GREAT DESIGNS IN STEEL

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GREAT DESIGNS IN STEEL

MICROSTRUCTURAL OPTIMIZATION OF AHSS AND PRESS HARDENED STEEL

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OUTLINE

- Background – Motivation for Performance Enhancement
- Specification Modifications
  - GMW3399 – Addition of MP780 and CP Grades
  - GMW14400 – Addition of IB Variant and 1800 MPa min TS
- Microalloying Strategies for Performance Optimization of:
  - MP780 – Global/Local Formability Balance
  - Press Hardening Steels – Improved Bendability
  - Press Hardening Steels – Delayed Fracture Resistance
- Summary

BACKGROUND

- The development of microalloyed steels and **strategies for additions of Nb, Ti, and V have centered on precipitation hardening and grain refinement of ferrite** in high strength low alloy steels (HSLA).
- The use of microalloying and other microstructural improvements can also be employed for optimization of mechanical properties of advanced high strength steels (AHSS) for enhanced performance and manufacturability.
- New multiphase steels are designed to correct observed manufacturing deficits in existing dual phase steel grades.
- Addition of microalloying to the existing 22MnB5 PHS chemistry increases fracture energy through increased bendability and resistance to cracking. Additionally, delayed fracture resistance may be improved.

IMPROVEMENTS IN DUAL PHASE STEELS

Dual Phase steels are known for their relatively good stamping performance and global formability at a given tensile strength. However, they are also well known for their poor resistance to local forming cracks in bending, edge stretch, and shear.

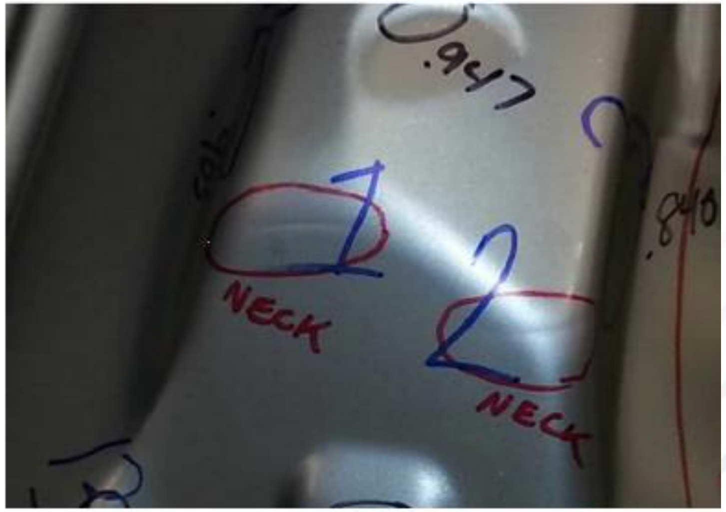
Local Formability Failures

Hole Expansion (out-of-plane edge stretch)

(In-Plane) Edge Stretching

Bending Cracks over Tight Radii

Necking (global) Formability Failures



GMW3399 – ADDITION OF MP780

Multiphase steels (MP) are being expanded in GMW3399 as more "balanced forming alternatives to conventional dual phase (DP) steels

- MP780 has been added (CR780T/440Y-MP)
- This grade mirrors the strategy of MP980 for better forming process robustness and edge damage tolerance relative to DP980 (e.g.: 980T/550Y vs 980T/700Y-MP-LCE

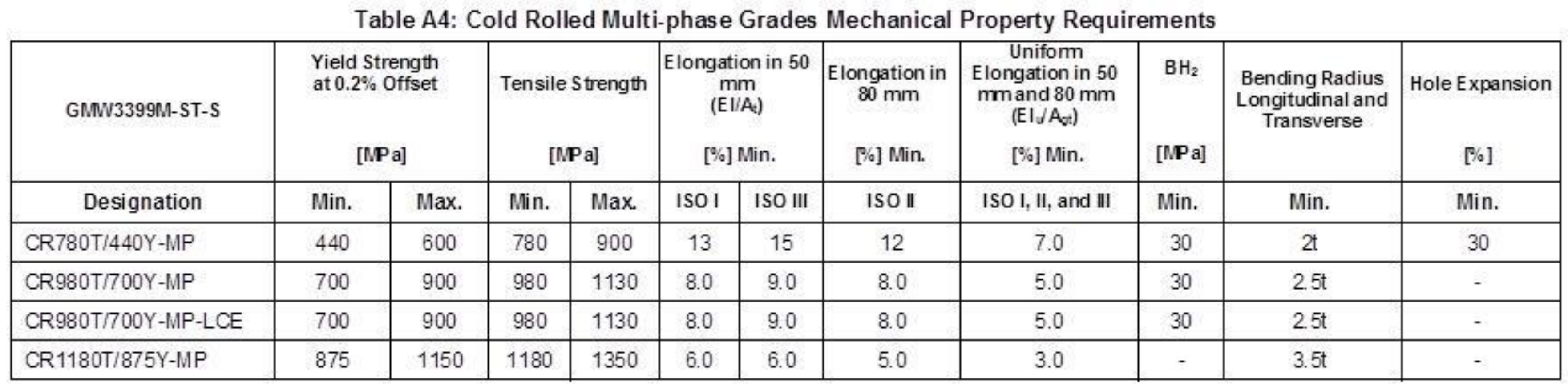


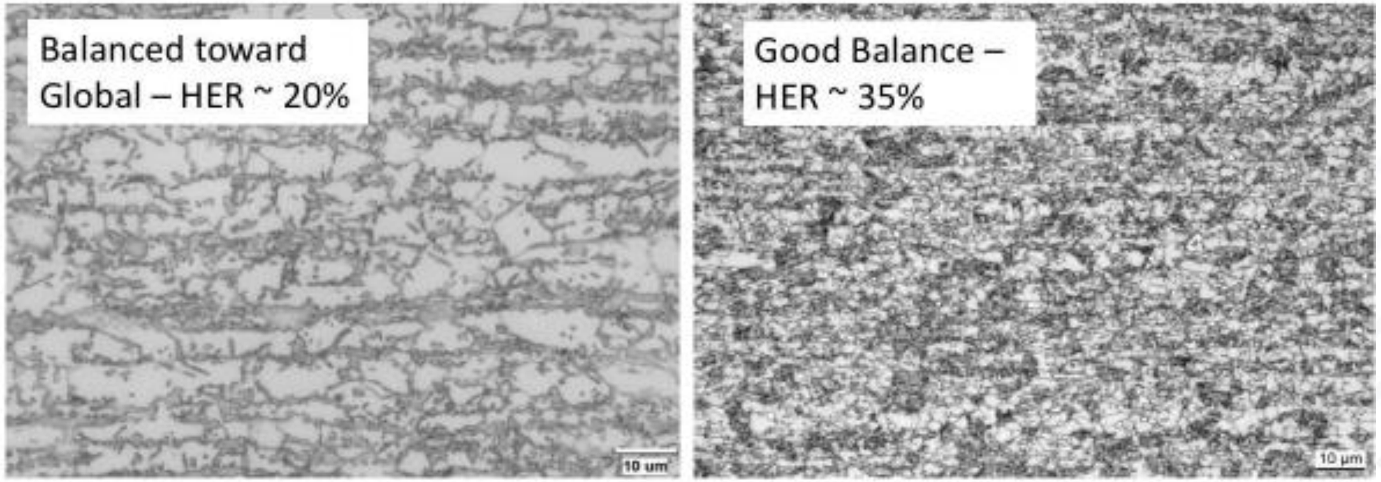
Table A4: Cold Rolled Multi-phase Grades Mechanical Property Requirements

GMW3399M-ST-S	Yield Strength at 0.2% Offset [MPa]		Tensile Strength [MPa]		Elongation in 50 mm (El/A_t) [%] Min.		Elongation in 80 mm [%] Min.	Uniform Elongation in 50 mm and 80 mm (El$_u$/A_{gt}) [%] Min.	BH$_2$ [MPa]	Bending Radius Longitudinal and Transverse	Hole Expansion [%]
Designation	Min.	Max.	Min.	Max.	ISO I	ISO III	ISO II	ISO I, II, and III	Min.	Min.	Min.
CR780T/440Y-MP	440	600	780	900	13	15	12	7.0	30	2t	30
CR980T/700Y-MP	700	900	980	1130	8.0	9.0	8.0	5.0	30	2.5t	-
CR980T/700Y-MP-LCE	700	900	980	1130	8.0	9.0	8.0	5.0	30	2.5t	-
CR1180T/875Y-MP	875	1150	1180	1350	6.0	6.0	5.0	3.0	-	3.5t	-

