Integral consideration of the lightweight design for railway vehicles

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Sites and employees of DLR

More than 6900 employees working in 33 research institutes and facilities

R & D Activities:
- Aeronautics
- Space
- Transportation
- Energy
- Defence and Security
Next Generation Train
Vehicle types

- Ultra-high-speed train
  NGT HGV

- Fast InterCity trainset
  NGT REGIO
  → train concept

- Fast freight transportation
  NGT Cargo
  → in future
Next Generation Train (NGT HGV)
Topics and Goals

• Increasing the certified train speed to 400 km/h
• Halving the specific energy consumption → double deck high speed train
• Noise reduction
• Increase of comfort
• Improvement of the driving safety
• Improvement of wear behaviour and life cycle costs
• Cost-efficient design: through modularization and system integration
• Increasing efficiency of development and permission processes
Motivation light weight design for trains

- Reduction of energy
  - Standardized service profiles for Highspeed, Intercity, Regional and Suburban passenger transport
  - Travel times and dwell times in stations defined in timetable
  - Free choice of velocity profile as long as timetable is kept

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<table>
<thead>
<tr>
<th>Suburban</th>
<th>Regional</th>
<th>Intercity</th>
<th>High-Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total km</td>
<td>40</td>
<td>70</td>
<td>250</td>
</tr>
<tr>
<td>Number of stations</td>
<td>12</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Maximum speed km/h</td>
<td>120</td>
<td>140</td>
<td>200</td>
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<tr>
<td>Min. station distance km</td>
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<td>2</td>
<td>15</td>
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<tr>
<td>Max. station distance km</td>
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<td>10</td>
<td>60</td>
</tr>
<tr>
<td>Mileage km/year</td>
<td>100000</td>
<td>130000</td>
<td>275000</td>
</tr>
</tbody>
</table>

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Energy saving per ton

- Suburban
- Regional
- Intercity
- High-Speed
Motivation light weight design for trains

- Reduction of energy
- Less energy consumption for acceleration and breaking
  - Motors and brake equipment lighter and smaller realisable
  - Less unsuspended weight
  - Reduction of cost of operation

Motivation light weight design for trains

• Reduction of energy

• Less energy consumption for acceleration and breaking

• Increased Payload (especially suburban passenger transport)

Motivation light weight design for trains

- Costs for route depend on axle load in some countries
- Increasing comfort demands
- Reduction of environmental impact (e.g. vibrations)
- Decrease of damage of the superstructure
  - Less effort for maintenance
  - Superstructure and infrastructure adaptable regarding low axle loads
  - Cost saving superstructure

Motivation light weight design for trains

- Limited vehicle weight because of approvable axle load
- Light car body structures allow
  - longer car bodies with the same number of wheel sets and axle loads
  - More passengers at the same unit of length
  - Reduction of the gangways
  - Reduction aerodynamic resistance
  - Fewer wheel sets at the same car body length
  - Modified running gears

Target NGT 16 t
Main assemblies

- Coach can be divided in three main groups:
  - equipment, propulsion, interior ...
  - running gears
  - car body structure
Influences on car body structure

- Operation purpose
- Standards, norms
- Car body concept
- Running gear concept
- Train concept
- Materials, joining technologies

State of the art car bodies

- **Differential style:**
  Welded metallic framework planked with blank sheets

- **Integral style:**
  Aluminium extruded profiles welded together in longitudinal direction

- **Hybrid style:**
  Mix of different materials that uses the potential of every material
Light weight design of car bodies

- Expert knowledge of actual car body styles (integral style, differential style)
- Further weight reduction is limited
- Global use of light weight principles

Requirements static / dynamic loads

- Load requirements for car bodies:
  - Static loads (e.g. DIN EN 12663)
  - Dynamic crash loads (DIN EN 15227)
- Maximal peak of dynamic crash loads (> 50ms) does not rise above maximum of static loads

\[ F_{\text{crash}} < F_{\text{stat}} \]

Reference: [1] SAFETRAIN
Methodology for reducing car body mass

- Definition of the design space

- Static loads of DIN EN 12663 for topology optimization, similar FEM

- Topology optimized car body based on loads of DIN EN 12663
Adaption of the construction

- Constructive adaption of load bearing structure regarding load paths
- Design implementation must reflect
  - Structural components
  - Manufacturing capabilities
  - Cost-effectiveness
  - Joining technologies
Methodology
Use of methodology

- Use of methodology regarding trailer vehicle

Load adapted comb-tube car body structure
Novel load bearing car body structure

Comb-tube car body
- Car body made bulkheads and continuous sole bars
- Bulkheads principal identical along the car body → “endless” tube possible
- Bulkheads consist of cranked beams connected with node elements
- Sole bars connected with beams by nodes
- Node elements e.g. double shell casting nodes, formed blank nodes
- Scalable car body in longitudinal direction
- Large number of same parts
Conclusion

• DLR and NGT-Project

• Motivation light weight design for trains

• Main assemblies of a carriage

• Influences on car body structure

• Potential of reducing weight of car bodies through a methodology which uses topology optimization

• Example for novel load bearing car body structure
Thank you for your attention