Welcome to the New Generation of Press Hardened Steels Webinar

1.7-2.0 GPA PHS WITH ENHANCED BENDABILITY

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New Generation of Press Hardened Steels

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New Generation of Press Hardened Steels

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Xiaochuan Xiong, Shu Zhou, Hongliang Yi (EasyForming Technology)
Outline

• Introduction – Background and Motivation for Enhanced Bendability
• 1.7 GPa Press Hardening Steel without AlSi-coating
  o Alloy Development
  o Property and Performance
• 2.0 GPa Press Hardening Steel with Slim AlSi-coating
  o Alloy Development
  o Property and Performance
• Status of Commercialization
• Summary
Background – Press Hardening Steels

**Source: Gestamp Presentation**

**EVOLUTION OF PHS IN TERMS OF TECHNOLOGY AND MATERIAL**

- **1st Gen**
- **2nd Gen**
- **3rd Gen**
- **4th Gen**

50% of BIW possible

**Market**

**Technology**

- **1983 Saab Door Beam**
- **AlSi-Coated PHS (~2000)**
- **Tailored Properties**

- **1st Gen (Bare PHS)**
  - Corrosion Protection
  - Oxidation Prevention

- **2nd Gen (AlSi-Coated PHS)**

- **3rd Gen (PHS Components with Tailored Properties)**
  - Mass & Performance

- **4th Gen (1.7-2.0GPa strength and enhanced toughness)**
  - Performance

**New Breakthroughs...**

- Strength 1.0 – 2.0GPa
- Enhanced Toughness
- Higher Resistance to Delayed Fracture (hydrogen assisted)
- Alternative Coatings

**Alloy**

- 22MnB5

**New Chemistry & Surface**

- grain refinement (microalloying)
- nano-carbide
- retained austenite
- surface carbon management
Why Improved Bendability for PHS

- Press hardened body structure components deform and fracture under a stress state close to plane strain bending during vehicle crash;
- Fracture strain of sheet metal is the lowest at plane strain bending mode;
- Future lightweighting calls for ~1.8GPa+ grades with adequate bendability;
- Tensile ductility does NOT correlate well to fracture limit – bendability does;
- Bendability is a good indicator of delayed fracture resistance.

Challenge to Maintain Adequate Bendability

3-point bending fixture (VDA 238-100)

1.4mm AlSi-coated boron steels (AS60/60 coating)
## 1.7GPa Coating-Free PHS – Development Goal

<table>
<thead>
<tr>
<th>Surface condition after hot stamping</th>
<th>Bare 22MnB5</th>
<th>AlSi-coated 22MnB5</th>
<th>Coating-free 20MnCr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor surface quality</td>
<td><img src="image1" alt="Bare 22MnB5" /></td>
<td><img src="image2" alt="AlSi-coated 22MnB5" /></td>
<td><img src="image3" alt="Coating-free 20MnCr" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oxide/coating morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxide layer 6~10μm</td>
</tr>
<tr>
<td>Thick oxide</td>
</tr>
<tr>
<td>AlSi coating (~40 μm)</td>
</tr>
<tr>
<td>Ultra-thin oxide</td>
</tr>
</tbody>
</table>

### Advantages & Drawbacks

<table>
<thead>
<tr>
<th>Advantages &amp; Drawbacks</th>
<th>Low cost but poor oxidation resistance</th>
<th>Good oxidation resistance but limited supply base</th>
<th>Good oxidation resistance</th>
</tr>
</thead>
</table>

# 1.7 GPa Coating-Free PHS – Composition

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Mn</th>
<th>Cr+Si+Mo</th>
<th>Nb+Ti</th>
<th>B</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 GPa AlSi-coated PHS (22MnB5)</td>
<td>0.19-0.25</td>
<td>≤1.4</td>
<td>≤1.0</td>
<td>≤0.12</td>
<td>0.0008-0.005</td>
<td>Fe</td>
</tr>
<tr>
<td>1.7 GPa Coating-free PHS (20MnCr)</td>
<td>0.19-0.25</td>
<td>≤1.4</td>
<td>≤4.0</td>
<td>≤0.12</td>
<td>None</td>
<td>Fe</td>
</tr>
</tbody>
</table>

- **Strength & hardenability**
- **Austenitization temperature**
- **Oxidation resistance (Cr/Si) & hardenability (Cr)**
- **Nb for grain size control. NO Ti needed.**
- **Boron NOT needed for hardenability**

- **Steel production**: manufacturable by existing process;
- **Component production**: seamless adoption to current hot stamping line;
- **Performance**: higher strength than AlSi-coated 22MnB5, while maintaining bendability;
- **Assembly and system integration**: weldable.
1.7GPa Coating-Free PHS – Microstructure

920°C/6min

AlSi-coated 22MnB5
(100% martensite)

Coating-free 20MnCr (~5% retained austenite)

