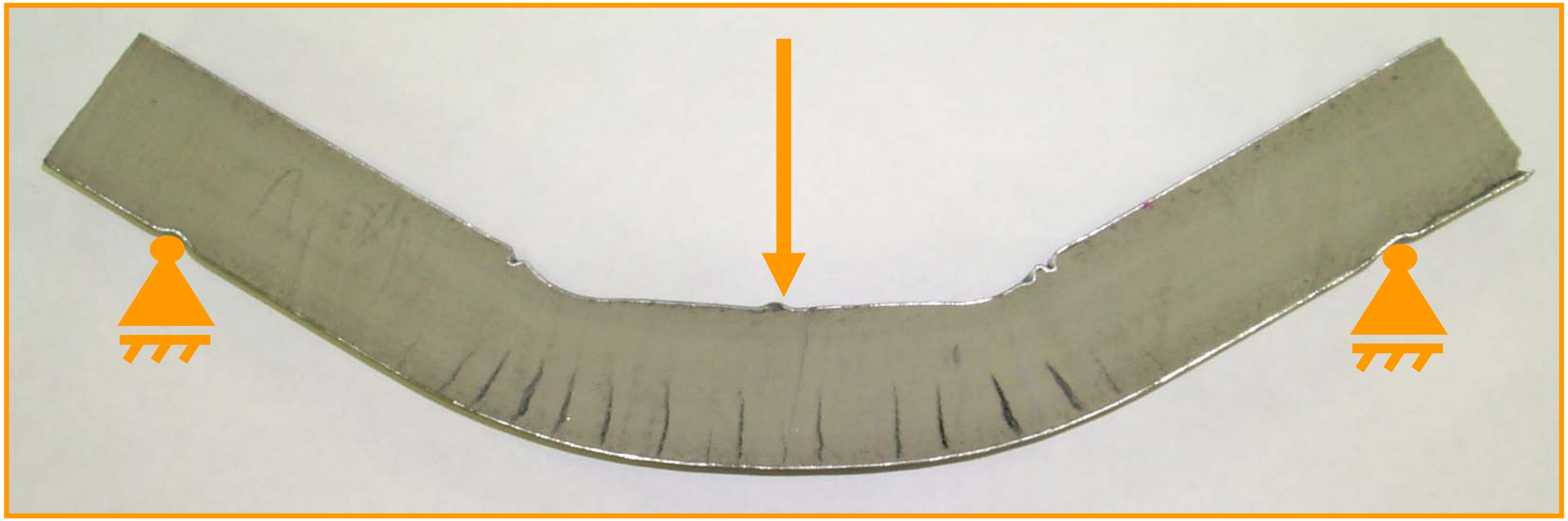
- Structural and crash performance enhancements
- Proven technology
- Potential to downgauge and/or eliminate BIW and tooling content
- Have one single/downgraded platform and use bulk foams to scale performance needs for different derivates – “Scalability”
- Design flexibility
  - Foam will fill any cavity shape and contour
  - Foam does not require re-design after sheet metal changes
  - Automated filling
- Validated FEA-Tools available for main grades

Cavity filling with BETAFOAM™



- BETAFOAM™ is a family of foam-based products
  - Two-component polyurethane foam applied as bulk
  - Fat cycle time, room temperature curing
  - Components form a rigid, closed cell foam
- Foam products range in density from 32 g/l to 641 g/l
- Higher density foams provide multi-functional benefits

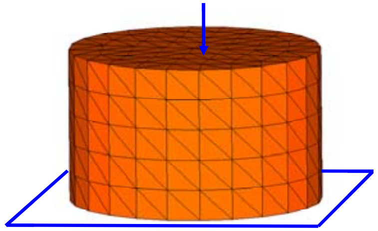
Basic working principal structural foams



- Dynamic test at 3,57m/s; 80 kg
- Foam adhesion to surrounding structure
- Prevention of bending and buckling effects
- Foam is acting as a shell connecting element
- Increased energy absorption capability of complete structure

