Future Material Opportunities and Direction for Lightweighting Automotive Body Structures

Advanced High-Strength Steels for Automotive Lightweighting
USCAR Offices - Southfield, Michigan
February 9, 2012

Curt D. Horvath – Technical Fellow

Marcel Cannon – Chief Body Architect

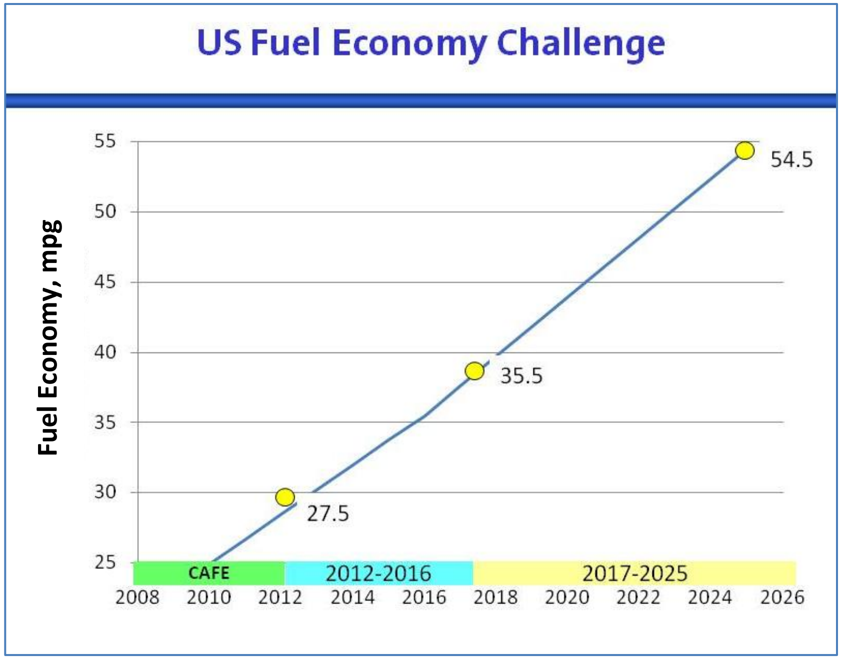
General Motors Company

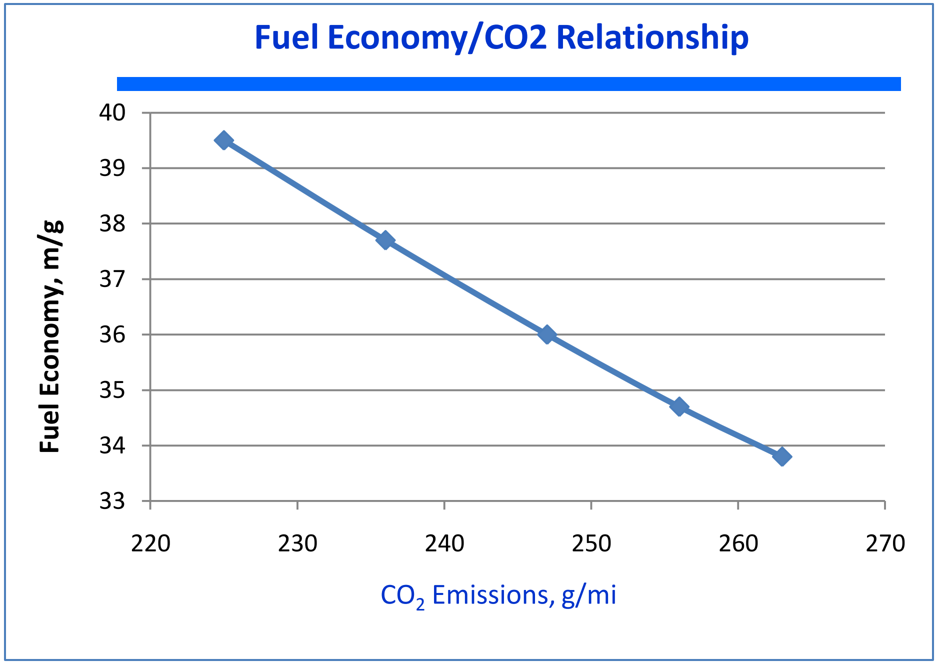
THE WORLD'S BEST VEHICLES

Thank You Slide
and
Introduction

Primary Automotive Industry Material Drivers

- Steep Increases in Fuel Economy
- Sharp Reduction in CO_2/Green House Gases
- Geo-Political Risks of Carbon Based Fuels
- Federal and IIHS Requirements

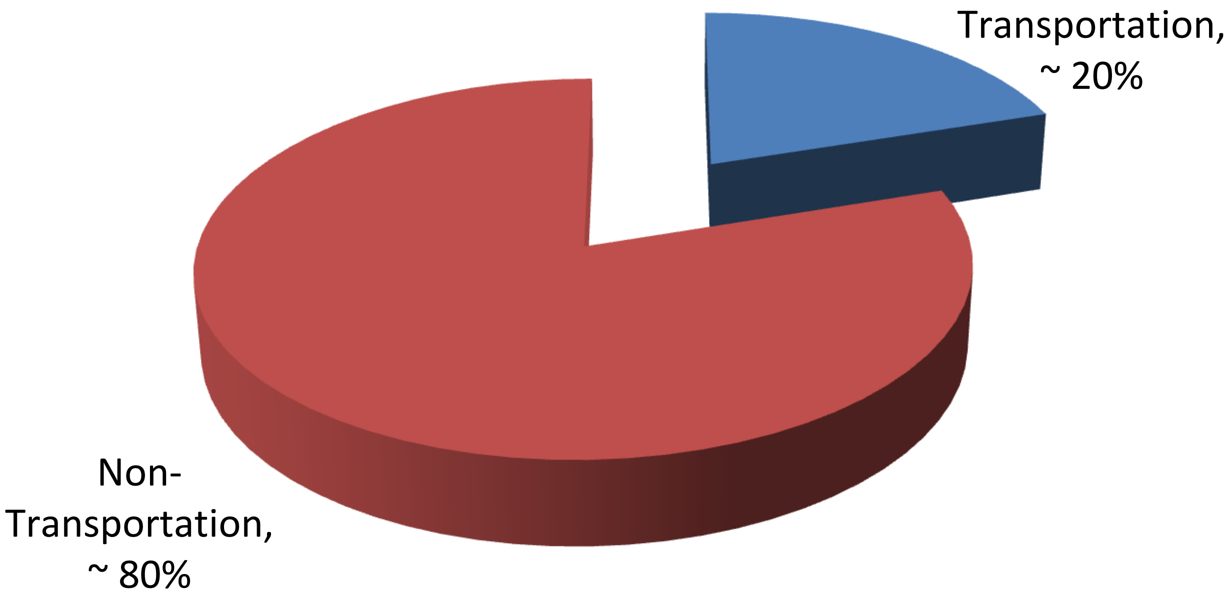




EPA Penalty Increased – Potential of $37,000 in Fines per Vehicle !

