POSSIBILITIES FOR THE USE OF METAL-HYBRID-STRUCTURES FOR VEHICLE CRASH LOAD CASES

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- Introduction of the institute of vehicle concepts
- Motivation and basic principle
- Simulation and Optimisation
- Possible applications
DLR – Overview

DLR's mission:

- exploration of the Earth and the solar system
- research aimed at protecting the environment
- development of environmentally-friendly technologies to promote mobility, communication and security.

7,700 employees are working at 32 research institutes and facilities in 9 locations and 7 branch offices.
The departments of the Institute - FK

Vehicle systems and technology assessment

Vehicle energy concepts

Alternative energy conversion

Lightweight and hybrid design methods

Innovative vehicle concepts for road and rail

FK designs and demonstrates innovations for the vehicle concepts and technologies of future compliant transport systems
DLR Institute of Vehicle Concepts
Lightweight & Hybrid Design Methods

- Development of resource-efficient, innovative vehicle concepts
- Safe, light and cost-effective
- Adaptation to alternative drive train concepts
Lightweight & Hybrid Design Methods
Passive safety / crash simulation and testing
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Motivation

- 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

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

www.DLR.de  •  Chart 9
Cavity filling with BETAFOAM™

- BETAFOAM™ is a family of foam-based products
  - Two-component polyurethane foam applied as bulk
  - Fast cycle time, room temperature curing
  - Components form a rigid, closed cell foam
- Foam products range in density from 30 g/l to 400 g/l
- Higher density foams provide multi-functional benefits

™Trademark of The Dow Chemical Company
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

- 3-point bending test, distance between supports: 1300 mm
- Cross section of the beam: 128 x 90 mm
- Diameter of the pole: 300 mm
- Energy absorption = force at the pole x displacement of the pole
Testing performed in cooperation with DOW (2)

- Increase of the energy absorption by a factor of 6
- Increase of the weight specific energy absorption by a factor of 3
Dynamic Testing

- Dynamic testing results in a slightly higher force level
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## Simulation and test

<table>
<thead>
<tr>
<th>Foam density [kg/m³]</th>
<th>Simulation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td><img src="image1" alt="Simulation Image" /></td>
<td><img src="image2" alt="Test Image" /></td>
</tr>
<tr>
<td>400</td>
<td><img src="image3" alt="Simulation Image" /></td>
<td><img src="image4" alt="Test Image" /></td>
</tr>
</tbody>
</table>

- A reduction of the core density leads to a deeper fold in the outer wall
- The tendency for folding of the outer wall can be predicted
- There are visible differences in the mode of deformation
Simulation and test

Results of simulation and test

- Influence of the foam density is lower in simulation
Influence of wall thickness

- Constant foam density of 200 kg/m³
- Increasing wall thickness -> reversal point at 0.86 mm
Possibilities for optimisation

**Goals:**
- Further increase of weight specific energy absorption
- Reduction of the weight of the core

**Strategies:**
- Variation of the outer wall, side walls and inner wall of the beam regarding:
  - Material
  - Wall thickness
Possibilities for optimisation (2)

- Constant foam density of 200 kg/m³
- Variation of the wall thickness of the outer and inner wall from 0.1 mm to 3 mm
- Optimisation of both parameters at the same time, with LS-Opt
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• Possible applications
Development of a door side intrusion beam

Variant 1
Beam from the hinge to the B-pillar

Variant 2
Y-shaped beams from the hinges to the B-pillar

Variant 3
X-shaped beams from the hinges to the B-pillar and lock

Variant 4
Y-shaped beams from the hinges to the lock

Variant 5
Two beams

Variant 6
Beam from the lower hinge to the lock

Variant 7
Double beam from the lower hinge to the lock
Development of a door side intrusion beam

Variant 1
Beam from the hinge to the B-pillar

Variant 2
Y-shaped beams from the hinges to the B-pillar

Variant 3
X-shaped beams from the hinges to the B-pillar and lock

Variant 4
Y-shaped beams from the hinges to the lock

Best ratio of performance to weight
Development of a door side intrusion beam (3)

- Deformation behaviour exceeds the requirements by far
- Energy absorption 10% higher than the reference
- Weight of the side intrusion beam reduced from 2 to 1 kg
A-ring shaped structure should lead to an even better distribution of plastic strain.

Absorption of crash energy through elongation of material

Stabilisation of the cross section

Application: Ring-shaped frame of a lightweight vehicle concept (metal-monocoque structure)
Simulation of crash tests

<table>
<thead>
<tr>
<th>Intrusion</th>
<th>Crashtest</th>
<th>Reference</th>
<th>Metal monocoque [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro-NCAP 40% overlap, offset deformable barrier</td>
<td>Euro-NCAP front ODB</td>
<td>84</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Euro-NCAP side impact</td>
<td>211</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>Euro-NCAP pole impact</td>
<td>381</td>
<td>207</td>
</tr>
</tbody>
</table>

Euro-NCAP side impact

Euro-NCAP pole impact
Euro-NCAP polecrash
Testing of components: Sandwich front structure

- Weight of the front structure: 12 kg
- Integration of various functions in one part:
  - Loads from the chassis
  - Support for various drive-train components
  - Energy absorption in frontal crash load cases
- Relatively uniform force-deformation-curve
- Regular folding of the aluminium layers
Thank you for your attention!