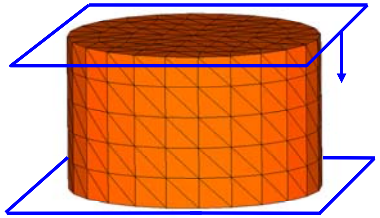
Material model – Development and validation

Static Correlation



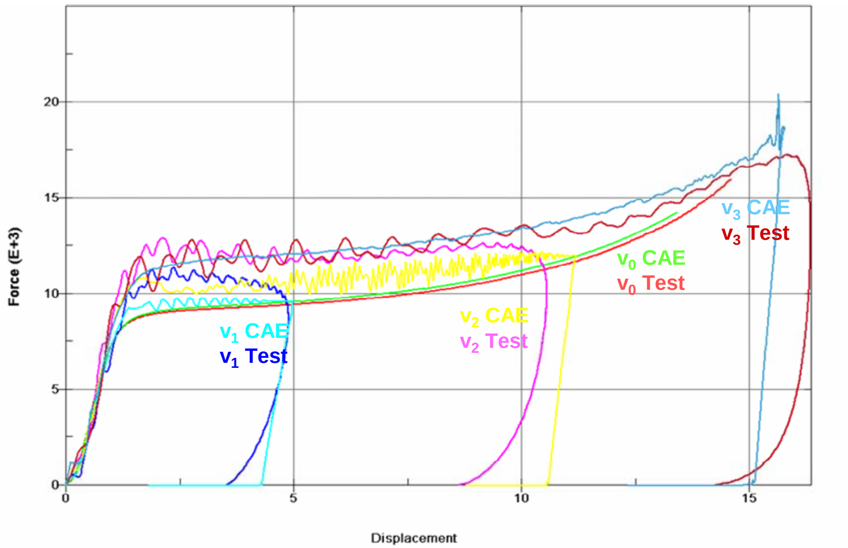
Boundary Prescribed Motion

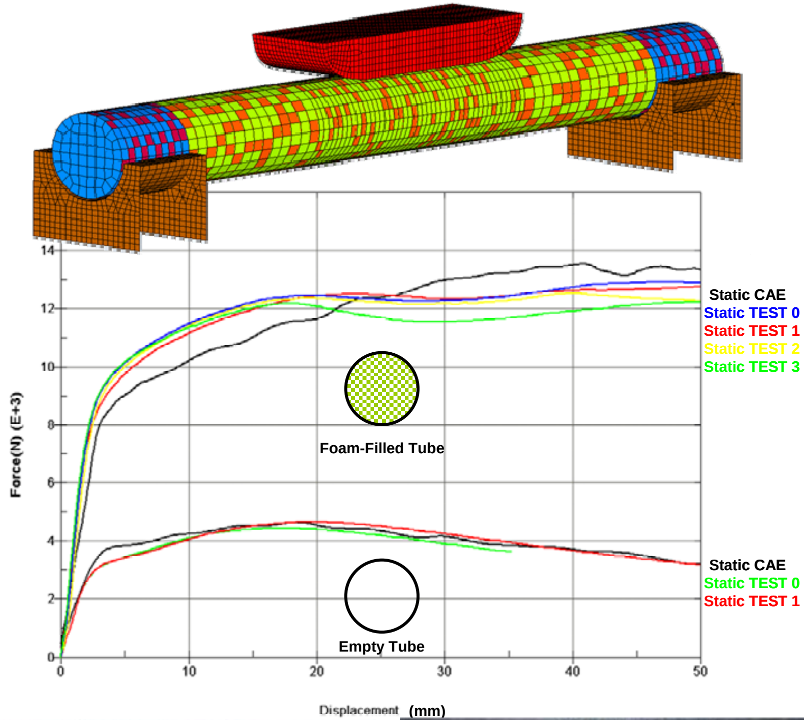
Dynamic Correlation



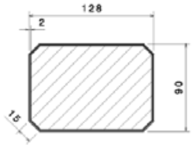
Moving Rigid Wall

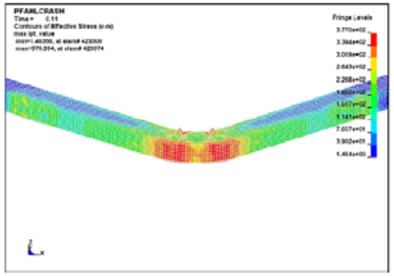
