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

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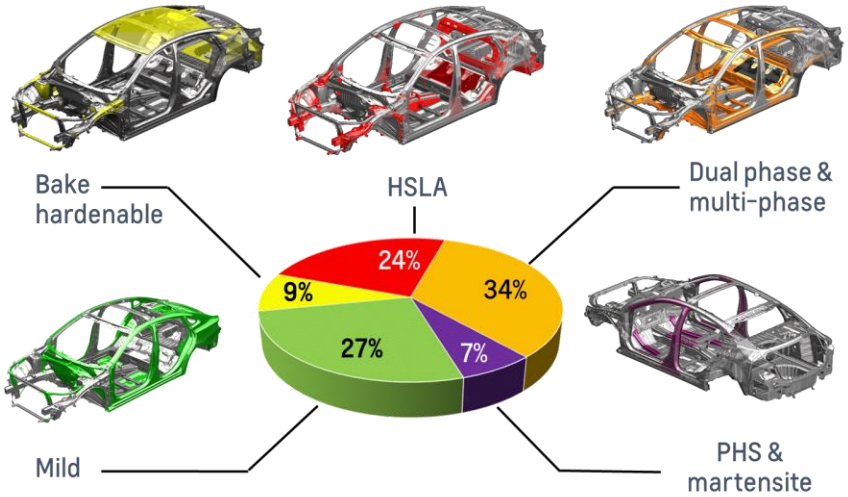
Outline

- 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.

