Opportunities and Challenges for 3rd Generation Advanced High-Strength Steels in Automotive Body Structures

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C. Matt Enloe – General Motors Company
Outline

• Background and Motivation
• AHSS Implementation – Current State
• 3rd Generation Steel Nomenclature and Qualification
• Application Philosophy
• Identified Applications
• Remaining Challenges and Next Steps
Background and Motivation

• The need for increased AHSS usage is required to maintain steel as the material-of-choice for light-weighting pending finalization of 2025 EPA/NHTSA mandates.

From: T.A. Swartzell, GDIS 2016

2016 Chevrolet Malibu
Background and Motivation

- Meanwhile, mixed material strategies for lightweight body structure design are strong competitors for steel intensive structures.

2016 Cadillac CT6

From: C.D. Horvath, GALM 2016
General Motors Material Philosophy

• Optimize Applications of Materials
  – Right Material in the Right Application

• Mixed Material Strategy
  – Advanced and Ultra High-Strength Steels
  – Aluminum Sheet, Castings and Extrusions
  – Balance Above Dictated by Cost/Performance Targets
Steel Strength Ductility Diagram

Future Opportunity
Third Generation AHSS
3rd Gen AHSS’s – Comparisons to 1st Gen Steels

Stress, MPa vs. Strain, %

- PHS
- 1180 DP
- 1180 G3
- 980 LCE
- 980 G3

Strain, %

0 5 10 15 20 25 30

Stress, MPa

0 200 400 600 800 1000 1200 1400 1600
GM issued a worldwide technical specification, using strength and ductility based nomenclature, for retained austenite bearing (TRIP) steels. The types of steels covered are:

- TRIP
- TBF (TRIP-Aided Bainitic Ferrite)
- CFB (Carbide Free Bainitic TRIP)
- Q&P (Quench and Partition TRIP)
- Medium Manganese TRIP/ TRIP-TWIP

Ultimate tensile strength levels range from 690 MPa to 1180 MPa for 3rd generation TRIP steels. Significantly less for medium manganese steels.
To assist with global grade definition and material homologation, GM has issued a worldwide technical specification for retained austenite bearing steels.
Nearly a decade of development between the global steel and automotive industries has resulted in production applications of third generation AHSS.

The first application on a GM vehicle → 2016 Chevy Sail (Quench and Partition, 980 MPa Min. Tensile Strength – 15% Min. Total Elongation @ ASTM E8) – GMW17627

Increased global applications require greater region-by-region availability

- Selected grades identified for global development
- Qualification in-process for select grades at 980 MPa and 1180 MPa strength levels.

Multiple additional applications are under consideration.
## Grade Definition for Global Availability

Retained Austenite Bearing Steel Mechanical Property Requirements

<table>
<thead>
<tr>
<th>Designation</th>
<th>Yield Strength at 0.2% Offset [MPa]</th>
<th>Tensile Strength [MPa]</th>
<th>Elongation in 50 mm [MPa]</th>
<th>Elongation in 80 mm [MPa]</th>
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<td>400-520</td>
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# Grade Definition for Global Availability

## Retained Austenite Bearing Steel Chemistry Requirements

<table>
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<tr>
<th>Grade Type</th>
<th>C Max (%)</th>
<th>Mn Max (%)</th>
<th>Al Min/Max (%)</th>
<th>Si Max (%)</th>
<th>P Max (%)</th>
<th>S Max (%)</th>
<th>Cu Max (%)</th>
<th>B Max (%)</th>
<th>N Max.%</th>
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<td>0.04</td>
<td>0.01</td>
<td>0.2</td>
<td>0.005</td>
<td>0.008</td>
</tr>
</tbody>
</table>
Both material performance and manufacturability cannot be sacrificed for increased strength-ductility combinations!

Global formability is not the only attribute of interest.

*Bold Denotes Material Qualification Requirement*
Opportunities for 3rd Generation Steel Applications

- Direct materials substitution for light-weighting
- Enhanced strength/elongation at given gauge for energy absorption (enhanced crashworthiness)
- Cost reduction via PHS replacement
- Part consolidation enabled by enhanced formability
- Geometric optimization due to enhanced formability
- Potential applications identified for A-, B-Pillar, Roof Rail, Roof Bow and underbody reinforcements.
Remaining Challenges and Next Steps

The good news...

• Global supply of 3rd generation TRIP steels is increasing, and supply and technical risk tolerance appears increasingly “manageable.”

• TRIP/TBF/Q&P display equivalency in tested metrics (via Pre-Qualification Testing)
Remaining Challenges and Next Steps

Ongoing Challenges...

• Liquid Metal Embrittlement of Spot Welded Zn-Coated TRIP Steels
• High Strain Rate Behaviors - as an Example of Fundamental (Inherent) Performance Analysis Challenges of Medium Manganese Steels
• Incorporation of UHSS and AHSS Fracture Phenomena in Design and CAE Best Practices
• Spot Welding and Spot Weld Strength
• Hydrogen Cracking and Low Yield Strengths (Medium Manganese Steels)
Remaining Challenges and Next Steps

Liquid Metal Embrittlement of Spot Welded Zn-Coated TRIP Steels
Remaining Challenges and Next Steps

*Note scale differences
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