Improvement of Bendability and Resistance to Hydrogen Embrittlement in Press Hardening Steels

Dr. Rafael Mesquita
CBMM

Dr. Hardy Mohrbacher
NiobelCon

Outline

- Press Hardening Steels: Advantages and Growth
- Challenges in Press Hardening Steels: Grain Size Control and Hydrogen Embrittlement
- Niobium Effect in Grain Size Stability and Decrease in Hydrogen Damage
- Conclusions
- Outlook

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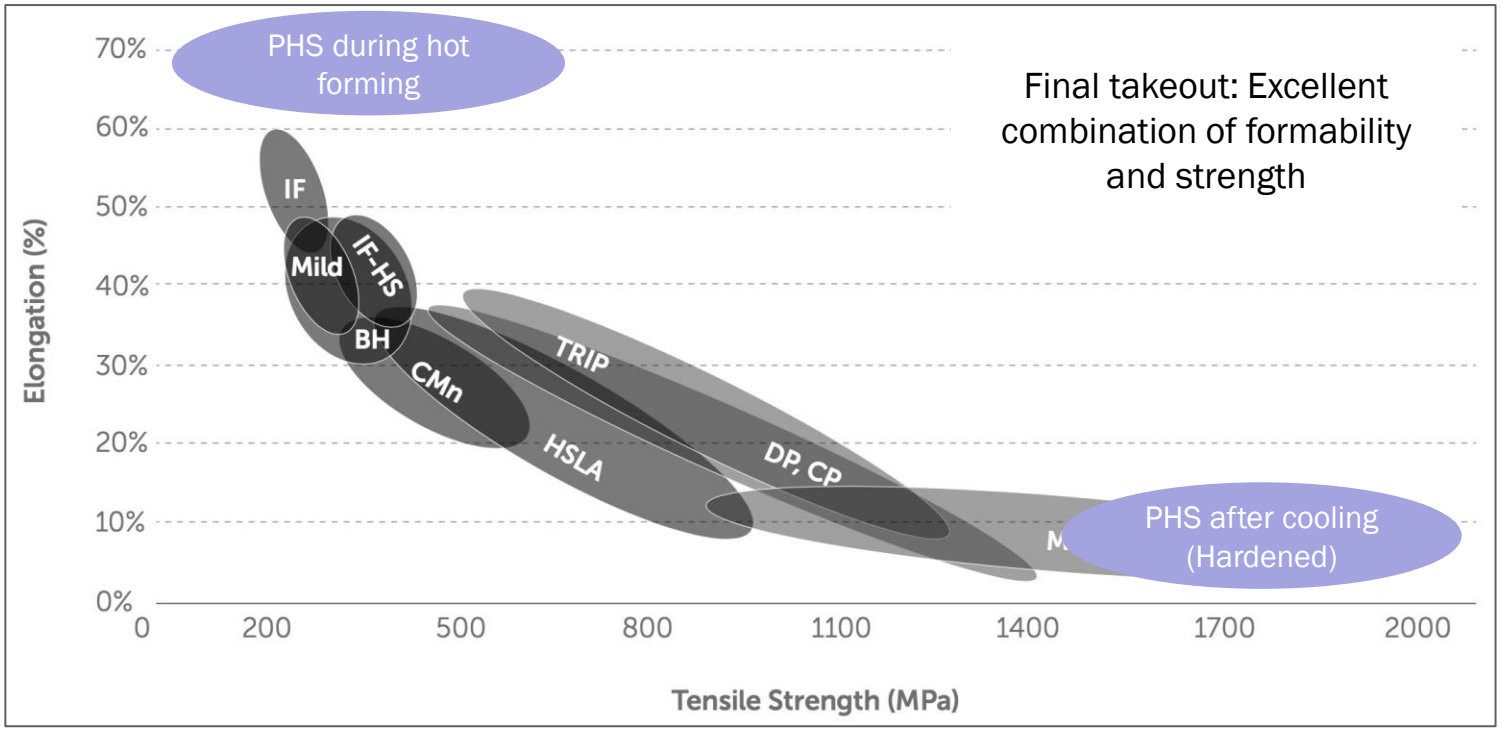
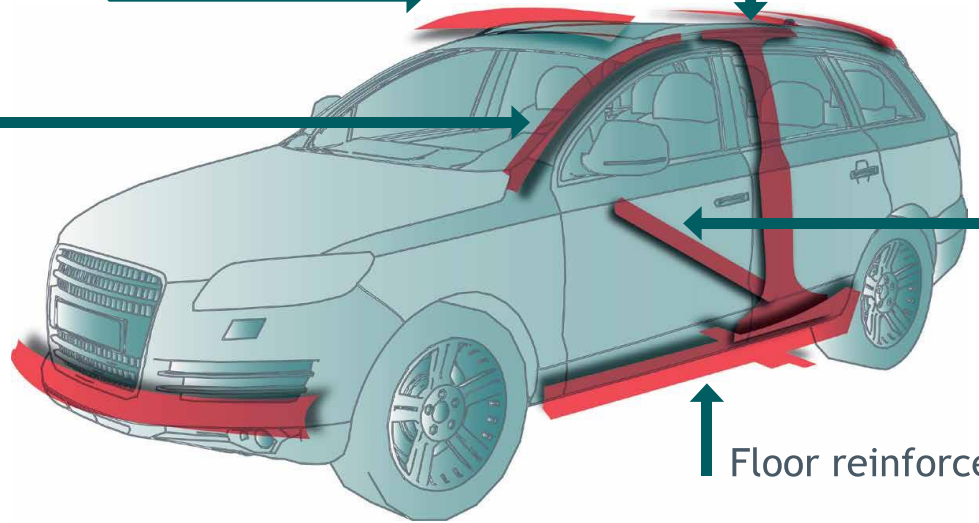
Background Press Hardening Steels

