FutureSteelVehicle: Stahl-Innovationen und neue Entwicklungsmethoden

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Hannover, 25.04.2012
Future Steel Vehicle

- Introduction of FSV
- Methodology
- Results
WorldAutoSteel
Automotive Group of the World Steel Association

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FutureSteelVehicle
Facts and goals of the study

Facts
• FSV is the **successor** of the recognized lightweight studies **ULSAB 1998 and ULSAB-AVC 2001**
• **Electrical vehicles** are currently more demanding regarding weight saving so they are more challenging to prove that steel is the best choice

Goals
• Development of a smart lightweight steel BiW for an electrical vehicle (and 3 derivates)
• Demonstration of latest **steel grades** and **steel part manufacturing technologies**
• Development of **sustainable** and **cost-effective** solutions

Project Approach

• Prestudy, specification
• Package and ergonomics
• Styling and CFD
• Optimization
• Structural analysis
• Feasibility
• Cost analysis
• Life Cycle Assessment
Advanced Powertrain Options

<table>
<thead>
<tr>
<th></th>
<th>BEV</th>
<th>PHEV20</th>
<th>PHEV40</th>
<th>FCEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSV 1</td>
<td>4-door hatchback</td>
<td>32km</td>
<td>64km</td>
<td>500km</td>
</tr>
<tr>
<td></td>
<td>3700 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 250km</td>
<td>Total: 500km</td>
<td>Total: 500km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max Speed: 150km/h</td>
<td>Max Speed: 161km/h</td>
<td>Max Speed: 161km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-100 km/h 11-13 s</td>
<td>0-100 km/h 10-12 s</td>
<td>0-100 km/h 10-12 s</td>
</tr>
<tr>
<td>FSV 2</td>
<td>4-door sedan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4350 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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- Introduction of FSV
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Topology Optimization Results

Phase 1 Technology Assessment
Packaging
Styling & aerodynamic

Phase 2 Report

Final Design Confirmation
Gauge Optimization
Design Confirmation
Detail Design
Sub-System Topography Optimization
Non-Linear Dynamic Topology Optimization (LF3G)

Linear-Static Topology Optimization

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LF3G Load path and 3G Optimization

Phase 1 Technology Assessment

Packaging

Styling & aerodynamic

Linear-Static Topology Optimization

Non-Linear Dynamic Topology Optimization (LF3G)

Detail Design

Sub-System 3G Optimization

Gauge Optimization

Final Design Confirmation

Phase 2 Report

Design Confirmation

T1

T2

T3

T4

T5

T6
## FSV Steel Portfolio

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum Yield Strength</th>
<th>Minimum Tensile Strength</th>
<th>Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild 140/270</td>
<td>DP 350/600</td>
<td>TRIP 600/980</td>
<td>Type of material minimum yield strength/minimum tensile strength</td>
</tr>
<tr>
<td>BH 210/340</td>
<td>TRIP 350/600</td>
<td>TWIP 500/980</td>
<td></td>
</tr>
<tr>
<td>BH 260/370</td>
<td>SF 570/640</td>
<td>HSLA 700/780</td>
<td></td>
</tr>
<tr>
<td>BH 280/400</td>
<td>HSLA 550/650</td>
<td>DP 700/1000</td>
<td></td>
</tr>
<tr>
<td>IF 260/410</td>
<td>TRIP 400/700</td>
<td>CP 800/1000</td>
<td></td>
</tr>
<tr>
<td>IF 300/420</td>
<td>SF 600/780</td>
<td>MS 950/1200</td>
<td></td>
</tr>
<tr>
<td>DP 300/500</td>
<td>CP 500/800</td>
<td>CP 1000/1200</td>
<td></td>
</tr>
<tr>
<td>FB 330/450</td>
<td>DP 500/800</td>
<td>DP 1150/1270</td>
<td></td>
</tr>
<tr>
<td>HSLA 350/450</td>
<td>TRIP 450/800</td>
<td>MS 1150/1400</td>
<td></td>
</tr>
<tr>
<td>HSLA 420/500</td>
<td>CP 600/900</td>
<td>CP 1050/1470</td>
<td></td>
</tr>
<tr>
<td>FB 450/600</td>
<td>CP 750/900</td>
<td>HF 1050/1500</td>
<td></td>
</tr>
<tr>
<td>HSLA 490/600</td>
<td></td>
<td>MS 1250/1500</td>
<td></td>
</tr>
</tbody>
</table>

State of the art steel grades and developments for the near future were applied for the project.
# FSV Crash Safety Analysis

## Global crash requirements

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>US NCAP</td>
<td></td>
</tr>
<tr>
<td>EURO NCAP</td>
<td></td>
</tr>
<tr>
<td>FMVSS 301 Rear</td>
<td></td>
</tr>
<tr>
<td>ECE R32</td>
<td></td>
</tr>
<tr>
<td>IIHS Side</td>
<td></td>
</tr>
<tr>
<td>FMVSS 2114 Pole</td>
<td></td>
</tr>
<tr>
<td>EURO NCAP Pole</td>
<td></td>
</tr>
<tr>
<td>FMVSS 216a, IIHS Roof</td>
<td></td>
</tr>
<tr>
<td>RCAR/IIHS Low Speed</td>
<td></td>
</tr>
</tbody>
</table>