IMPROVEMENTS IN DUAL PHASE STEELS

Successful developments to meet the necessary balance of MP780 have four primary components:

1. Low C (sub-peritectic)
2. Grain Refinement from Microalloying Addition (Minimizes Phase Hardness Difference and Martensite Connectivity)
3. Steel Cleanliness (low S)
4. Addition of Secondary Bainite Phase



Traditional GI DP780

Grain Refined Concept on GI DP780

Rafael Mesquita, Improvement of Bendability and Resistance to Hydrogen Embrittlement in Press Hardening Steels, GDIS 2018

GMW3399 – ADDITION OF COMPLEX PHASE

CP (Complex Phase) Steels have been added to GMW3399 for their superior bendability and high yield to tensile ratio’s primarily for roll forming applications

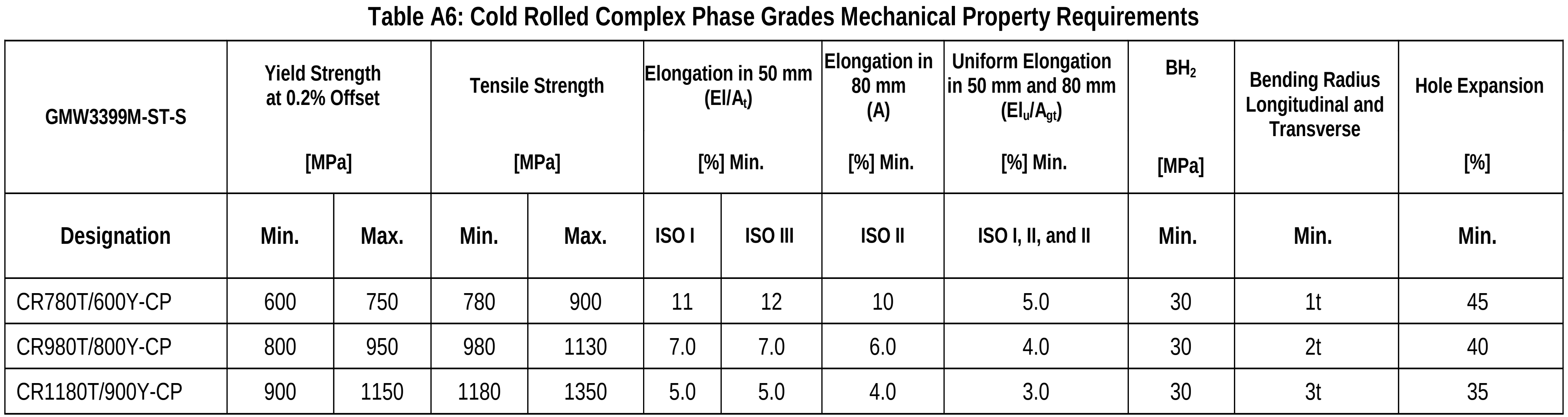


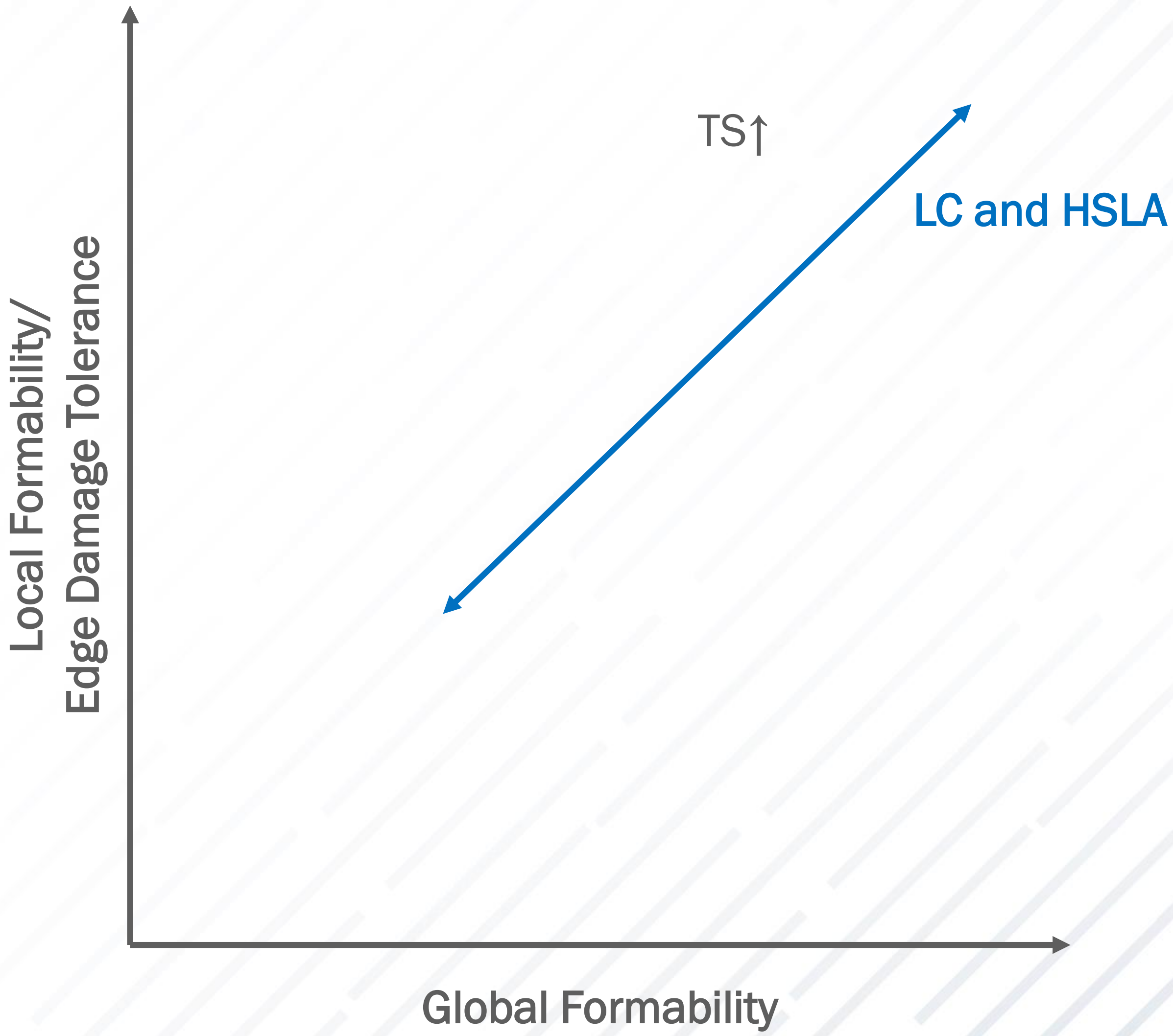
Table A6: Cold Rolled Complex Phase Grades Mechanical Property Requirements

GMW3399M-ST-S	Yield Strength at 0.2% Offset [MPa]		Tensile Strength [MPa]		Elongation in 50 mm (El/A_t) [%] Min.		Elongation in 80 mm (A) [%] Min.	Uniform Elongation in 50 mm and 80 mm (El_u/A_{gt}) [%] Min.	BH_2 [MPa]	Bending Radius Longitudinal and Transverse	Hole Expansion [%]
Designation	**Min.**	**Max.**	**Min.**	**Max.**	**ISO I**	**ISO III**	**ISO II**	**ISO I, II, and II**	**Min.**	**Min.**	**Min.**
CR780T/600Y-CP	600	750	780	900	11	12	10	5.0	30	1t	45
CR980T/800Y-CP	800	950	980	1130	7.0	7.0	6.0	4.0	30	2t	40
CR1180T/900Y-CP	900	1150	1180	1350	5.0	5.0	4.0	3.0	30	3t	35

Note: Grades specified not by a strict microstructure, but by manufacturing performance and mechanical properties