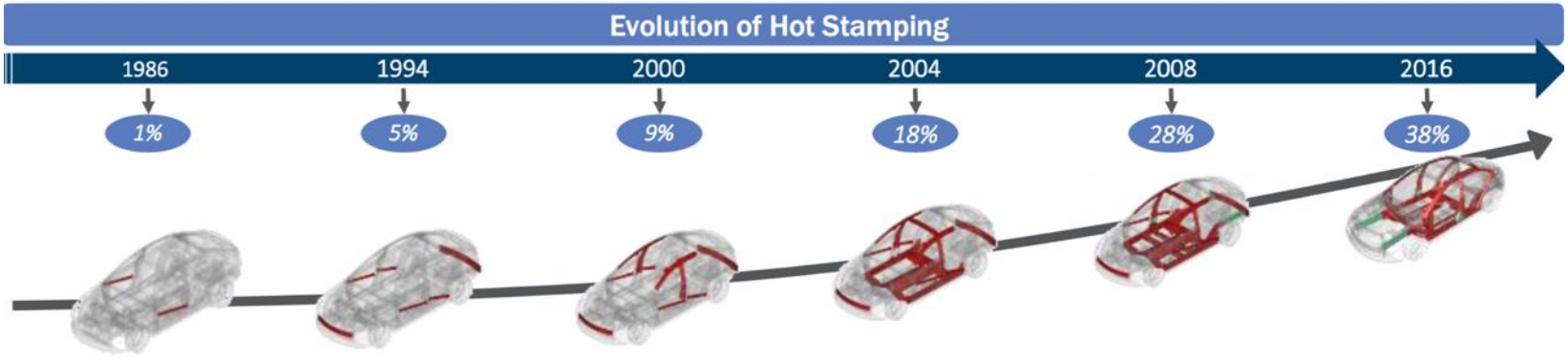


Source: *adapted from WorldAutoSteel*

Typical Applications



Growth Press Hardening Steel



Gestamp's historical performance

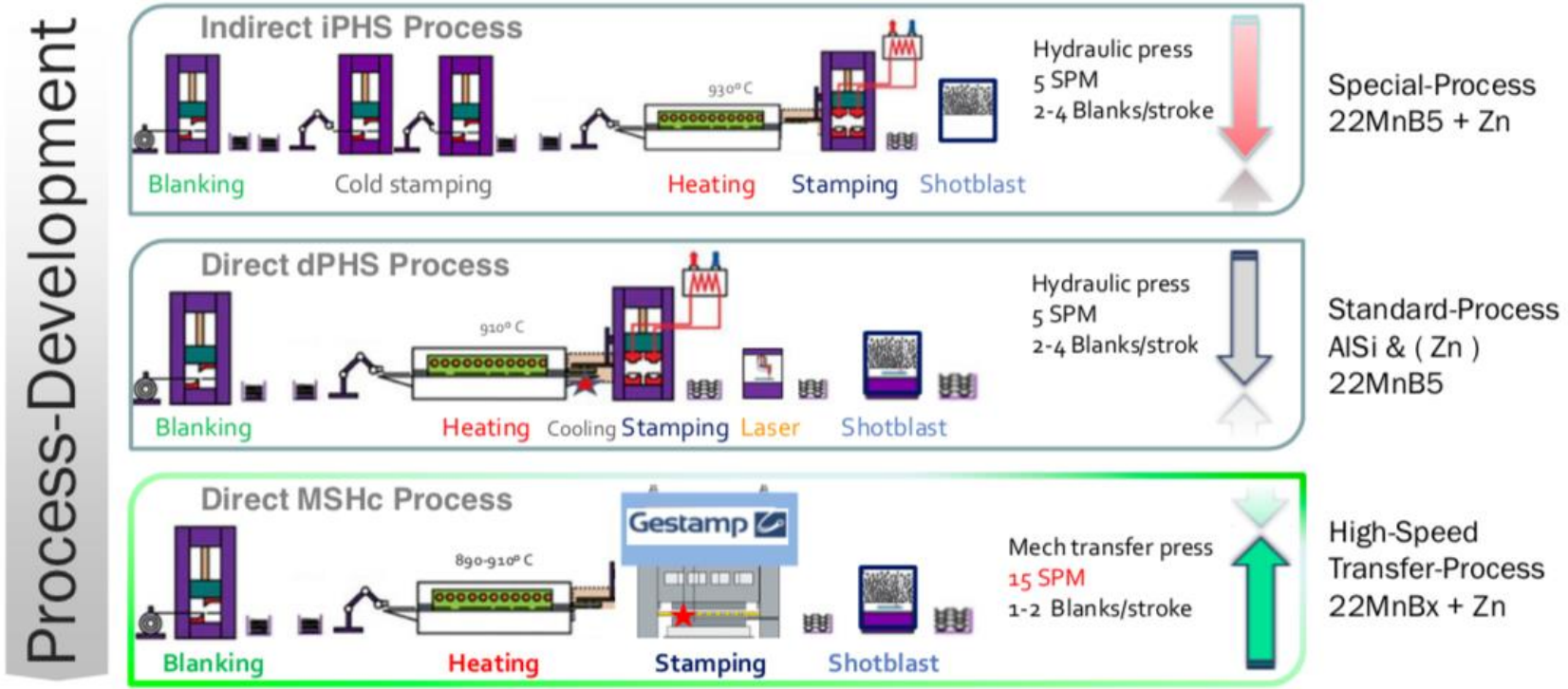
1) Gestamp Hardtech > 30 years expierence
2) Quadrupled # Lines since 2007
3) Co-Development Partner BIW content 1% -38%
4) Driving the tailored material properties

Gestamp 'growing' forward

1) 1st to break 10 s cycle time
2) 1st to in-die soft zone
3) **1st to Multistep & eliminate laser**
4) **1st to Hot Stamping cost reduction**

Source: Paul Belanger , New Zn Multistep Hot Stamping Innovation , GDIS2017

Growth Press Hardening Steel



Note: inclusion of a furnace in the auto part production, which affect dramatically the microstructure and properties.

