Future Material Opportunities and Direction for Lightweighting Automotive Body Structures

Advanced High-Strength Steels for Automotive Lightweighting
USCAR Offices - Southfield, Michigan
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Thank You Slide and Introduction
Primary Automotive Industry Material Drivers

• Steep Increases in Fuel Economy
• Sharp Reduction in CO₂/Green House Gases
• Geo-Political Risks of Carbon Based Fuels
• Federal and IIHS Requirements

EPA Penalty Increased – Potential of $37,000 in Fines per Vehicle!
Global CO₂ Emissions
Transportation and Other Sources

Transportation, ~ 20%
Non-Transportation, ~ 80%

Total of 8.7 Billion Tons CO₂ Produced in 2007

Source: www.sciencedaly.com/releases/2009/07/090727080836.html
Sources of CO₂ Emissions in the US

- 24% Transportation
- 29% Electrical Generation
- 15% Residential
- 32% Commercial/Industrial

Source: US Energy Administration/Annual Energy Outlook 2011
World Carbon Dioxide Emissions by Region, Reference Case, 1990-2030

China CO₂ Trendline

China Forecast

USA

OECD Europe

Organization for Economic Co-operation and Development Countries (OECD)

Lightweight Metal Options

http://rainforests.mongabay.com/09-carbon_emissions.htm
Industry Responses to Fuel Economy Increases.....

• Mass Reduction
  – Increased use of AHSS’s and UHSS’s for Mass Reduction
  – The use of Alternative Materials to Steel – Aluminum, Magnesium, Carbon Fiber, Composites, etc.....

• Improvements in Powertrain Efficiency
  – Alternative Powertrains/Hybridization
  – Small Turbocharged Engines
  – Diesel’s
  – More Efficient Transmissions
    • 6 and 8 speed automatics
    • CVT’s

• Improved Aerodynamics
• Reduced Rolling Resistance
Body Structure Weight vs. Gross Vehicle Weight

Hybrid Powertrains

Chevy Volt
Full Electric with small gas engine for charging and extended range

Toyota Prius
Gas/Electric Hybrid

Nissan Leaf
Full Electric

Ford Fusion
Gas/Electric Hybrid
Aerodynamic Improvements

Aerodynamic Improvements - Reduce Frontal Area!

Results in lowered roof and occupants

Rail section size reduction driven by lowered roof height for aero

Smaller sections require increased gage for stiffness
Safety Requirements Driving Mass-Efficient Materials

- Highest ultimate strength
- High strength & ductility
- Primarily stiffness dominant
- Minimum gauge closeouts contribute some strength & stiffness

- 88.7 kph MVSS 301 rear offset barrier 70% overlap
- 80 kph side moving barrier impact
- 50 kph IIHS High Side Impact at B-pillar
- 64 kph IIHS 40% overlap offset deformable barrier impact
- 64 kph IIHS 25% overlap shallow offset rigid barrier impact

* MVSS 216 2 Sided Roof Strength
IIHS 4x Veh Wt

New/Pending
High Potential Applications for Ultra High Strength Steel

Passenger “safety cage” and bumpers represent highest potential uses for UHSS’s
Evolution and integration
Material concept

Weight division by material and semi-finished products

Source: Audi A8 from 2010 EuroCarBody presentation
Future Opportunities in 3rd Generation AHSS

Steel Property Combinations Identified as “Breakthrough Steels” for Automotive Applications

Future Opportunity 3rd Generation AHSS

1500 MPa 20%

1000 MPa 30%

Mild, IF, IF-HS, ISO, BH, CMn, HSLA, TRIP, MART, PHS
Where From Here??

- “Improved” Second Gen AHSS’s
- Higher Strength Martensite and PHS up to 2 GPa!
- “Breakthrough” and Third Gen AHSS’s
  - 1000 MPa and 30% elongation
  - 1500 MPa and 20% elongation
  - High Modulus and Low Density Steels
- Aluminum
- Magnesium
- Advanced Composites/Carbon Fiber?
The Steel Competitors – “Lightweight” Metals
Specific Strength Comparison of Materials

Steels > 900 MPa have a higher strength to density ratio than aluminum and magnesium!

