Automotive Workshop on BiW-Structures

Body Engineering Trends - The FP7 SEAM Cluster

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Thilo Bein
Fraunhofer LBF
Outline

- Preface
- Lightweight design for mobility
- The SEAM cluster
- Future mobility
- Summary
Preface

- In the year 2050 more than 9 bn. humans will live on earth. (UN)

- In the next 30 years 450 mill. Chinese people will live in cities, which are not existing, yet. (Lutz Engelke, Trias Projektgesellschaft mbH, auto motor sport-Kongress 2010)

- Up to the year 2030 appr. 500 cities will exist with a population over a million citizens. 27 of them will be megacities. (8th world congress of network Metropolis - World Ass. of Major Metropolises)

⇒ Increasing demand on urban mobility

... with zero-emission ideally
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Challenges for Future Mobility

**Reduced emissions**

<table>
<thead>
<tr>
<th>PM</th>
<th>NOX</th>
<th>CO</th>
<th>HC</th>
</tr>
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</table>

**CO₂ emission development**

<table>
<thead>
<tr>
<th>2006</th>
<th>2012</th>
<th>2020</th>
<th>2025</th>
</tr>
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<tbody>
<tr>
<td>160</td>
<td>130</td>
<td>95</td>
<td>70</td>
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**Price / availability of oil**

![Image showing oil price fluctuations](www.in-brasilien.de)

**Increasing traffic (passenger and transport)**

Until 2030 in the transport sector, the predicted increase of fuel demand totals 55 %

⇒ We have to reduce weight of all kind of vehicles

[Source: Grotendorst, Continental, 2009]
Life cycle fuel efficiency improvement by lightweight

Data from: Helms, LCA case studies – 2006
Global fuel savings by lightweighting

Data from: Helms, LCA case studies – 2006

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Body & chassis/suspension components are loaded by fluctuating forces.

Significant improvement on material & mass efficiency can be generated only by managing the stress vs. strength interference.
Challenges and strategies of lightweight design

- Components and functions integration
- New material and production techniques
- Cost-weight-optimisation

Source: M. Goede, VW Group Research
Material mix/technology to lower vehicle weight

- **Steel intensive** vehicle structure is **cost effective**
- **Aluminum** and **composites** become more often used
- Vehicle life cycle and **end-of-life-vehicle** have to be considered
Trend towards multi-material design

Source: M. Goede, VW Group Research, SLC
But ... GHG emission must be considered over the complete life-time.

Production (cradle-to-gate)

Materials are not directly comparable, because of different properties, applications, and functionalities.

- Only production is analysed.

Source: M. Goede, S. Krinke, VW Group Research

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CO₂-profiles in the production phase

- The usage of hot formed steel (MQB-measures) already reduces the CO₂ emissions in the production phase. Break-even: 0 km
- The usage of aluminum leads to an increase of CO₂ emissions in the production phase.

Source: M.Goede, S. Krinke, VW Group Research
Lightweight design throughout the life-cycle

- LCA must consider the specific materials and vehicle design options.
- Intelligent lightweight design leads to less emission over the entire life cycle.

Source: M. Goede, S. Krinke, VW Group Research
Additional manufacturing costs

Values estimated based on a collection of MSL vehicle cost analyses and other sources

Source: Fine, Roth, MIT MSL, MIT Manufacturing Round Table, 2010
Weight saving considering secondary savings

Source: Fine, Roth, MIT MSL, MIT Manufacturing Round Table, 2010

Based on secondary mass savings of 0.8kg for every 1kg primary mass saving
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Lightweight as development target

- to meet the CO₂ targets of ICE-driven cars (-100 kg = 8.5 gCO₂/km)
- to compensate for the mass of the battery
- to reduce the mass of the battery
- to extend the range of HEV/FEV

Base data: Affenzzeller, AVL
Main Challenges: Driving Range and Battery Costs

80% of all customers drive less than 50 km per day

⇒ Besides battery technologies, light weight is the key

[Data: Corsini, GM Europe, 2009]
Mass vs. energy for zero-emission vehicles

10 kWh
Approach

Two different proposals were initiated, each addressing the complete vehicle (BiW, hang-on parts, chassis (suspension) and interior) but:

- ALIVE addressing matured technologies focusing on their deployment in vehicle structures,
- ENLIGHT addressing highly innovative materials.
- Differentiation is done by type of materials considered

- both projects are based on vehicle architecture currently being considered in ELVA and e-LIGHT
- target vehicle is a 2-4 passenger car for mass production
- weight reduction will be assessed against energy and CO2-reduction
- ALIVE will be the benchmark for solutions developed in ENLIGHT
Correlation between ALIVE and ENLIGHT
ENLIGHT/ ALIVE display production volume correlation
Modeling and testing for improved safety of key composite structures in alternatively powered vehicles
Coordinator: fka

Unsafe small electric vehicles through advanced simulation methodologies
Coordinator: VfF