Source: Paul Belanger , New Zn Multistep Hot Stamping Innovation , GDIS2017

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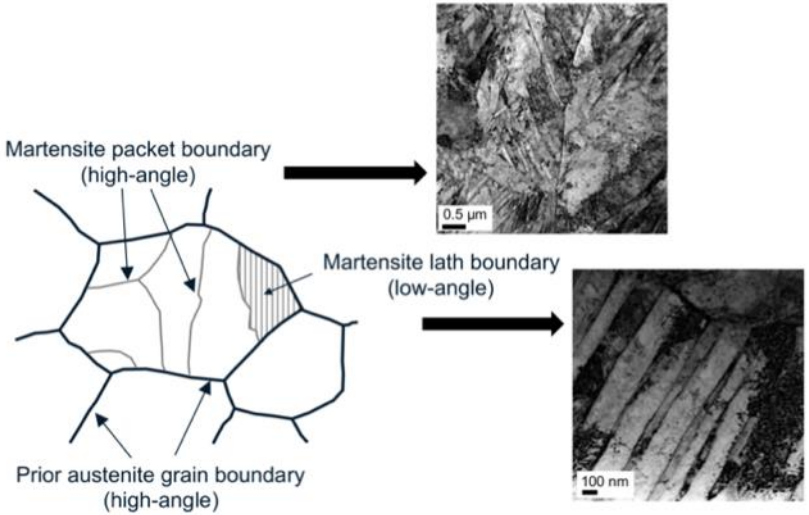
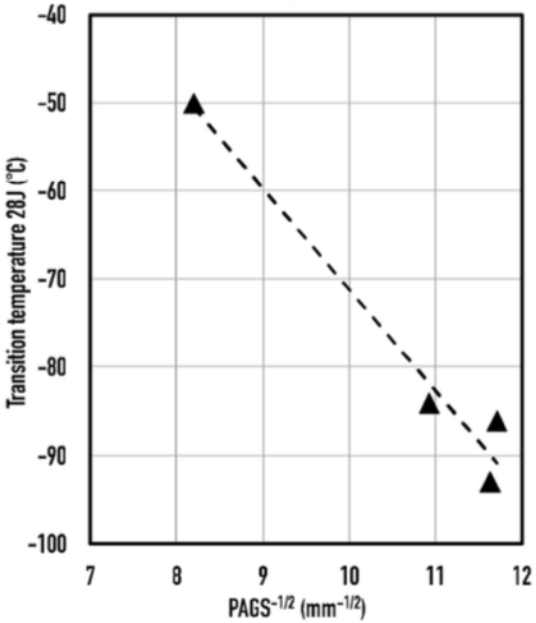
PHS Challenge 1: Prior Austenite Grain Size Control



Important to Consider: Complex Grain Structure

Source: Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;



Finer Grains → Lower Transition Temperature

(0.16% C-1.1% Mn-0.5% Cr-0.5% Ni-Mo)

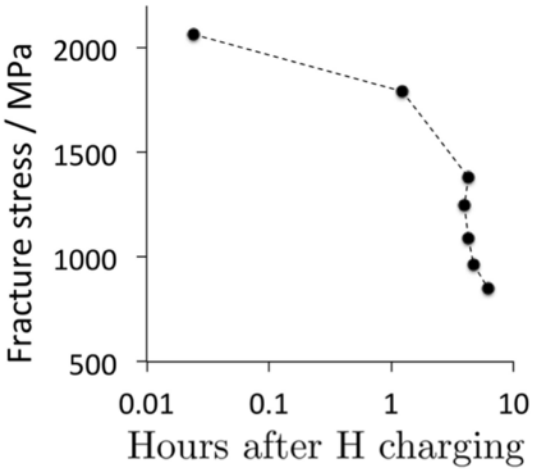
$$\sigma_f = K_f d_{eff}^{-1/2}$$

Finer Grains → Higher Fracture Strength

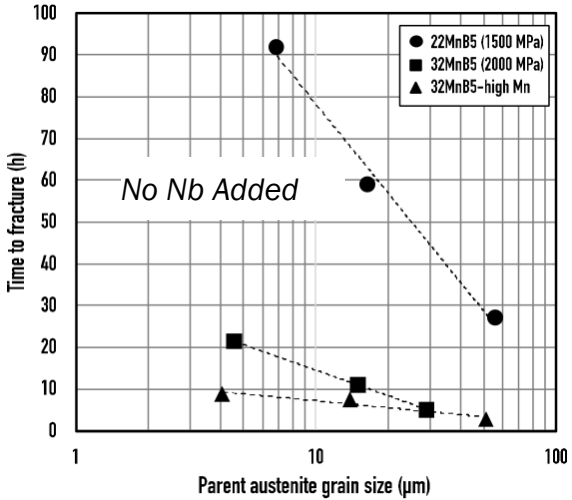
Source: Naylor, J.P.; Blondeau, B. The Respective Roles of the Packet Size and the Lath Width on Toughness. Metall. Trans. 1976, 7, 891–894.

PHS Challenge 2: Hydrogen Embrittlement

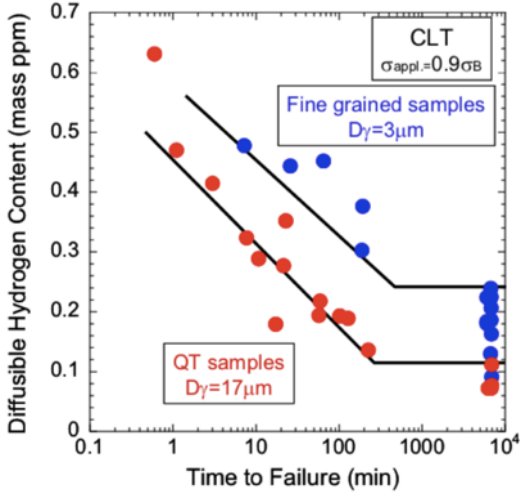
Hydrogen: extremely harmful to fracture properties



0.39C-0.76Mn- 0.28Si-1.8Ni-0.75Cr-0.24Mo wt%, with a 0.2% proof strength of 1516 MPa. Source: H. K. D. H. Bhadeshia, *ISIJ International* 56 (2016) 24-36.



