

Microstructure Differences Driving Formability Behavior in AHSS

Sarah Tedesco, General Motors

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Overview



Introduction

980DP vs 980MP-LCE and 1180MP- Chemistry and Microstructure

980DP vs 980MP-LCE and 1180MP- Tensile Properties

Evaluation Methods Discussion

T-Die Testing and Results

Conclusions



Introduction

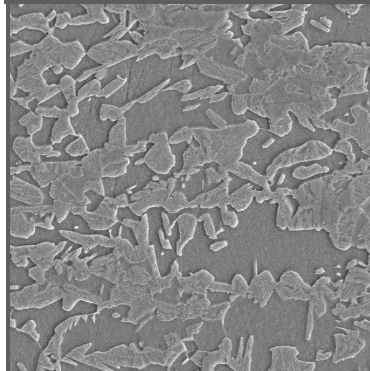
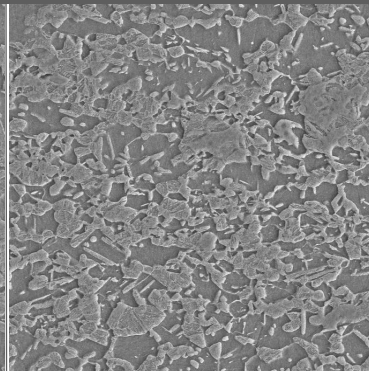
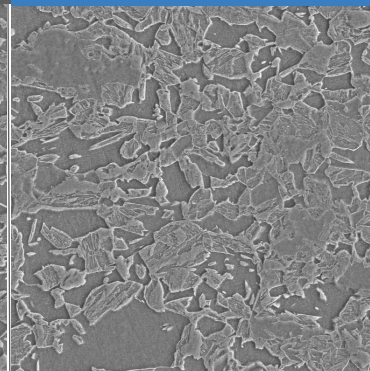
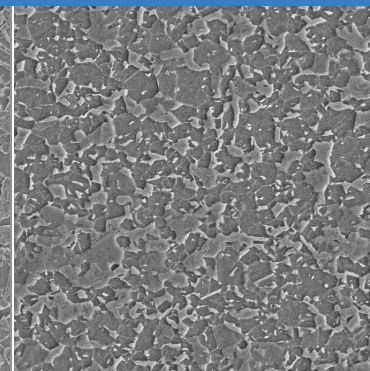
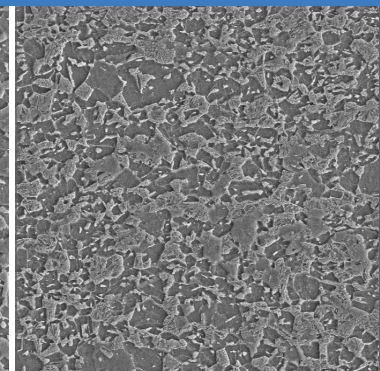
- Modern vehicle structures are under enormous design pressure between the demands of passenger protection and intrusion protection for battery packs.
- Future vehicles require significant structural design changes to improve intrusion resistance, especially for battery systems.
- Higher yield strength steels in the 1.0GPa range with complex phase (CP) and multi-phase (MP) microstructures are emerging as the primary material choice, replacing conventional dual-phase (DP) grade.
- Balancing DP grades, with their lower yield strengths, against CP/MP grades, with their lower total elongation, requires close discernment between global and local formability needs.