Global CO_2 Emissions

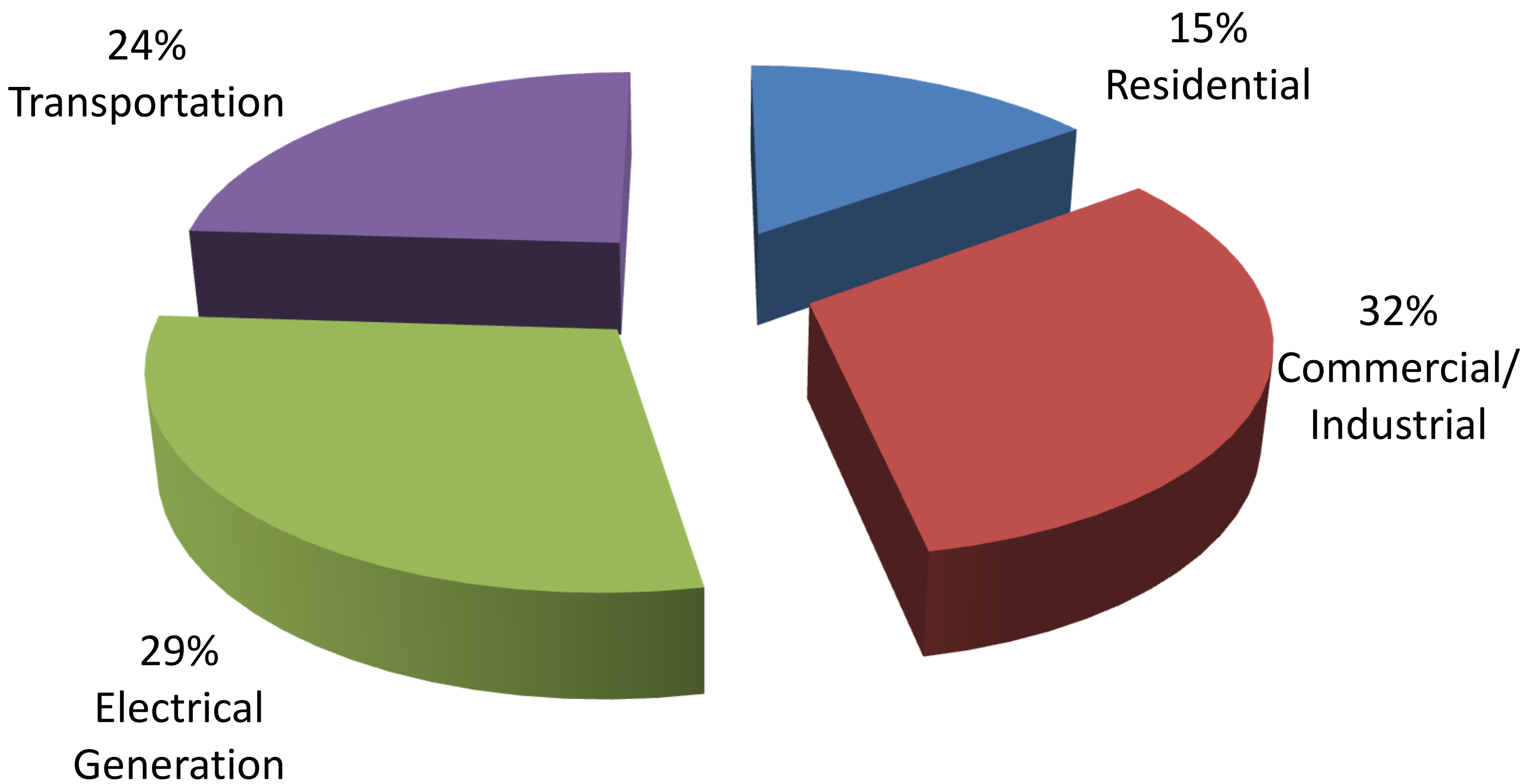
Transportation and Other Sources



Total of 8.7 Billion Tons CO_2 Produced in 2007

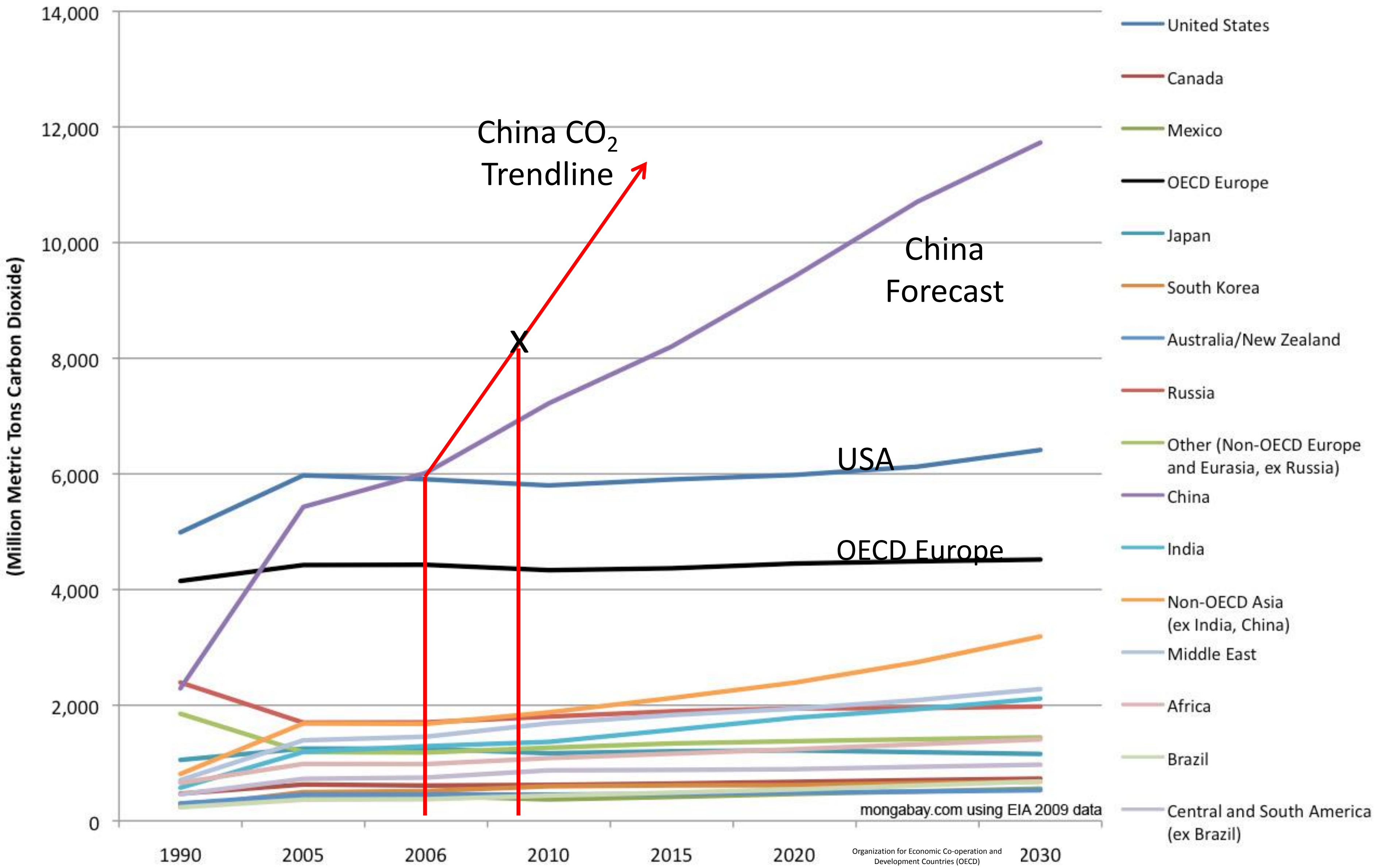
Source: www.greencarcongress.com/2008/09/global-co2-emis.html

Sources of CO_2 Emissions in the US



Source: US Energy Administration/Annual Energy Outlook 2011

World Carbon Dioxide Emissions by Region, Reference Case, 1990-2030



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

Australia
Austria

Belgium
Canada
Chile

Czech Republic

Denmark
Estonia
Finland

France

Germany
Greece
Hungary

Iceland

Ireland
Israel
Italy

Japan
Korea

Luxembourg

Mexico

Netherlands

New Zealand
Norway
Poland

Portugal
Slovak Republic

Slovenia
Spain
Sweden

Switzerland

Turkey
United Kingdom
United States

Slide 38

[Lightweight Metal Options]

