AHSS - Fastest Growing Automotive Material

Net Pounds per Vehicle (average)

- 81 lbs
- 108 lbs
- 148 lbs
- 450 lbs

Source: Ducker Worldwide

15% CAGR

16.5% CAGR

10% CAGR

---

ULSAB
UltraLight Steel Auto Body

ULSAC
UltraLight Steel Auto Closures

ULSAS
UltraLight Steel Auto Suspensions

ULSAB-AVC
Advanced Vehicle Concepts

FutureSteelVehicle – Investment in Automotive
#1 – State-of-the-Future Design Innovations

- **Phase 1**
  - Technology Assessment
  - Packaging
  - Styling & Aerodynamic
  - Non-Linear Dynamic Topography Optimization (LF3G)

- **Phase 2**
  - Report
  - Final Design Confirmation
  - Design Confirmation
  - Detail Design
  - Subsystem Topography Optimization
  - Gauge Optimization

- **T1**
- **T2**
- **T3**
- **T4**
- **T5**
- **T6**

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Materials – Crash Performance

6% weight reduction

1.60 mm HSLA 350/450

24% weight reduction

1.50 mm DP 350/600

1.25 mm DP 500/800
## #2 – 39% Mass Savings

### FSV BEV Manufacturing Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Mass Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping - Laser</td>
<td>41%</td>
</tr>
<tr>
<td>Welded Blanks - 38%</td>
<td></td>
</tr>
<tr>
<td>Open Rollforming - 2%</td>
<td></td>
</tr>
<tr>
<td>Hot Stamping - Laser</td>
<td>9%</td>
</tr>
<tr>
<td>Hot Stamping - 3%</td>
<td></td>
</tr>
<tr>
<td>Closed Rollforming - 7%</td>
<td></td>
</tr>
</tbody>
</table>

### Body Structure

<table>
<thead>
<tr>
<th>Body Structure</th>
<th>FSV-1 BEV Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>290</td>
</tr>
<tr>
<td>Target</td>
<td>190</td>
</tr>
<tr>
<td>Achieved</td>
<td>188</td>
</tr>
</tbody>
</table>

BEV – 188 kg
PHEV\textsubscript{20} – 175 kg
FSV-2: PHEV\textsubscript{40} and FCEV – 201 kg
FutureSteelVehicle Compared to UltraLight – Mass

Body Structure Mass
(Actual vs. Regression Analysis Prediction)

Body Structure Mass (Actual)

Body Structure Mass (Regression Analysis Prediction)

- a2mac1 (database)
- 1998 ULSAB_AVC Ref. Vehicle
- ULSAB-AVC
- 35%
- 11%
- Audi A2
- Jaguar XK

\[
\hat{m} = 3.418(GVM, kg)^{0.438}(Area, m^2)^{0.599}
\]

Source – A/SP Benchmarking Project

At mass par with aluminum
#3 – 97% HSS and AHSS

FSV BEV Steel Types as % of Body Structure

- HSLA 450, BH 340, 400 - 32.7%
- DP 500-600 - 11.8%
- DP 800 - 9.5%
- DP 1000 - 10%
- TRIP 980 - 9.5%
- TWIP 980 - 2.3%
- CP 1000 - 1470 - 9.3%
- Mild Steels - 2.6%
- HF 1500 - 11.1%
- MS 1200 - 1.3%

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#4 – Nearly 50% GigaPascal Steels

FSV BEV Steel Types as % of Body Structure

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<th>Steel Type</th>
<th>Percentage</th>
</tr>
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<tr>
<td>HSLA 450, BH 340, 400</td>
<td>32.7%</td>
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<tr>
<td>Mild Steels</td>
<td>2.6%</td>
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<tr>
<td>CP 1000 - 1470</td>
<td>9.3%</td>
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<td>MS 1200</td>
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<tr>
<td>DP 500, 600</td>
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<tr>
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</tbody>
</table>
## Range of Steel Grades