980DP vs 980MP-LCE and 1180MP- Chemistry and Microstructure



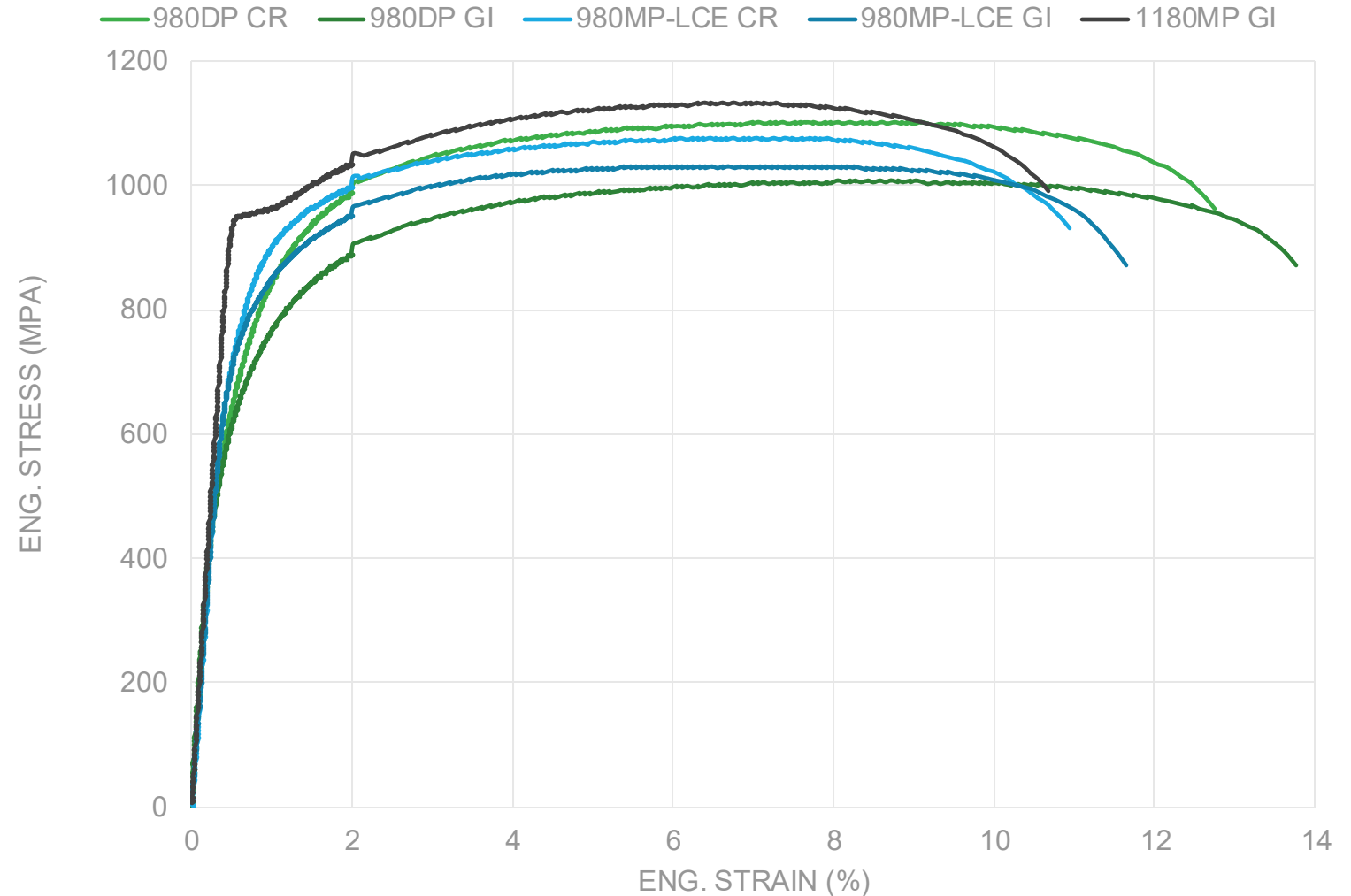
- 980-DP grades show ferrite and martensite microstructure.
- 980MP-LCE Uncoated shows ferrite and martensite microstructure.
- 980MP-LCE and 1180-MP coated exhibit fine ferrite, bainite, and martensite microstructure.

980-DP grades (Ferrite & Martensite)				980MP-LCE & 1180-MP grades					
									
C (%)	0.138	C (%)	0.104	C (%)	0.118	C (%)	0.100	C (%)	0.150
Mn (%)	1.909	Mn (%)	2.304	Mn (%)	1.666	Mn (%)	2.148	Mn (%)	2.286
Si (%)	0.502	Si (%)	0.010	Si (%)	0.494	Si (%)	0.051	Si (%)	0.060
980 DP Uncoated		980 DP Coated		980MP-LCE Uncoated		980MP-LCE Coated		1180-MP LCE Coated	