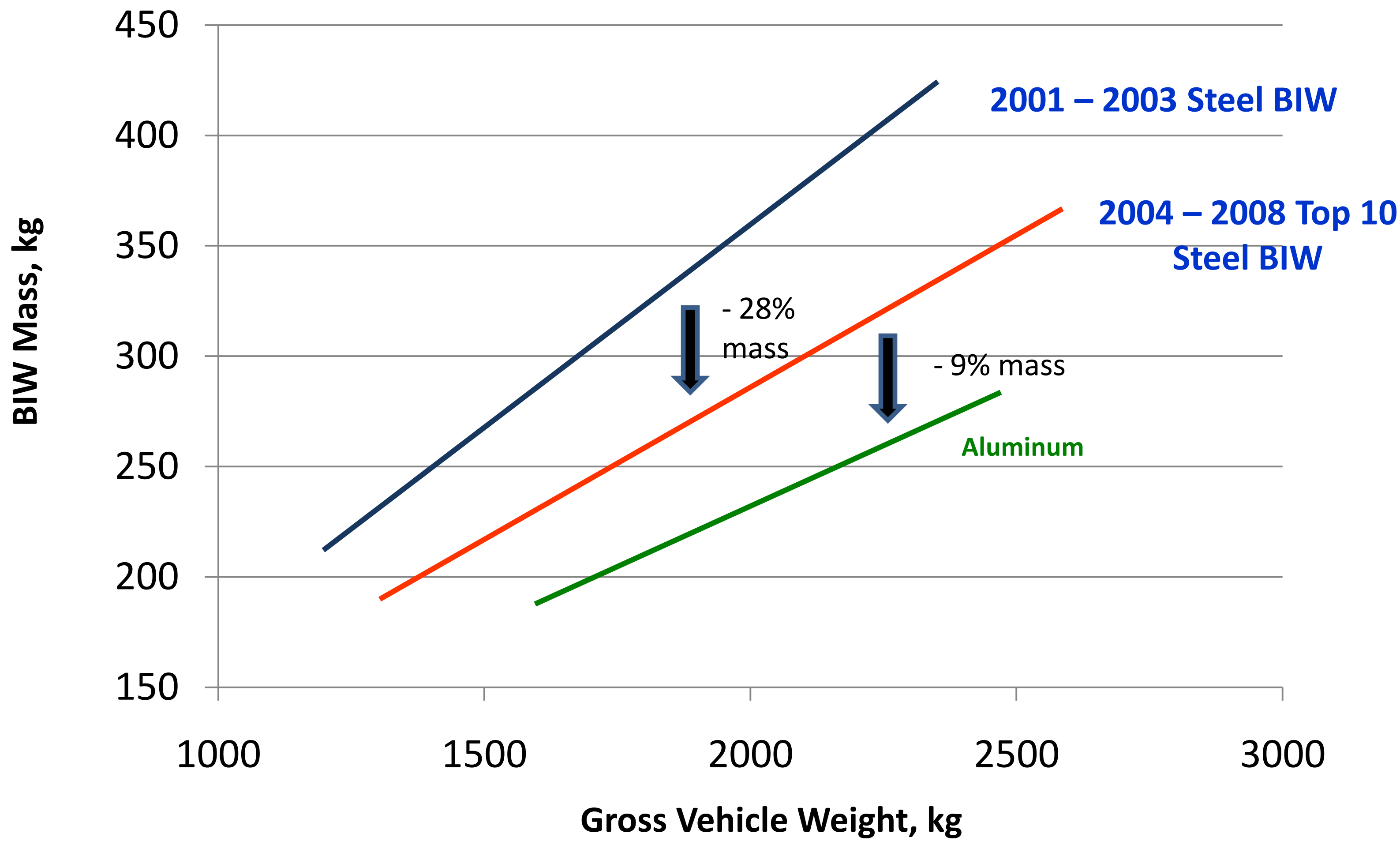
http://rainforests.mongabay.com/09-carbon_emissions.htm

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 Tubocharged Engines
  - Diesel's
  - More Efficient Transmissions
    - 6 and 8 speed automatics
    - CVT's
- Improved Aerodynamics
- Reduced Rolling Resistance

THE WORLD'S BEST VEHICLES

Body Structure Weight vs. Gross Vehicle Weight



Source:
http://www.autosteel.org/~/media/Files/Autosteel/Great%20Designs%20in%20Steel/GDIS%202010/01%20-%20FSV%20with%20Jody%20Shaw%20Harry%20Singh%20and%20Akbar%20Farahani.ashx

THE WORLD'S BEST VEHICLES

Hybrid Powertrains

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

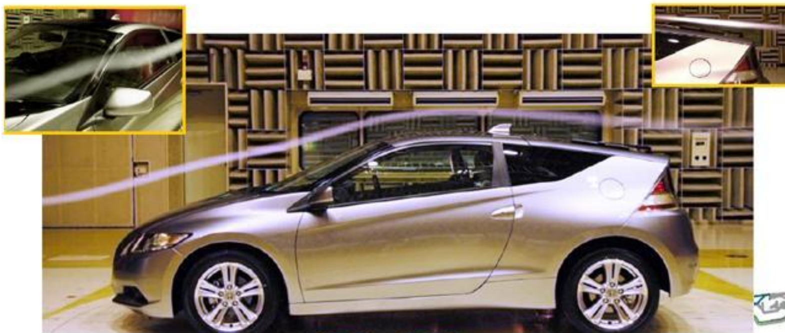
Toyota Prius
Gas/Electric Hybrid

Nissan Leaf
Full Electric

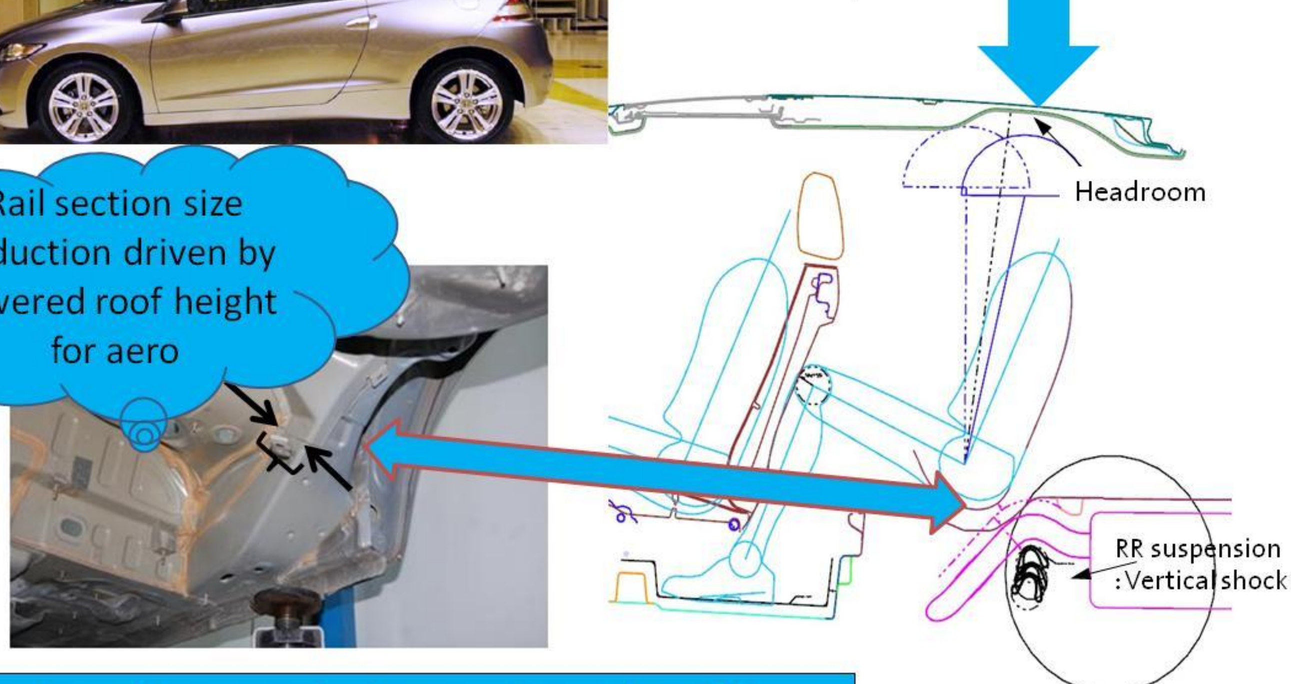
Ford Fusion
Gas/Electric Hybrid

Aerodynamic Improvements

Aerodynamic Improvements - Reduce Frontal Area!