MP780 – BALANCED FORMABILITY

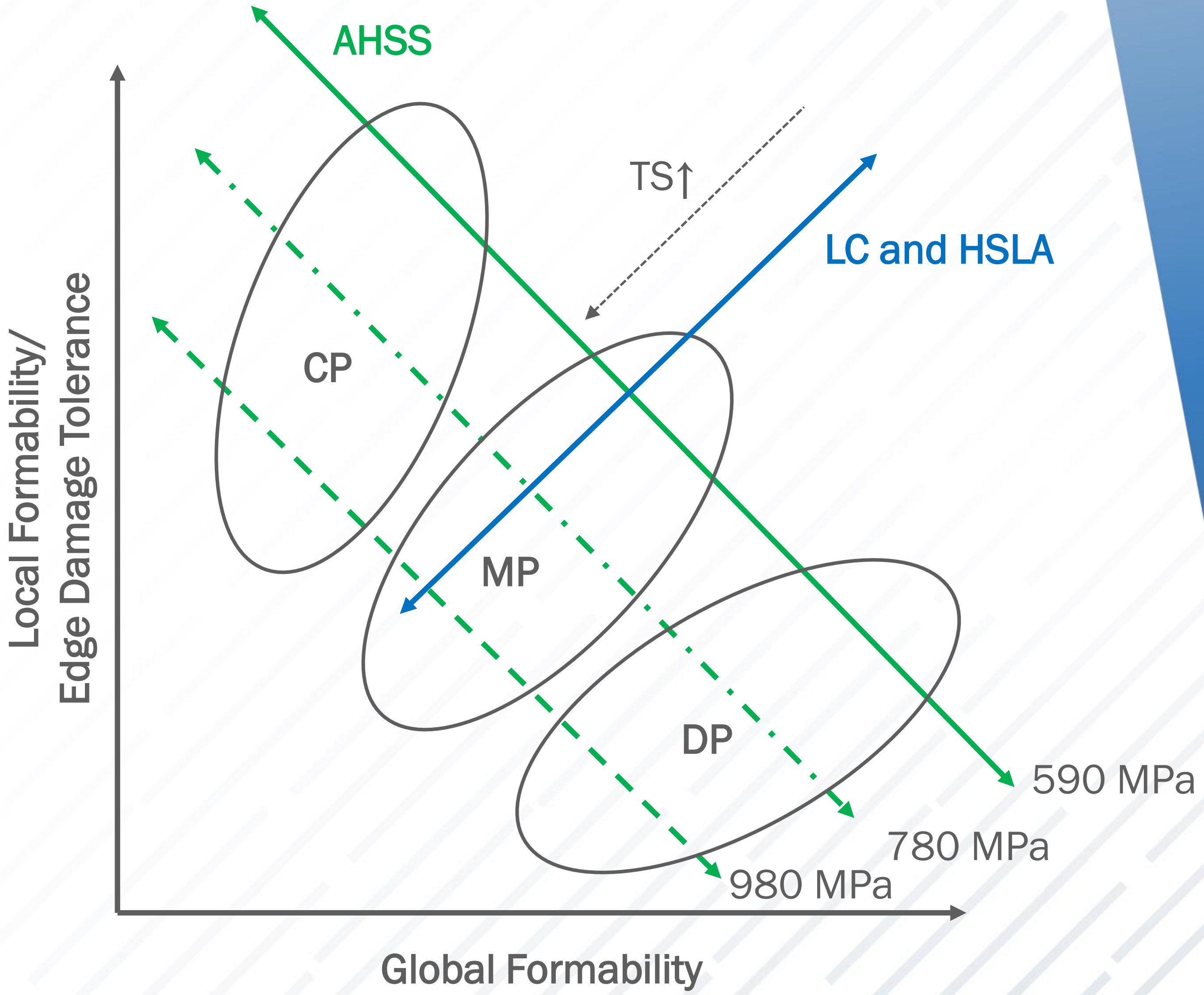
For Conventional Ferritic Steels, Global and Local Formability are Positively Correlated (Shown in Blue)



MP780 – BALANCED FORMABILITY

For Conventional Ferritic Steels, Global and Local Formability are Positively Correlated (Shown in Blue)

Global and Local Formability are Negatively Correlated for 1st Gen AHSS's DP, MP and CP (Shown in Green)

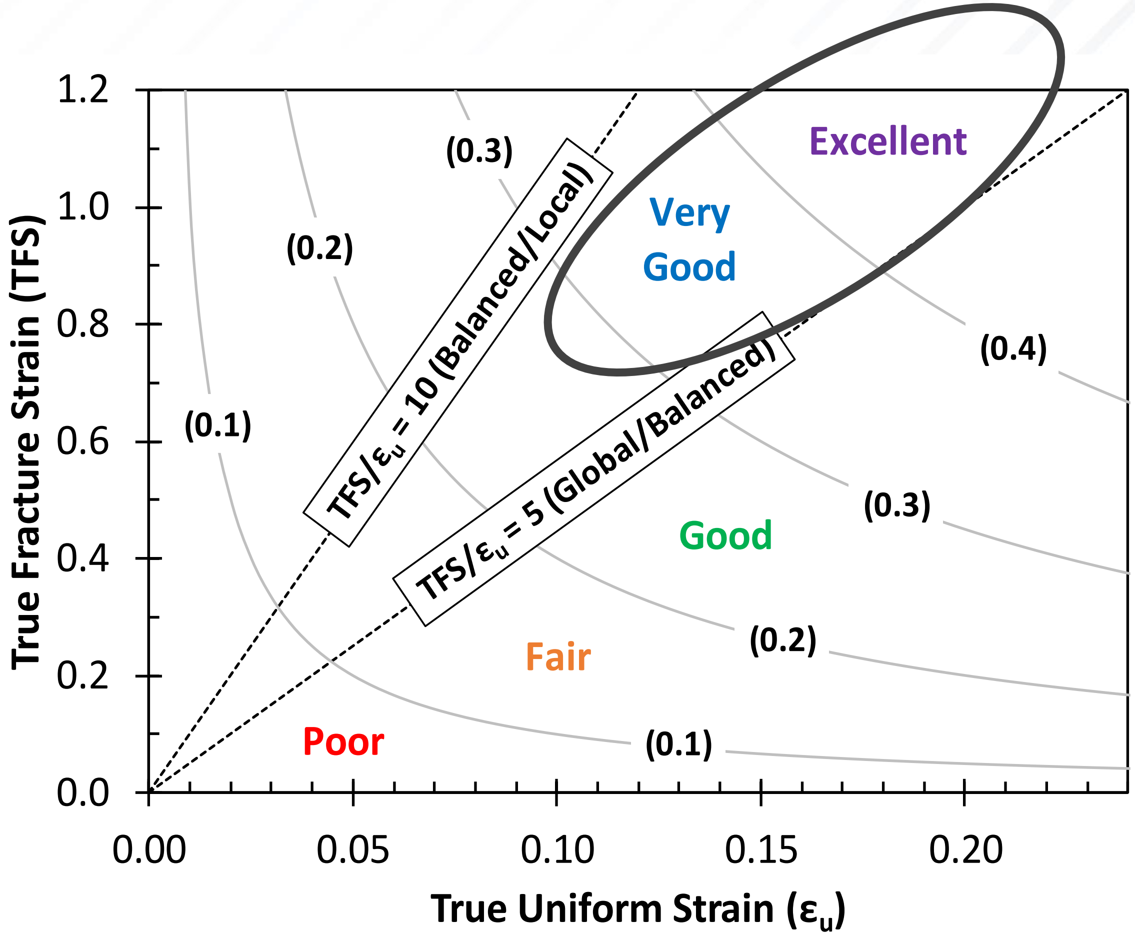


MP780 – BALANCED FORMABILITY

A Multiphase Steel Grade is Between Dual Phase (DP) and Complex Phase (DP) in its balance of global and local formability performance

- Global forming - FLD
- Local forming – Bend Test (VDA 238)
- Local forming – hole expansion/edge stretch (ISO 16630)

Additional Characteristics: Intentionally low silicon and no retained austenite!