Source: Senuma, T.; Takemoto, Y. Influence of Nb Content on Delayed Fracture and Crash Relevant Properties of 2000 MPa class hot stamping steel sheets. In Proc. Int. Conf. Steels in Cars and Trucks, Amsterdam, The Netherlands, 2017.



Effect of Grain Size and H-embrittlement: Source: Y. Kimura,, S.Takagi, T. Hara, S. Terasaki, K. Tsuzaki, Journal de Physique IV-Proceedings France 112, (2003), p.403.

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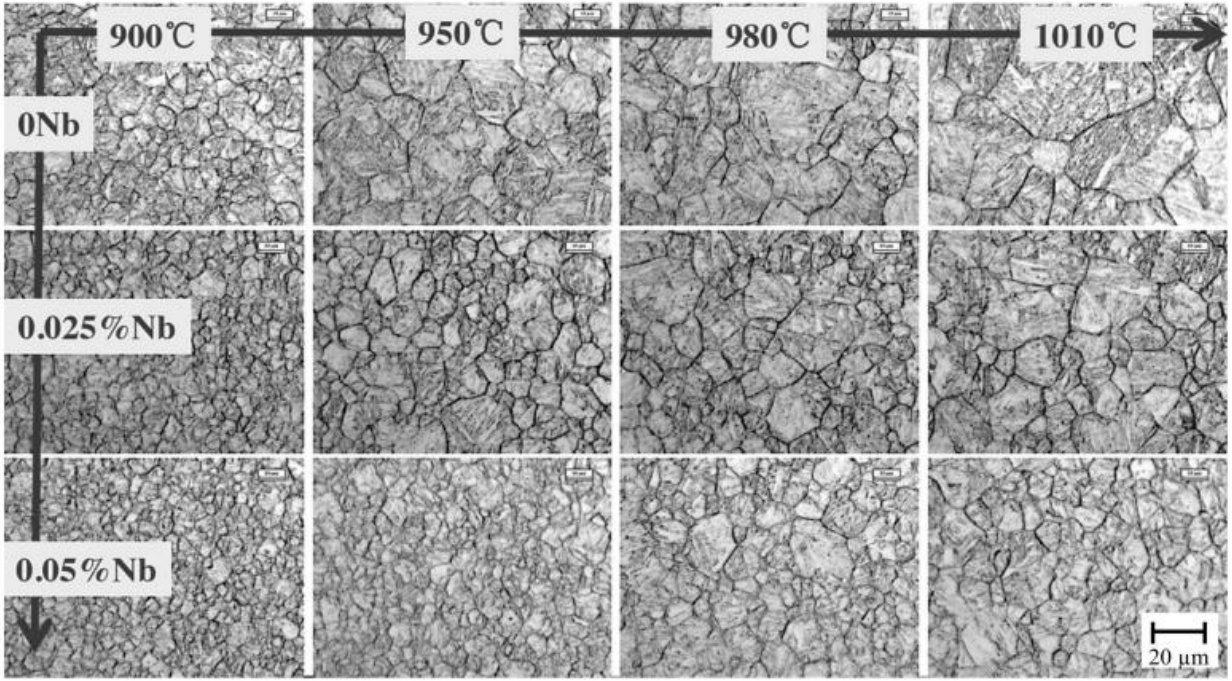
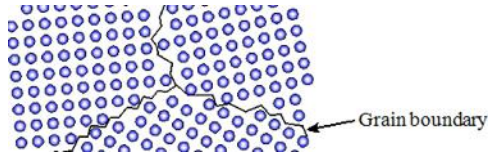
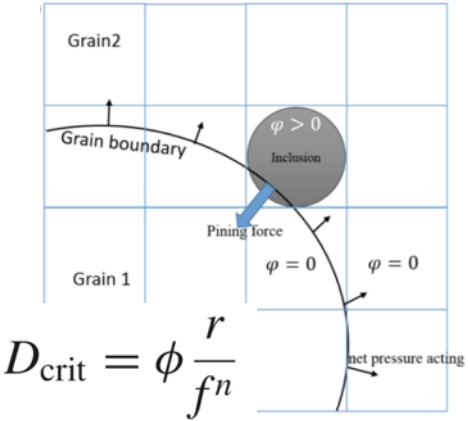
Niobium on the Prior Austenite Grain Stability



Source: Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;