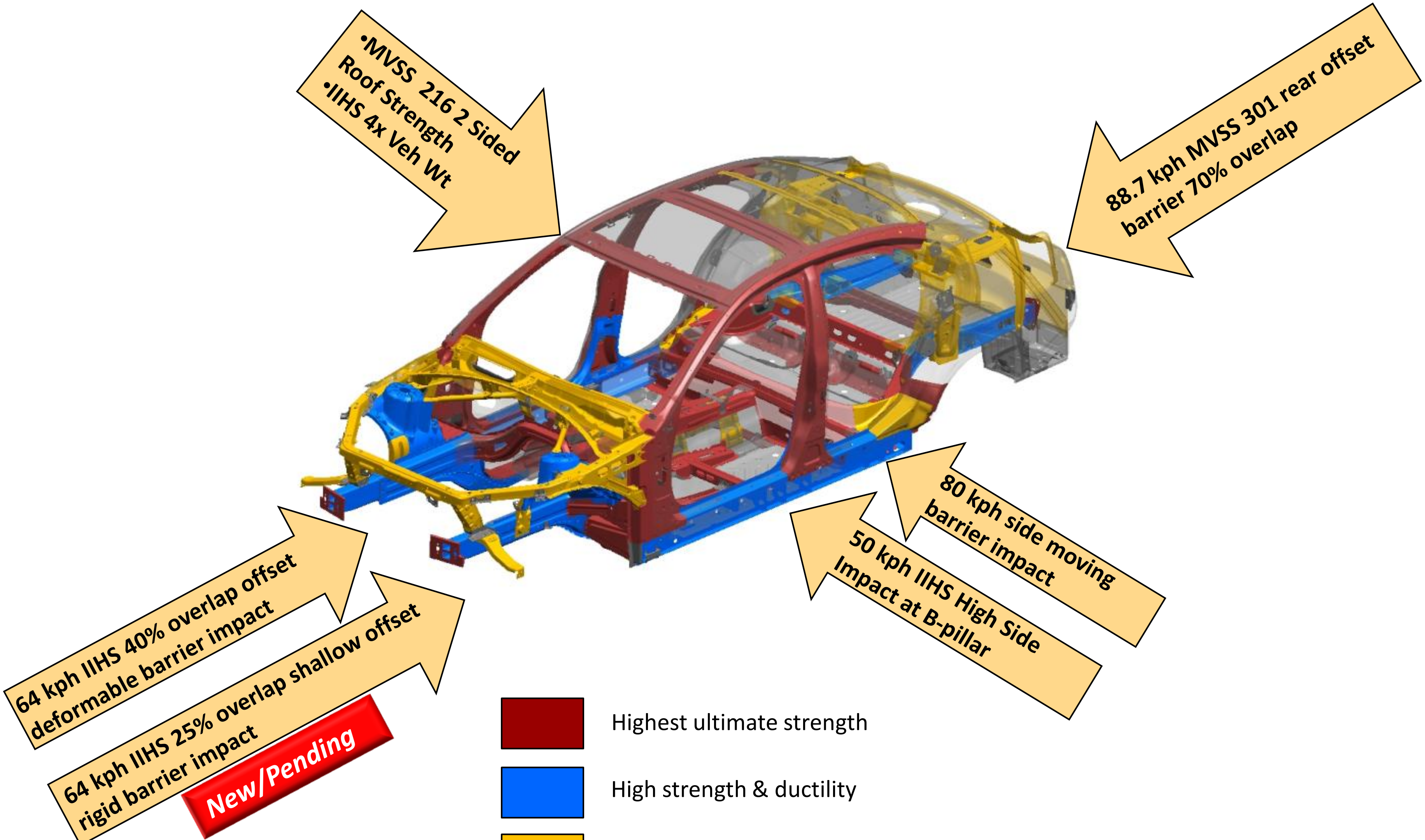
Results in lowered roof and occupants



Rail section size reduction driven by lowered roof height for aero

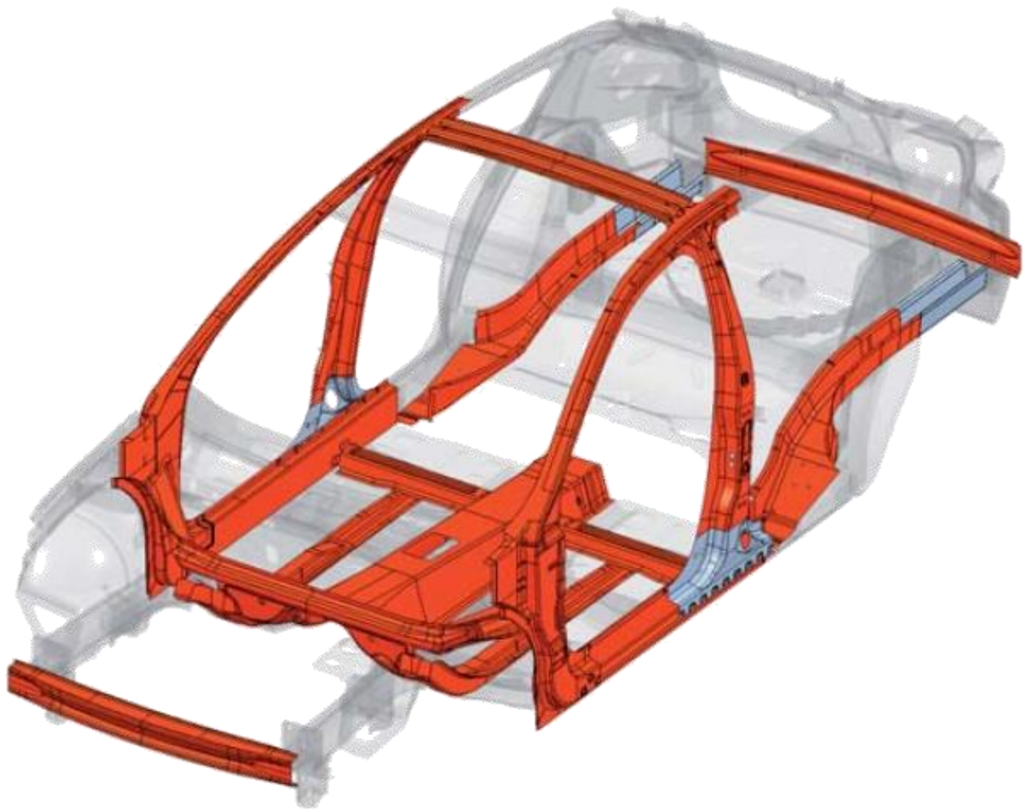
Smaller sections require increased gage for stiffness

Safety Requirements Driving Mass-Efficient Materials



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

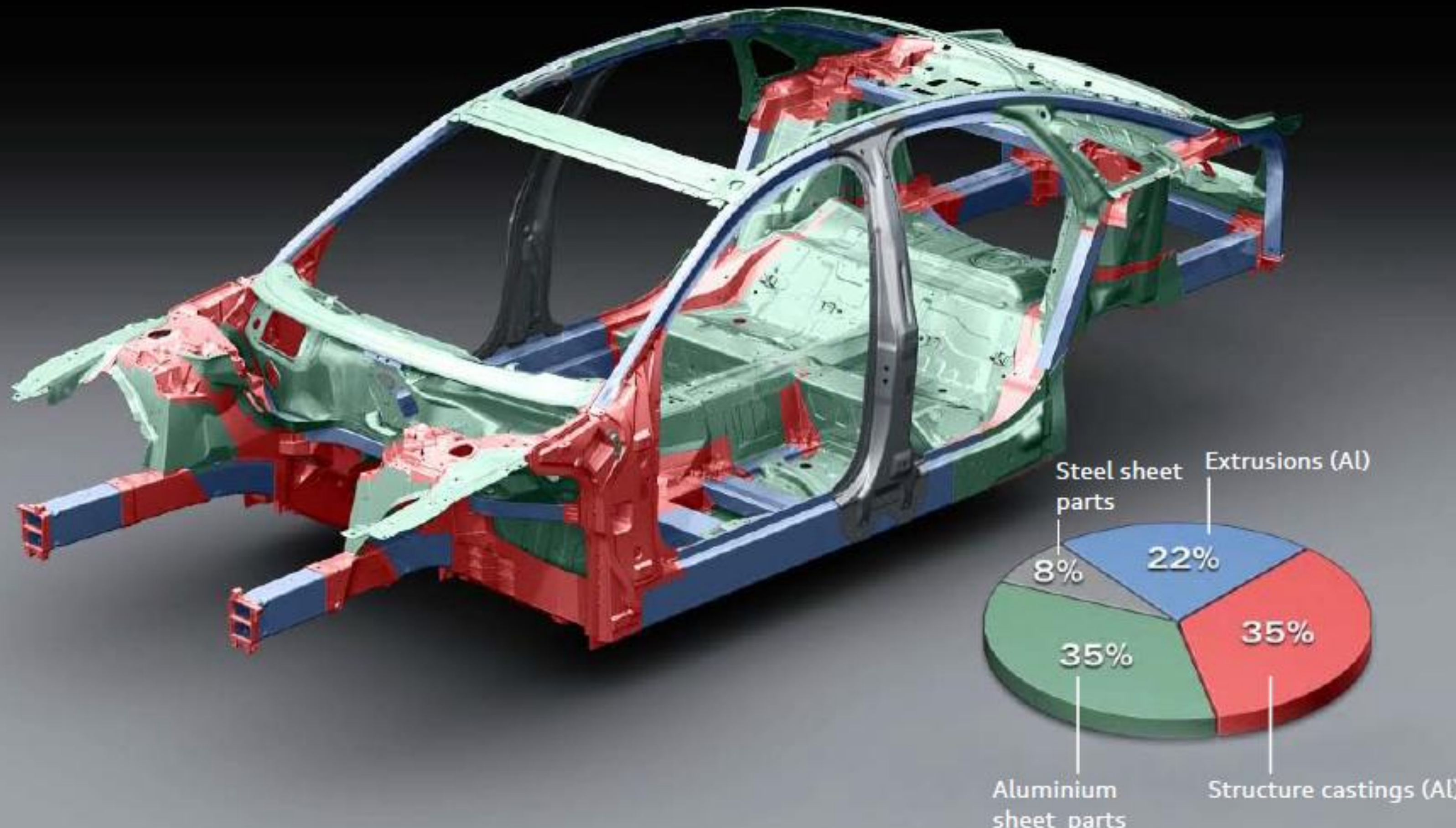
High Potential Applications for Ultra High Strength Steel



