



Welcome to the New Generation of Press Hardened Steels Webinar

1.7-2.0 GPA PHS WITH ENHANCED BENDABILITY

SEPTEMBER 29, 2020



New Generation of Press Hardened Steels

Introduction: John Catterall

Vice President, Automotive Program

American Iron and Steel Institute



New Generation of Press Hardened Steels

Presenter: Jeff Wang

Site Leader, General Motors China
Science Lab and Manager, Structural
Metallic Systems Research



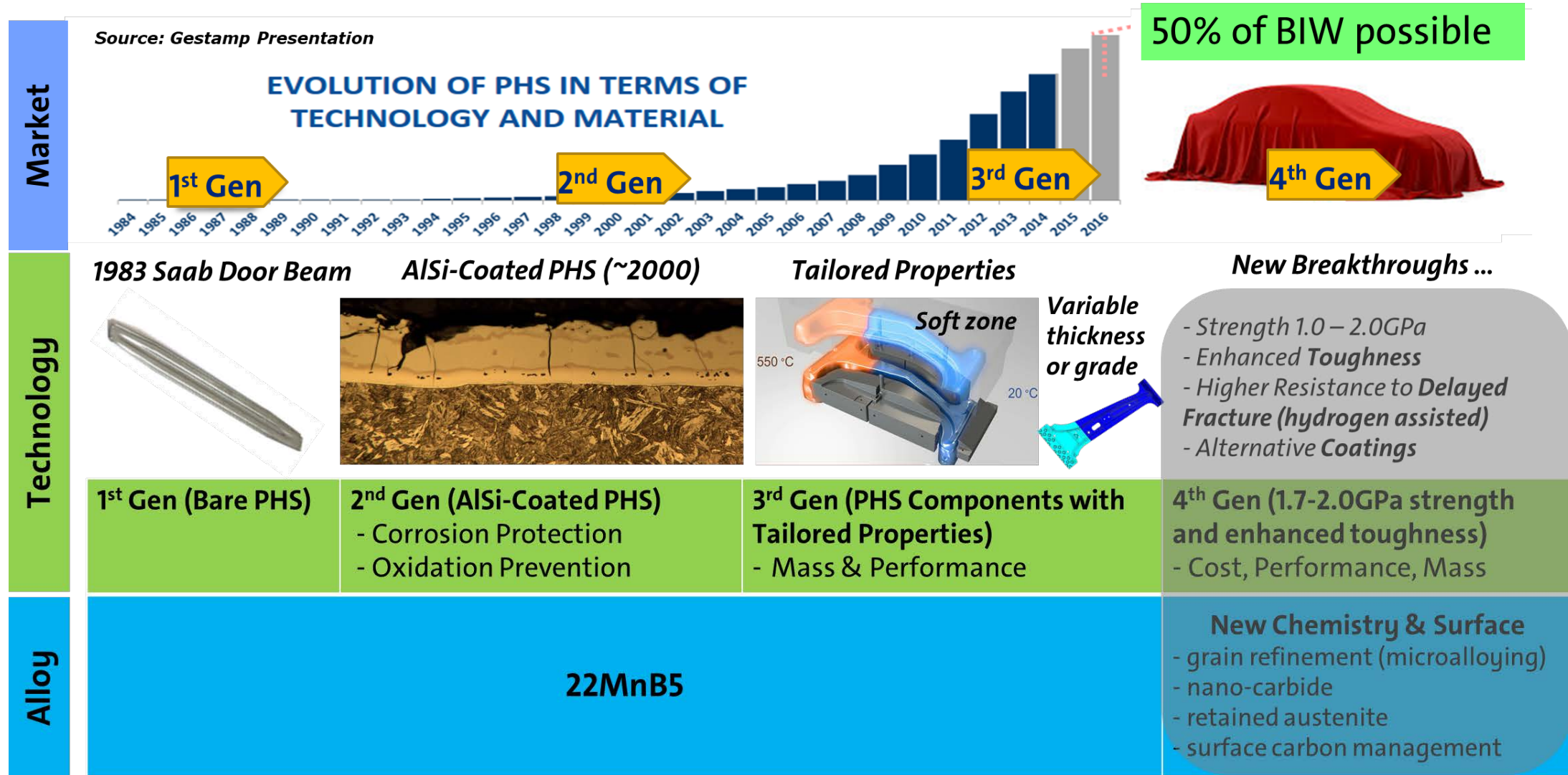
Co-authors: Qi Lu (General Motors)