$v_1 < v_2 < v_3$



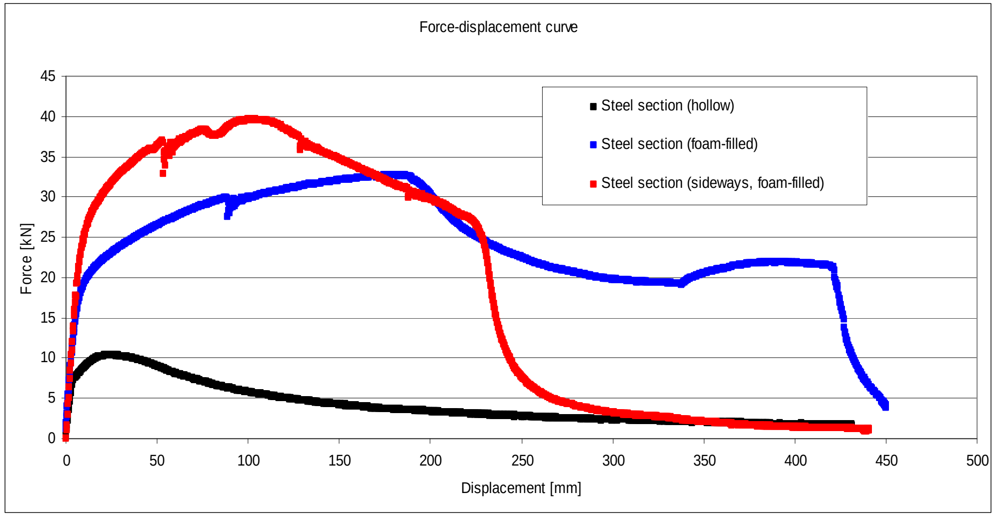


Geometric variations

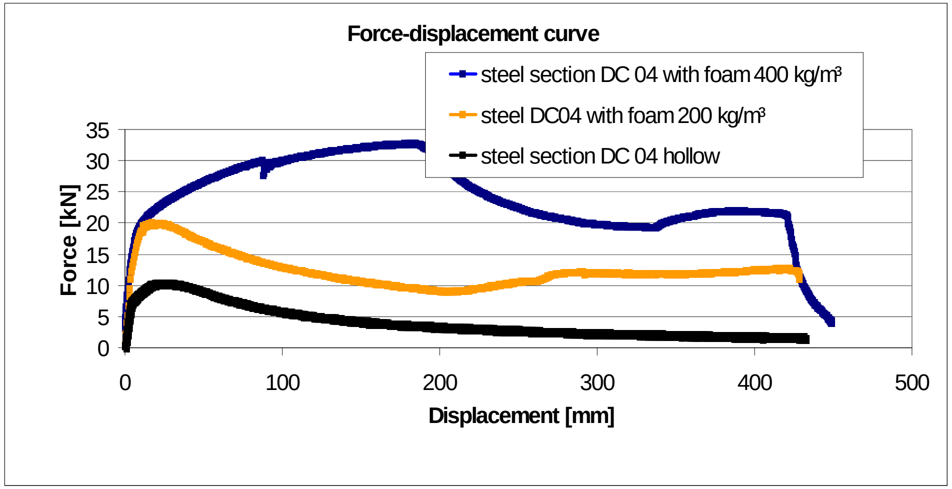


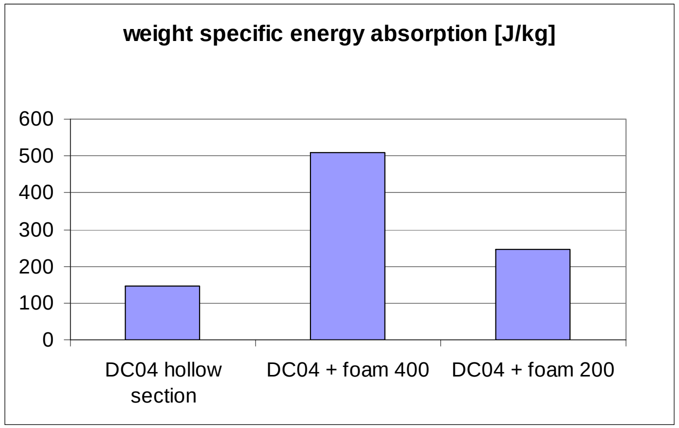


- deformation mode stays the same for different cross sections
- test with a crosssection rotated by 90 ° leads to higher peak force but earlier failure of the material -> steel with a higher max. strain would lead to even better results



Variation of foam density



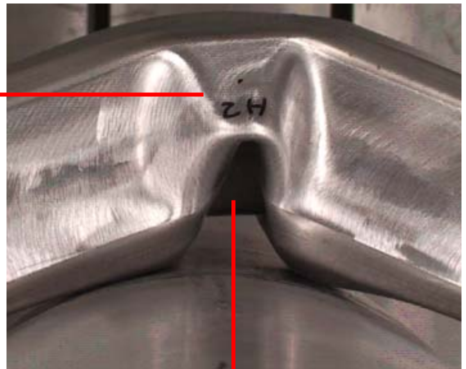


- foam density 200 kg/m³ -> weight increase by a factor of 1,37 compared to a hollow beam
- insufficient stabilisation of the steel shell due to use of low density foam -> no significant gain in weight specific energy absorption

