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

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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

Final takeout: Excellent combination of formability and strength

Source: adapted from WorldAutoSteel
Typical Applications

- Roof reinforcements
- Windscreen reinforcements
- Bumper
- B-pillar reinforcements
- Door reinforcements
- Floor reinforcements
Growth Press Hardening Steel

Evolution of Hot Stamping

1% 5% 9% 18% 28% 38%

Gestamp’s historical performance
1) Gestamp Hardtech > 30 years experience
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

Finer Grains $\rightarrow$ Lower Transition Temperature

$(0.16\% \text{ C}-1.1\% \text{ Mn}-0.5\% \text{ Cr}-0.5\% \text{ Ni-Mo})$

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


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

Finer Grains $\rightarrow$ Higher Fracture Strength
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.


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Niobium on the Prior Austenite Grain Stability

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

$D_{\text{crit}}$: critical austenite diameter.
$r$: particle radius.
$f$: fraction.

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

Source: Crystals 2017, 7(10), 308
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;
Niobium Effect: strong up to 0.04% Nb: increase in toughness and bending angle

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.

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

Finer prior austenite grains also naturally reduce the H embrittlement.

Case Study in North America

Conditions tested: semi industrial and industrial conditions

<table>
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<tr>
<th>Conditions</th>
<th>Aust. Parameter T[K] \cdot (37+\log t ,[s])</th>
</tr>
</thead>
<tbody>
<tr>
<td>900C 6min</td>
<td>46400</td>
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<td>950C 12min</td>
<td>48746</td>
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<tr>
<td>930C 20 min</td>
<td>48215</td>
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</tbody>
</table>

**GM Semi-Industrial Results**

Equivalente Austenitizing Temperature \([\text{°C}], \text{for 6 min}\)

![Graph showing the comparison between Standard 22MnB5 and 22MnB5+Nb in terms of bend angle, VDA test, with less sensitivity to high T exposition.]
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• 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**

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

**Concept tested by GM USA**

- Balanced toward Global – HER ~ 20%
- Good Balance – HER ~ 35%

**Grain Refinement: Improving formability in DP Steels by refining martensite islands.**
Thank You for Your Attention!

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