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

Outline

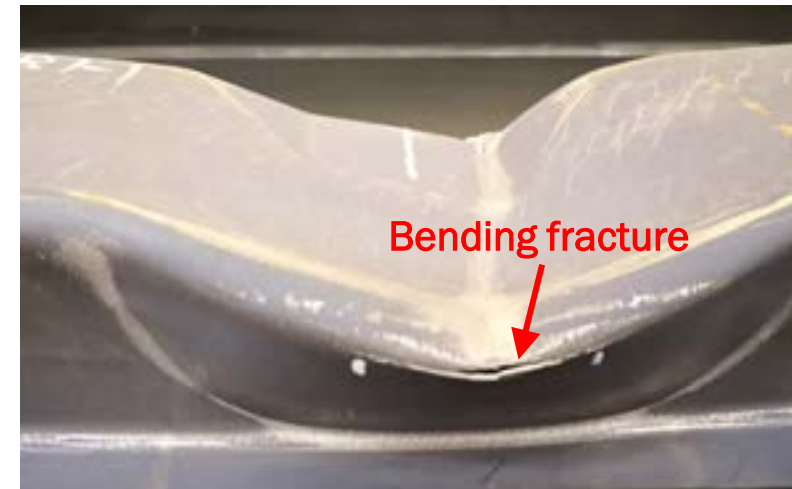
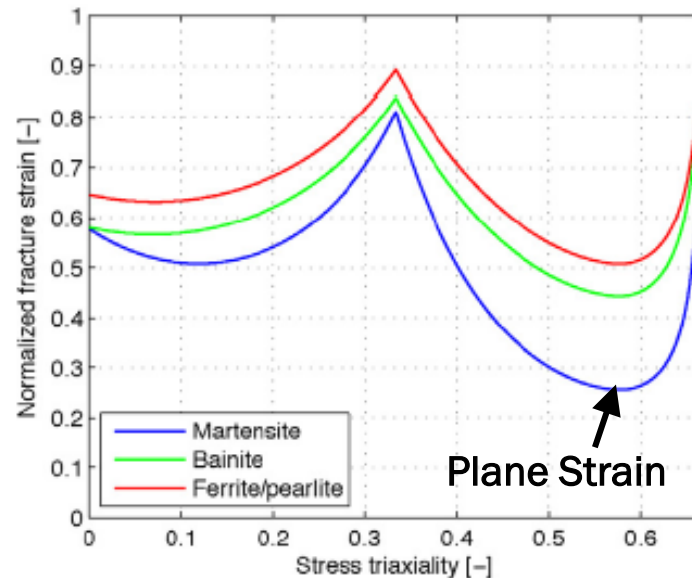
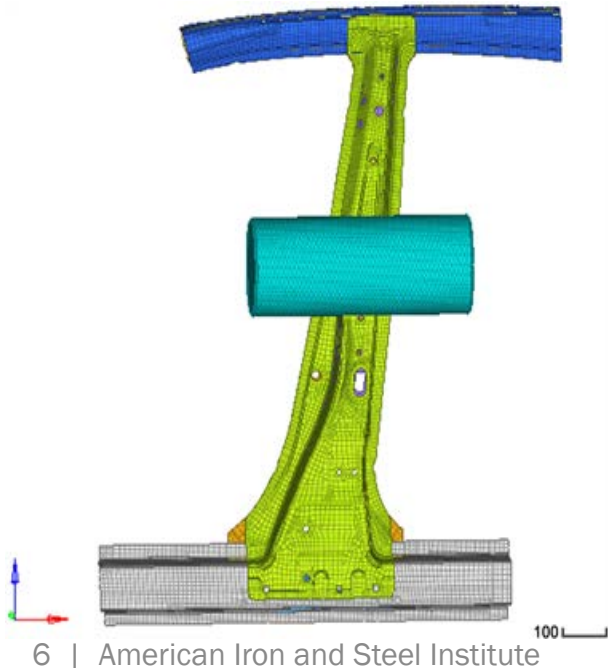
- Introduction – Background and Motivation for Enhanced Bendability
- 1.7 GPa Press Hardening Steel without AlSi-coating
 - Alloy Development
 - Property and Performance
- 2.0 GPa Press Hardening Steel with Slim AlSi-coating
 - Alloy Development
 - Property and Performance
- Status of Commercialization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

Background – Press Hardening Steels



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.