Passenger "safety cage" and bumpers represent highest potential uses for UHSS's

Evolution and integration
Material concept

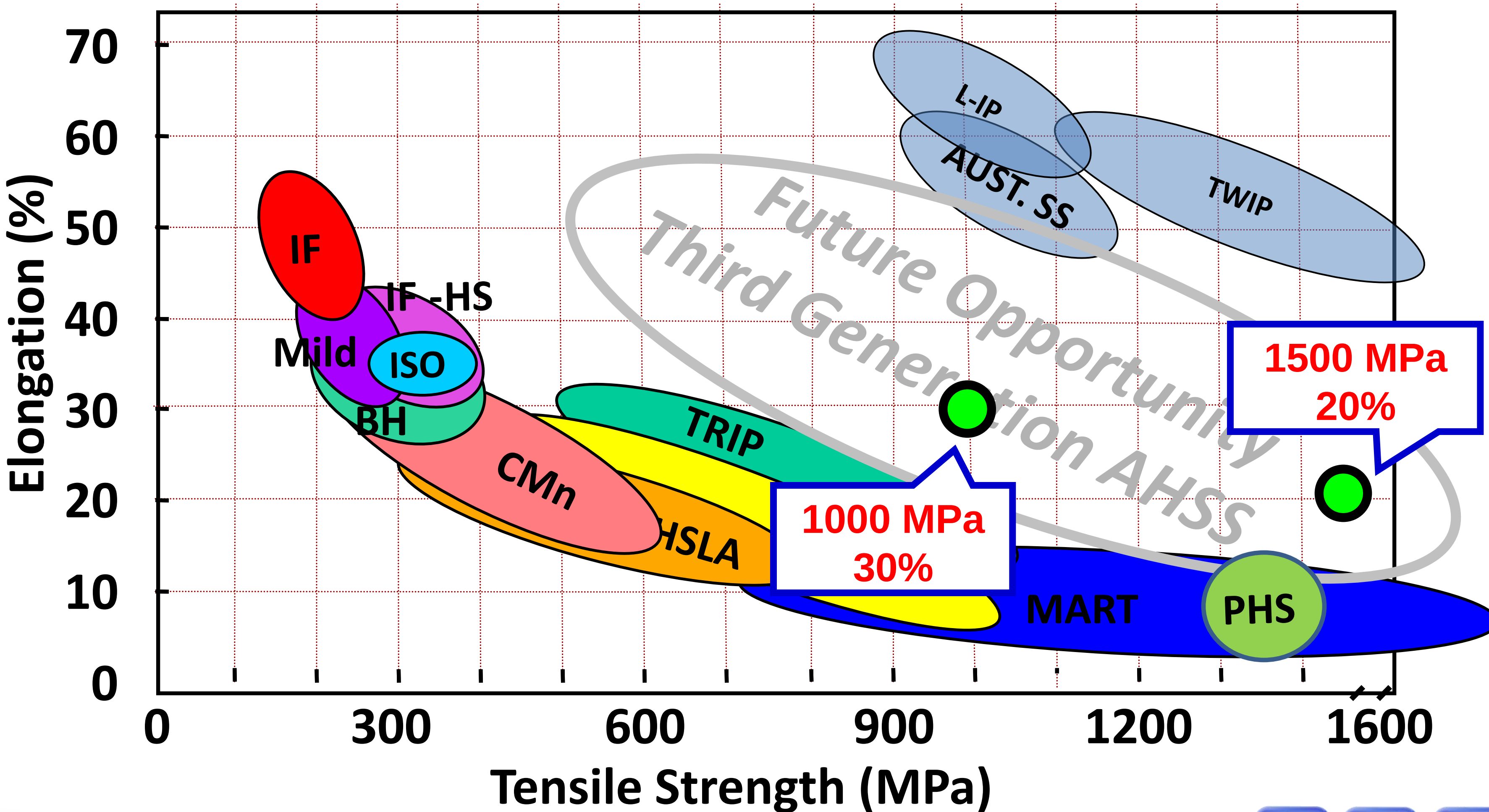
Weight division by material and semi–finished products



Source: Audi A8 from 2010 EuroCarBody presentation

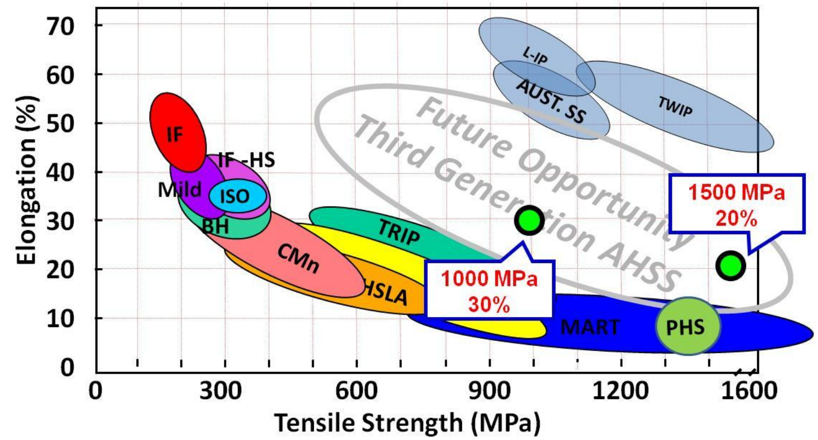
Future Opportunities in 3rd Generation AHSS

Steel Property Combinations Identified as "Breakthrough Steels" for Automotive Applications



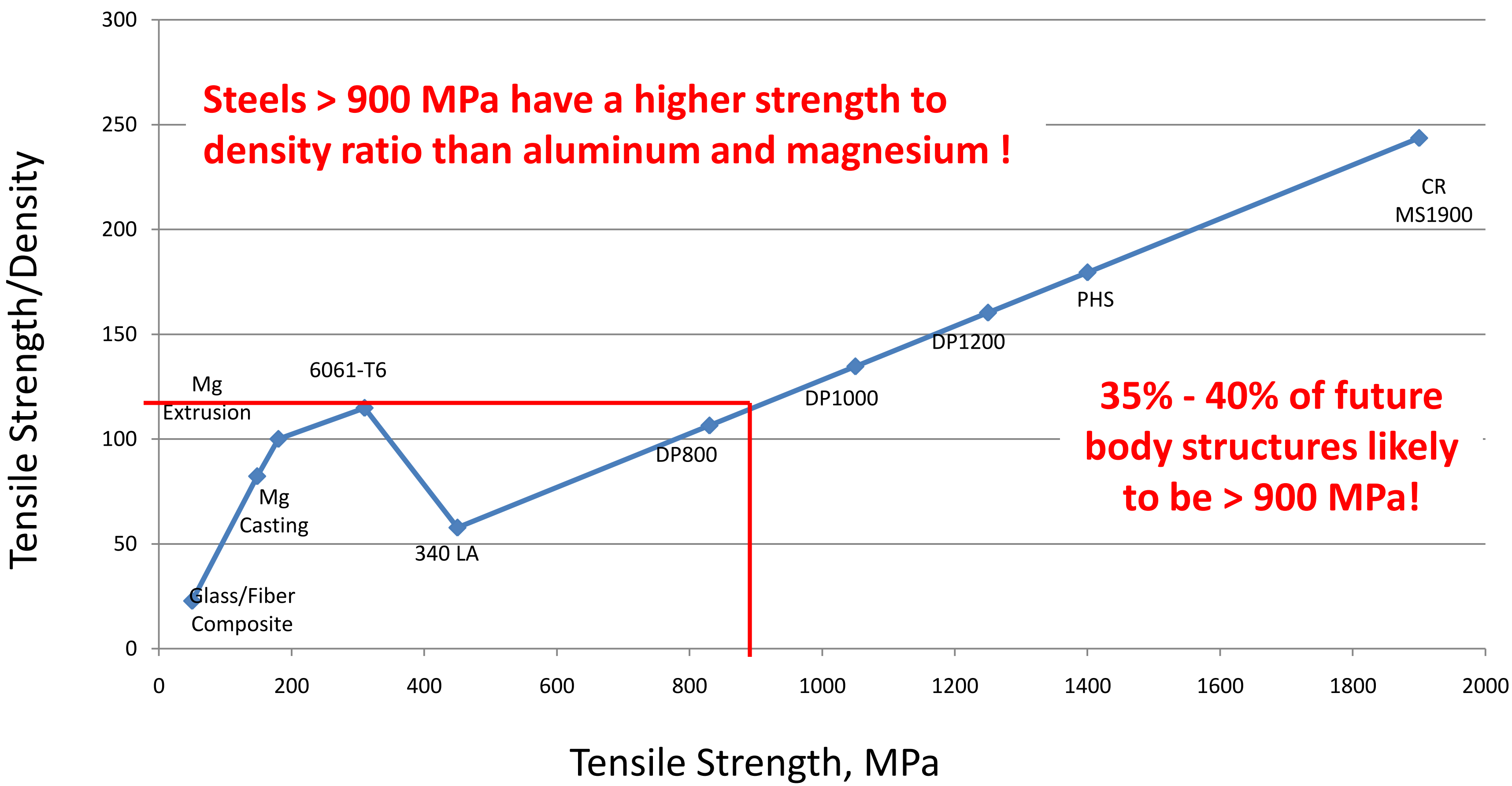
Where From Here??

