What’s New with Automotive Steels

Ronald Krupitzer
Vice President, Automotive Market

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Agenda

- Steel Market Development Institute
- Automotive Challenge: Safety
- Automotive Challenge: Fuel Economy and Emissions
- Technologies Including Lightweighting
- R&D Leading to Advancements in North American Steels
- The Life Cycle Assessment Story
- Conclusion
Steel Market Development Institute

- SMDI is a business unit of the American Iron and Steel Institute (AISI).
- SMDI’s Automotive Applications Council (AAC) member companies jointly fund pre-competitive steel applications research.
- AAC works with auto manufacturers, tier suppliers, universities, and government agencies to promote steel-intensive automotive solutions.
1928 Model A wood structure with steel skins. A common design was wood frames with steel skins in the early 1900s.

Starting in 1930, car companies replaced wood structured bodies with all-steel bodies.
Breakthroughs Now with Steel

Materials Process Design
Increasing Crash Requirements

1991 FMVSS 208 30MPH Front
1995 IIHS 40MPH 40%
2000 SINCAP 38.5MPH Side
2003 FMVSS 301 50MPH 50%
2006 FMVSS301 55MPH 70%
2009 FMVSS 214 Dyn. Side Pole
2011 FMVSS 216 3.0X GVW

1990 FMVSS 214 Side
1994 FMVSS 216 1.5X GVW
1997 FMVSS 201 Side Pole
2003 USNCAP 35MPH Front
2006 IIHS Side Higher, Heavier Barrier
2012 IIHS 25% Small Offset Front
Increasing Crash Requirements

IIHS Side Impact

FMVSS 214 Dynamic Side-Pole Impact

IIHS Small Offset

FMVSS 216 Roof Crush
Crashworthiness Fundamentals – Two Key Zones

**Crumple Zones** (engine compartment, trunk) deform to absorb energy and control magnitude of deceleration.

**Safety Cage** (passenger compartment) resists deformation to prevent intrusion.

Source: AISI

[Website: www.smdisteel.org]
Steels for Crumple Zone

- Highest Energy Absorbing
- Strength AND Ductility
- Dual Phase and TRIP Grades Preferred

Dual Phase and TRIP are Higher Energy Absorbing Grades

Source: AISI
WWW.SMDISTEEL.ORG
AHSS Advancements for Crash

Steels for Safety Cage Zone

- Highest Strength
- Boron Hot Formed, Martensite, 3GAHS

Source: SMDI

www.smdisteel.org
AHSS Growth in NA Vehicles

AHSS - Fastest Growing Automotive Material

Projected Market Penetration by 2020

Source: Ducker Worldwide 2009
Total of 3,863 pounds, approximately 60% steel
Fuel Economy Regulations

New CAFE Standards

2012-2016 and 2017-2025

54.5 mpg fleetwide average in 2025

PASSenger CARS

LIGHT TRUCKS

MASS REDUCTION

miles per gallon equivalent


Model year

MY1978-2011 figures are NHTSA Corporate Average Fuel Economy (CAFE) standards in miles per gallon. Standards for MY2012-2025 are EPA greenhouse gas emission standards in miles per gallon equivalent, incorporating air conditioning improvements. Dashed lines denote that standards for MY2017-2025 reflect percentage increases in Notice of Intent.
Technologies Including Weight Reduction

Figure compliments of Ford Motor Company
DOE-Funded ICME Project

Integrated Modeling for 3rd Generation AHSS

Brown
Clemson
Colorado (Mines)
Illinois
Mich. State
PNNL
EDAG
LSTC

$6 million over four years
Automotive Grade Fe Content Trend

Wide Ranges of Strength, Microstructure, and Chemistry

- HSLA, 97.5 % Fe
- TRIP, 96.4 % Fe
- CA: 3GAHSS, 95.1% Fe
- BA: 3GAHSS, 88.1 % Fe

Elongation (%) vs. Tensile Strength (MPa) diagram showing various steel grades and their respective iron content.
Special Processes for AHSS