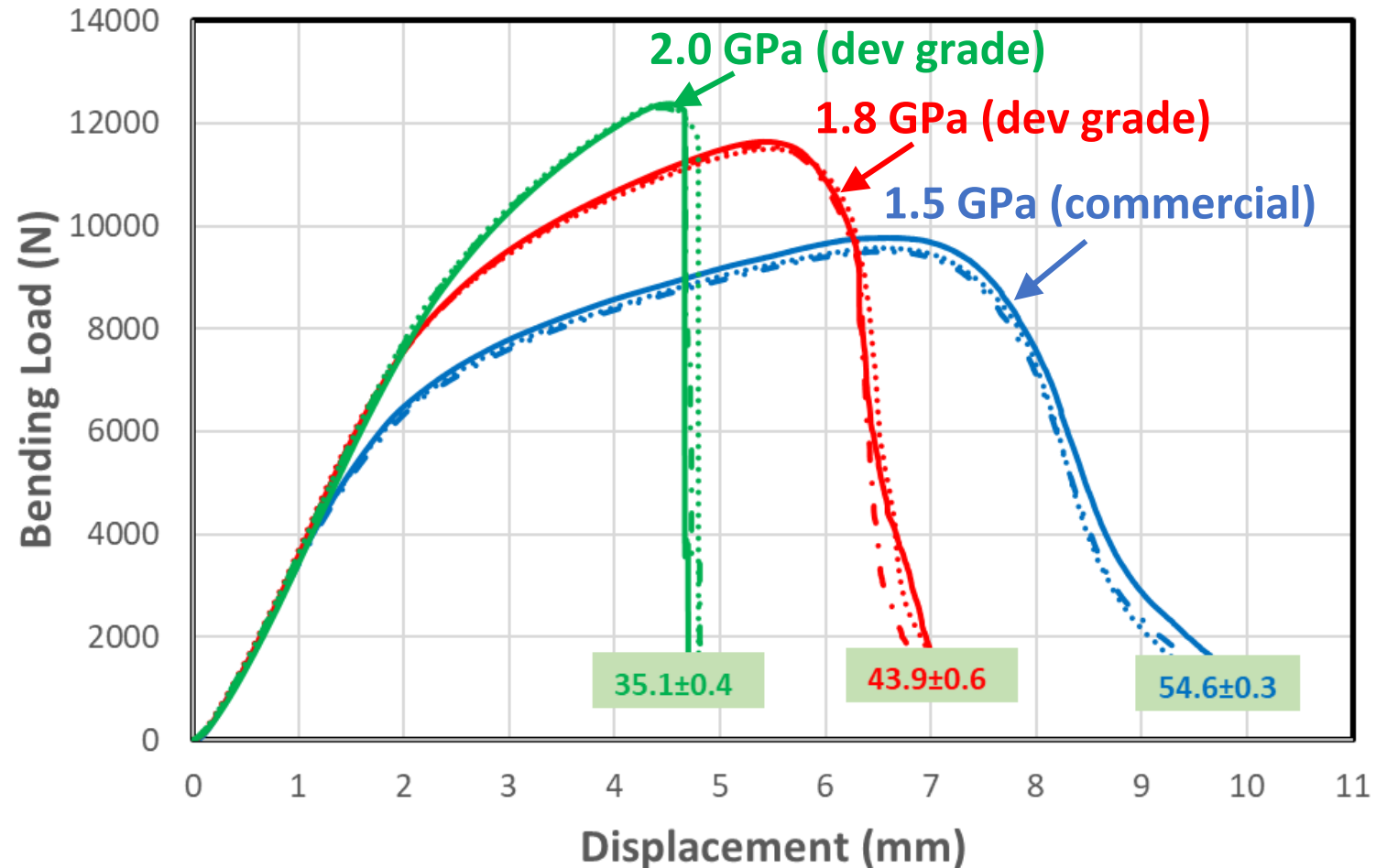


Ref: T.K. Eller, *Int. J. Mat. Proc.*, 214 (2014), p1211.

Challenge to Maintain Adequate Bendability



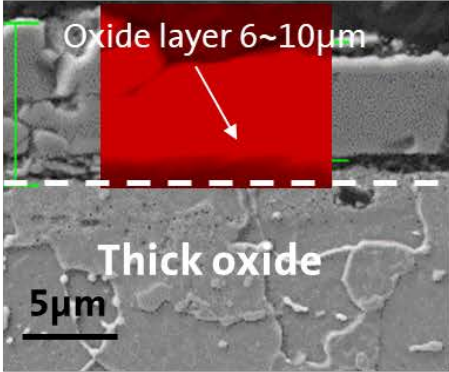
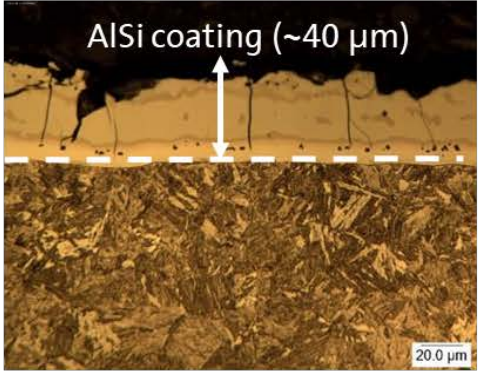
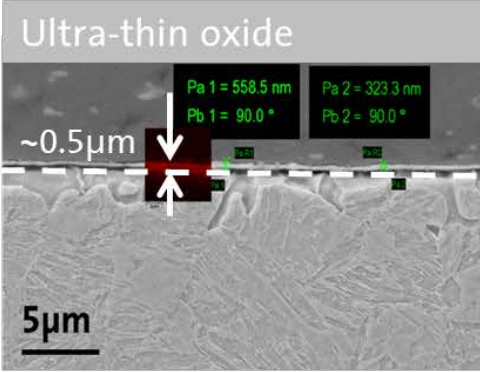


3-point bending fixture
(VDA 238-100)