PAGs: ~10 μm

PAGs: ~5 μm
1.7GPa Coating-Free PHS – Material Property

Hot stamping at 920°C/360s + baking, and all samples are 1.4 mm

Uniaxial tensile

- Oxidation free PHS
- 22MnB5

New PHS: ~1.7 GPa/9%
vs. 22MnB5 (1.5 GPa/7%)

VDA 238-100 3-pt bending

- AlSi coated PHS 1500 MPa
- Oxidation free PHS 1680 MPa
- AlSi coated PHS 1800 MPa

New PHS: similar bending performance vs AlSi-coated PHS 1.5 GPa; same peak force vs AlSi-coated PHS 1.8 GPa.
New PHS has ~20% higher energy absorption (integration of force vs. displacement curve up to the peak force) than the current 1.5 GPa AlSi-coated PHS
**1.7GPa Coating-Free PHS – System Integration**

Same weld strength with existing AlSi-coated PHS (2.0mm PHS/PHS stack-up).

Tape adhesion test (GMW 14829): AlSi-coated PHS = Bare PHS = Oxidation free PHS

Stone chip test (GMW 14700): AlSi-coated PHS = Bare PHS = Oxidation free PHS
# 2.0GPa PHS with Slim AlSi-Coating – Goal

## Surface Carbon Distribution

<table>
<thead>
<tr>
<th>Regular AlSi coating (AS60/60)</th>
<th>Slim AlSi coating (AS20/20) $\rightarrow$ less C-enrichment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C % Fe</td>
<td>C % Fe-Al α-Fe Fe</td>
</tr>
<tr>
<td>0% C</td>
<td>0% C</td>
</tr>
<tr>
<td>C-free High-C Martensite Crack</td>
<td></td>
</tr>
</tbody>
</table>

## Coating morphology

- **Thickness (~40 μm)**, 4 layer structure after hot stamping.
- **Thickness (~15 μm)**, 1-3 layered structure after hot stamping.

## Advantages & Drawbacks

- **Good oxidation resistance but limited supply base**
- **Slim AlSi coating $\rightarrow$ better bendability; Different intermetallic layers $\rightarrow$ new IP;**
# 2.0GPa PHS with Slim AlSi-Coating – Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Nb/Ti/Mo/Cr</th>
<th>B</th>
<th>V</th>
<th>Al</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlSi-coated PHS/1.5GPa (22MnB5)</td>
<td>0.19-0.25</td>
<td>≤1.4</td>
<td>≤1.0</td>
<td>Nb+Ti≤0.12; Cr+Mo≤1.0;</td>
<td>0.0008-0.005</td>
<td>-</td>
<td>-</td>
<td>Fe</td>
</tr>
<tr>
<td>AlSi-coated PHS/1.8GPa (34MnB5)</td>
<td>0.37 max</td>
<td>1.4</td>
<td>≤0.7</td>
<td>Nb+Ti≤0.12; Cr+Mo≤1.4;</td>
<td>0.0008-0.005</td>
<td>-</td>
<td>-</td>
<td>Fe</td>
</tr>
<tr>
<td>Slim AlSi-coated (34MnBV)</td>
<td>0.32-0.35</td>
<td>1.5-2.5</td>
<td>≤0.8</td>
<td>0.02/0/0/0</td>
<td>0.0008-0.005</td>
<td>0.1~0.2</td>
<td>0.5-1.0</td>
<td>Fe</td>
</tr>
</tbody>
</table>

Strength & hardenability  
Austenitization temperature  
No Ti (avoid TiN)  
Vanadium needed for precipitation  
Al as the nitrogen getter

- **Steel production**: manufacturable by existing process;  
- **Component production**: seamless adoption to current hot stamping line;  
- **Performance**: higher strength than AlSi-coated 34MnB5, with better bendability;  
- **Assembly and system integration**: weldable.
2.0GPa PHS with Slim AlSi-Coating – Microstructure

As-received (coating & substrate)

Hot Formed (coating & substrate)
2.0GPa PHS with Slim AlSi-Coating – Microstructure

22MnB5

34MnBV

PAGS: ~10μm

PAGs: 4–5μm
2.0GPa PHS with Slim AlSi-Coating – Microstructure

Nano-VC precipitates: 0.21 vol.%
- Toughening by grain refinement
- Toughening by reducing carbon in the martensite (hence less brittle matrix)
- Precipitate strengthening

Particle Size / nm

Frequency / %

1~5 5~10 10~15 15~20 20~40 40~80
2.0GPa PHS with Slim AlSi-Coating – Tensile Property