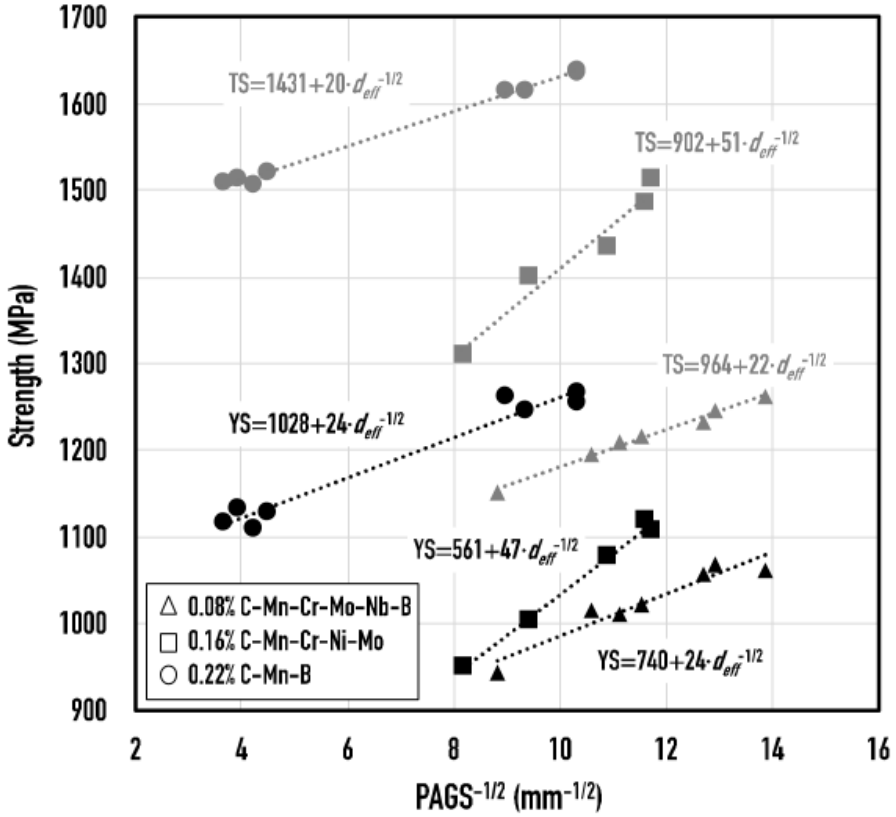


$$D_{\text{crit}} = \phi \frac{r}{f^n}$$

Dcrit: critical austenite diameter.
r = particle radius.f = fraction

Source: Crystals 2017, 7(10), 308

Grain Size and Strength

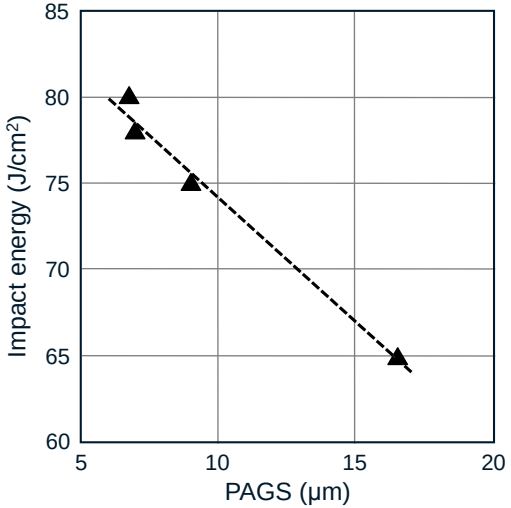


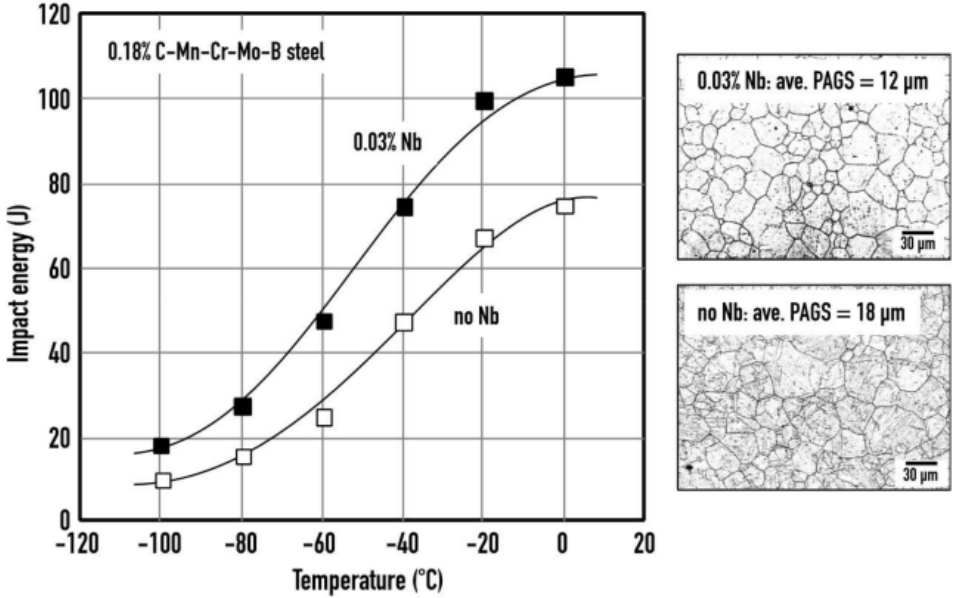
Hall – Petch also applies when considering the prior-austenite grain size effect on strength

Source: Hall–Petch type plot indicating the effect of parent austenite grain size (pancake thickness for direct quenched steels) on yield (black symbol) and tensile (grey symbol) strength. Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;

Grain Size and Toughness

Grain Refinement Effect: increase in toughness and decrease in transition temperature.

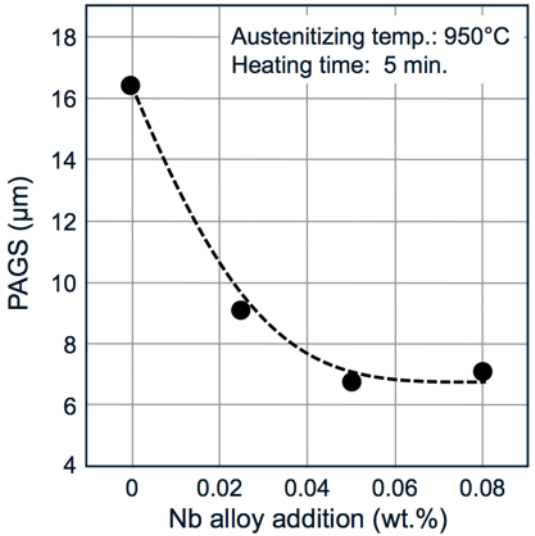


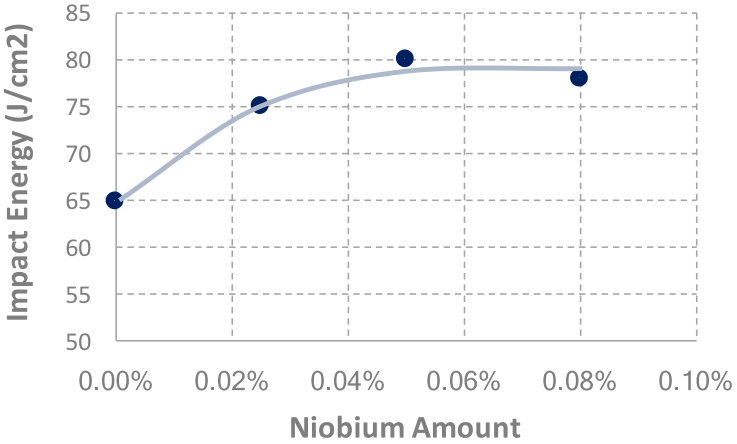


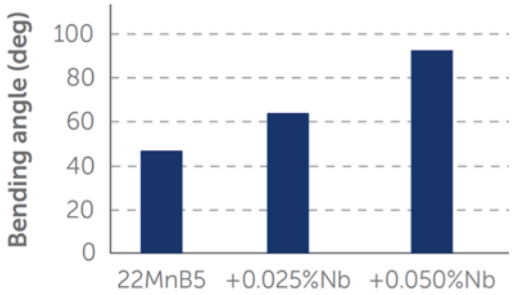
Source: Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;