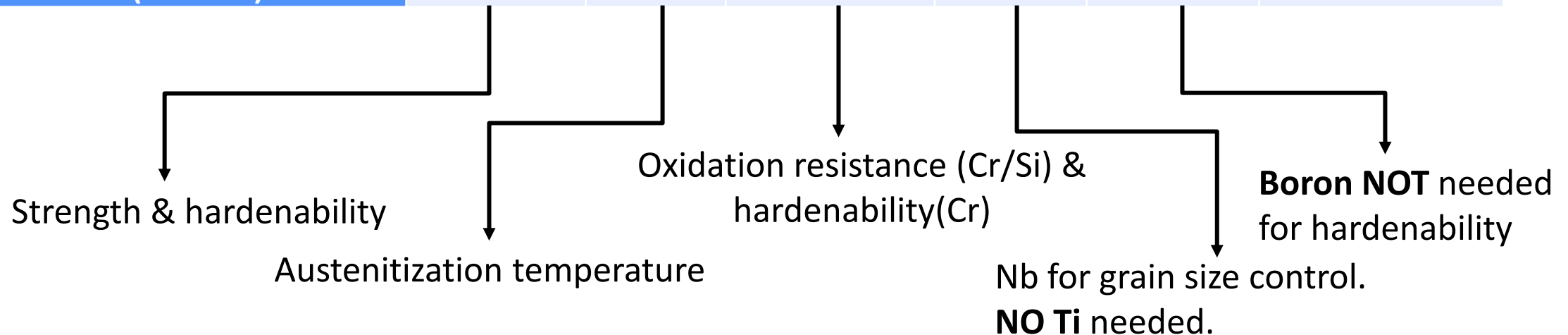
1.4mm AlSi-coated boron steels (AS60/60 coating)

1.7GPa Coating-Free PHS – Development Goal

<p>Surface condition after hot stamping</p>	 <p>Bare 22MnB5 Poor surface quality 10mm</p>	 <p>AlSi-coated 22MnB5 Good surface quality 10mm</p>	 <p>Coating-free 20MnCr “Shiny” as mirror 10mm</p>
<p>Oxide/ coating morphology</p>	 <p>Oxide layer 6~10μm Thick oxide 5μm</p>	 <p>AlSi coating (~40 μm) 20.0 μm</p>	 <p>Ultra-thin oxide ~0.5μm Pa 1 = 558.5 nm Pa 2 = 323.3 nm Pb 1 = 90.0° Pb 2 = 90.0° 5μm</p>
<p>Advantages & Drawbacks</p>	<p>Low cost but poor oxidation resistance</p>	<p>Good oxidation resistance but limited supply base</p>	<p>Good oxidation resistance</p>

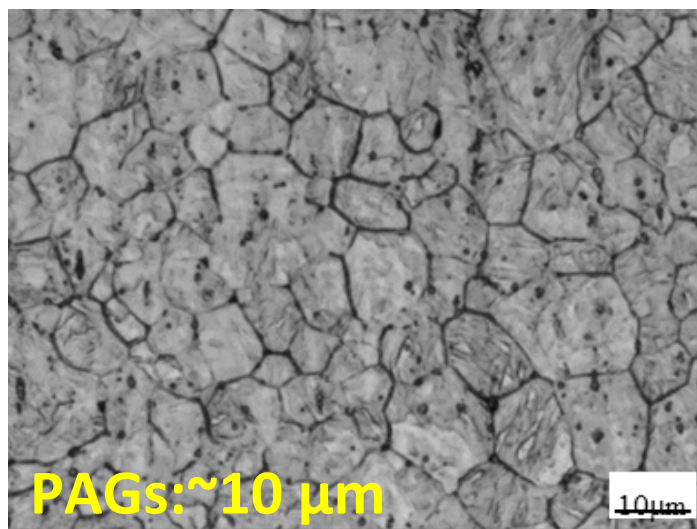
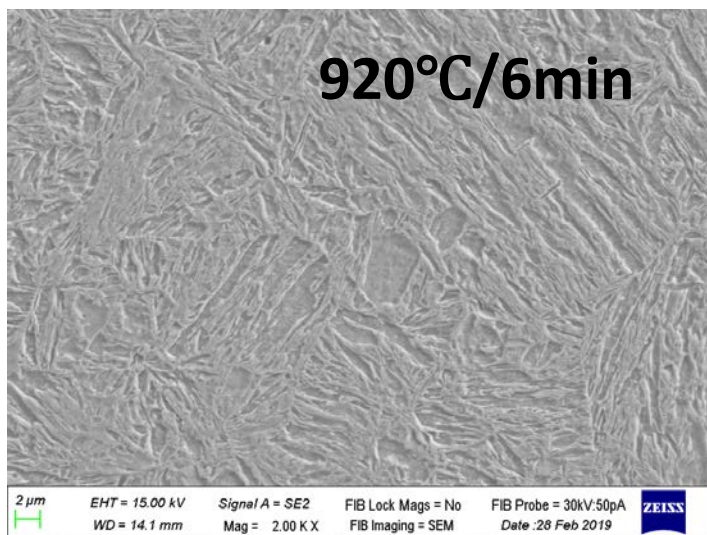
1.7GPa Coating-Free PHS – Composition