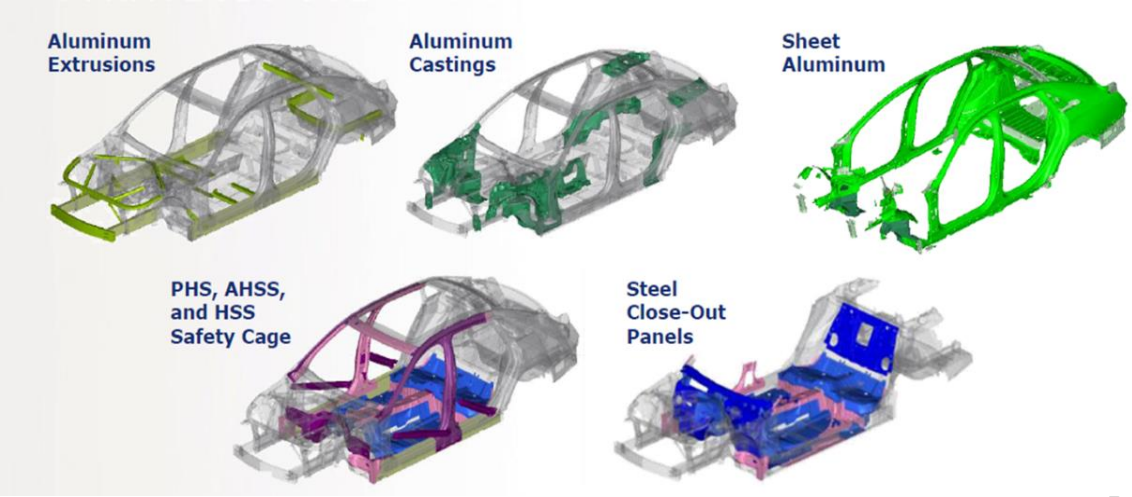


From: T.A. Swartzell, GDIS 2016

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

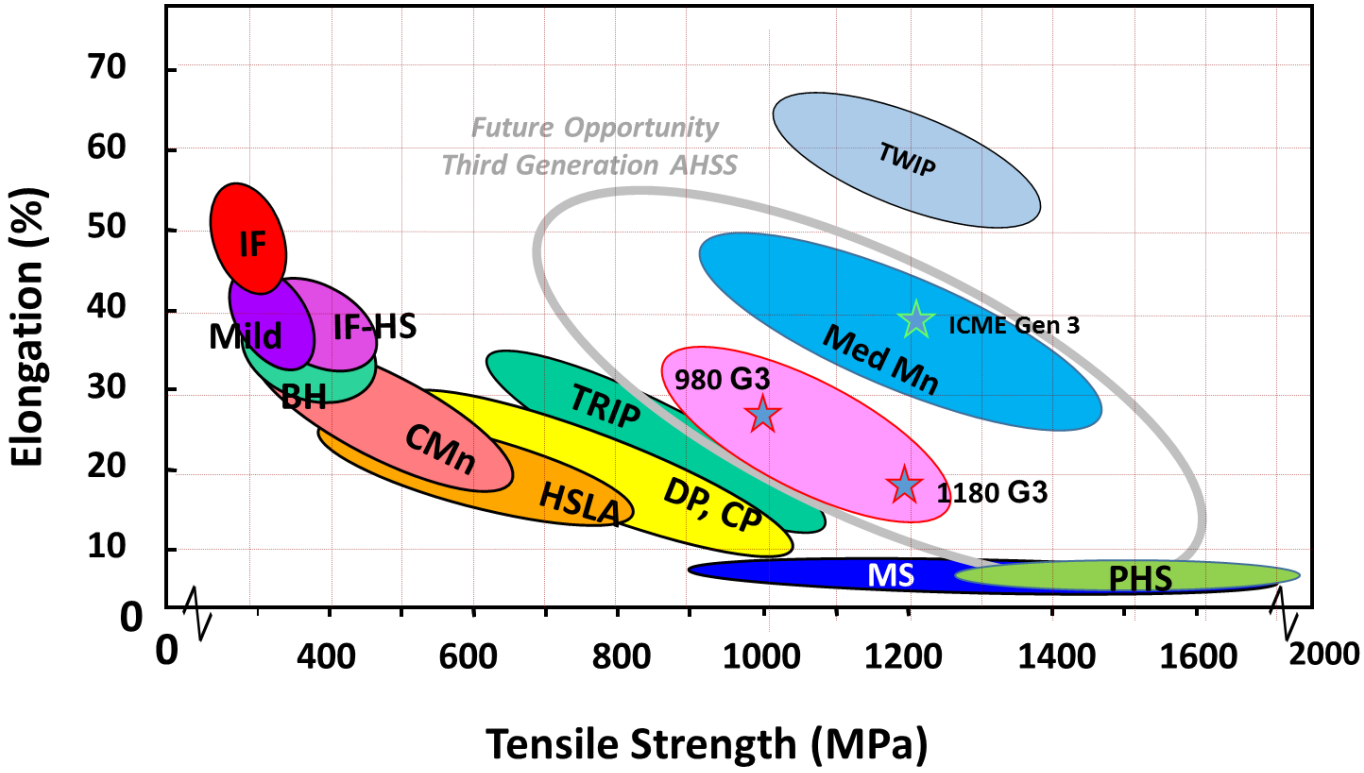
From: C.D. Horvath, GALM 2016

General Motors Material Philosophy

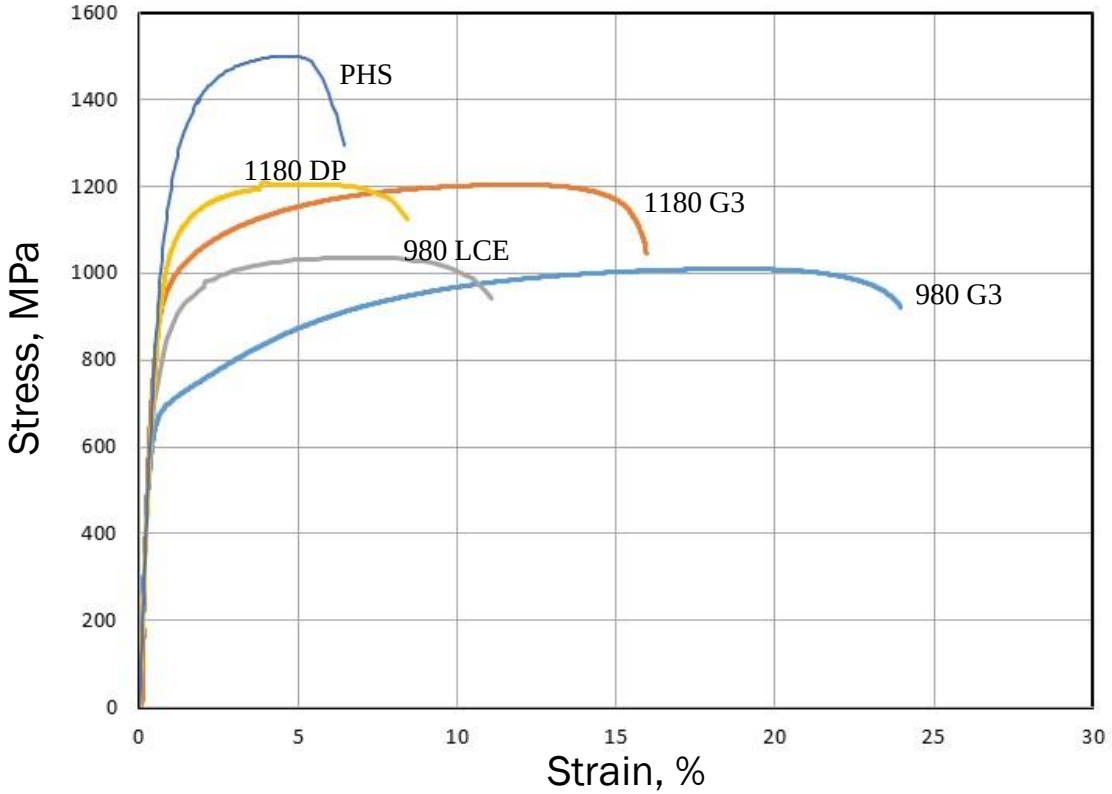
- Optimize Applications of Materials
  - Right Material in the Right Application