980DP vs 980MP-LCE and 1180MP- Tensile Properties



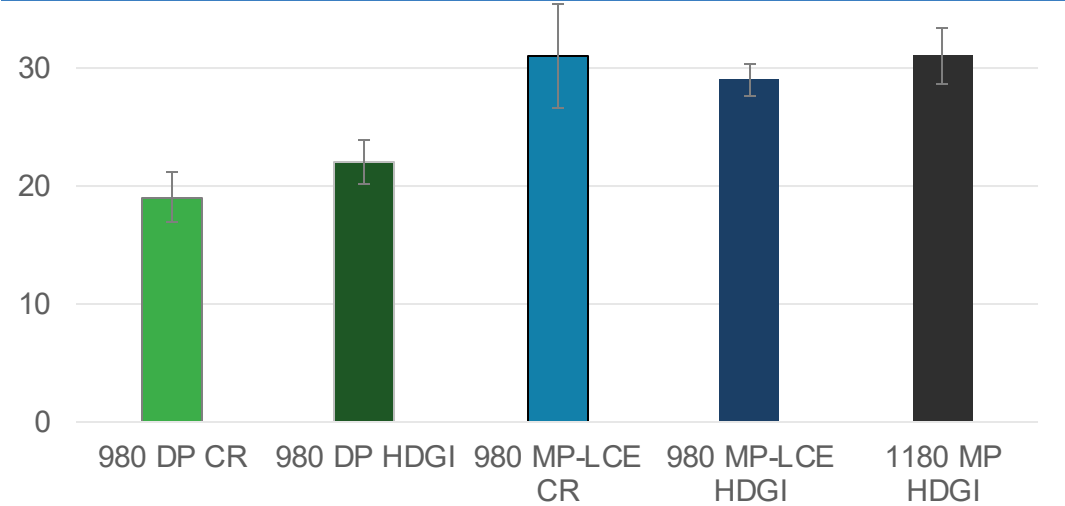
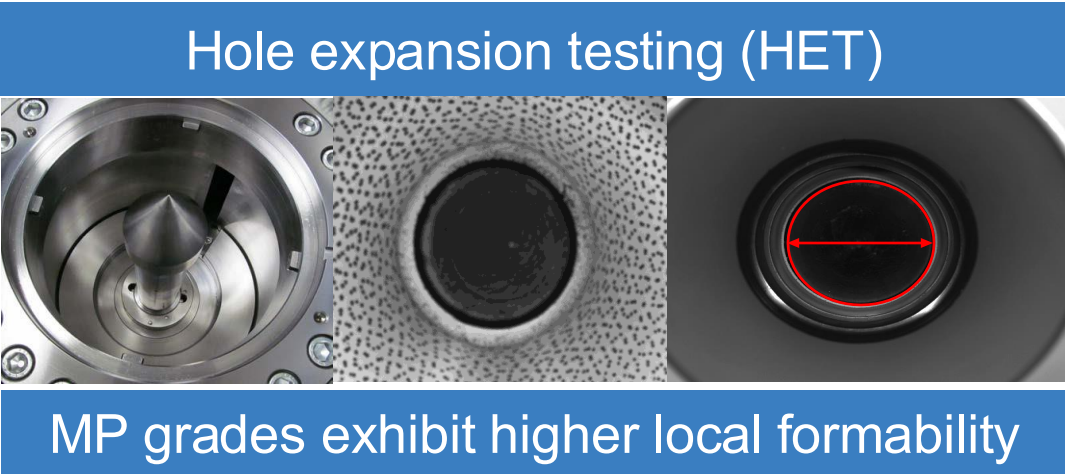
- MP grades exhibit higher yield strength compared to dual-phase (DP) steels of similar tensile strength
- %TE and n-value are nearly identical for 980/1180 MPa MP grades, indicating minimal difference in global formability
- Lightweighting potential exists by replacing DP grades with MP grades while maintaining comparable global formability