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

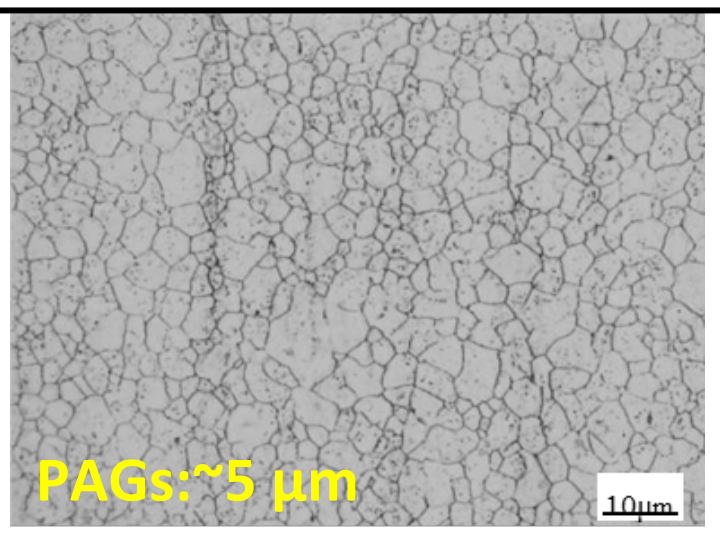
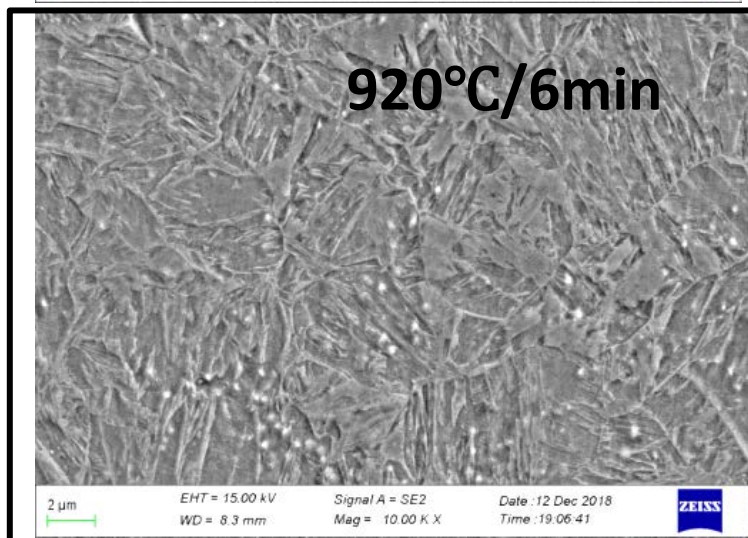


- **Steel production:** manufacturable by existing process;
- **Component production:** seamless adoption to current hot stamping line;
- **Performance:** higher strength than AlSi-coated 22MnB5, while maintaining bendability;
- **Assembly and system integration:** weldable.

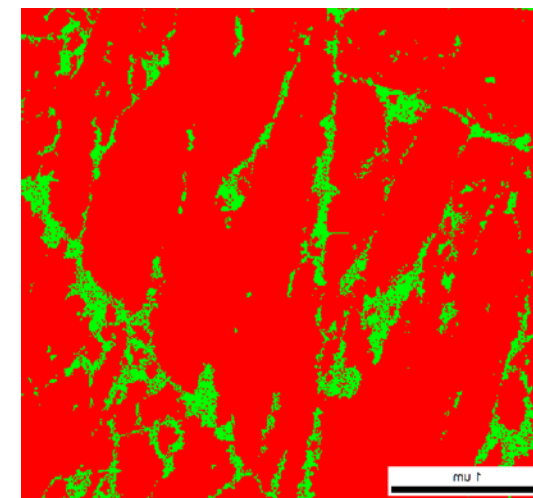
1.7GPa Coating-Free PHS – Microstructure



AlSi-coated 22MnB5
(100% martensite)