Source: Brandon Hance-used with permission

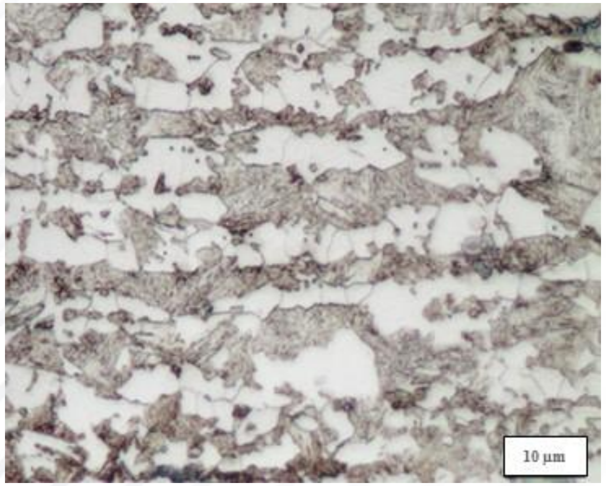
MP 980 – BALANCED FORMABILITY

The MP 980T/700Y-MP-LCE Utilizes Some of the Critical Microstructural Factors, However, it can be Improved

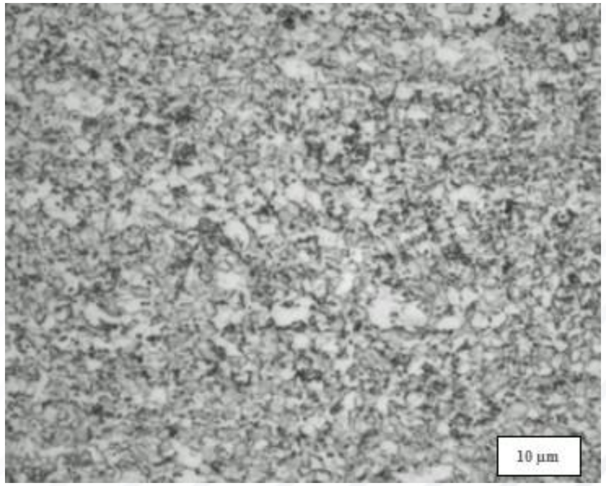
- Low Carbon (~0.10%)
- Refined Microstructure (ASTM Grain Size 12)
- Low Silicon (<0.6%)
- Low Sulfur (<30 ppm)
- Nb ~ 0.015% (or other microalloying strategies for refinement and ferrite strength)

DP 980T/550Y

HER~15%



MP 980T/700Y-LCE



HER~30%

GMW14400 – ADDITION OF IB GRADE & 1800PHS

An improved bending (IB) variant of PHS has been added to GMW14400 to improve the crash energy management of PHS components. Strategies to achieve the bending requirements are still under development, but one such strategy is discussed later in the presentation.

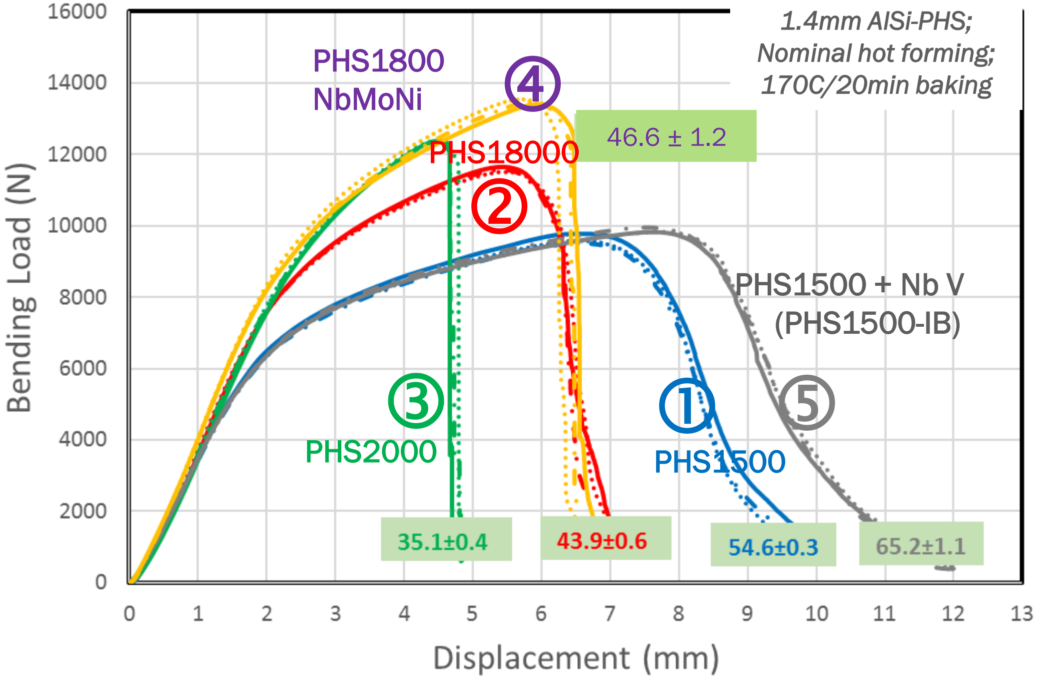
1800 PHS has been added to the specification, and this is currently not being considered for spot welded applications.

GMW14400M	C	Mn	Al	Si	P	S	Cr	Ti	B
Grade Type	Min % - Max. %	Min % - Max. %	Min. %	Max. %	Max. %	Max. %	Max. %	Min.% - Max. %	Min % - Max. %
HS1300T/950Y-MS	0.17 - 0.24	1.00 - 2.30	0.01	0.8	0.03	0.005	0.5	-	-
HS1300T/950Y-MS-IB	0.17 - 0.24	1.00 - 2.30	0.01	0.5	0.03	0.005	0.35	0.020 – 0.055	0.0005 – 0.004
HS1800T/1200Y-MS	0.28 - 0.37	0.30 - 2.30	0.01	0.8	0.03	0.005	0.5	0.010 – 0.060	0.0005 – 0.004

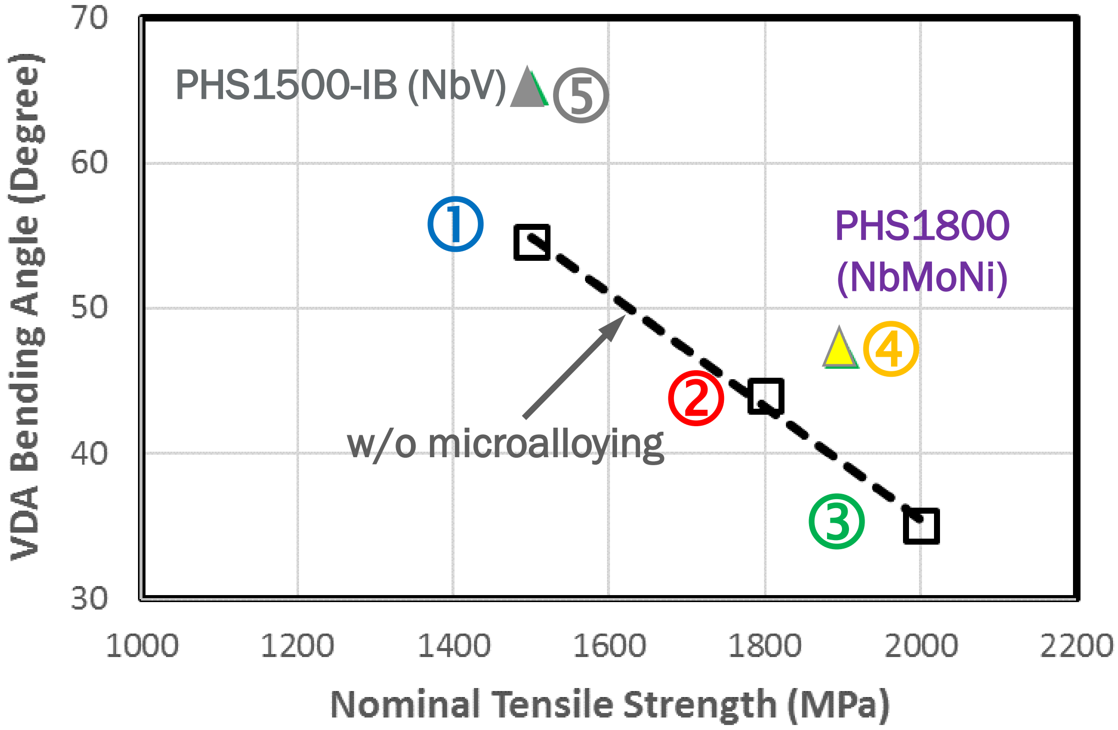
Note: Nitrogen (N) shall not exceed 60 ppm (N < 0.006 %)

PHS1500 IB AND THE ROLE OF MICROALLOYING

In a similar manner to cold stamped AHSS, a need exists to obtain better balance of strength and bendability in PHS for crash energy management. This may be accomplished by several means, and one such strategy involves the addition of microalloying elements to both refine the austenite grain structure and subsequent martensite and improve resistance to H-embrittlement through introduction of strong traps (such as TiC, NbC, VC etc.).

