Extreme sandwich-lightweight design with high degree of functional integration

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Lunar rover

Aircraft for flight testing
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
Motivation for lightweight design
Politics, Society / Environment und legislation

- Shortage of resources
- Climate change
- Population and mobility growth
- Decrease of consumption and emissions necessary
- Increasing demand for more efficient mobility

Source: Internet, Naisbitt
Importance of low vehicle mass

- 2/3 of the total fuel consumption are weight-dependent
- Secondary mass reduction of the drive train and energy storage is especially important with electric vehicles

### Cost per weight reduction

<table>
<thead>
<tr>
<th>Type</th>
<th>EUR/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Engine</td>
<td>~3</td>
</tr>
<tr>
<td>Hybrid electric</td>
<td>5-14</td>
</tr>
<tr>
<td>Battery electric</td>
<td>18-20</td>
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</tbody>
</table>

Source: based on McKinsey Study „Lightweight materials and design - a perspective across key industries“, 2012
State of the art body in white construction

- Very low cost in large scale production
- Mass: around 180-250 kg for a 4-seater
- Hollow structures, joined with spot-welds,
- Relatively complex geometry, around 200-300 parts
- High stiffness but tendency for buckling under certain load conditions
Use of sandwich parts - examples

- High stiffness, even in simply shaped parts
- Shaping of the parts is difficult
- Cost for semi-finished parts relatively high
- Crash behaviour must be examined

Sources:
- H C Davies; M Bryant; M Hope; C Meiller: Design, development, and manufacture of an aluminium honeycomb sandwich panel monocoque chassis for Formula Student competition; Journal of Automobile Engineering 2011
- Metawell GmbH
- KTM Sportscar GmbH
Concept idea: Metal monocoque development

Targets:

- High crashworthiness, by use of sandwich-structures
- Low investment costs due to low number of parts
- Low initial requirements for production facilities
- Use of conventional materials (e.g. PU-foam, aluminium sheet metal)
- Construction method similar to a race car
- Weight of the body in white approx. 80 kg, for a two seater
A ring-like shaped structure with a foam core should lead to comparatively low strain values, distributed over a large portion of the structure.

Absorption of crash energy through elongation of material

Stabilisation of the cross section

Slight imperfections in the mode of deformation

FE-simulation
Ring-frame optimisation

Initial design

- Mass: 23.6 kg
- Deformation under frontal load: 271 mm
- Deformation under side load: 247 mm

Optimised design:

- Mass: 22.5 kg - 4.8%
- Deformation under frontal load: 175 mm - 35.3%
- Deformation under side load: 228 mm - 7.6%
Crash-Simulation - EURO-NCAP-pole-crash

- Good overall crash behaviour under highly concentrated loads (29 km/h, pole diameter 254 mm)
- Lower intrusion than with a conventional structure, no collapse
Components for a fuel cell drive train

1 Fuel cell stacks
2 Fuel cell control module
3 Cooling module
4 Air supply module
5 H₂-storage
6 Battery

- Mass of drive train components depends on vehicle mass
  → secondary effects of body weight reduction

- Energy storage difficult in alternative drive train concepts
  → high importance of secondary weight reduction
Crashbox for AZT-testing

- Testing formalities:
  - Velocity: 15 +1/-0 km/h
  - 40% overlap

- Comparison 100% and 40% overlap:
Vehicle front structure

- Novel sandwich architecture related to automotive front structures
- Static stability (sub-frame connection)
- High safety for passengers
- Good-natured failure mechanism of the front structure
- High degree of functional integration
  - suspension/ sub-frame
  - components
  - crash performance
- Closed structures (sandwich panels)
- Segmentation of the front structure (central crashbox and sidewise structures)
- Integrated inserts in fabrication process
- Little geometrical complexity
Vehicle front structure
Crash-Simulation - US-NCAP front crash

- 56 km/h
- Rigid barrier

- Damage tolerant crash-behaviour, even when overloaded, little tendency for catastrophic collapse
Summary and overview

- Implementation of an overall sandwich car body concept
- Low mass (80 kg)
- High degree of functional integration
- First successful execution of numeric simulation
  - US-NCAP frontal
  - Pole-crash
  - Component test
- Good-natured failure mechanism
Challenges

- Validation of assembly concept
- Validation of the suspension concept
- Crash testing on the dynamic component testing facility
- Validation of assumed framework conditions in simulation
  - Material behaviour
  - Numerical settings
- Manufacturing concept (prototype and small series)
Future prospects

- Design of the external shell
- Driveable demonstrator
- Crash testing (components and complete car body)
- Shape and topography optimization
- Aerodynamic investigation (with partners)
- Investigations of structures with high fatigue strength
- Investigations in additional crash scenarios
- Systematic examination of crash behaviour of sandwich structures
Thank you for your attention!