Lightweight Design: Construction Methods and Vehicle Concepts

Dipl.-Ing. Marco Münster
Prof. Dr.-Ing. Horst E. Friedrich
Dipl.-Ing. Elmar Beeh
Dipl.-Ing. Gundolf Kopp

03. December 2013
Agenda

1. DLR
2. The growing importance of lightweight design
3. Methodical approach in the development process
4. Lightweight design strategies
5. Concepts for current and future cars
6. Summary
DLR – German Aerospace Center

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.
DLR – German Aerospace Center

Institute of Vehicle Concepts:

- 72 employee

- Vehicle systems and technology assessment
- Vehicle energy concepts
- Alternative energy conversion
- Lightweight and hybrid construction

<table>
<thead>
<tr>
<th>SPACE</th>
<th>AERONAUTICS</th>
<th>TRANSPORT</th>
<th>ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Space Image" /></td>
<td><img src="image2.png" alt="Aeronautics Image" /></td>
<td><img src="image3.png" alt="Transport Image" /></td>
<td><img src="image4.png" alt="Energy Image" /></td>
</tr>
</tbody>
</table>

Source: DLR
Megatrends

• We are reaching the limits of oil extraction
• Climate change is taking place
• Growing population, concentrated in big cities and conurbations
• Demographic trend

Vehicle concepts

• Lower energy consumption
• Reduced CO₂ emissions
• Alternative and regenerative energy sources
• Automated driving / connectivity
• …
CO₂ emissions in new vehicles in Germany and EU CO₂ limits

Source: KBA; DLR

* Mass-dependent
Driving resistances and consumption

\[ \sum F_r = b \cdot (m_t + \sum m_{rot}) + m_t \cdot g \cdot f_r \cdot \cos(\alpha) + m_t \cdot g \cdot \sin(\alpha) + \frac{\rho}{2} \cdot c_d \cdot A \cdot v^2 \]

\[ F_{\text{acceleration}} + F_{\text{rolling}} + F_{\text{gradient}} + F_{\text{drag}} \]

-1 \% -Point
-0.10 l/100km -2.5 g CO$_2$/km

-10 \(c_d\) -Points
-0.04 l/100km -1.0 g CO$_2$/km

-0.08 m$^2$
-0.04 l/100km -1.0 g CO$_2$/km

-100 kg
-0.30 l/100km -7.5 g CO$_2$/km

Source: DLR; Daimler
Extension of range with small electric vehicles

Example: vehicle parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle mass</td>
<td>1000 kg</td>
</tr>
<tr>
<td>Coefficient of resistance</td>
<td>0.01</td>
</tr>
<tr>
<td>Air resistance factor</td>
<td>0.32</td>
</tr>
<tr>
<td>Front surface</td>
<td>2.2 m²</td>
</tr>
<tr>
<td>Usable battery capacity</td>
<td>28.2 kWh</td>
</tr>
<tr>
<td>Efficiency of drive train</td>
<td>70%</td>
</tr>
</tbody>
</table>

→ 25 % mass reduction can achieve 28 % increase in range

Source: DLR
State of the art vehicle Golf 7

Weight saving:
- weight reduced about 100 kg
  - Electrics - 6 kg
  - Drive train - 40 kg
  - Chassis - 26 kg
  - Body - 37 kg

Lightweight design measures:
- High-strength and higher-strength types of steel, reduced sheet thickness (TRB)
- Only using material where it is needed
- Optimal geometry of profiles and surfaces

→ Holistic, methodical approach in the product development process to achieve the CO₂ limits

Source: VW
From the chain of effects of the traffic system to the methodical development process

Demand for mobility
- CO₂
- Legislation
- Energy prices
- ...

Transport system
- Requirements
- Target function
- ...

Vehicle concepts and architecture
- Simulation
- Optimization
- ...

Technology
- Structural components
- Crash components
- Energy converters
- ...

Lightweight requirement

Lightweight design by requirement for electrical vehicles

Lightweight design strategies

Source: DLR
Methodical Development Process
Vehicle lightweight design concept

- Vehicle concept/measure concept/package
- Requirements/market/customer
- CAD-designed spacemodel and topology optimization
- Conceptual structure-variants suitable for any material
- Design and simulation
- Vehicle- and lightweight design-concept

Source: DLR (Münster)
From the chain of effects of the traffic system to the methodical development process

Demand for mobility
- CO₂
- Legislation
- Energy prices
- ...

Transport system
- Requirements
- Target function
- ...

Vehicle concepts and architecture
- Simulation
- Optimization
- ...

Technology
- Structural components
- Crash components
- Energy converters
- ...

Lightweight requirement

Lightweight concept

Lightweight materials

Lightweight shape

Lightweight design by requirement for electrical vehicles

Lightweight design strategies

Source: DLR
Lightweight requirement

Objective:
• light vehicle with high crash performance (L7e)

Solution:
• Body structure in sandwich architecture
  • Skin layers aluminium alloy
  • Foam core polyurethane
• Joining process
  • Crash-stable structural adhesive
  • Welded parts

BIW < approx. 80 kg

Euro-NCAP frontal crash → intrusion approx. 102 mm

Source: DLR (Kriescher, Brückmann)
Lightweight design concept

Objective:
- Crash modular, adaptable vehicle front

Solution:
- Energy absorbed through cutting
- Three-dimensional, reinforced light front vehicle structure
- Peeling pipes for adjustment of energy

Approx. 20% lighter than steel reference structure

Source: DLR (Beeh)
Lightweight material design

Objective:
- Light CFRP B-pillar

Solution:
- Layer structure (0/90/±45)
- Manufacture using VARI procedure
- Internal reinforcement with additional Omega profile
Lightweight shape

Objective:
• A lighter and more cost-effective cast A-pillar node

Solution:
• New design with magnesium alloy
• Integration of suspension strut slot and A-pillar
• Weight saving approx. 50 %
• Component weight 6 kg
Summary

• CO₂ limits and gradual electrification are reinforcing the trend towards lightweight construction in vehicle design
  • Compensation for extra weight of new components
• Gradual electrification as a chance for:
  • new vehicle concepts, lightweight design concepts and a push for lighter materials
• Focus for research and development:
  • Holistic, methodical approach in the product development process
Thank you for your attention!

Dipl.-Ing. Marco Münster

DLR Institute of Vehicle Concepts
Pfaffenwaldring 38-40
70569 Stuttgart
Germany

marco.muenster@dlr.de
www.DLR.de/fk
+49 711 6862-707