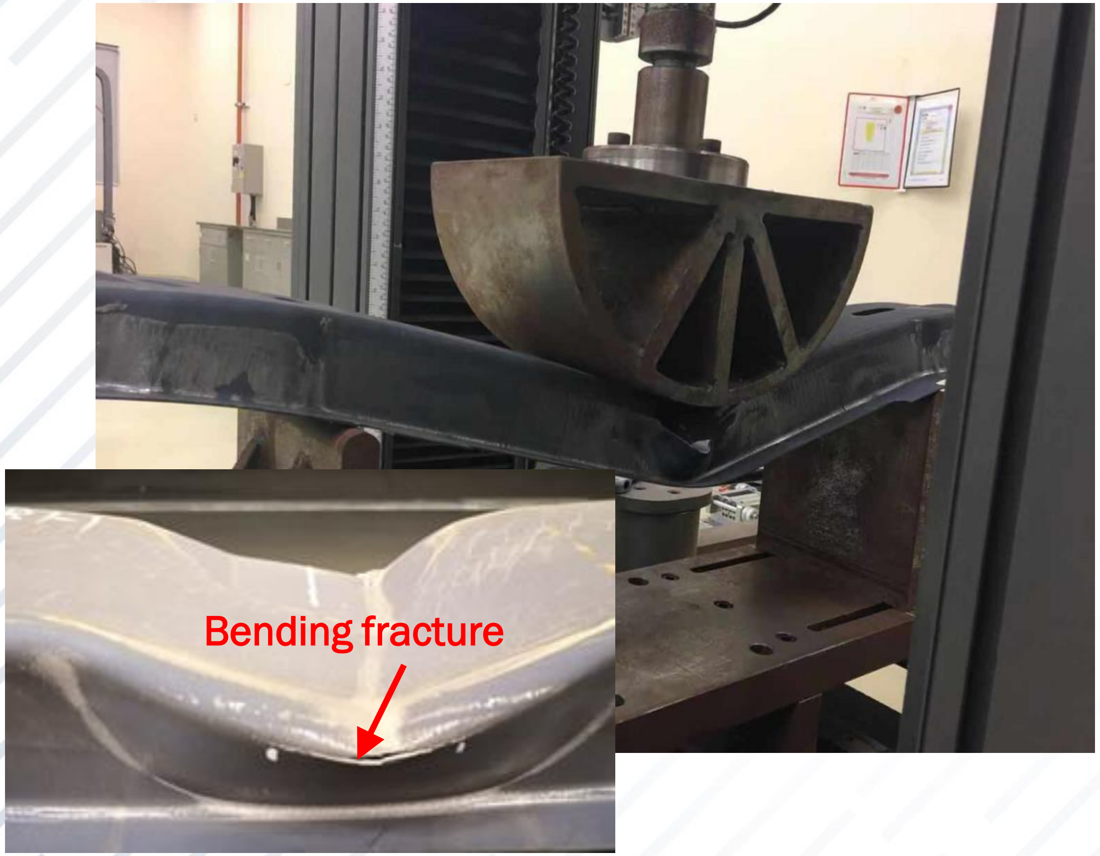


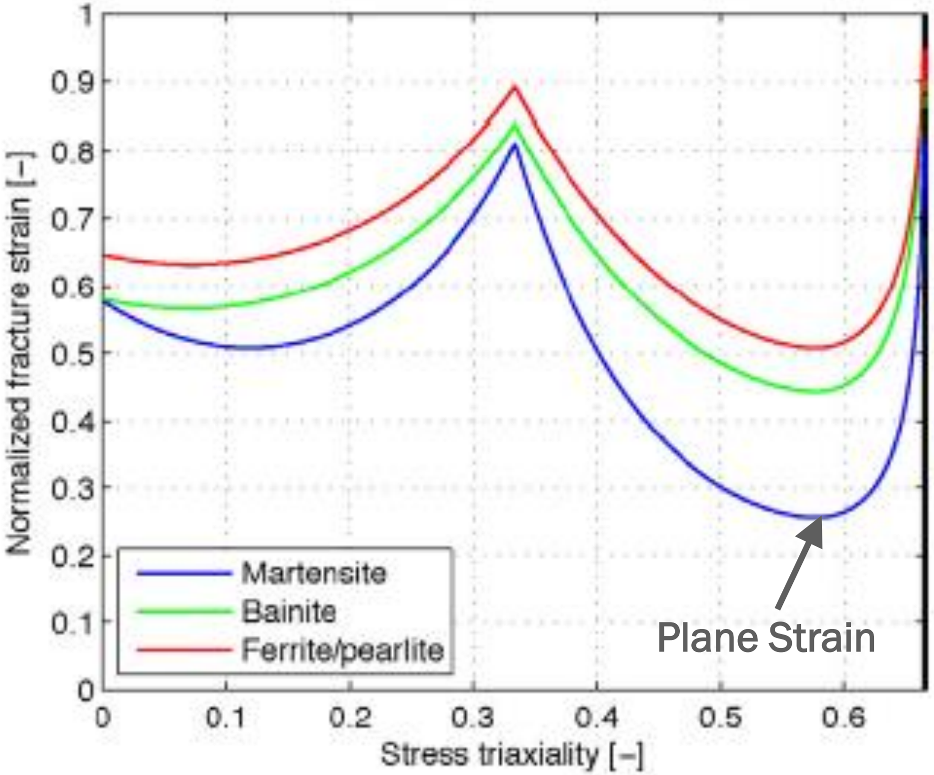
VDA Bending Curve of PHS with UTS from 1.5 – 2.0GPa



WHY IMPROVED BENDABILITY FOR PHS?

1) Body structure parts made of PHS deform and fracture close to plane strain bending mode during vehicle crash;
2) Fracture strain of sheet metal is the lowest at plane strain bending mode;





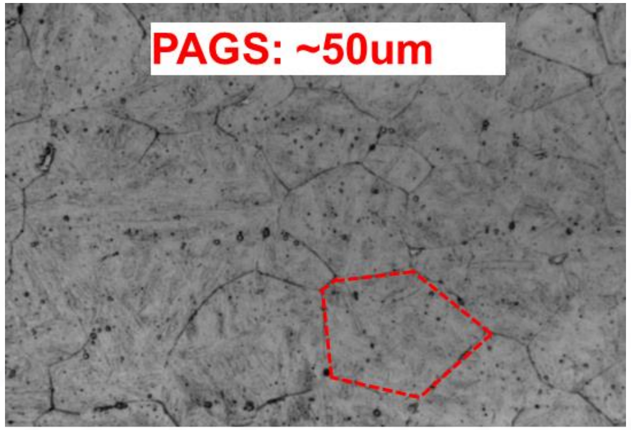
Ref: T.K. Eller, Int. J. Mat. Proc., 214 (2014), p1211.

WHY IMPROVED BENDABILITY FOR PHS

3) Tensile ductility of PHS DOES NOT correlate to its bendability or fracture limit;
4) Bendability is a good indicator of fracture resistance.