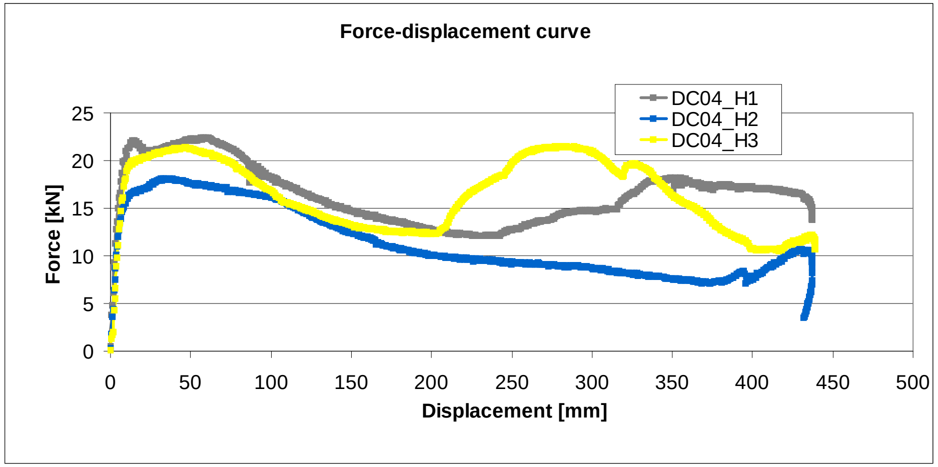
Variation of core material

H3 H2 H1

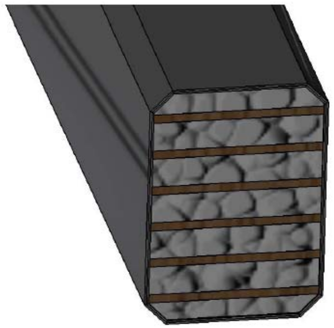
large fold beneath the core



core remains intact, and partially stabilises the beam

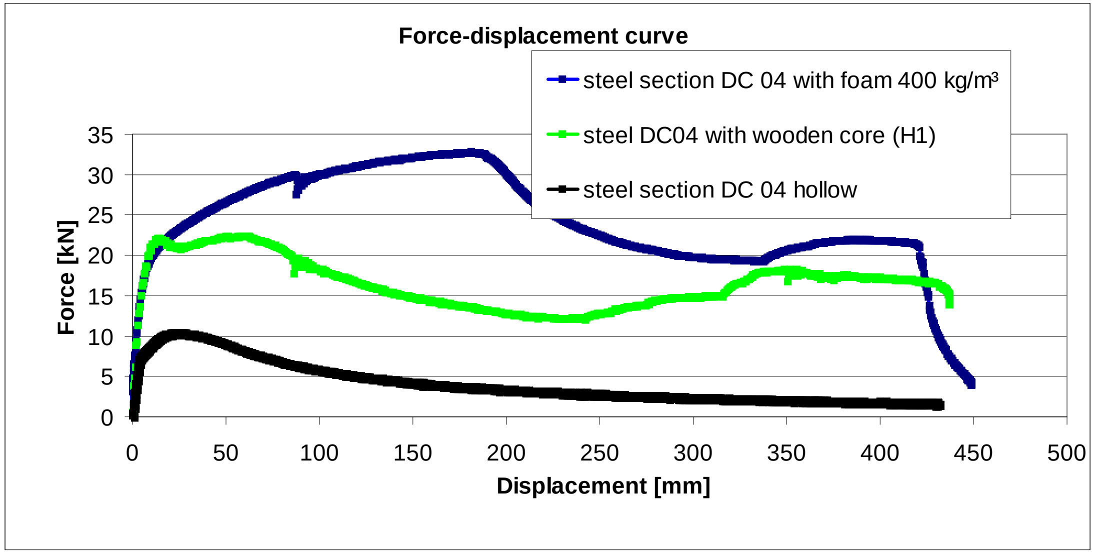


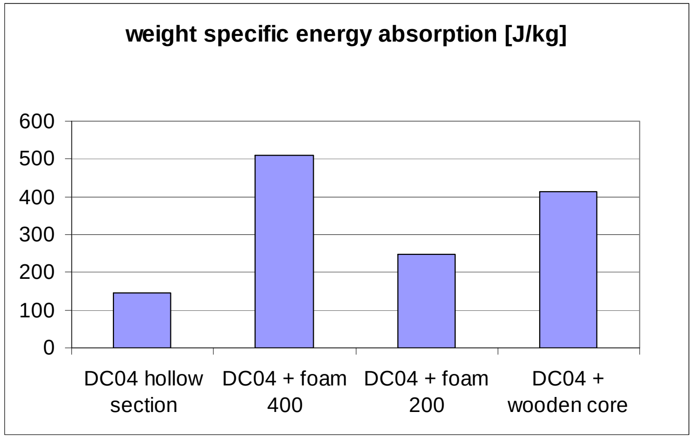
further development: combination of solid core structures and light foam



- use of wooden cores: high ratio of compression strength / density
- higher density than foam