Advanced high volume affordable lightweighting for future electric vehicles
Coordinator: VW

Enhanced lightweight design by advanced lightweight materials
Coordinator: Fraunhofer LBF

Biggest European RTD-Cluster on lightweight design
47 partner from 11 countries, about 19 Mio. € funding
joint dissemination activities between the SEAM projects
The two new projects EPSILON & URBAN-EV will join as associated partners in September 2013

Contact:
Prof. Dr.-Ing. Thilo Bein
E-Mail: info@seam-cluster.eu
Web: www.seam-cluster.eu
All 4 SEAM projects are linked and have ties to several European projects.
The ALIVE Project - Motivation

- Affordable weight reduction is one key for a more intensive market introduction of electric vehicles (EV)
- For an EV with 200 km range (and with battery capacity of 200-300 Wh/kg) the allowable costs of weight saving would be around €8/kg (statement 2010).
- For above mentioned €8/kg (= $10/kg) more than 40% of lightweighting seem to be obtainable (statement 2012).
- However, further weight reduction leads to an exponential cost increase.
- Avoiding such cost increase is the main challenge of the ALIVE project.
The ALIVE Project - Objectives

- Achieve a significant reduction in weight of electric cars destined for mass-production with minimal additional costs
  - Biw with integrated battery housing: approx. 45% (i.e. from 355 kg to 200 kg)
  - Chassis: approx. 25% (i.e. from 260 kg to 200 kg)
  - Hang-on parts: at least 25% (i.e. from 100 kg to 75 kg)
  - Interior components: in the range of 30% (i.e. from 100 kg to 70 kg)
- Development of design and simulation capabilities
- Building a data-rich novel fast and reliable LCA simulation tool
- Demonstration by means of a full scale validator that integrates body-in-white, closures, heavy interior components and chassis / suspension subassemblies
- Demonstration of real crash performance on module level using destructive testing
- Full vehicle non-destructive experimental testing results validating the virtual performance validation of all key performance criteria
- Advancements in joining technologies aimed at realistic industrial solutions that can reliably and economically join a variety of materials
The ALIVE Project – Weight Targets

- **EV specific weight**
  - SotA: 355 Kg
  - Biw: 256 Kg
  - Supporting frame: 69 Kg
  - 30 Kg for battery safety

- **30% weight reduction**
  - SLC savings: 77 Kg

- **Additional 20% weight reduction**
  - ALIVE: 198 Kg
  - Weight target: 143 Kg
  - Battery case: 55 Kg

- **Biw weight targets**
  - -30% Biw: 179 Kg
  - -20% Biw: 36 Kg
  - -20% Biw with battery case: 143 Kg
The ALIVE Project - Key Deliverables

- Design capabilities and innovative structural layouts for affordable high volume lightweight EV
- Materials and manufacturing capabilities for affordable high volume lightweight EV
- Experimental and simulation validation environments to allow for quick & reliable multi-parameter design & optimisation loops
- Demonstration of the abovementioned results into a full scale demonstrator vehicle covering BiW, hang-on parts, chassis and heavy interiors, including battery pack integration, innovative safety mechanism and several new materials and manufacturing technologies
The ENLIGHT Project - Objectives

- Development of highly innovative lightweight / low embedded CO$_2$ materials for their application in medium-volume automotive production (50,000 units/year)
- Design capabilities for affordable medium-volume lightweight EVs
- Manufacturing and joining capabilities for affordable medium-volume lightweight EVs
- Demonstration of the proposed solutions through the realization of at least 5 full scale demonstrator modules, covering different distinguishing features of purpose-designed EVs:
  - Front module,
  - Firewall,
  - Central floor section,
  - Sub-frame & suspension, and
  - Doors / enclosures
## The ENLIGHT Project - Weight targets

<table>
<thead>
<tr>
<th>Module</th>
<th>Benchmark EV (Nissan Leaf)</th>
<th>SLC impact</th>
<th>ALIVE</th>
<th>ENLIGHT</th>
<th>% reduction over ALIVE</th>
<th>% reduction over SLC</th>
<th>% reduction over benchmark EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BiW (medium risk)</td>
<td>380</td>
<td>266</td>
<td>215-230</td>
<td>172-184</td>
<td>-20.00%</td>
<td>-33.83%</td>
<td>-53.68%</td>
</tr>
<tr>
<td>BiW (high risk)</td>
<td>380</td>
<td>266</td>
<td>200</td>
<td>160</td>
<td>-20.00%</td>
<td>-39.85%</td>
<td>-57.89%</td>
</tr>
<tr>
<td>Chassis</td>
<td>270</td>
<td>270</td>
<td>200</td>
<td>160</td>
<td>-20.00%</td>
<td>-44.00%</td>
<td>-44.00%</td>
</tr>
<tr>
<td>Heavy interior</td>
<td>100</td>
<td>100</td>
<td>70</td>
<td>56</td>
<td>-20.00%</td>
<td>-40.00%</td>
<td>-40.00%</td>
</tr>
<tr>
<td>Hang-on parts</td>
<td>100</td>
<td>100</td>
<td>75</td>
<td>60</td>
<td>-20.00%</td>
<td>-40.74%</td>
<td>-40.74%</td>
</tr>
<tr>
<td>Overall (best case)</td>
<td>850</td>
<td>736</td>
<td>545</td>
<td>436</td>
<td>-20.00%</td>
<td>-40.76%</td>
<td>-48.71%</td>
</tr>
<tr>
<td>Overall (worst case)</td>
<td>850</td>
<td>736</td>
<td>575</td>
<td>460</td>
<td>-20.00%</td>
<td>-37.50%</td>
<td>-45.88%</td>
</tr>
</tbody>
</table>
The ENLIGHT Project – Key deliverables