- "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?

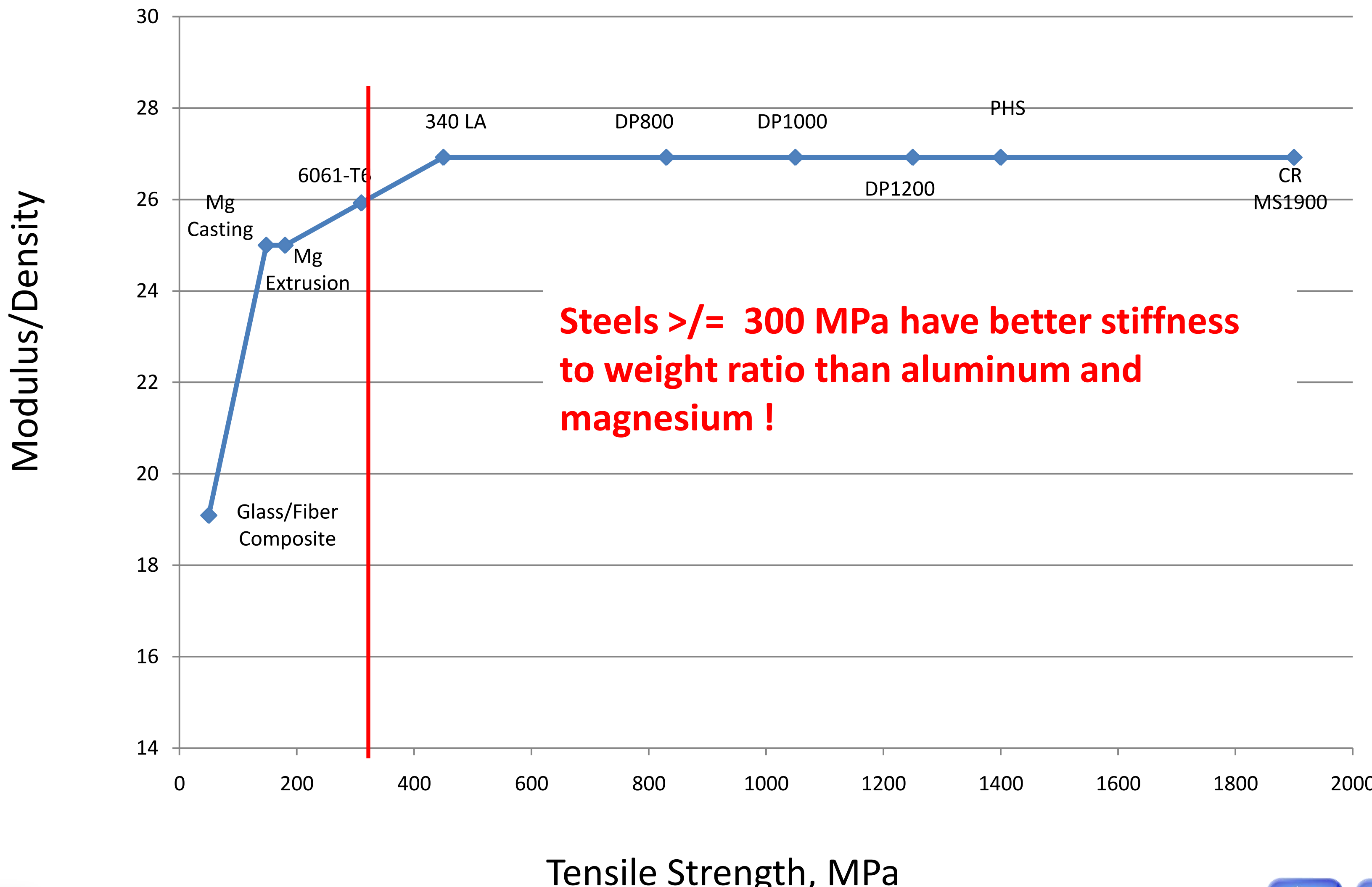


The Steel Competitors – "Lightweight" Metals

Specific Strength Comparison of Materials



Specific Stiffness of Materials



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 CO_2

Steel production results in approximately 1.2 tons of CO_2 being emitted per ton of steel

* Stuart Burns, “Aluminum Buoyed by Coal and CO_2”, *MetalMiner,* July 2, 2008

Lightweight Metal Options

<u>Magnesium</u>

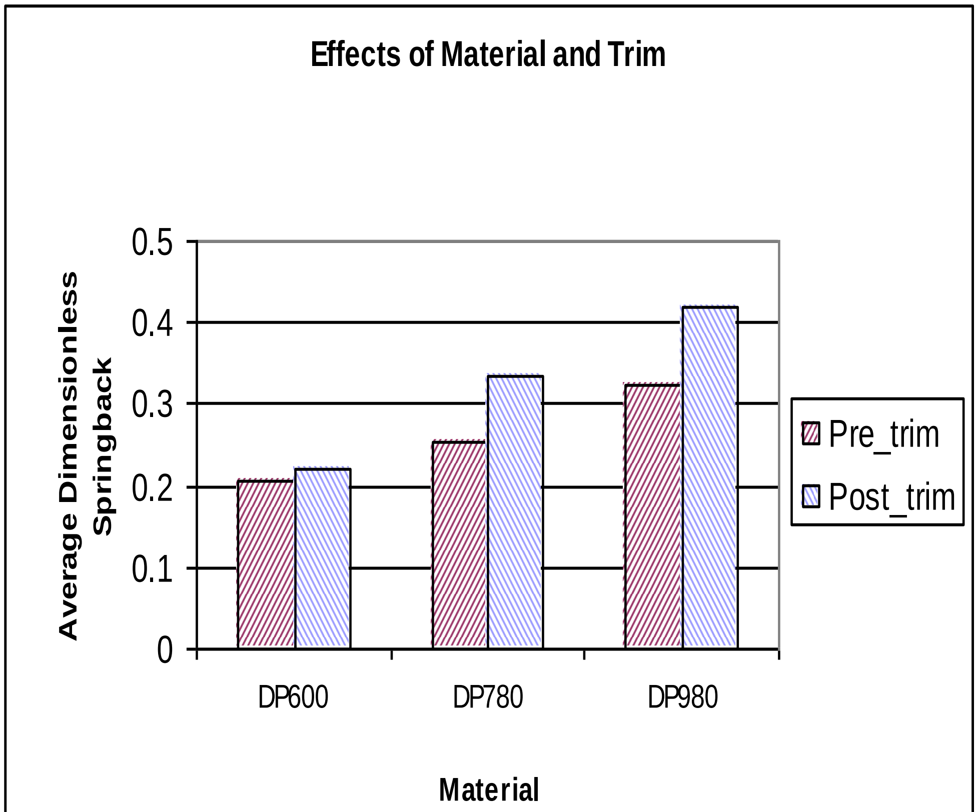
- Strong competitor to steel, especially in chassis and exterior metal applications
- Challenged by the large amount of energy needed to extract primary metal
- Production of carbon dioxide from production and refining of the metal "produces 13.5 tons of CO_2 for every ton of metal , when the electricity that is required to make 1 ton of magnesium is included".

