Reinventing Automotive Steel
California ARB Lightweighting Workshop - May 18, 2010

Jody Shaw - U. S. Steel

AISI Steel Market Development Institute

Automotive Applications Council
AK Steel
ArcelorMittal Dofasco
ArcelorMittal USA
Nucor Corporation

Partner Funding
$6, 827, 000
United States Steel Corporation

Today’s Presentation

• Past steel projects and impact on vehicle structures
• Future Steel Vehicle
  - The new drivers of materials selection
  - New capability of steel.
  - Objectives
  - Performance criteria
  - Design methodology
  - Preliminary results
Steel Industry Investment in Automotive Lightweighting

More than $60 Million

22% to 32% Weight Reduction

Lightweight Closures
- 22% Mass reduction
- At no additional cost

Lightweight Rear Chassis
- 24% Mass reduction
- At no additional cost

Future Generation Passenger Compartment
- 10% Mass reduction
- Improved crash performance
- At no additional cost

Lightweight Front End Structures
- 32% Mass reduction
- At no additional cost

Light Weight Control Arm
- Same mass as aluminum baseline
- At 66% of the cost

Source: Auto/Steel Partnership

Impact of AHSS Solutions

Body Structure Weight vs. Gross Vehicle Weight

Body Structure: W/O Closures + IP Beam + Engine Cradle

2001-2003 Steel BIW
2004-2008 Top 10 Steel BIW
2004-2008 Top 10 Steel BIW

Source: a2mac1 database 2001-2008 production vehicles
Impact of AHSS Solutions

**Body Structure Weight vs. Gross Vehicle Weight**

(a2mac1 database 2001-2008 production vehicles)

**Impact of AHSS Solutions**

AHSS - Fastest Growing Automotive Material

Source: Ducker Worldwide

**Impact of AHSS Solutions**

Body Structure Weight vs. Gross Vehicle Weight

(a2mac1 database 2001-2008 production vehicles)

**Steel Industry Investment in Automotive Lightweighting**

- **ULSAB** UltraLight Steel Auto Body
- **ULSAC** UltraLight Steel Auto Closures
- **ULSAS** UltraLight Steal Auto Suspensions
- **ULSAB - AVC** Advanced Vehicle Concepts
Why Future Steel Vehicle? – The New Drivers

**Automotive CO₂ Emissions Regulation.**

- Japan
- Europe
- Australia
- China
- USA

**Early Introductions of Dedicated Platform Advanced Powertrain Vehicles**

- Honda Clarity FCX
- Mercedes E cell Plus
- Mercedes F cell

**Body Structure Weight vs. Gross Vehicle Weight**

(a2mac1 database 2001-2008 production vehicles)

1. SLC states 35% mass reduction (≈ 47 kg)
2. SLC to 35% less than avg. of best 10 steel

Why Future Steel Vehicle? – The New Drivers

Future Steel vehicle will address:
- Future emissions regulations
- Advanced powertrains vehicles
- Competitive material solutions
  for 2015 to 2020
### What is New in Steel?

#### FSV’s Steel Portfolio

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Tensile Strength (MPa)</th>
<th>Yield Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild 140/270</td>
<td>140/270</td>
<td>270</td>
</tr>
<tr>
<td>DP 350/600</td>
<td>350/600</td>
<td>600</td>
</tr>
<tr>
<td>HSLA 550/850</td>
<td>550/850</td>
<td>850</td>
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<tr>
<td>TRIP 500/800</td>
<td>500/800</td>
<td>800</td>
</tr>
<tr>
<td>SF 570/640</td>
<td>570/640</td>
<td>640</td>
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<tr>
<td>DP 700/1000</td>
<td>700/1000</td>
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</tr>
<tr>
<td>BH 210/340</td>
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<tr>
<td>BH 260/370</td>
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<tr>
<td>SF 570/640</td>
<td>570/640</td>
<td>640</td>
</tr>
<tr>
<td>DP 700/1000</td>
<td>700/1000</td>
<td>1000</td>
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</tbody>
</table>

**Expanded range of steel grades**

- Denotes steel grades added for FSV

### What is New in Steel?

#### FSV’s Manufacturing Options

- Conventional Stamping
- Laser Welded Blank
- Tailor Rolled Blank
- High Frequency 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 Roll Formed
- Tailor rolled Blank Roll Formed
- Roll Form with Quench
- Multi Walled Hydroformed Tubes
- Multi-Walled Tubes
- Laser Welded Finalized Tubes
- Laser Welded Tube Profiled Sections