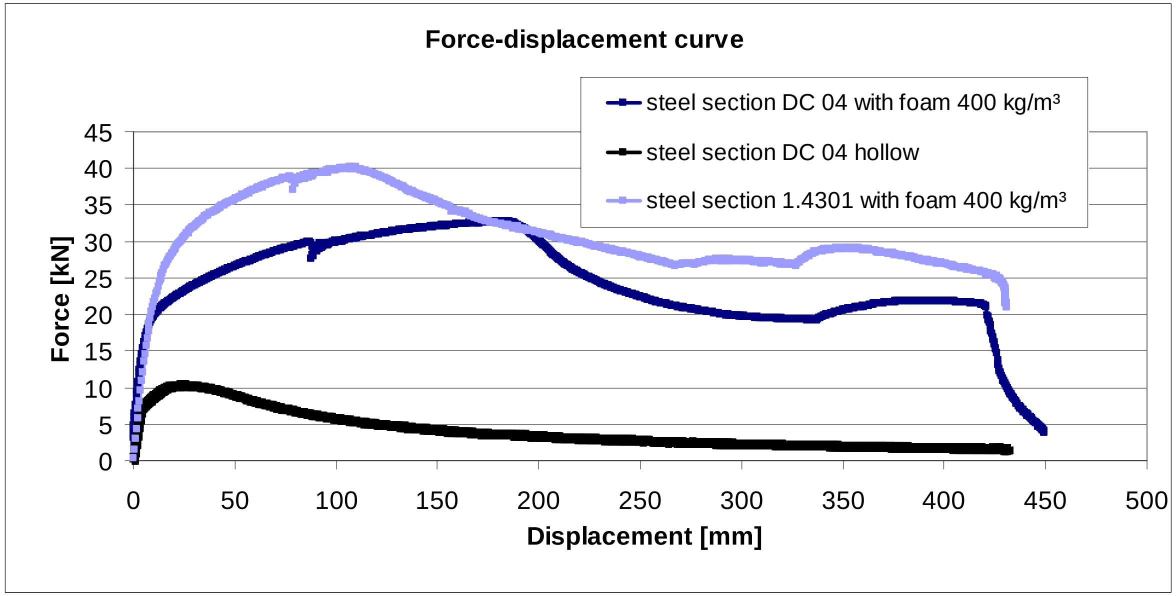
Variation of core material (2)

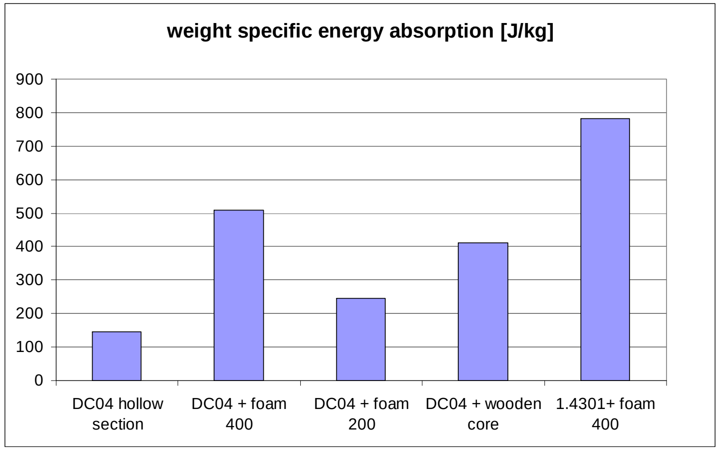




- wooden core H1: weight increase by a factor of 1,41 compared to a hollow beam

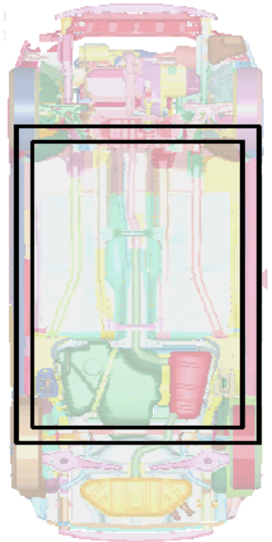
Variation of shell material





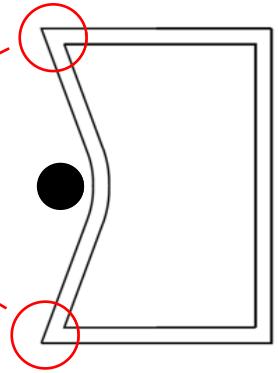
- use of stainless steel 1.4301 (higher tensile strength) -> weight increase by a factor of 1,74 compared to hollow beam