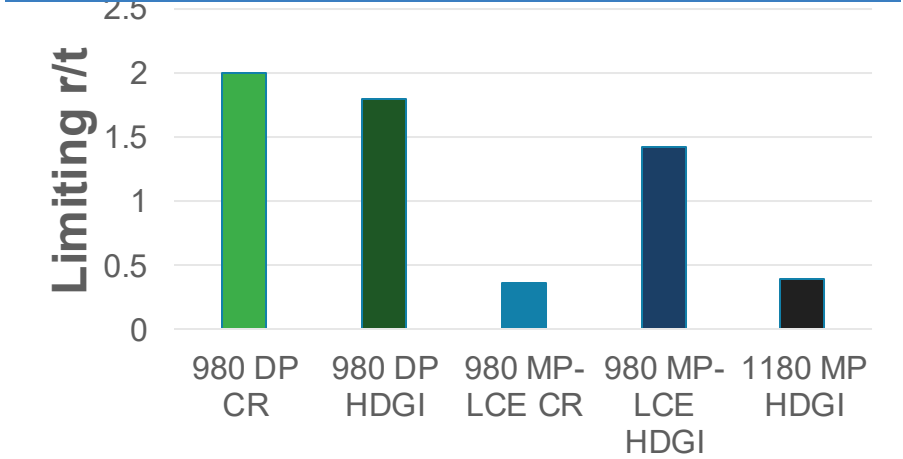
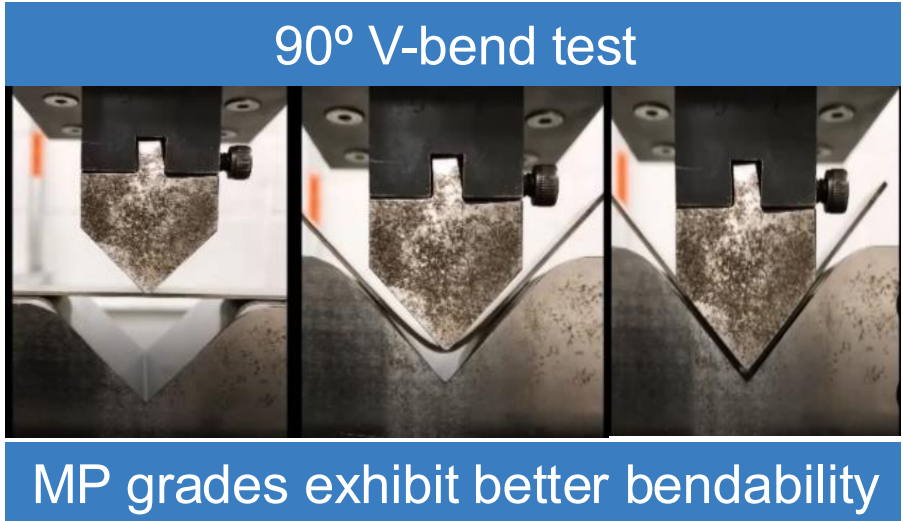
Evaluation Method Discussion: Hole Expansion & V-Bend



Hole Expansion Per ISO16630, 3x per material, 10mm Hole



V-Bend Per ISO7438, L and T, 5x per material



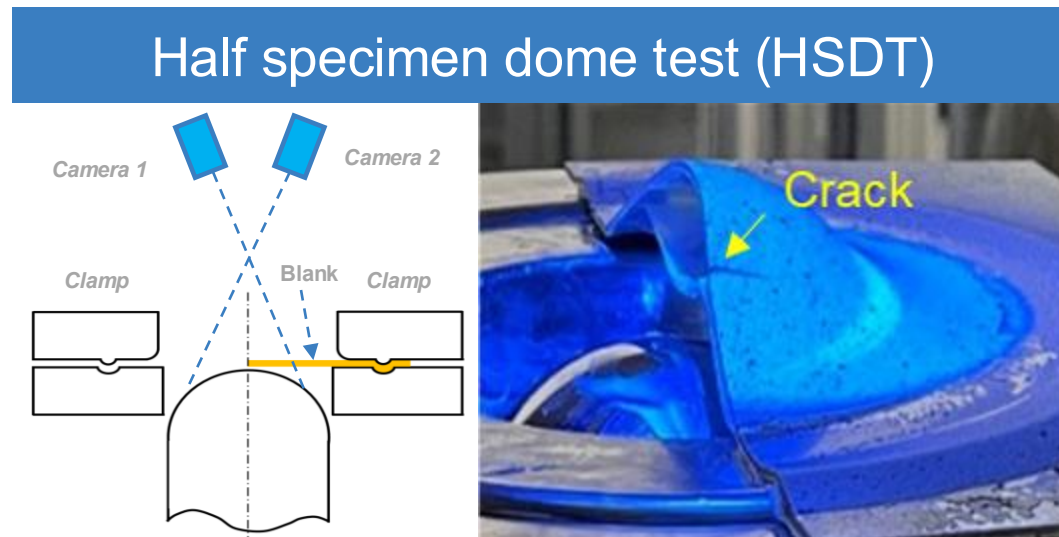
Evaluation Method Discussion: Half Specimen Dome Test