Grain Size and Toughness

Niobium Effect: strong up to 0.04% Nb: increase in toughness and bending angle



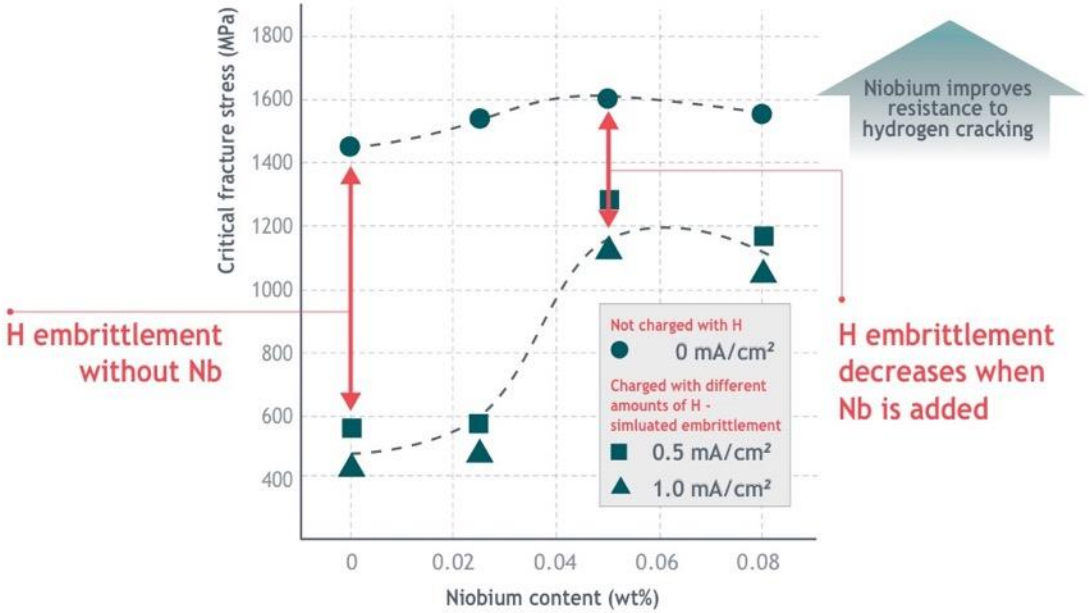


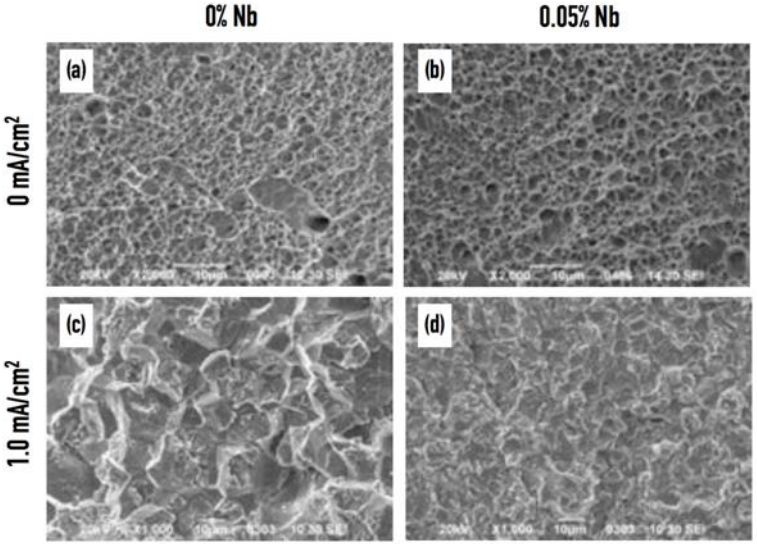


Source: *J. Bian, W. Li, H. Mohrbacher, L. Hongzhou; W. Wenjun, Advanced Materials Research, 2014, Vol. 1063, p. 7*