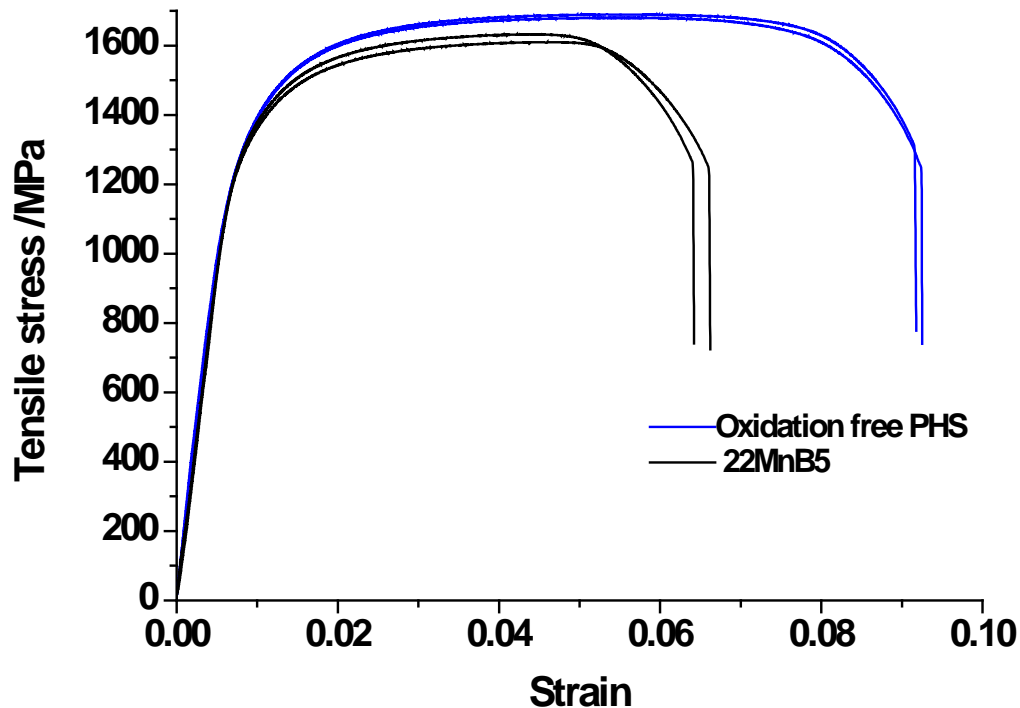
Coating-free 20MnCr (~5%
retained austenite)



1.7GPa Coating-Free PHS – Material Property

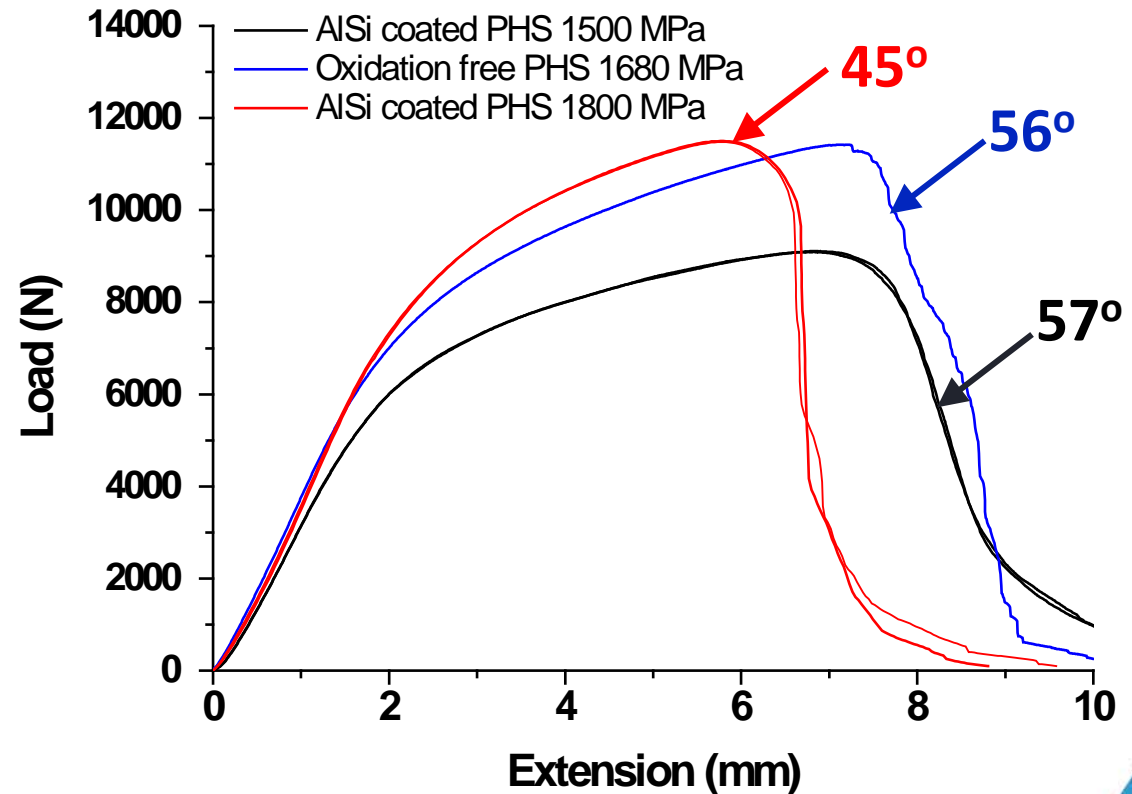
Hot stamping at 920 °C/360s +baking, and all samples are 1.4 mm