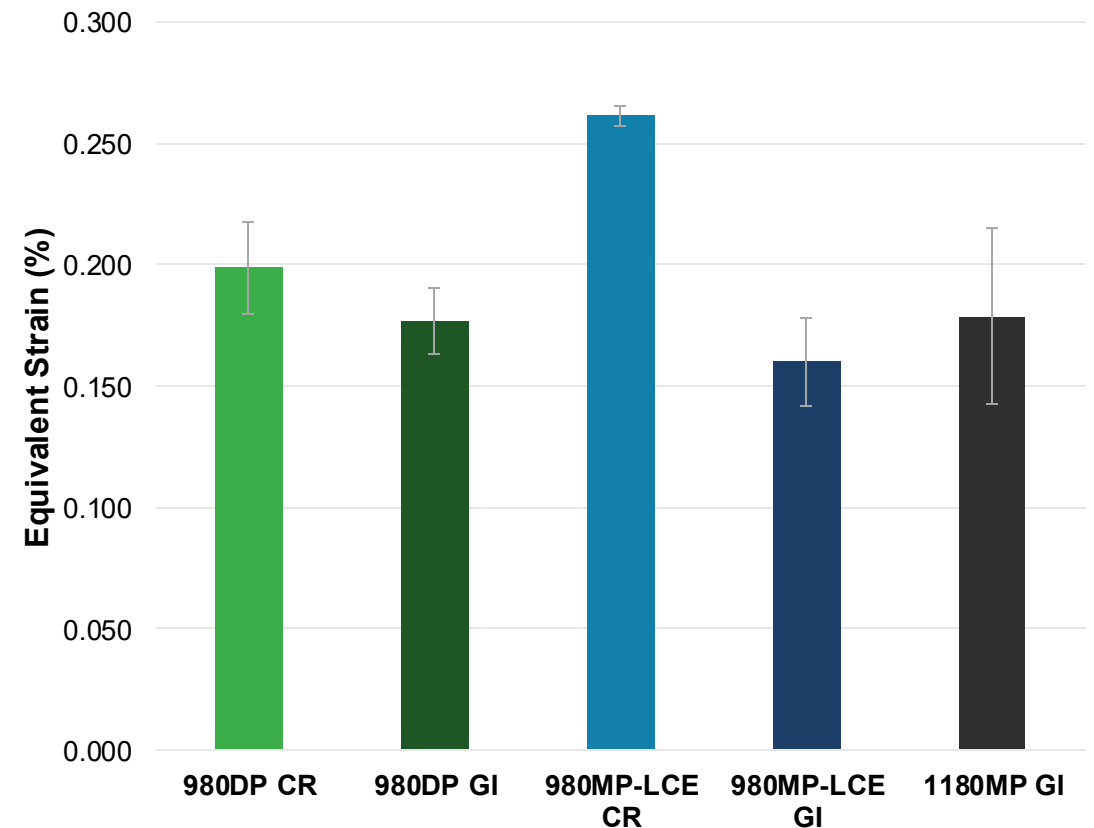
Half Specimen Dome Testing conducted per the method described in:

Hua-Chu Shih, Ming F. Shi, "Robust Shearing Process for Improving AHSS Sheared Edge Stretchability," ASME 2012 International Manufacturing Science and Engineering, MSEC 2012-7318, 2012.

Using a 13% clearance sheared edge specimen held at the mid point of the dome, the final fracture equivalent strains were captured using Digital Image Correlation technology (DIC).