Source: *www.nretas.nt.gov.au/__data/assets/.../**greenhousegasemissions**.pdf*

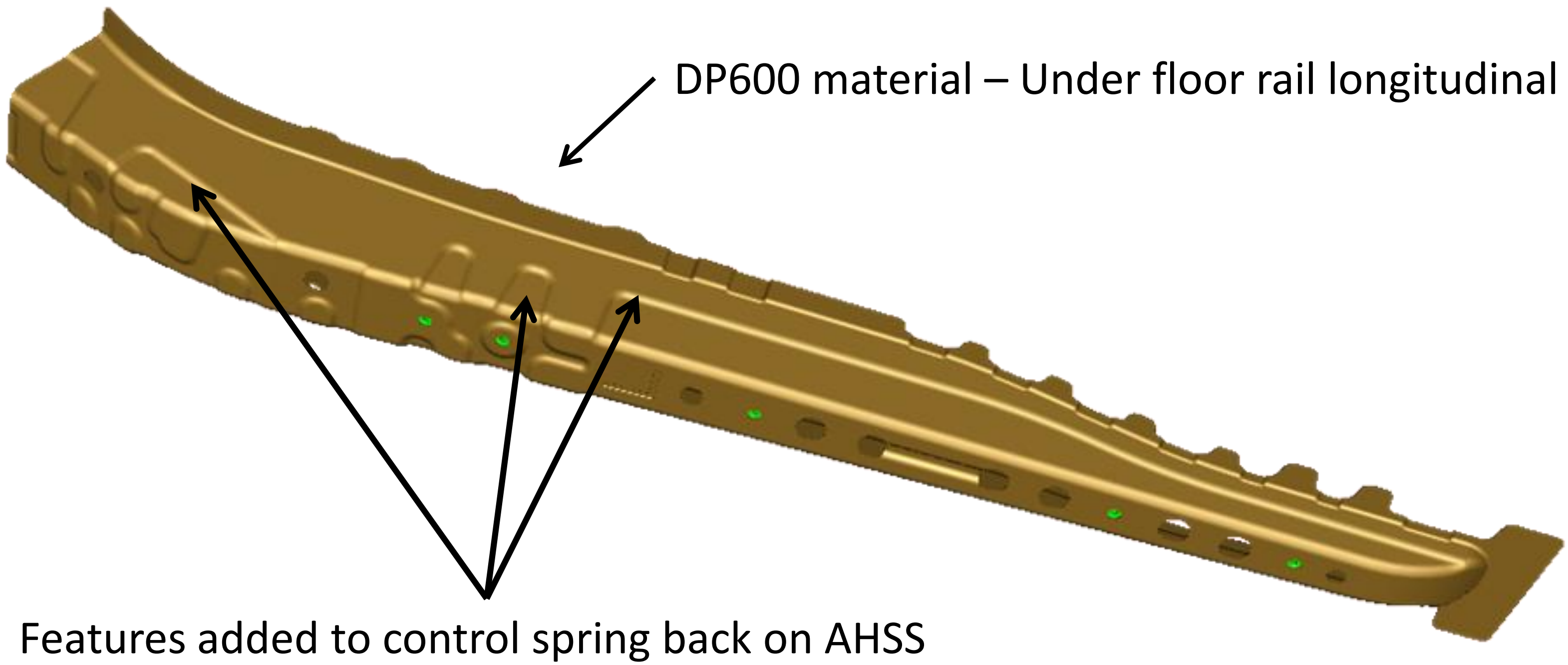
Steel Challenges

Springback

- Springback increases with strength
- Prediction remains challenging



Springback



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

Flatness Issues with UHSS

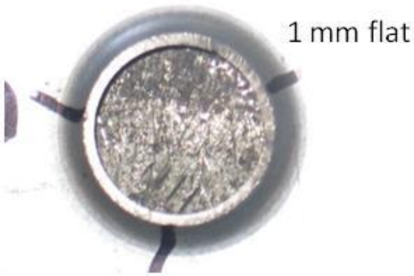
Lack of flatness of UHSS…

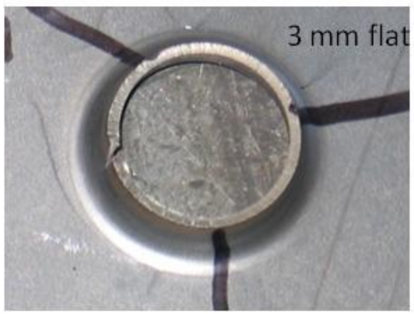
…….Can result in dimensional issues with roll formed parts

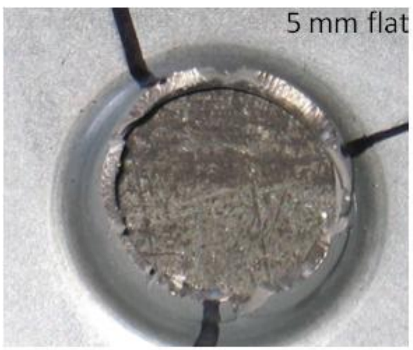
Die Wear

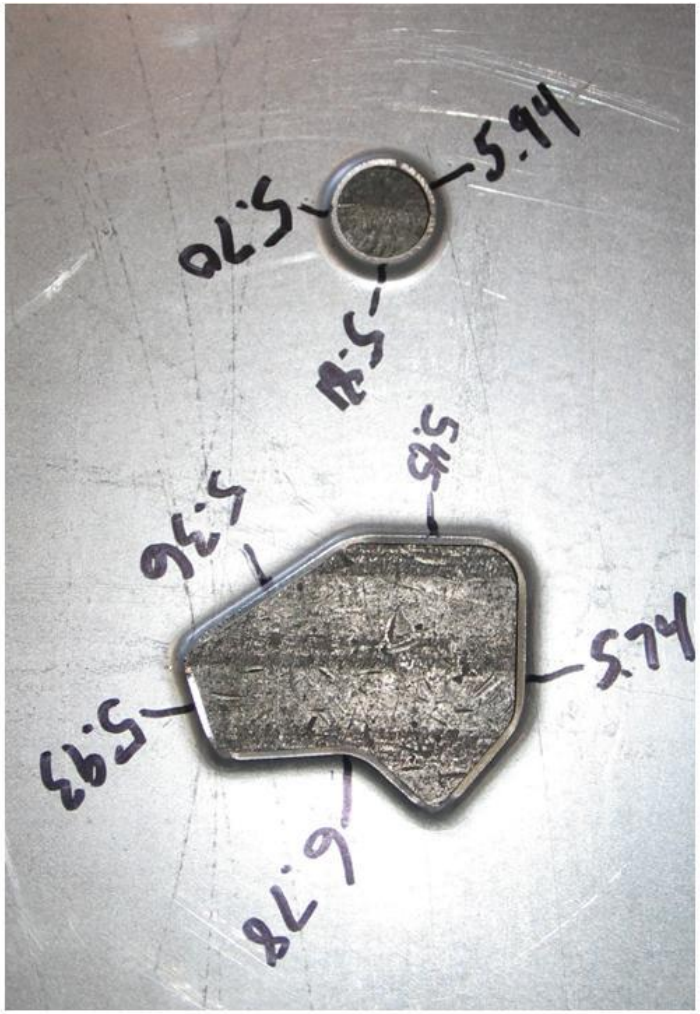
Excessive die wear with less than 20,000 parts. Wear most noticeable at stiffening beads, wrinkles, other features