Niobium on the Decrease of Hydrogen Embrittlement

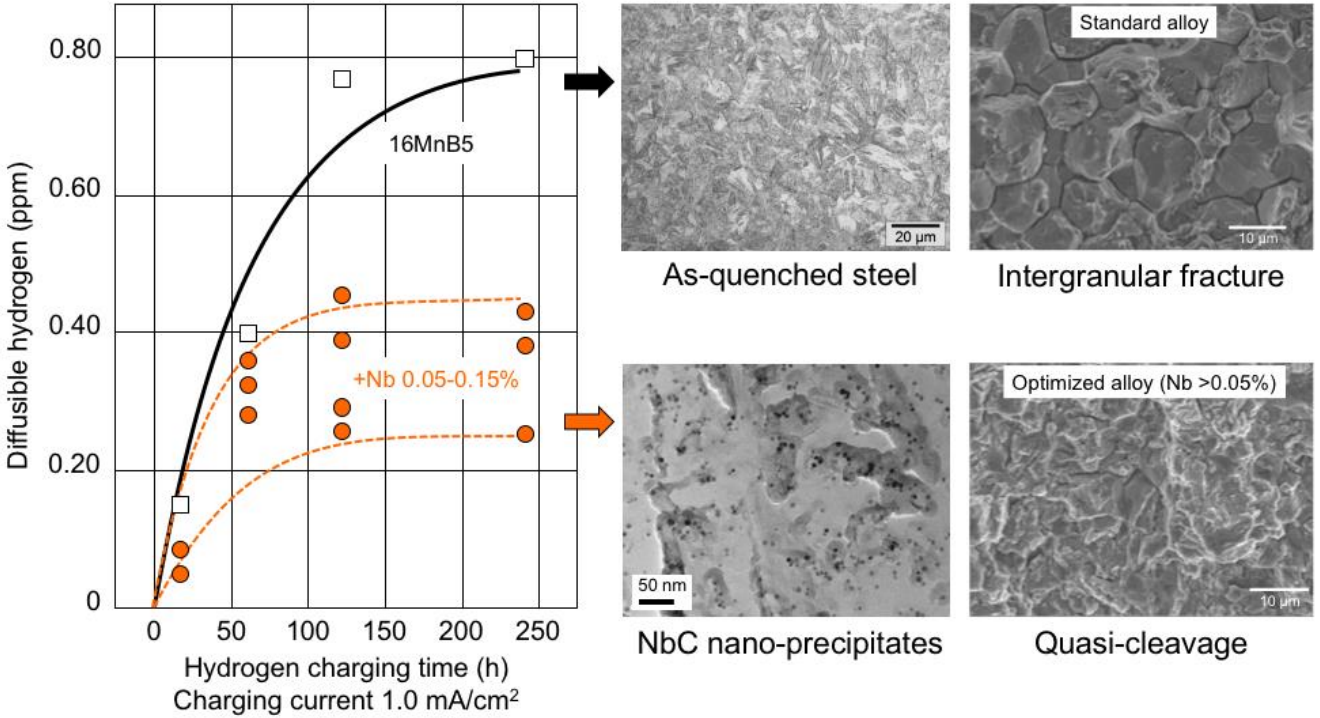
When Nb is added: the sensitivity to H embrittlement decreases: difference between charged and not charged is almost 3 times smaller when Nb is added





Source: adapted from: J. Bian, W. Li, H. Mohrbacher, L. Hongzhou; W. Wenjun, Advanced Materials Research, 2014, Vol. 1063, p. 7

Explanation for Lower H sensitivity: H Trapping by Nano NbCN

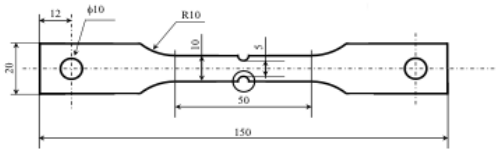


Diffusion of H is the first step for combination of H atoms and embrittlement. Decrease of H diffusion, decreases the H embrittlement damage

Source: Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;

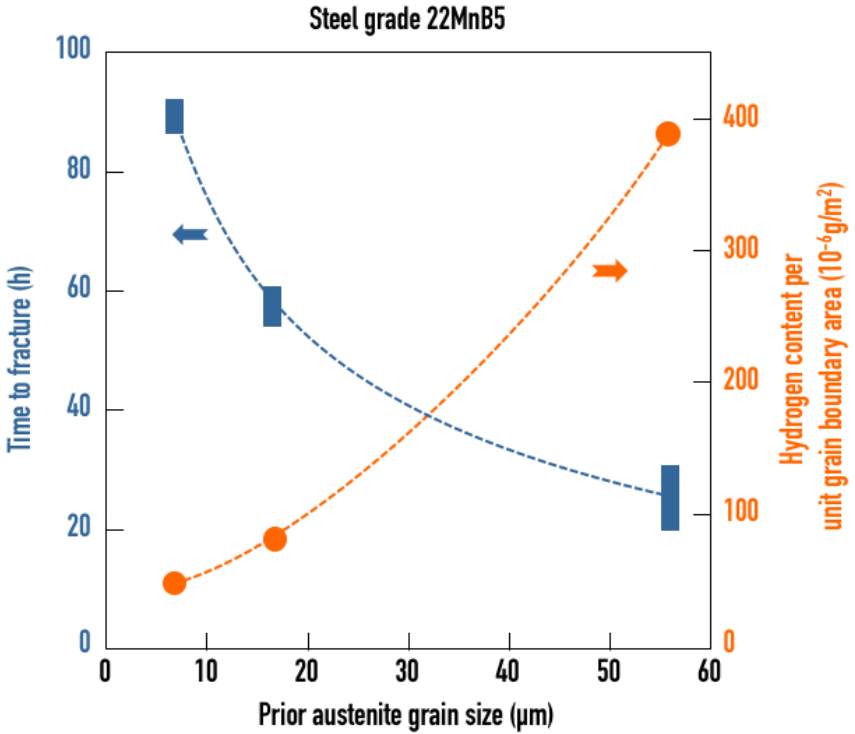
Explanation for Lower H sensitivity: Effect of Grain Refining

Test set-up



The delayed fracture tests in 20% ammonium thiocyanate solution at notch stress of 1000 MPa

Courtesy: Prof. T. Senuma, Okayama University



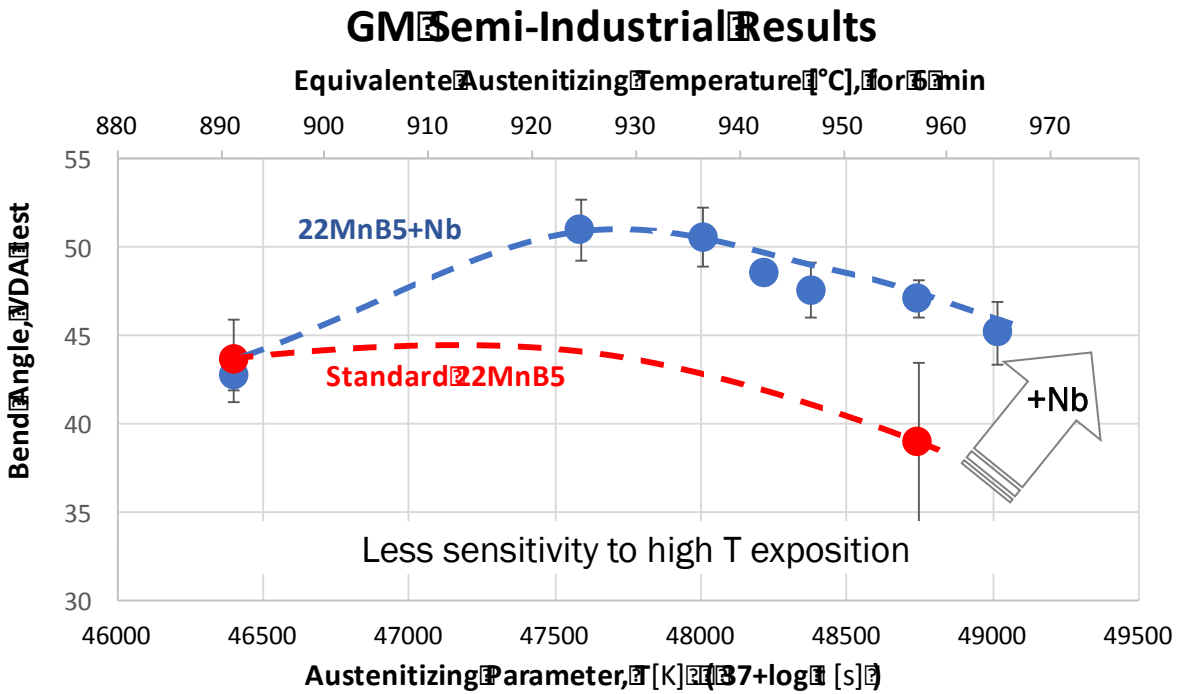
Finer prior austenite grains also naturally reduce the H embrittlement.