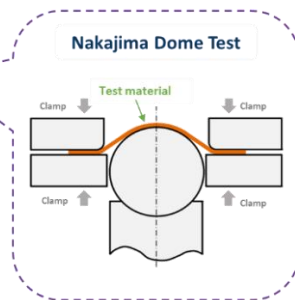
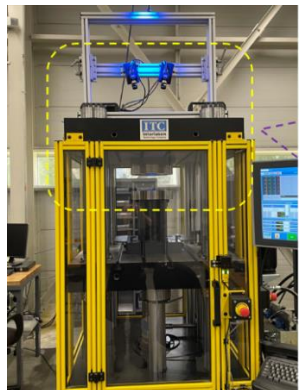
MP grades exhibit better edge stretchability



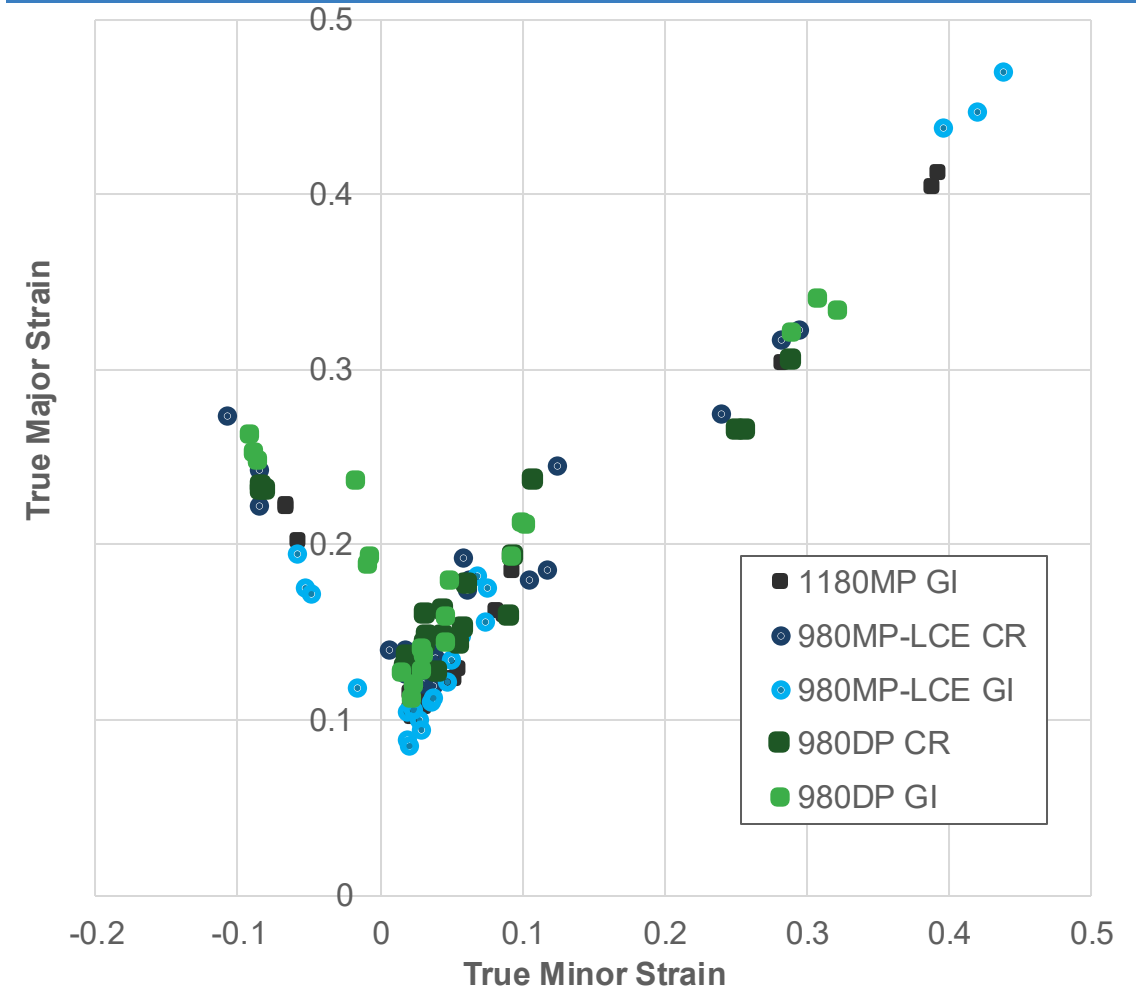
Evaluation Method Discussion: FLC Nakajima Dome

- FLC tests performed per ISO12004-2 using DIC to determine strain.
- ISO12004-2 standard method is used to determine strains at onset of localized necking.
- Per the results, under equal-biaxial stretch forming condition, both GI MP grades (980, 1180 MPa) show a slightly better formability than others, which indicates relatively higher formability in the transverse directions under the biaxial stretching forming condition.
- Differences in the formability between the grades is relatively small, indicating a level of interchangeability between the materials in a die.