## Evaluation

<table>
<thead>
<tr>
<th>Test</th>
<th>Diagram</th>
</tr>
</thead>
</table>
| EURO NCAP | ![Diagram](image1.png)  
| | ![Diagram](image2.png)  
| | ![Graph](image3.png)  

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Additional Structural Analysis

- Static and Dynamic Stiffness
  - Torsion Stiffness
  - Bending Stiffness
  - Global Modes

- Noise, Vibration and Harshness

- Durability, Ride and handling analysis
  Fish-hook test, double lane change maneuver (ISO 3888-1), 3g pothole test, 7g constant radius turn test, 0.8g forward braking test
Forming, Cost and LCA

- Manufacturing simulation:
  - One step forming simulation
  - Incremental analysis for complex parts
  - Hot stamping simulation

- Manufacturing planning and cost study

- Life Cycle Assessment

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Design Optimization Process

- Topology optimization
- LF3G design optimization
- Subsystem optimization
  - Submodel selection
    - Front rail
    - Shotgun
    - Rocker
    - B-pillar
    - Rear rail
    - Roof rail
    - Tunnel reinf.
- Complete model optimization

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### Subsystem Analysis

<table>
<thead>
<tr>
<th></th>
<th>Cold forming</th>
<th>Hot forming</th>
<th>Rollforming</th>
<th>Hydroforming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoblank</td>
<td><img src="image1" alt="Monoblank" /></td>
<td><img src="image2" alt="Monoblank" /></td>
<td><img src="image3" alt="Monoblank" /></td>
<td><img src="image4" alt="Monoblank" /></td>
</tr>
<tr>
<td>Laser Welded Blank</td>
<td><img src="image5" alt="Laser Welded" /></td>
<td><img src="image6" alt="Laser Welded" /></td>
<td><img src="image7" alt="Laser Welded" /></td>
<td><img src="image8" alt="Laser Welded" /></td>
</tr>
<tr>
<td>Tailor Rolled Blank</td>
<td><img src="image9" alt="Tailor Rolled" /></td>
<td><img src="image10" alt="Tailor Rolled" /></td>
<td><img src="image11" alt="Tailor Rolled" /></td>
<td><img src="image12" alt="Tailor Rolled" /></td>
</tr>
</tbody>
</table>

- Consideration of all conceivable material and technology combinations

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T4 Comparison FSV Subsystems: Rocker

Cost vs Mass
Parallels of constant value: US $9.39/kg

Cost vs GHG
Parallels of constant value: US $100/tonne

R Tailor Rolled, W Tailor Welded, M Multi-Walled, E Extrusion, S Stamping

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FSV Decision of Subsystem Solutions

- Rollforming single thickness
  - DP 700/1000
  - BH 280/400
- Hot stamping LWB
  - HF 1050/1500
- Cold stamped LWB
  - TRIP 600/980
- Hot stamping LWB
  - HF 1050/1500

- Rollforming single thickness
  - CP 1050/1470
- Hot stamping LWB
  - HF 1050/1500
- Cold stamping LWB/TRB
  - CP 1000/1200
  - DP 700/1000
  - HSLA 350/450
  - Mild 140/270

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Materials Breakdown

- 97% higher strength and ultra high strength steels

100% BiW weight = 188 kg
## Cost Analysis

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Structure Manufacturing Costs</td>
<td>$775</td>
</tr>
<tr>
<td>Body Structure Assembly Costs</td>
<td>$340</td>
</tr>
<tr>
<td>Total Body Structure Manufacturing &amp; Assembly</td>
<td><strong>$1,115</strong></td>
</tr>
</tbody>
</table>

![Cost Analysis Image](image-url)
## FutureSteelVehicle

**Results at a glance**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight</td>
<td>Body in white weight: 188kg</td>
</tr>
<tr>
<td>Sustainable</td>
<td>High Reduction of CO₂-Emissions&lt;br&gt;• 10% material production&lt;br&gt;• Significant reduction due to electric drive&lt;br&gt;100 % recycling of the car body possible</td>
</tr>
<tr>
<td>Innovative</td>
<td>3rd gen. Hightech-Steels&lt;br&gt;97 % use of HSS and UHSS, 50 % GigaPascal-steels&lt;br&gt;State-of-the-art development process</td>
</tr>
<tr>
<td>Safe</td>
<td>5 star crash rating possible</td>
</tr>
<tr>
<td>Affordable</td>
<td>Cost-effective reduction of weight and emission</td>
</tr>
</tbody>
</table>

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![WorldAutoSteel](www.worldautosteel.org)
FutureSteelVehicle
Hannover Messe 2012

Executive summary
www.worldautosteel.org

Full report phase 2
www.futuresteelvehicle.org

Halle 6, Stand D23
Stahl-Informations-Zentrum

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