Source: Hardy Mohrbacher, *Review - Property Optimization in As-Quenched Martensitic Steel by Molybdenum and Niobium Alloying*, Metals, N. 8, Vol. 234, 2018;

Case Study in North America

Conditions tested: semi industrial and industrial conditions

Conditions	Aust. Parameter T[K] . (37+log t [s])
900C 6min	46400
900C 5min	46307
930C 6min	47586
950C 3min	48009
950C 6min	48377
950C 20 min	49017
950C 12min	48746
930C 20 min	48215



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Conclusions

- The press hardening process brings several advantages in body-in-white applications, due a unique combination of high tensile strength (important for weight savings) and high formability (important for productivity and design). However, challenges in reliability exist, due to the tendency to low toughness and hydrogen embrittlement.
- Niobium additions between 0.04 and 0.06% improve the grain size control and as a consequence toughness and bending strength. Fine carbides also reduce hydrogen embrittlement, due to microstructural trapping effects (interface and atomic bounding effects).
- As a final result, micro-additons of Niobium are becoming popular in 1500MPa in 22MnB5 or similar press hardening steels. In >1800MPa PHS, most grades contain Nb for improvement of performance and reliability.

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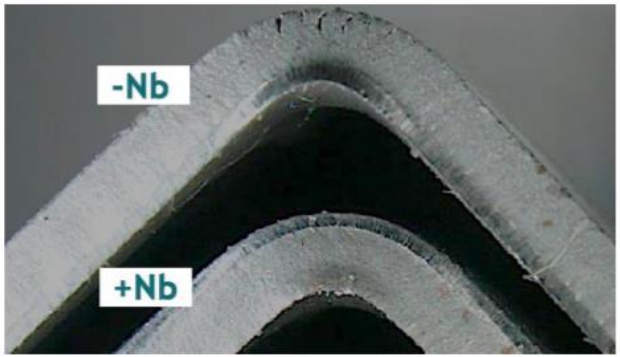
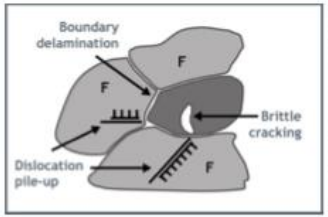
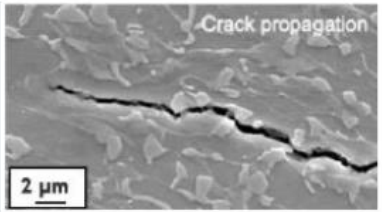
Niobium in Dual Phase Steels

Nb: Better Formability in DP



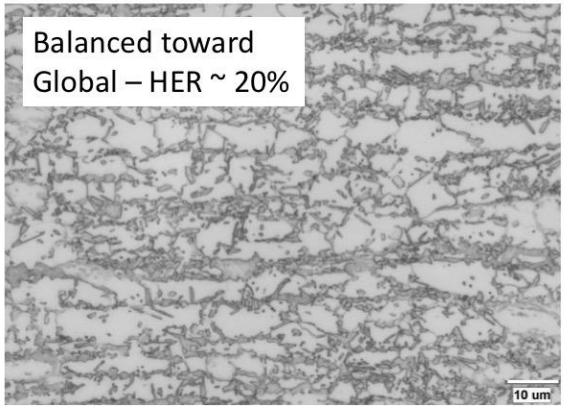




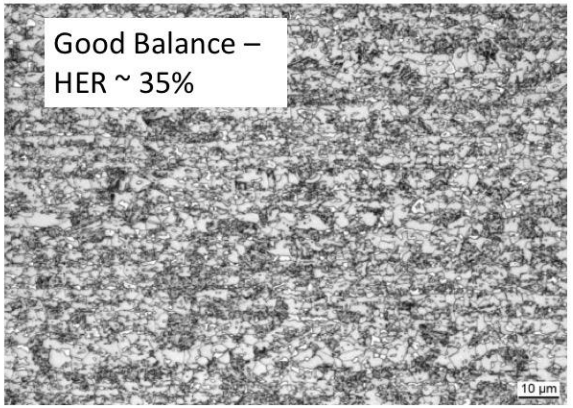
Source: Reference: H. Mohrbacher. Intl. Symp. on New Developments in Advanced High-Strength Sheet Steels, AIST, 2013, p. 319-329

Concept tested by GM USA

The balance of **global formability** and **local formability** is microstructurally determined.



Traditional GI DP780



Grain Refined Concept on GI DP780

Grain Refinement: Improving formability in DP Steels by refining martensite islands.

Thank You for Your Attention!

Dr. Rafael Mesquita

CBMM

412.418.1406

mesquita@rafconsult.com

Presentations will be available May 21 at www.autosteel.org