Nakajima Dome Test



FLC comparison

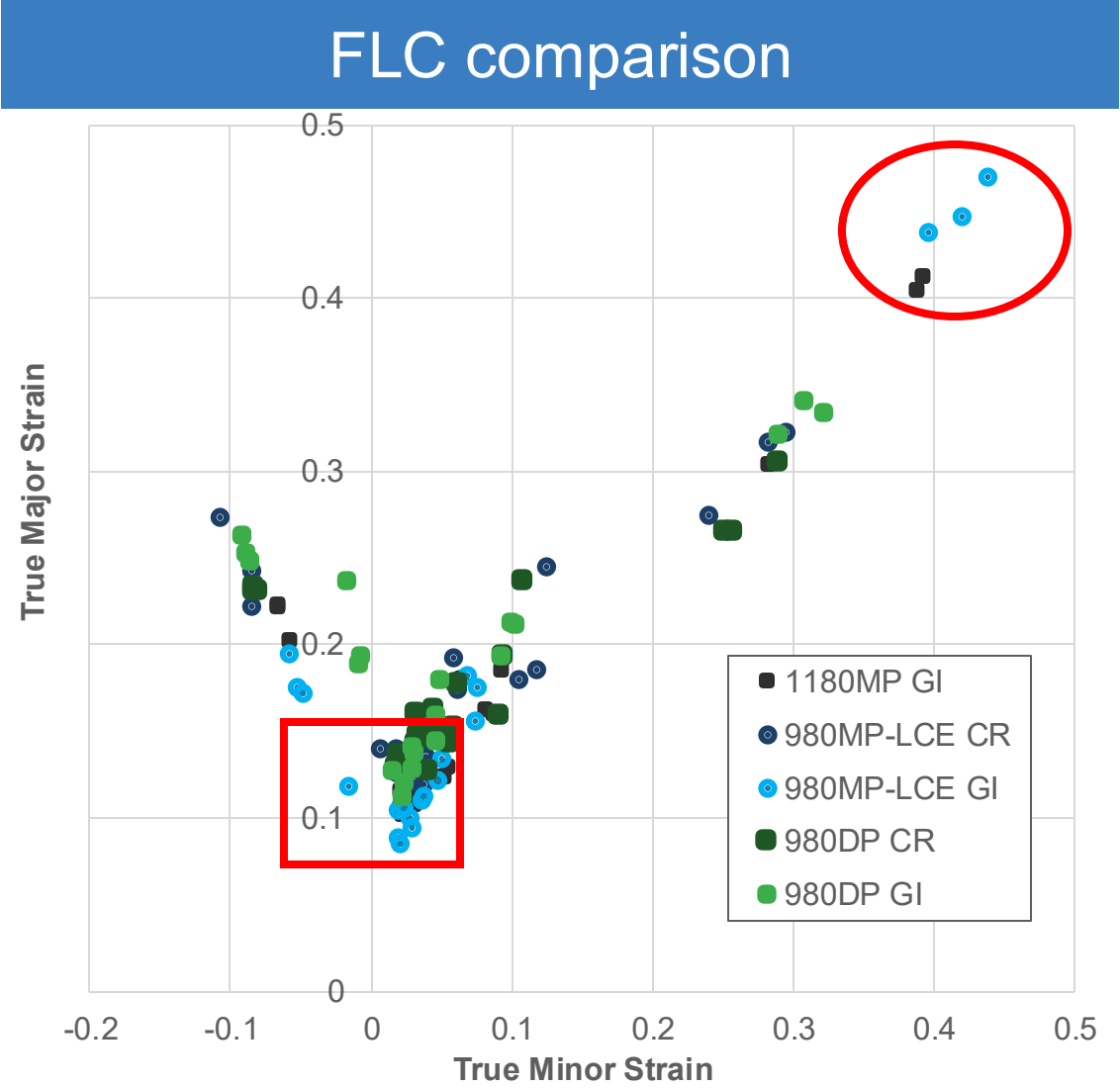


Results Discussion



- The 980MP-LCE CR material showed improved performance over both coated and uncoated 980DP materials.
- Biaxial stretch for both 980MP-LCE & 1180-MP grades better than 980-DP HDGI and 980 CR grades (red circle).
- FLC_0 is roughly the same for all grades (red square).
- These results indicate a good level of interchangeability between the grades.