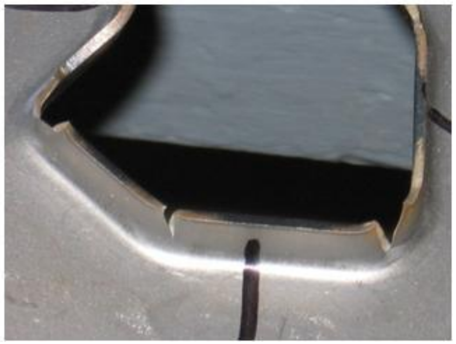
Edge Fracture Issues with AHSS’s





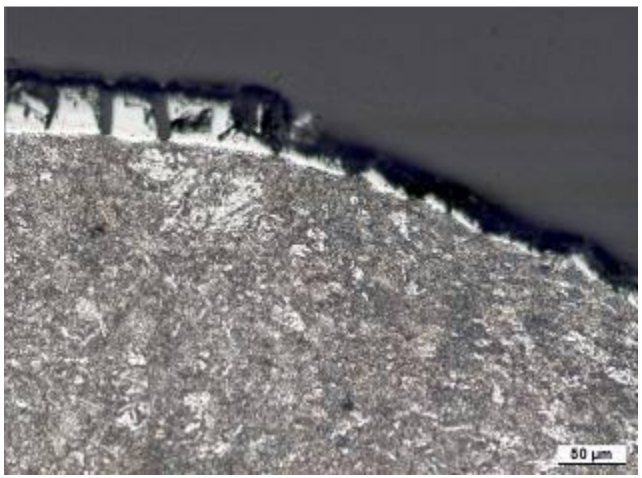




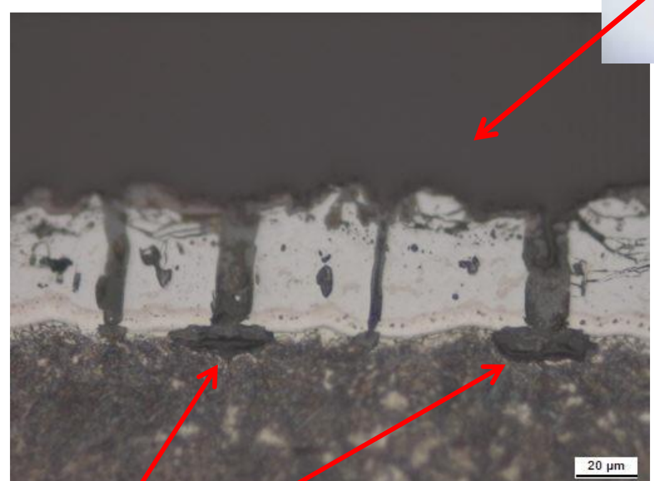


Corrosion on AlSi Coated PHS

Formed Section Showing Coating Loss



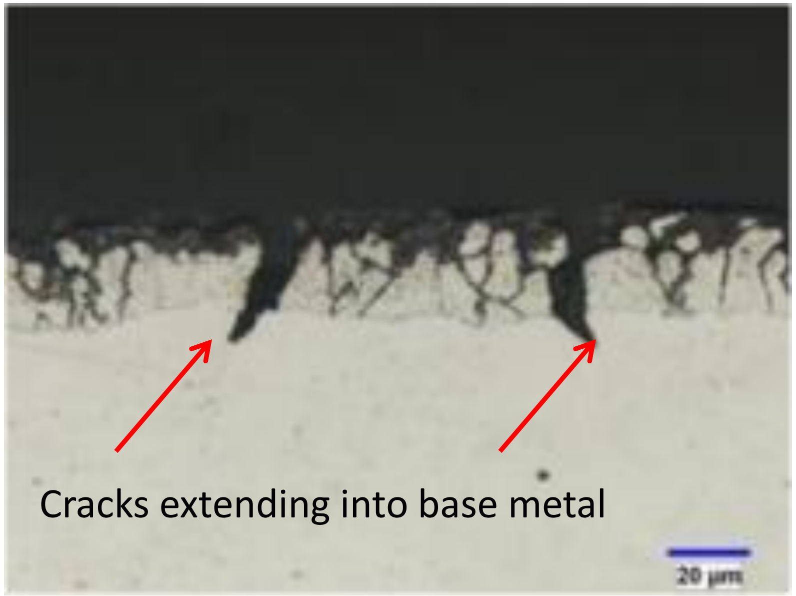
After 120 hrs. Corrosion Exposure



Corrosion undercutting of cracked, barrier coating of AlSi

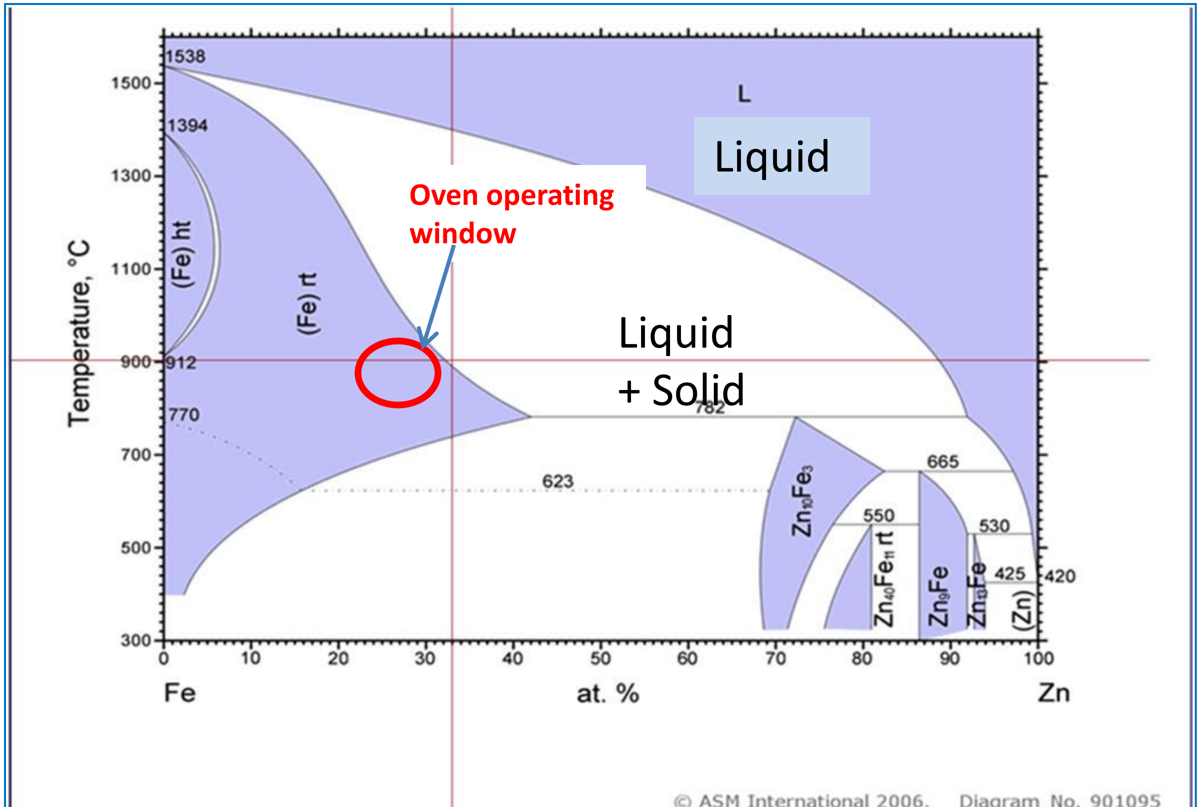
Coating Development on PHS

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

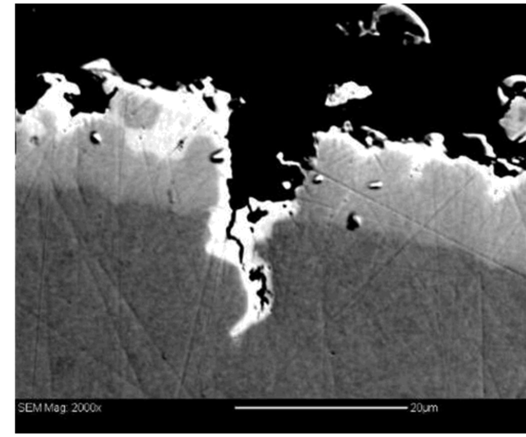
Zinc based coatings on PHS steel may be susceptible to Liquid Metal Embrittlement if not processed correctly



Fe-Zn Phase Diagram (1990 Okamoto H.)

Close Window

ASM Alloy Phase Diagrams Center, P. Villars, editor-in-chief; H. Okamoto and K. Cenzual, section editors; http://www.asminternational.org/AsmEnterprise/APD, ASM International, Materials Park, OH, USA, 2006-2011

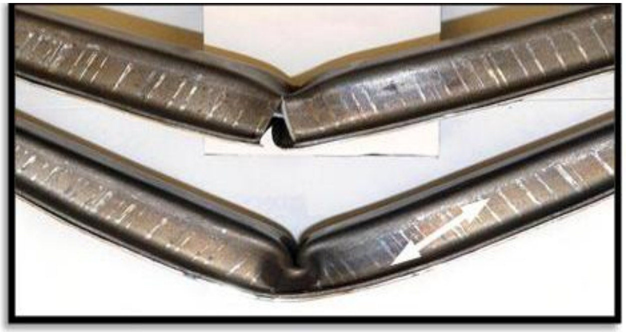


THE WORLD'S BEST VEHICLES

Hydrogen Induced Cracking

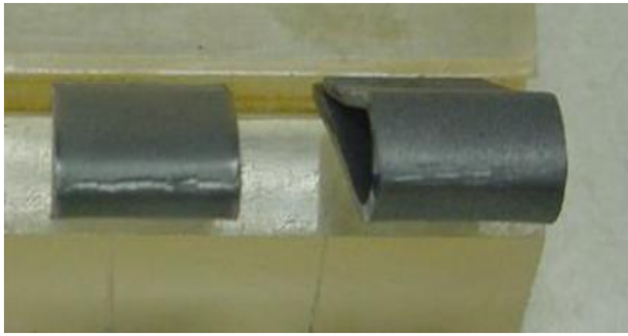
Issue:

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_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_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

Conclusion

- 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_2 limits.

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

Australia	France	Japan	Portugal
Austria		Korea	Slovak Republic
Belgium	Germany	Luxembourg	Slovenia
Canada	Greece		Spain
Chile	Hungary	Mexico	Sweden
Czech Republic	Iceland	Netherlands	Switzerland
Denmark	Ireland	New Zealand	Turkey
Estonia	Israel	Norway	United Kingdom
Finland	Italy	Poland	United States