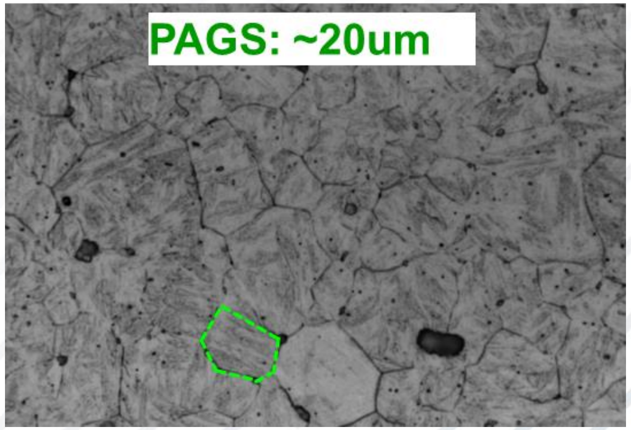
Over-baked door beam

YS: 1004 ± 29 MPa
UTS: 1483 ± 6 MPa
TEL: 6.6 ± 0.7%

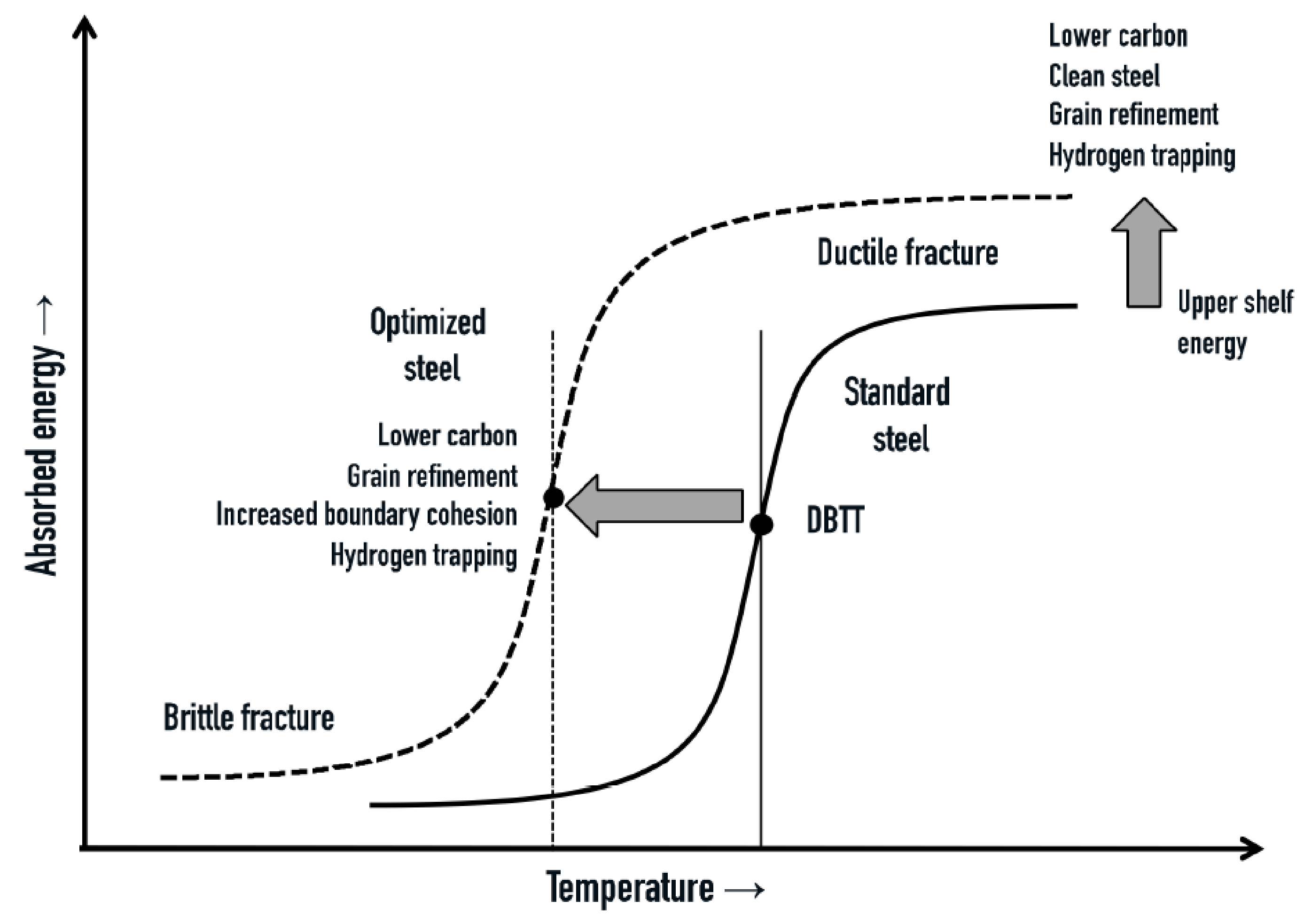


Properly processed door beam

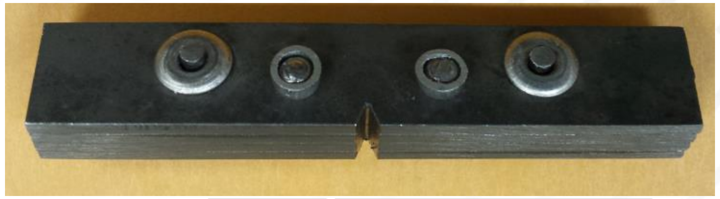
YS: 1066 ± 21 MPa
UTS: 1519 ± 19 MPa
TEL: 7.4 ± 0.4%