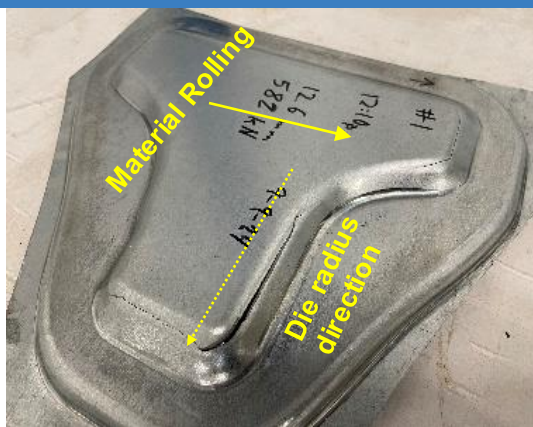
Material	Hole Expansion	V-Bend	HSDT
980DP CR	-	-	=
980DP GI	-	-	=
980MP-LCE CR	+	+	+
980MP -LCE GI	+	+	=
1180MP GI	+	+	=



T-Die Testing and Results

- T-Die testing completed under real-world stamping conditions:
 - Bending, stretching and edge strain concentration
 - Assessing local formability, edge-crack resistance and fracture resistance
- Materials were tested to fracture. Draw depths were comparable between the grades.
- Slight benefit found in MP grades when forming direction is parallel to the transverse direction.

T Shape forming die

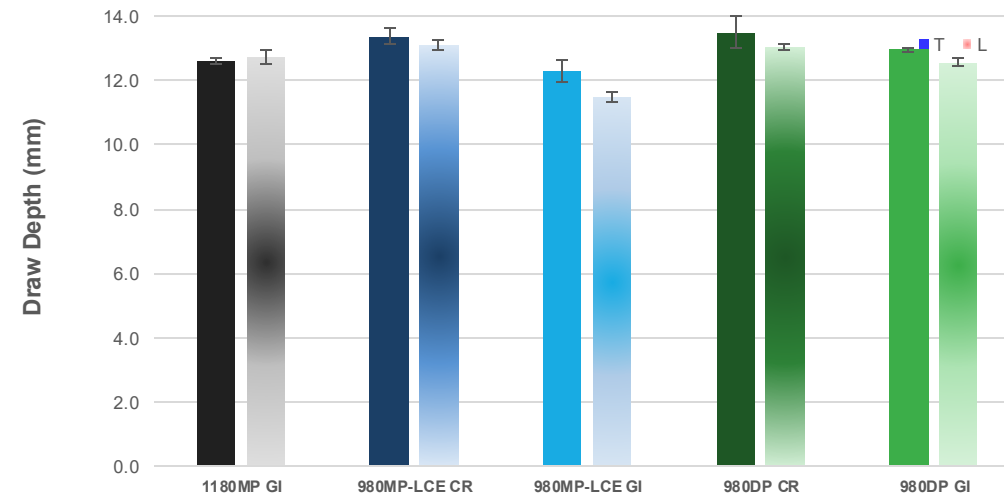


Fracture specimen with rolling transverse to die radius direction



Fracture specimen with rolling parallel to die radius direction

MP Grades Show Similar Formability



Conclusions

- Global formability of MP grades is comparable to DP grades, but outperform DP grades in biaxial stretchability
- Local formability: MP grades consistently outperform DP in HER, edge stretchability, and bendability
- Microstructural advantages (fine ferrite–bainite–martensite) in MP grades contribute to improved strength–formability combination.
- 1180MP GI has a comparable formability as 980MPa strength grade of AHSS (MP-LCE and DP).
- Down-gaging opportunities (mass and cost savings) may exist in transitioning some parts from 980DP to 1180MP.
- MP grades can be used to replace DP grades for the parts that were originally designed for DP grades.



Thank you to:

Hua-Chu (Mike) Shih- US Steel, Vasant
Pednekar- US Steel,
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Dave Plozai- GM AML.



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