### What’s New in Design?

- **FSV Pilot Program**
  - Donor Vehicle
  - A/SP LWB
  - TWT
  - FSV Pilot Project
- **Donor Vehicle Rail**
- **A/SP LWB Concept**
- **TWT Concepts**
- **FSV Pilot Project**
- **Topography Optimization**

**Design Optimization**

- Mass Reduction
  - 22.4%
  - 32%
  - 45%

### What is New in Steel?

- Lightweighting technologies
  - Expanded materials portfolio
  - Expanded manufacturing technology portfolio.
  - Aggressive design optimization technologies
Future Steel Vehicle Performance Criteria

Design Performance Criteria
- Manufacturing cost
- Mass reduction
- Vehicle's carbon foot print

Future Steel Vehicle – Design Methodology

What is Future Steel Vehicle?

Vehicle Size & Powertrain Configurations

<table>
<thead>
<tr>
<th></th>
<th>PHEV</th>
<th>Total Range: 500km</th>
<th>Max Speed: 161km/h</th>
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<tbody>
<tr>
<td>FSV 1</td>
<td>4-door hatchback</td>
<td>Electric Range: 50km</td>
<td>0-100 km/h: 11-13 s</td>
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<tr>
<td></td>
<td>3700 mm</td>
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</table>

FSV 2
4-door sedan
4250 mm
PHEV
Electric Range: 64km
Total: 500km
Max Speed: 150km/h
0-100 km/h: 10-12 s
FCV
Total Range: 500km
Max Speed: 161km/h
0-100 km/h: 10-12 s

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Future Steel Vehicle – Design Methodology
Future Steel Vehicle – Design Methodology

- **Phase 1**
  - Technology Assessment
  - Packaging
  - Design Confirmation
  - Gauge Optimization
  - Detail Design
  - Non-Linear Dynamic Topology Optimization (LF3G)

- **Phase 2**
  - Report
  - Styling & Aerodynamic Design
  - Confirmation

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Future Steel Vehicle – Design Methodology

Detailed Steel Alternative Solutions for Critical Load Paths

Linear-Static Topology Optimization
Gauge Optimization
Final Design Confirmation
Packaging
Styling & Aerodynamics

Phase 1
Technology Assessment

Phase 2
Conventional Stamping
Hot Stamping
Roll Forming
Hydroforming
Blank
LWB
TRB

Future Steel Vehicle – Design Methodology

Subsystem Optimization

Detailed Steel Alternative Solutions for Critical Load Paths

Linear-Static Topology Optimization
Gauge Optimization
Final Design Confirmation
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Styling & Aerodynamics

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Future Steel Vehicle – Design Methodology

Subsystem Optimization

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Blank
LWB
TRB
### HF3G Technology Assessment

#### High Volume Manufacturing Feasibility Sub-System Mass (kg)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Baseline B</th>
<th>Conservative</th>
<th>LCA CO2 Savings (kg)</th>
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<td>19.99</td>
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<td>10.38</td>
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<td>ST Roll Form</td>
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<td>18.48</td>
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<td>ST TRB Roll Form TRB</td>
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<td>RF Roll Form</td>
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<td>HF LWB Hydroform LWB</td>
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<tr>
<td>Al Extrusion</td>
<td>7.53</td>
<td>39.70</td>
<td>-32.17</td>
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### FSV – Rocker Cost, Mass & LCA CO2 eq Assessment

**Subsystem Optimization - Rocker**

#### Rocker Technology Options (Mass vs Cost Value)

- **MWT Hydroform MWT**
- **LWT Hydroform LWT**
- **ST Roll Form**
- **ST TRB Stamping TRB**
- **ST LWB Stamping LWB**
- **ST Stamping**
- **ST LWB Stamping LWB**
- **ST Roll Form**
- **ST TRB Roll Form TRB**
- **ST LWB Roll Form LWB**
- **HF LWT Hydroform LWT**
- **HF TRB Hydroform TRB**
- **HF LWB Hydroform LWB**
- **RF Roll Form**
- **RF TRB Roll Form TRB**
- **RF TWC Roll Form TWC**
- **HF LWT Hydroform LWT**
- **HF TRB Hydroform TRB**
- **HF LWB Hydroform LWB**

#### LCA CO2 eq. Saved (Kg) vs. Cost ($)

- **Baseline B**
- **Conservative**
- **Mid-Term**

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### FSV – Mass Paradigm Shift

**Subsystem Optimization - Rocker**

#### Rocker Technology Options (Mass vs Value)

**Parallels of Constant Value (7.22/kg)**

**FSV – Rocker Cost & Mass Assessment**

**FSV – Rocker Cost & LCA CO2 eq Assessment**