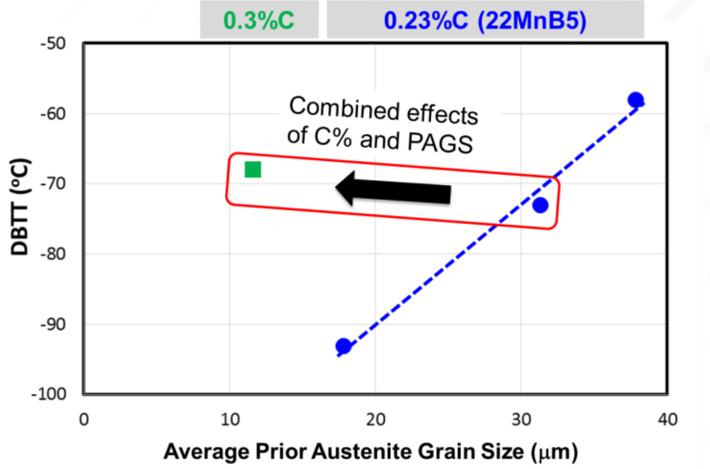


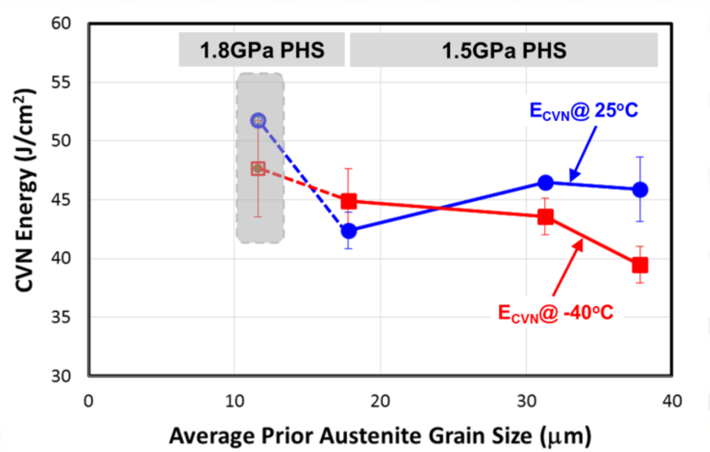
GRAIN REFINEMENT VIA MICROALLOYING



Ref: *H. Mohrbacher, Metals, 8 (2018), p234.*



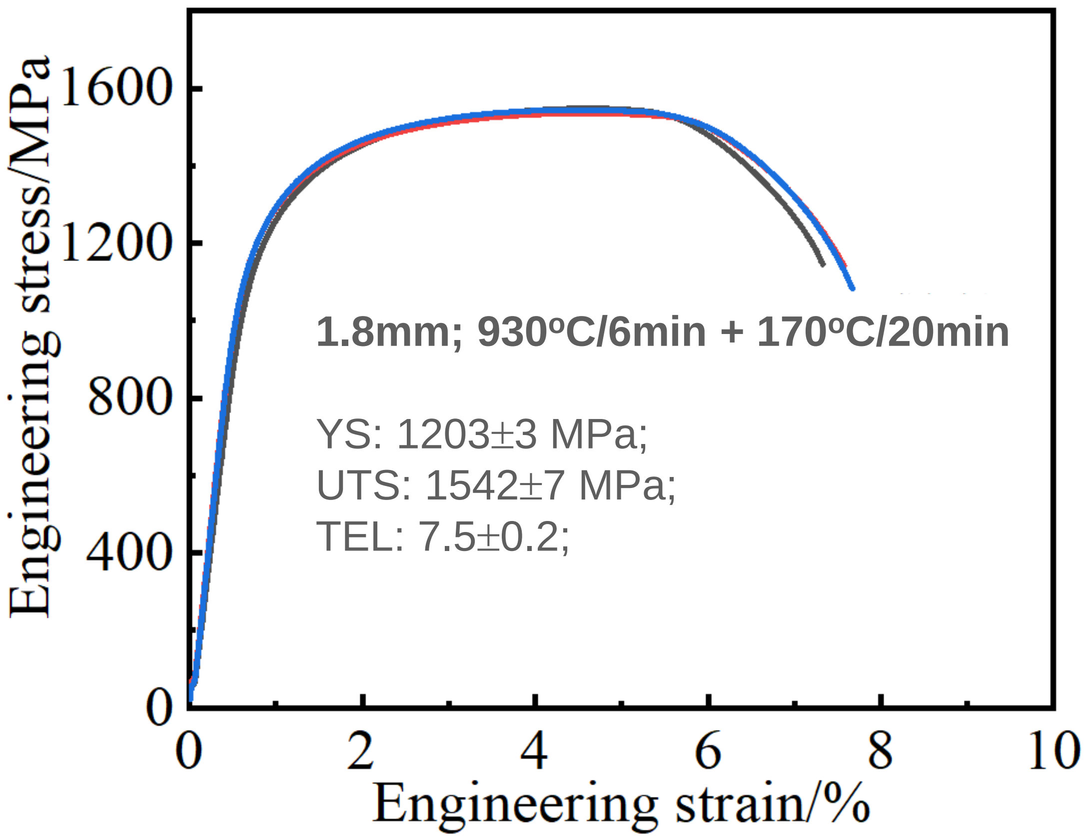




Ref: *J. Wang et al, SAE Int. J. Mater. Manf, 9(2): 2016.*

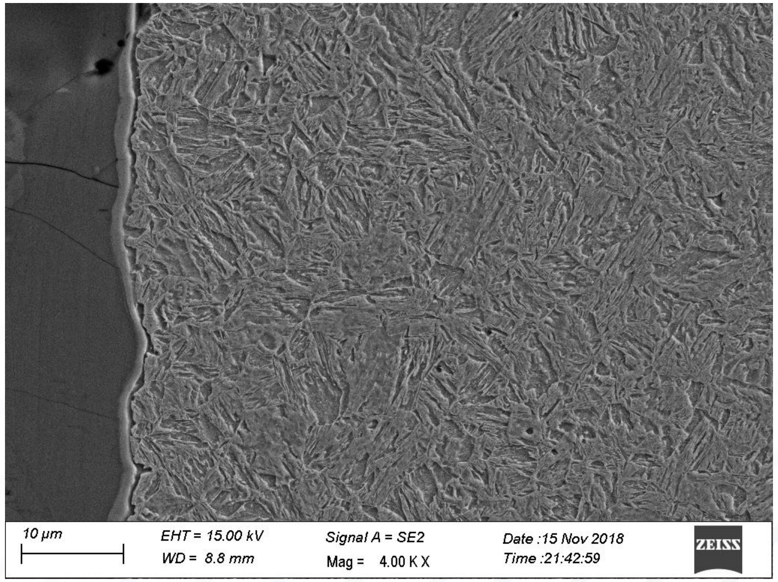
NB+V MICROALLOYED PHS (PHS1500-IB)

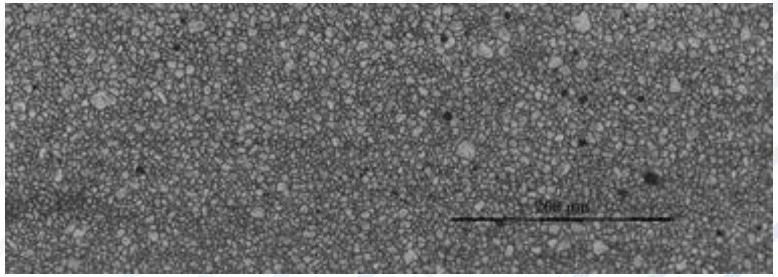
Coil#	AlSi	C	Si	Mn	P	S	Ti	Cr	V	Nb	Al	B	Others
D189026120	75G75G	0.23	0.24	1.21	0.0171	0.0032	0.042	0.19	**0.04**	**0.04**	0.044	0.0027	0.046



1.8mm; 930°C/6min + 170°C/20min

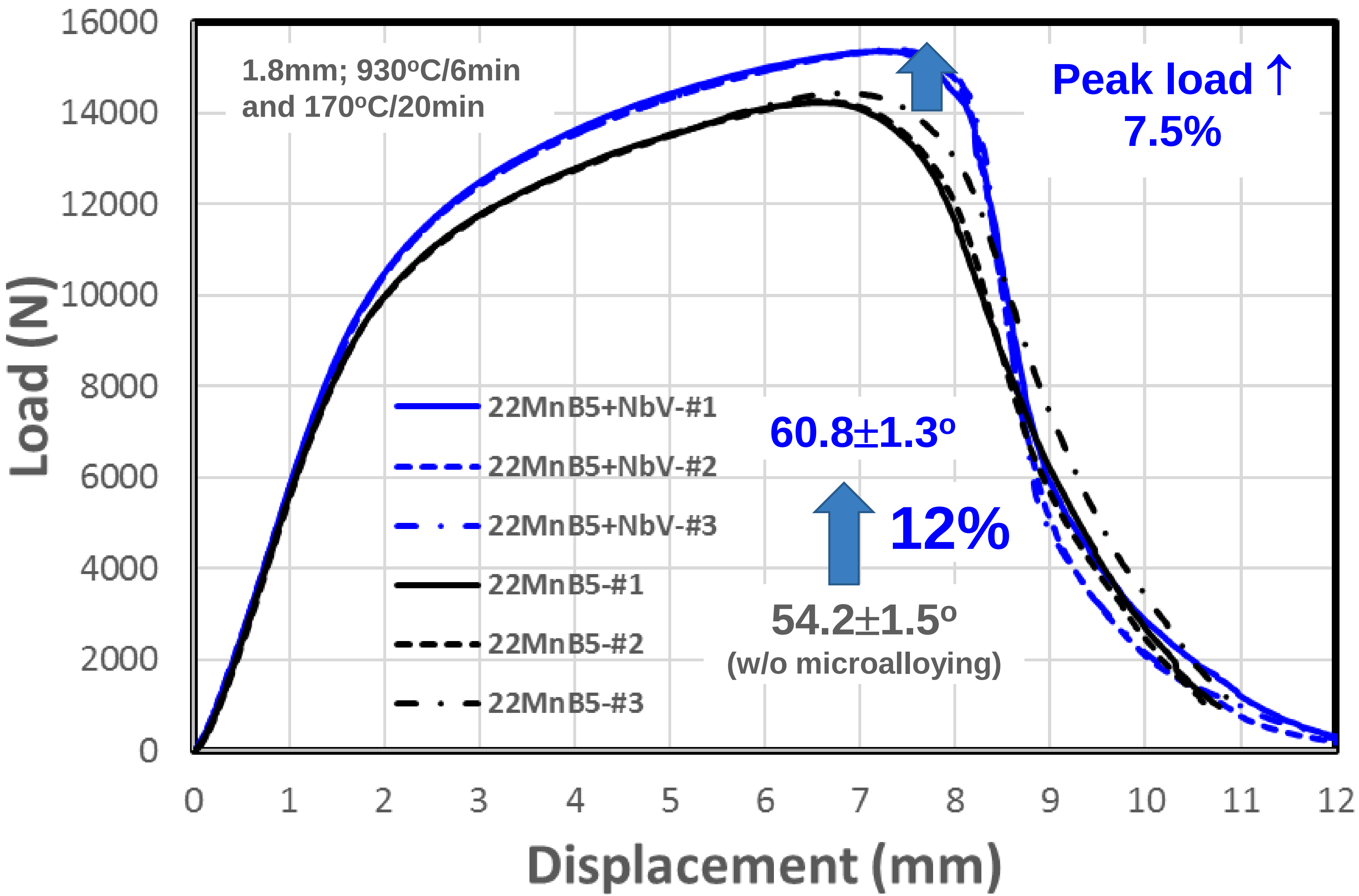
YS: 1203±3 MPa;
UTS: 1542±7 MPa;
TEL: 7.5±0.2;