- 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



3rd Gen AHSS's – Comparisons to 1st Gen Steels



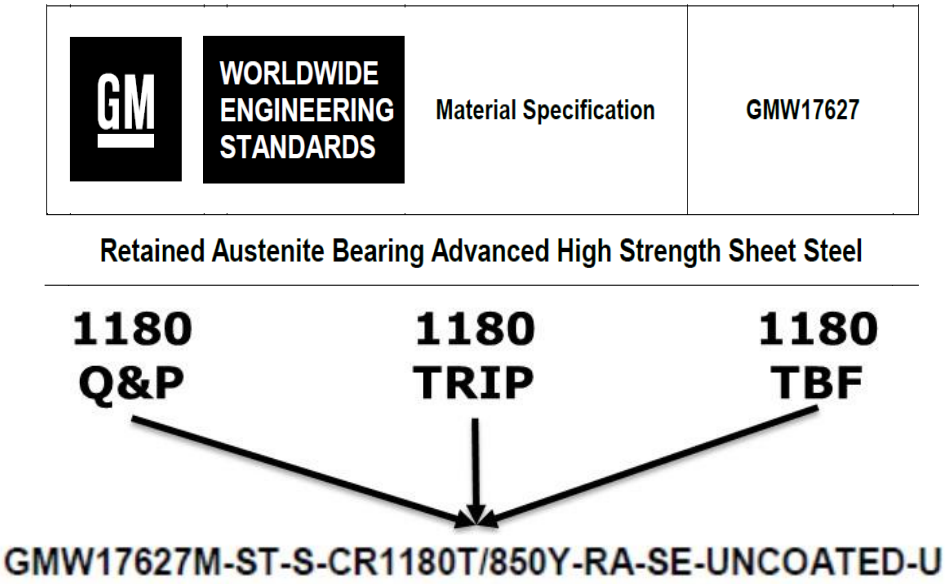
GM Global Specification– Grades Included

- 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.

Third Generation AHSS – Grade Definition

- To assist with global grade definition and material homologation, GM has the issued a worldwide technical specification for retained austenite bearing steels.



Current 3rd Generation AHSS Implementation

- 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

GMW17627M-ST-S	Yield Strength at 0.2% Offset [MPa]		Tensile Strength [MPa]		Elongation in 50 mm [MPa]		Elongation in 80 mm [MPa]
Designation	Min.	Max.	Min.	Max.	ISO I	ISO III	ISO II
CR690T/400Y-RA-SE	400	520	690	825	25	27	24
CR780T/450Y-RA-SE	450	570	780	900	22	23	21
CR980T/600Y-RA-SE1	600	850	980	1100	15	16	14
CR980T/700Y-RA-SE2	700	900	980	1100	13	14	13
CR1180T/850Y-RA-SE	850	1100	1180	1300	13	14	13
CR980T/600Y-RA-HE1	600	850	980	1100	20	21	19
CR980T/700Y-RA-HE2	700	950	980	1100	28	30	27
CR980T/600Y-RA-HE3	600	850	980	1100	28	30	27
CR1180T/700Y-RA-HE1	700	950	1180	1300	17	18	16
CR1180T/850Y-RA-HE2	850	1125	1180	1300	24	25	23
CR1180T/800Y-RA-HE3	800	1050	1180	1300	24	25	23