Integration into the underbody structure, basic principle

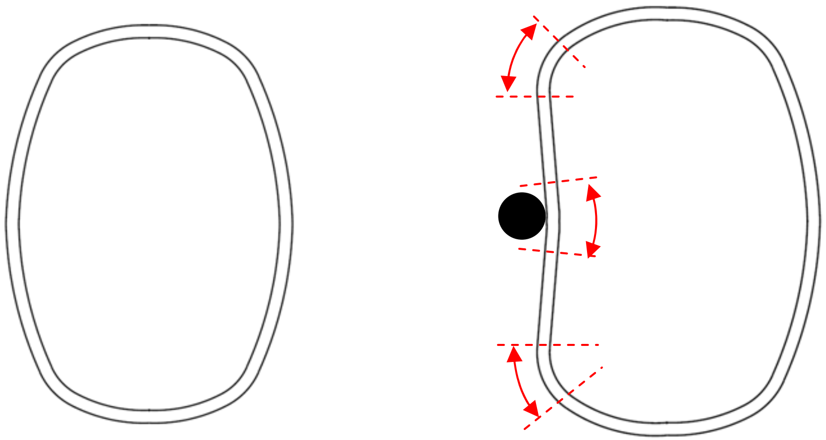


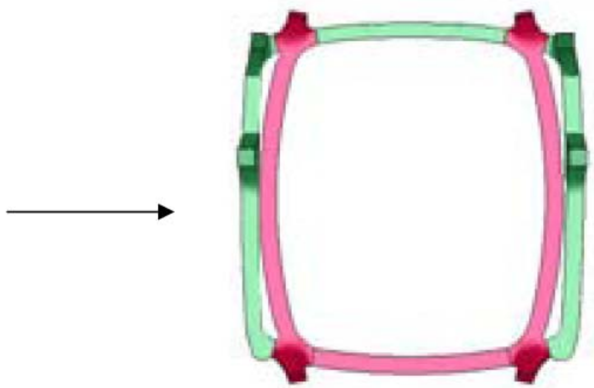
conventional rectangular topology:

difficulty in designing an appropriate support structure



a ring-like shaped, filled structure should lead to comparatively low strain values, distributed over a large portion of the structure





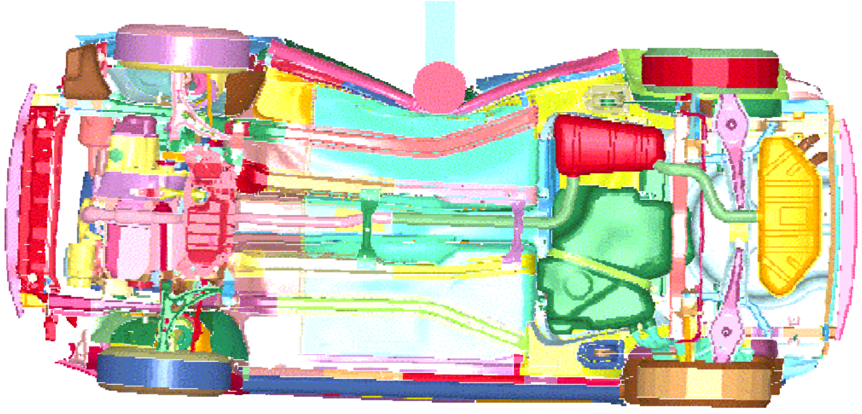
LS-Dyna-Simulation results with a simplified body structure

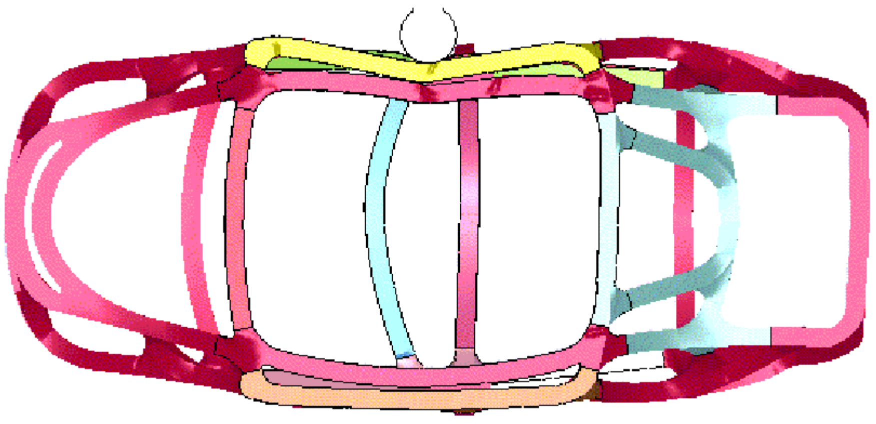
modified pole crash:

the modified pole crash was performed to avoid the addition of virtual weights

- car body is fixed
- weight of pole= 1380 kg
- speed of pole = 29 km/h
- intrusion is slightly more severe compared to a regular pole crash