Alloys Elements
Carbon       Manganese
Chromium     Nickel
Molybdenum   Titanium
Phosphorus   Sulfur
Selenium     Niobium
Nitrogen     Silicon
Cobalt       Tantalum
Copper

Phases
Ferrite
Martensite
Austinite
Bainite
Perlite
Cementite

Iron Phase Diagram, Chemistry and Thermal Processing

Phases
Ferrite
Martensite
Austinite
Bainite
Perlite
Cementite

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Copper

Iron Phase Diagram, Chemistry and Thermal Processing
Representing 70% market share worldwide:

- **Small cars**
  (up to 4,000mm, A/B class)
- **Mid-Class cars**
  (up to 4,900mm, C/D class)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Front Leg Room (mm)</th>
<th>Rear Leg Room (mm)</th>
<th>Luggage (Liters)</th>
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<tbody>
<tr>
<td>FSV 1</td>
<td>1065</td>
<td>925</td>
<td>250</td>
</tr>
<tr>
<td>FSV 2</td>
<td>1065</td>
<td>925</td>
<td>370</td>
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<table>
<thead>
<tr>
<th>FutureSteelVehicle</th>
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<tbody>
<tr>
<td>FSV 1</td>
</tr>
<tr>
<td>4-door hatchback</td>
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<td>3700 mm</td>
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- **FSV 2**
  4-door sedan
  4350 mm

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<tbody>
<tr>
<td>PHEV20</td>
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<td>Electric Range: 32km Total: 500km Max Speed: 150km/h 0-100 km/h 11-13 s</td>
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<tr>
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<tbody>
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<td>BEV</td>
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<td>Total Range: 250km Max Speed: 150km/h 0-100 km/h 11-13 s</td>
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<tr>
<td>PHEV40</td>
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<tr>
<td>Electric Range: 64km Total: 500km Max Speed: 161km/h 0-100 km/h 10-12 s</td>
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<th>FutureSteelVehicle</th>
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<tr>
<td>FCEV</td>
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<tr>
<td>Total Range: 500km Max Speed: 161km/h 0-100 km/h 10-12 s</td>
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More AHSS Grades = More Mass Reduction

FutureSteelVehicle’s Steel Portfolio

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

denotes steel included in ULSAB-AVC

denotes steel grades added for FSV
Lightweighting Potential of AHSS

Maximum weight reduction occurs when advanced materials are combined with efficient load path design.

- 2-G = Grade and Gauge optimization, typical of a “carryover-constrained” design

- 3-G = Geometry, Grade, and Gauge optimization, typical of a “clean sheet” design

FutureSteelVehicle (FSV)
FutureSteelVehicle Advanced Manufacturing 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
Steel Mass Similar to Aluminum
AHSS clamshell design was same weight as baseline forged aluminum, but 34% lower in cost.

The OEM using the forged aluminum design switched to steel for the same weight and lower cost.
Lightweighting Needed for 54.5 MPG

- 2009 US Average Fuel Economy: 25 MPG
- Improvements From Power Train: 20 MPG
- Improvements From Weight Reduction: 5 MPG
- Gap: 14 MPG
- 2025 US Mandate: 54.5 MPG
AHSS Gets Fleet to 54.5 MPG

NHTSA Volpe Model Results for Full 2025 US Fleet

Based on EPA projections of US 2025 vehicle sales

Includes 7.2% vehicle weight reduction from other, non BIW-related components

BIW weight reductions of up to 25% will get the fleet to 54.5 MPG, even if the powertrain improvements fall well short of those forecasted by EPA/NHTSA
LCA Research at UC Davis, UCSB

LCA of Lotus Study (HD vs LD BIW)

Kg CO2e

HD BIW
LD BIW

Recycling
Use
Production

Materials Matter

Al, Magnesium, C Fiber Structure
AHSS Structure

7%
“The day of the passenger car made primarily of iron and steel is on the wane”
giving ground to aluminum, magnesium and plastics.