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>DP 350/600</th>
<th>TRIP 600/980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild 140/270</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BH 210/340</td>
<td>TRIP 350/600</td>
<td>TWIP 500/980</td>
</tr>
<tr>
<td>BH 260/370</td>
<td>SF 570/640</td>
<td>HSLA 700/780</td>
</tr>
<tr>
<td>BH 280/400</td>
<td>HSLA 550/650</td>
<td></td>
</tr>
<tr>
<td>IF 260/410</td>
<td>TRIP 400/700</td>
<td>CP 800/1000</td>
</tr>
<tr>
<td>IF 300/420</td>
<td>SF 600/780</td>
<td>MS 950/1200</td>
</tr>
<tr>
<td>DP300/500</td>
<td>CP 500/800</td>
<td>CP 1000/1200</td>
</tr>
<tr>
<td>FB 330/450</td>
<td>DP 500/800</td>
<td>DP 1150/1270</td>
</tr>
<tr>
<td>HSLA 350/450</td>
<td>TRIP 450/800</td>
<td>MS 1150/1400</td>
</tr>
<tr>
<td>HSLA 420/500</td>
<td>CP 600/900</td>
<td>CP 1050/1470</td>
</tr>
<tr>
<td>FB 450/600</td>
<td>CP 750/900</td>
<td>HF 1050/1500</td>
</tr>
<tr>
<td>HSLA 490/600</td>
<td></td>
<td>MS 1250/1500</td>
</tr>
</tbody>
</table>

*denotes steel used in ULSAB-AVC

*denotes steel grades available for FSV*
FutureSteelVehicle Steel Technology Portfolio

Broad Bandwidth of Manufacturing Options

- Conventional Stamping
  - Laser Welded Blank
  - Tailor Rolled Blank
- Induction Welded Hydroformed Tubes
  - Laser Welded Hydroformed Tubes
  - Tailor Rolled Hydroformed Tubes
- Hot Stamping (Direct & In-Direct)
  - Laser Welded Blank Quench Steel
  - Tailor Rolled Blank Quench Steel
- Roll Forming
  - Laser Welded Coil Rollformed
  - Tailor Rolled Blank Rollformed
  - Rollform with Quench
- Multi-Walled Hydroformed Tubes
  - Multi-Walled Tubes
  - Laser Welded Finalized Tubes
- Laser Welded Tube Profiled Sections
#5 – Enables 5-Star Safety Rating
#6 – Reduces Life Cycle Emissions

<table>
<thead>
<tr>
<th>Vehicle/Powertrain</th>
<th>Material &amp; Recycling (kg CO₂e)</th>
<th>Use Phase (kg CO₂e)</th>
<th>Total Life Cycle (kg CO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark V ICEg</td>
<td>1,479</td>
<td>32,655</td>
<td>34,134</td>
</tr>
<tr>
<td>FSV BEV USA grid</td>
<td>1,328</td>
<td>13,844</td>
<td>15,172</td>
</tr>
<tr>
<td>FSV BEV Europe grid</td>
<td>1,328</td>
<td>9,670</td>
<td>10,998</td>
</tr>
</tbody>
</table>

FSV vs. Benchmark – USA Grid - 56% CO₂e reduction
FSV vs. Benchmark – Europe Grid - 68% CO₂e reduction

---

### Current Average Greenhouse Gas Emissions Primary Production (kg CO₂e/kg of material)

- Steel: 2.0 – 2.5
- Aluminum: 11 – 13
- Carbon FRP: 21 – 23
- Magnesium: 18 – 45

**Source:** Argonne National Laboratory
## #7 – No Cost Penalty

<table>
<thead>
<tr>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Structure Manufacturing Costs</td>
</tr>
<tr>
<td>Body Structure Assembly Costs</td>
</tr>
<tr>
<td>Total Body Structure Manufacturing &amp; Assembly</td>
</tr>
</tbody>
</table>
#8 – Offers Near-term Production-application solutions

- Final Design Confirmation FEA
- Near-Term Longitudinal Rail Study
- Integrated 3B Forming
- Gauge Optimization
- Design Confirmation FEA
- Detail Design
- Phase 1 – Technology Assessment
- Powertrain Layout
- Styling & CFD
- Phase 2 – Design Development & Optimization
- Topology Optimization
- Low-Fidelity 3G Design Optimization
- T1
- T2
- T3
- T4
- T5
- T6
- May 2011 Reporting

Steel Market Development Institute