Modified pole crash results with a simplified body structure



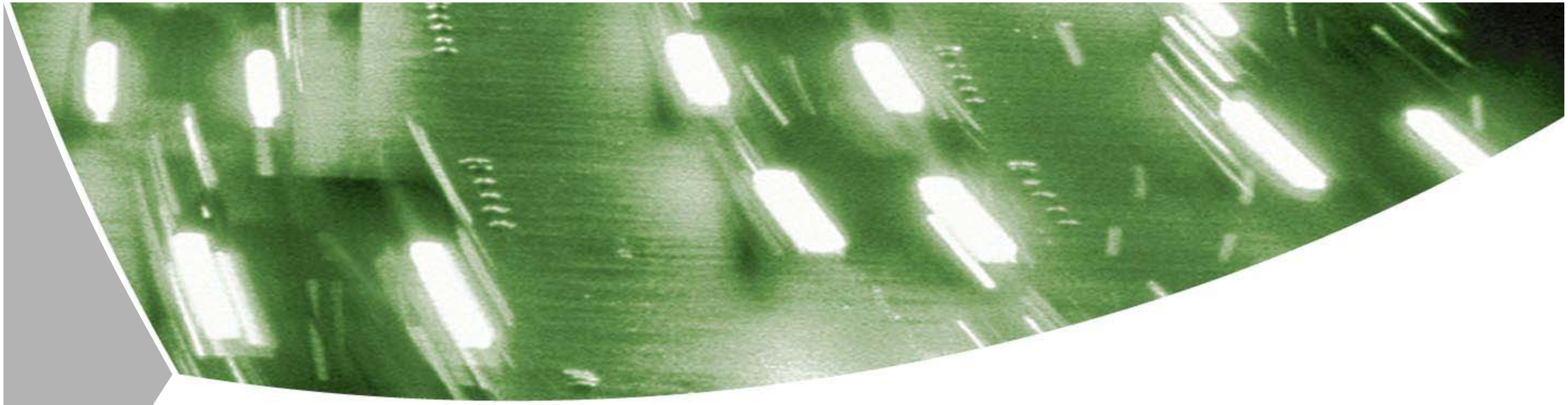


results of the new structure:

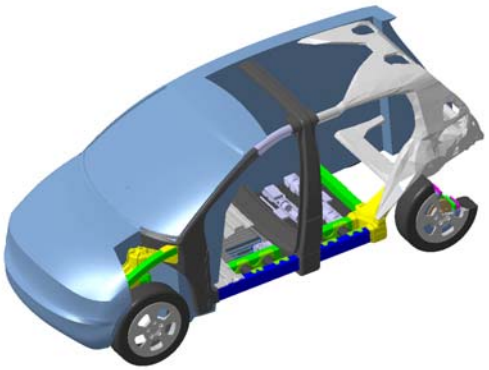
- high energy absorption, compared to a full vehicle with interior, even without floor panel, seat structure etc.
- proof of the basic principle: the underbody structure is deformed as one „ring“, without any collapse of particular parts

Summary and conclusions

- filling of beam structures drastically increase their intrusion resistence and weight -specific energy-absorption
- an underbody structure composed of a ring-like filled structure results in a very high intrusion resistance during pole crash. A large portion of the underbody could therefore be used for the storage of critical components like Li-Ion batteries
- a more detailed car body structure is needed to make accurate weight predictions
- optimization of the structure by decreasing intrusion resistance in favor of reduced weight seems reasonable
- since the frame structure alone absorbs all of the crash energy, other components, like the floor panel, can be designed differently, leading to a potential weight reduction



Thank you for your attention



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