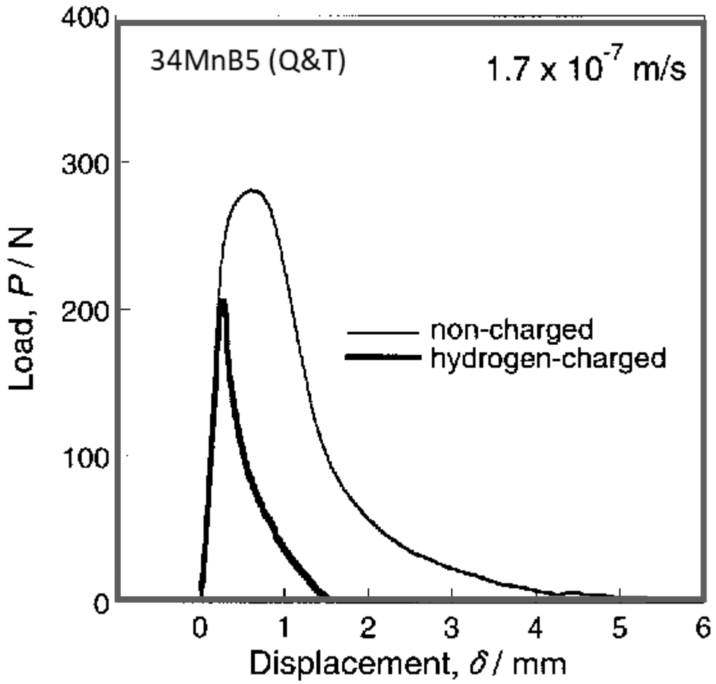
NB+V MICROALLOYED PHS – BENDABILITY

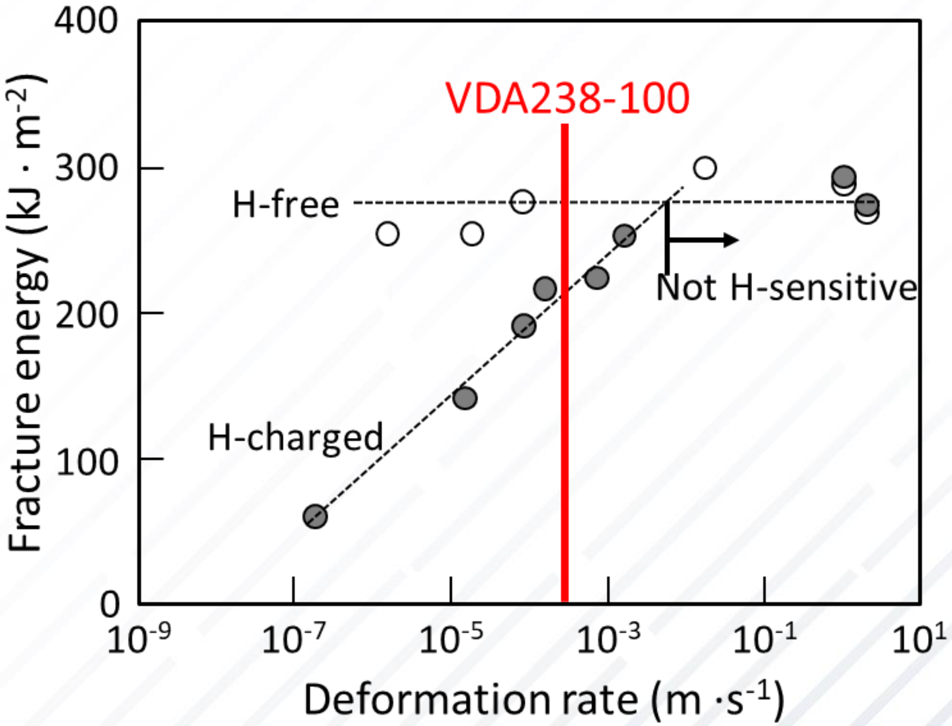
(VDA 238-100 Bend Test)



DELAYED FRACTURE RESISTANCE

The existence of hydrogen embrittlement is strongly affected by strain rate. Increasing strain rate reduces hydrogen embrittlement as shown by an increase in fracture energy of hydrogen charged low carbon martensitic steels. At higher strain rates, hydrogen does not have enough time to diffuse on prior austenite grain boundaries.

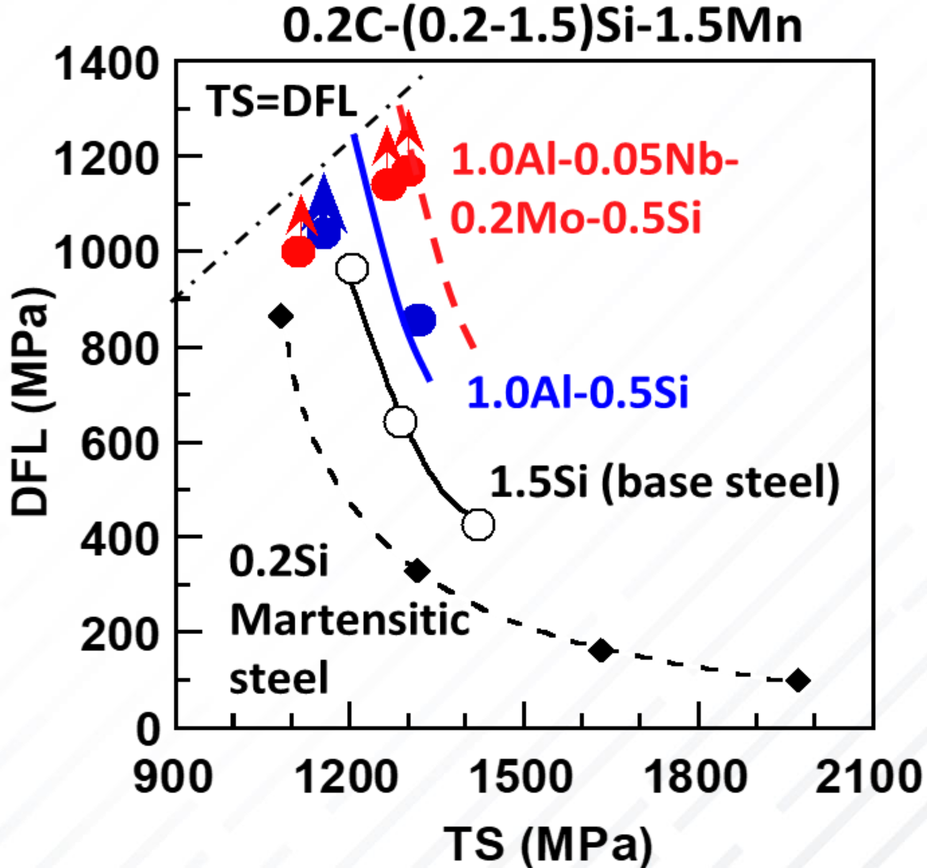




Ref.: Shin-ichi KOMAZAZKI, Shingo WATANABE and Toshihei MISAWA
ISIJ International, Vol. 43 (2003), No. 11, pp. 1851–1857

DELAYED FRACTURE RESISTANCE

The presence of strong traps within the microstructure in the form of alloy carbides, e.g., NbC, can act to the reduce the total level of diffusible hydrogen in AHSS prior to paint baking. This, in turn, will lessen the propensity for delayed fracture in PHS (and cold stamping AHSS) components during transportation and fabrication prior to paint baking (in which diffusible hydrogen is effused and the risk is lessened).



CONCLUSIONS

- Motivation remains for continuous improvement of conventional AHSS, e.g., PHS and multiphase steels, for body structure applications.
- To capture the required performance attributes for these improved or "optimized" grades, specifications have been developed and recently published, e.g., GMW3399 for MP780 and GMW14400 for PHS1500-IB.
- An enabling strategy for the achievement of newly specified multiphase steel properties is through use of microalloying additions, notably Nb, for structural refinement, promotion of structural uniformity, and strengthening of ferrite in reduced carbon chemistries.
- Microalloying strategies also show great potential in PHS, wherein structural refinement and carbide precipitation improve bendability and lessen the propensity for hydrogen-induced delayed fracture.

COMMENTS & QUESTIONS

THANK YOU!

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