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Yield/MPa</th>
<th>UTS/MPa</th>
<th>TEL/%</th>
<th>UEL/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-deg (RD)</td>
<td>1403±2</td>
<td>2025±26</td>
<td>7.4±0.4</td>
<td>6.0±0.2</td>
</tr>
<tr>
<td>45-deg</td>
<td>1361±2</td>
<td>2050±26</td>
<td>6.3±0.4</td>
<td>5.2±0.2</td>
</tr>
<tr>
<td>90-deg (TD)</td>
<td>1430±52</td>
<td>2074±24</td>
<td>6.5±0.3</td>
<td>5.1±0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Yield/MPa</th>
<th>UTS/MPa</th>
<th>TEL/%</th>
<th>UEL/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-deg (RD)</td>
<td>1514±15</td>
<td>1927±4</td>
<td>7.3±0.8</td>
<td>5.1±0.5</td>
</tr>
<tr>
<td>45-deg</td>
<td>1503±5</td>
<td>1905±3</td>
<td>7.3±0.3</td>
<td>5.3±0.3</td>
</tr>
<tr>
<td>90-deg (TD)</td>
<td>1571±5</td>
<td>1963±3</td>
<td>7.1±0.3</td>
<td>5.1±0.3</td>
</tr>
</tbody>
</table>

34MnBV: decent ductility before baking with 2.0 GPa UTS (drop to 1.9 GPa post baking)
2.0GPa PHS with Slim AlSi-Coating – Bendability

**Hot stamped**

Bending angle:
RD: 47.5±1.8 / TD: 45.7±0.2

**Hot stamped + 170°C bake**

Bending angle:
RD: 55.4±0.2 / TD: 51.6±0.2
2.0GPa PHS with Slim AlSi-Coating – Performance

Test conditions

- All samples baked at 170°C for 20 minutes;
- Initial solution 0.1 mol/L (with PH=1) HCL. Record PH value daily;
- Total time of immersion 96 hours;
- 2 sample per stress level;
- Terminate test if sample cracks.
2.0GPa PHS with Slim AlSi-Coating – Performance

<table>
<thead>
<tr>
<th>SN</th>
<th>Thickness (mm)</th>
<th>Pre-stress (MPa)</th>
<th>Fracture</th>
<th>Time to Fracture</th>
<th>Photos before test</th>
<th>Photos after test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>1.407</td>
<td>1213.3 (0.8*YS)</td>
<td>N</td>
<td>/</td>
<td><img src="image1" alt="Photo" /></td>
<td><img src="image2" alt="Photo" /></td>
</tr>
<tr>
<td>1-2</td>
<td>1.406</td>
<td></td>
<td>N</td>
<td>/</td>
<td><img src="image3" alt="Photo" /></td>
<td><img src="image4" alt="Photo" /></td>
</tr>
<tr>
<td>2-1</td>
<td>1.415</td>
<td>1364.9 (0.9*YS)</td>
<td>N</td>
<td>/</td>
<td><img src="image5" alt="Photo" /></td>
<td><img src="image6" alt="Photo" /></td>
</tr>
<tr>
<td>2-2</td>
<td>1.416</td>
<td></td>
<td>N</td>
<td>/</td>
<td><img src="image7" alt="Photo" /></td>
<td><img src="image8" alt="Photo" /></td>
</tr>
<tr>
<td>3-1</td>
<td>1.414</td>
<td>1516.6 (1.0*YS)</td>
<td>N</td>
<td>/</td>
<td><img src="image9" alt="Photo" /></td>
<td><img src="image10" alt="Photo" /></td>
</tr>
<tr>
<td>3-2</td>
<td>1.399</td>
<td></td>
<td>N</td>
<td>/</td>
<td><img src="image11" alt="Photo" /></td>
<td><img src="image12" alt="Photo" /></td>
</tr>
</tbody>
</table>

PH value changes from 1 at the start of testing to 2.3 when test ends.
Reg AlSi 1.5 GPa:
commercial product of 22MnB5 chemistry with 60g/m² coating;

Reg AlSi 1.8 GPa:
commercial product of 34MnB+NiMoNb with 60g/m² coating;

Slim AlSi 2.0 GPa:
New 34MnBV steel with 20g/m² coating;
2.0GPa PHS with Slim AlSi-Coating – Integration

<table>
<thead>
<tr>
<th>Materials</th>
<th>Thickness</th>
<th>Electrode Diameter</th>
<th>Welding Time</th>
<th>Electrode Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>34MnBV</td>
<td>1.4mm</td>
<td>5.5mm</td>
<td>380ms</td>
<td>4500N</td>
</tr>
</tbody>
</table>

All specimens were pull-out failure mode.
Both the 1.7 and 2.0 GPa steels have been successfully produced via conventional steel making processes.
Status of Commercialization – Component

Austenitization in a roller hearth furnace:
900-930 °C/ 4-8 min

(20MnCr – with N2;
34MnBV – with dew point control)
Summary

- Novel alloy design concept enables next generation PHS with strength and bendability better than existing commercial grades;
- Combination of higher strength and adequate bendability gives BETTER energy absorption of component;
- Enhanced bendability results in higher resistance to delayed fracture of PHS;
- Adoption of these new steels is expected to happen quickly.
THANK YOU
TO OBTAIN DOWNLOADS

Visit:  www.AutoSteel.org