35% - 40% of future body structures likely to be > 900 MPa!
Specific Stiffness of Materials

Steels $\geq 300$ MPa have better stiffness to weight ratio than aluminum and magnesium!
Lightweight Metal Options

Aluminum

- Strong competitor to steel, especially in chassis and exterior metal applications
- Challenged by the large amount of energy needed to extract and refine primary metal
- Carbon dioxide emissions from production and refining of the metal “produces 2 tons of CO2 for every ton of metal but a further 12 tons of CO2 are produced making the electricity that is required to make 1 ton of aluminum” *
- Use of fluorocarbon fluxes which are far more environmentally detrimental than CO2

Steel production results in approximately 1.2 tons of CO2 being emitted per ton of steel

* Stuart Burns, “Aluminum Buoyed by Coal and CO2”, MetalMiner, July 2, 2008
Lightweight Metal Options

Magnesium

- Strong competitor to steel, especially in chassis and exterior metal applications
- Challenged by the large amount of energy needed to extract primary metal
- Production of carbon dioxide from production and refining of the metal “produces 13.5 tons of CO2 for every ton of metal, when the electricity that is required to make 1 ton of magnesium is included”.

Source: www.nretas.nt.gov.au/__data/assets/.../greenhousegasemissions.pdf
Steel Challenges
Springback

- Springback increases with strength
- Prediction remains challenging

![Graph showing effects of material and trim on springback]

- Average Dimensionless Springback
- Pre_trim
- Post_trim

Material: DP600, DP780, DP980

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Features added to control spring back on AHSS

Shape changes required for spring back control may act as crush initiators and conflict with load carrying efficiency!
Flatness Issues with UHSS

Lack of flatness of UHSS...

.......Can result in dimensional issues with roll formed parts
Excessive die wear with less than 20,000 parts. Wear most noticeable at stiffening beads, wrinkles, other features
Edge Fracture Issues with AHSS’s
Corrosion on AlSi Coated PHS

Formed Section Showing Coating Loss

Corrosion undercutting of cracked, barrier coating of AlSi

After 120 hrs. Corrosion Exposure
Coating Development on PHS

Zinc based PHS coatings can cause microcracks through the coating into the base metal. The affect of these cracks is not well understood.
Coating Development on PHS

Zinc based coatings on PHS steel may be susceptible to Liquid Metal Embrittlement if not processed correctly.

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Oven operating window
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*Fe-Zn Phase Diagram (1990 Okamoto H.)*

Hydrogen Induced Cracking

Issue:
Steels with tensile strengths >1000 MPa and high strength steels with high volume fractions retained austenite may be susceptible to hydrogen assisted cracking. Automotive industry needs to understand, in an automotive environment, if a material could be susceptible to hydrogen assisted cracking.

Status:
The A/SP Sheet Steel Harmonization Task Force has initiated a study to develop a simple test to address this issue. Longer term, the team wants to understand how much hydrogen it takes to cause cracking in automotive UHSS’s and how much hydrogen is charged into these steels through normal use and aging.
Additional Future Challenges

• Availability of very thin gauge UHSS.... ~ 0.60 – 0.70 mm

• Ductility of materials >/=1000 MPa
  - Lower ductility limits use to simple shapes and roll forms
  - Current “best” option is PHS......
    - High piece costs
    - Corrosion coating challenges

Will the “Gen 3” steels be able to reduce predicted PHS usage?

• Joining AHSS’s with high carbon equivalents
Conclusion

• The need for mass reduction and CO\textsubscript{2} emission reductions will focus automotive designers on the use of AHSS’s, UHSS’s, PHS’s and next generation materials in the foreseeable future.

• Alternative materials, such as magnesium and aluminum are competitive with AHSS’s if they are used in conjunction with very efficient designs

• Production of primary aluminum, which is required for any significant expansion in its use, creates high amounts of CO\textsubscript{2} and remains a significant life cycle issue

• Ultra High Strength Steels have a stiffness, strength and mass efficiency advantage over light weight metals if design efficiencies are similar
The future use AHSS’s and UHSS’s will be determined by how efficient automotive designers can utilize steel and how aggressive countries are at increasing MPG and reducing CO\textsubscript{2} limits.
### Organization for Economic Co-operation and Development Countries (OECD)

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