Grade Definition for Global Availability

Retained Austenite Bearing Steel Chemistry Requirements

GMW17627M-ST-S Grade Type	C Max (%)	Mn Max (%)	Al Min/Max (%)	Si Max (%)	P Max (%)	S Max (%)	Cu Max.(%)	B Max (%)	N Max.%
CR690T/400Y-RA-SE	0.25	2	0.005 to 2.00	2	0.04	0.01	0.2	0.005	0.008
CR780T/450Y-RA-SE	0.28	2.5	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR980T/600Y-RA-SE1	0.3	3	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR980T/700Y-RA-SE2	0.3	3	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR1180T/850Y-RA-SE	0.35	3.5	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR980T/600Y-RA-HE1	0.3	3.5	0.005 to 2.00	2.5	0.04	0.01	0.2	0.005	0.008
CR980T/700Y-RA-HE2	0.3	8	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR980T/600Y-RA-HE3	0.4	5	0.005 to 2.00	2.6	0.04	0.01	0.2	0.005	0.008
CR1180T/700Y-RA-HE1	0.35	4	0.005 to 2.00	2.5	0.04	0.01	0.2	0.005	0.008
CR1180T/850Y-RA-HE2	0.35	12	0.005 to 2.00	2.2	0.04	0.01	0.2	0.005	0.008
CR1180T/800Y-RA-HE3	0.45	6	0.005 to 2.00	2.6	0.04	0.01	0.2	0.005	0.008

Additional Performance Metrics

- Material Characterization - Microstructure
- Mat
  - U
  - M
  - H
  - T
  - F
  - B
  - F
  - T
  - Hole Expansion Ratio / True Strain at Fracture
  - H Embrittlement Sensitivity (GMW17058 and SEP1970)
- Weld Performance (Supplier and

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…

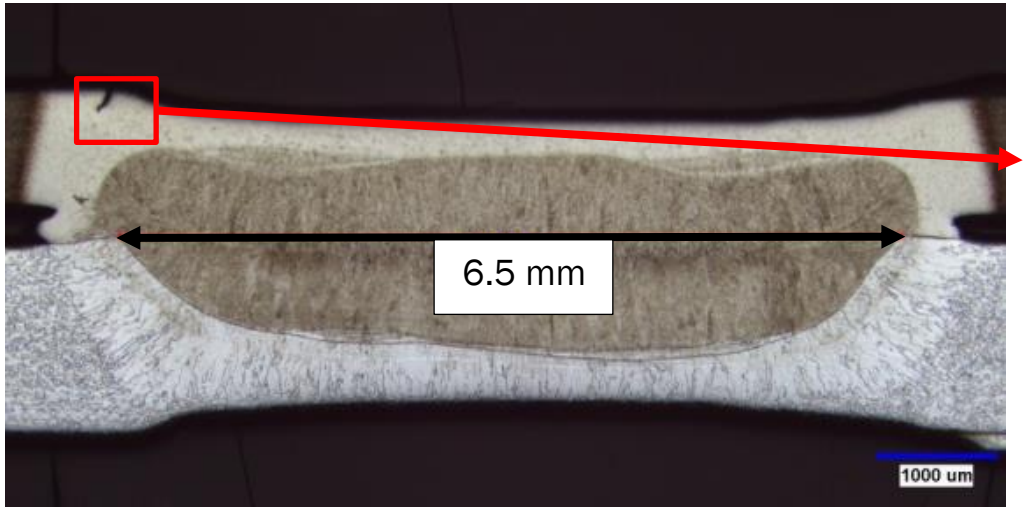
- Global supply of 3rd generation TRIP steels is increasing, and supply and technical risk tolerance appears increasingly “manageable.”
- TRIP/TBF/Q&P display equivalency in tested metrics (via Pre-Qualification Testing)