- each considered module saves 20% weight compared to the respective component of the ALIVE project
- Availability and implementation of advanced lightweight materials such as hybrids, CFRPs or thermoplastics
  - Qualification of renewables and low-cost fibres for the automotive sector meeting current automotive standards and required manufacturing costs
  - New, advanced materials meet specifications regarding weight savings, crashworthiness and applicability in medium-scale production (50,000 units/year)
- Elaboration of material data and models for new lightweight materials such that they can be implemented in the vehicle design
- Elaboration of testing procedures for new materials, components and sub-systems
  - Validated accelerated test methods reducing test time by half
  - Durability of components and sub-systems proven according automotive standards
  - Crashworthiness of components and sub-systems proven meeting a EuroNCAP of between 4 and 5*
The MATISSE Project - Objectives

- Define, investigate and assess future crash scenarios involving lightweight APVs
- Develop advance modelling methodologies that specifically address the difficulties in modelling FRP composites in comparison to metals
- Apply new methodologies and material models to the investigation, design and testing of FRP pressurised adaptive crash structures and improved FRP high-pressure storage tank
- Develop a modelling and simulation tool chain that will allow APV designers to predict and optimise the safety performance of parts
- Focus is set on:
  - Modelling (FRP materials for crash simulation considering load history, non-linearity, anisotropy)
  - Conceptual design and simulation of pressurised structures (CNG tank and e.g. A-pillar)
  - Building up demonstrators of pressurised structures (CNG tank and e.g. A-pillar)
  - Testing of pressurised structures (CNG tank and e.g. A-pillar)
  - Development of virtual evaluation criteria and conduction of benefit analysis of FRP usage
  - Training and publication
The SafeEV Project - Objectives

- Analysis of future accident scenarios as well as taking the introduction of active safety systems into account

- Provide the methods, criteria and advanced active and passive safety evaluation tools needed for pedestrian and occupant protection

- Evaluate the virtual testing environment and find generic solutions for compatibility, pedestrian and occupant protection

- Validation of the advanced methodology through prototypical safety component(s) being tested and compared with simulation

- Deliver reference electric vehicles models for the evaluation of virtual testing

- Provide a best practice guidelines for the virtual testing of SEVs
The SEAM cluster facilitates interaction between the 4 projects

- Coordinating meetings between projects
- Follow up common GANTT chart, deliverables exchanges
- Preparing / organising the Liaison Group telcons and meetings
- Coordination of common dissemination / exploitation activities
- Final exhibitions, workshops, conferences, and training courses
- Establishing web-pages, email newsletter, and leaflet
- Communication of relevant events / information to partners
- Providing best practices for exploitation activities and coordinating them
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Shaping future mobility

- Sustainable vehicle technology moves to electric drives
- Conversion design provides chance to market products initially
- Performance, weight and costs of battery systems are an open issue
- New vehicle concepts have to „re-invent“ the structure of a passenger car

... evaluating stress vs. strength interference ...

... moving to new vehicle technology
Future concepts for zero-emission vehicles

- Integration of **wheel + drive**
- Centralized/de-centralized **energy storages**
- Active and passive **assistant systems**
  - How-to-drive (speed, distance etc.)
  - Where-to-drive (route, traffic jam, parking etc.)
- Reduction of resistance
  - **Aerodynamics**
  - Lightweight structures + optimized tire/wheel systems
New driveline concepts for small urban vehicles

- Flexibility with regard to design and package
- »Torque vectoring« and all-wheel traction
- Co-operative braking
Summary

- Population and economic growth create a **huge demand for transportation**
- **Energy is »driving« transportation engineering** – searching for more sustainable and efficient concepts related to transport & vehicles
- **Lightweight** helps to improve energy efficiency especially **for passenger cars and trucks**
- **Materials and manufacturing** are enablers to come up with the **most cost efficient and robust lightweight solutions**
- Lightweight design needs sophisticated methods for **data acquisition, data processing, material characterization & fatigue testing, as well as design & development**