Uniaxial tensile



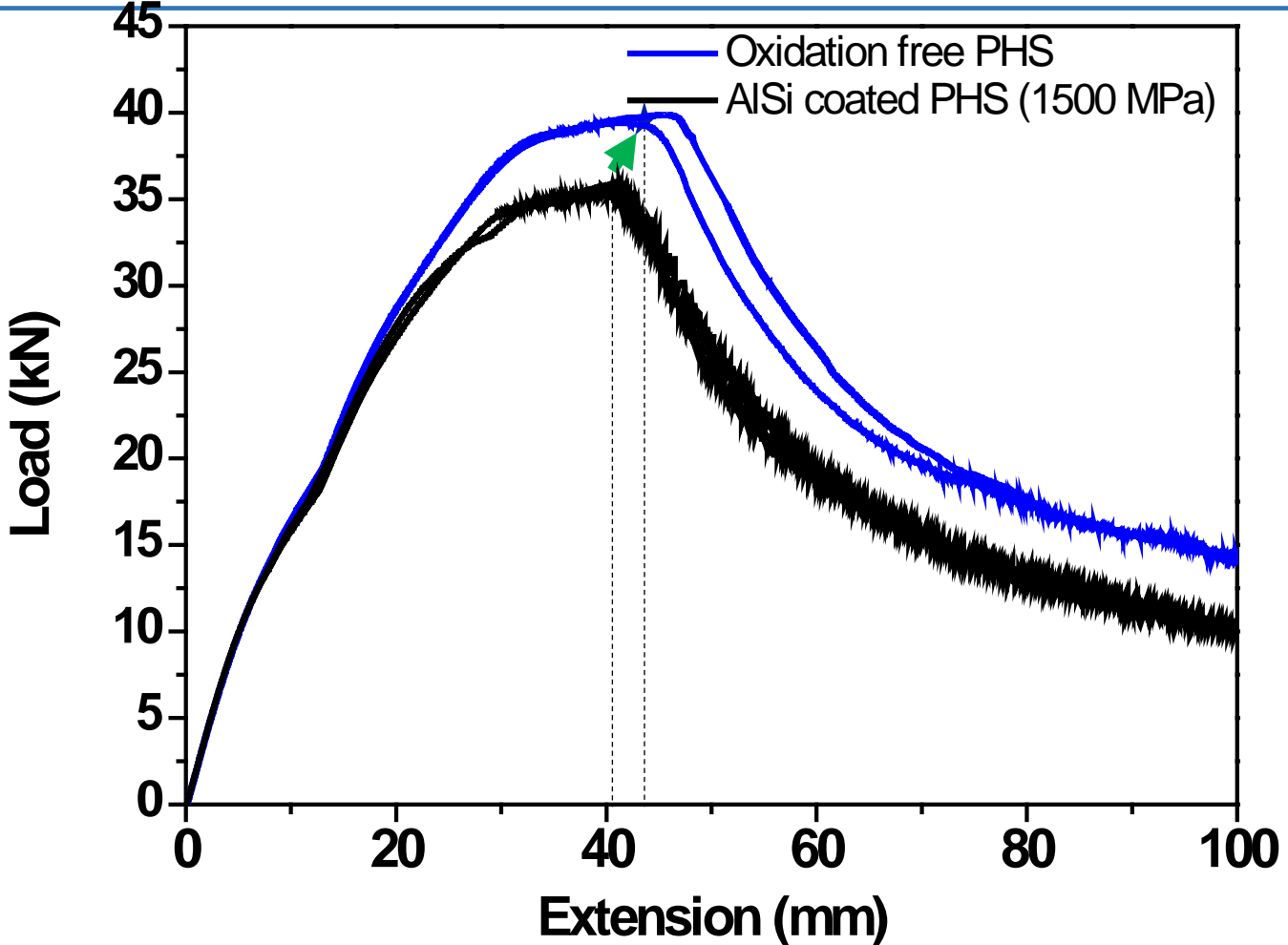
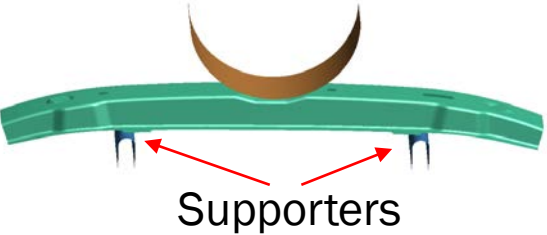
New PHS: ~1.7 GPa/9%
vs. 22MnB5 (1.5 GPa/7%)