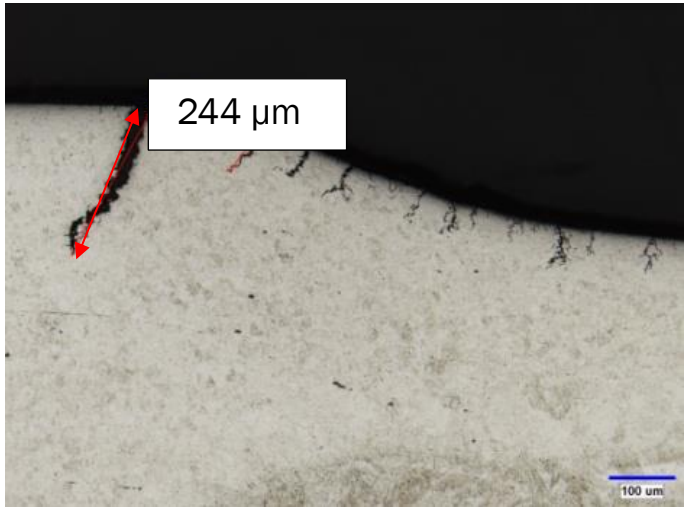
Remaining Challenges and Next Steps

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)

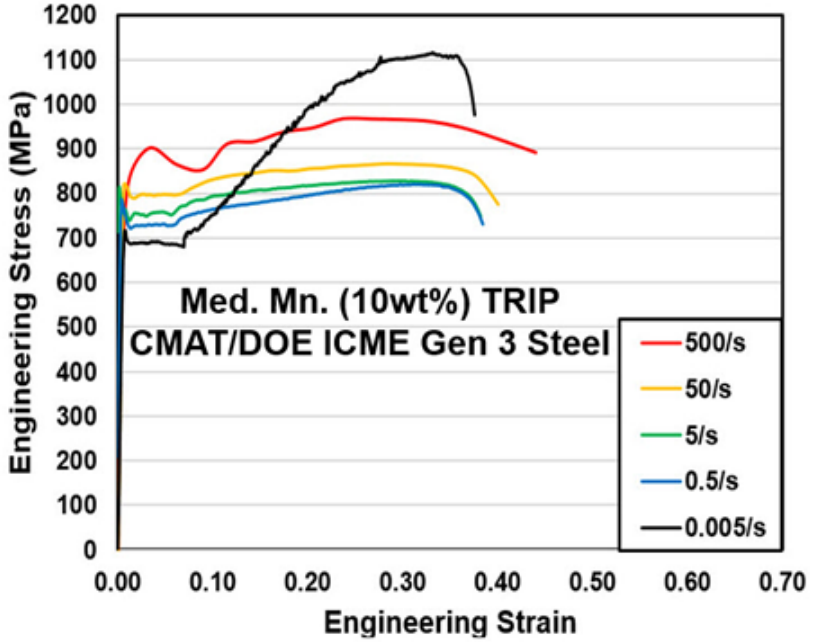
Remaining Challenges and Next Steps

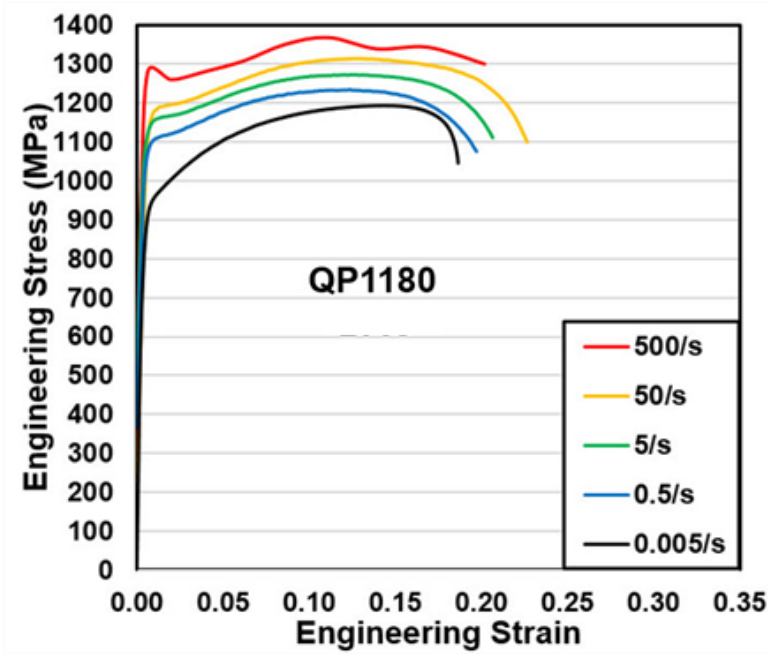




Liquid Metal Embrittlement of Spot Welded Zn-Coated TRIP Steels

Remaining Challenges and Next Steps





*Note scale differences

Comments/Questions

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