VDA 238-100 3-pt bending



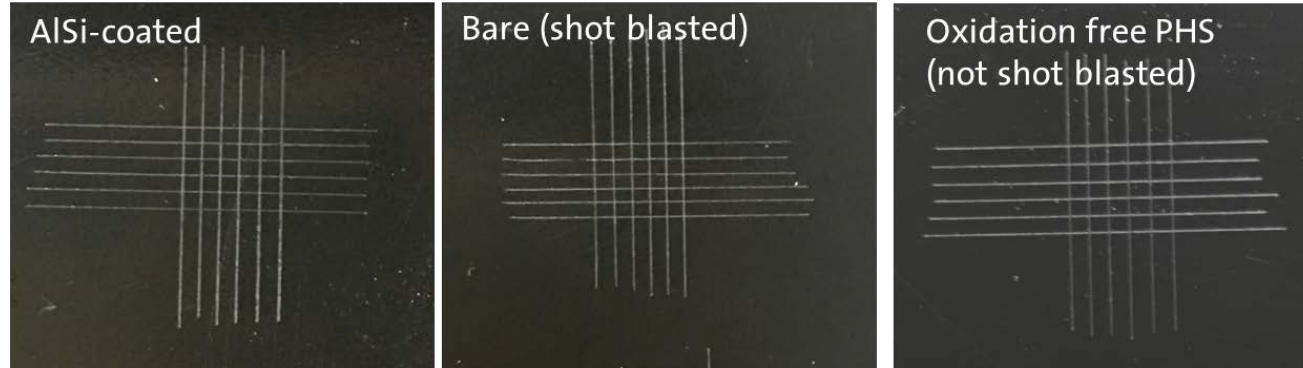
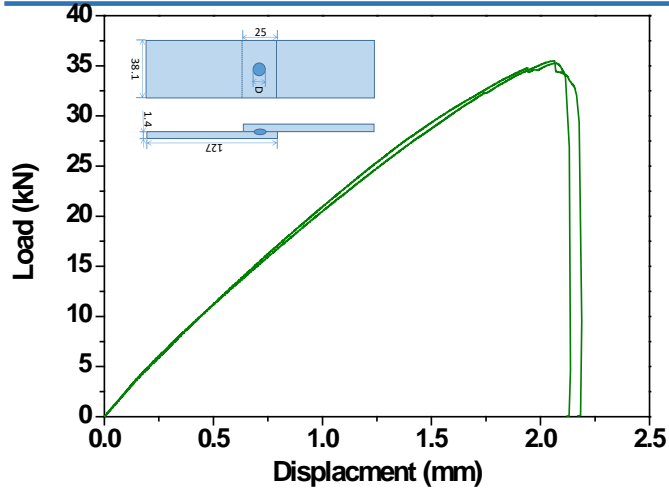
New PHS: similar bending performance
vs AISi-coated PHS 1.5 GPa; same peak
force vs AISi-coated PHS 1.8 GPa.

1.7GPa Coating-Free PHS – Component Performance

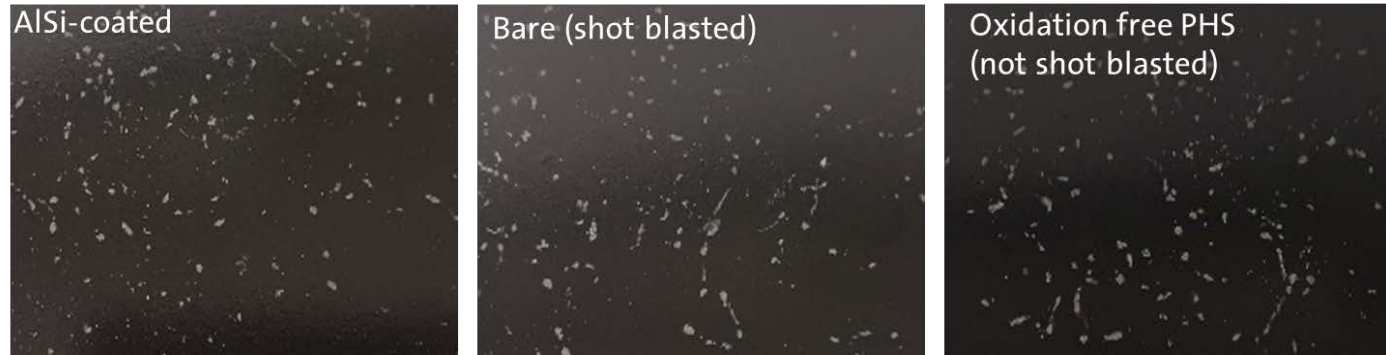
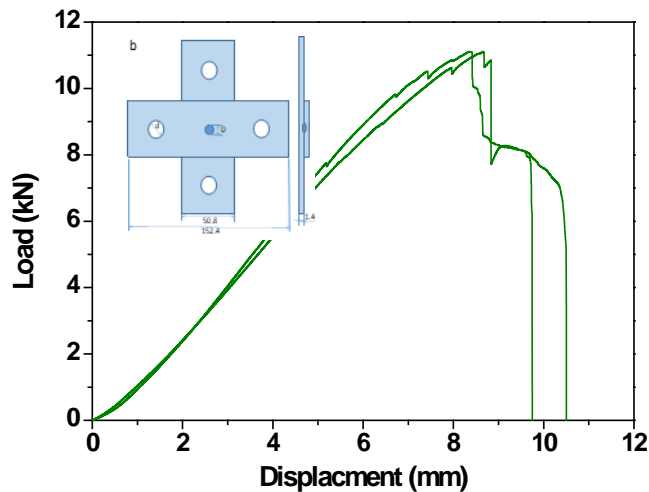


New PHS has ~20% higher energy absorption (integration of force vs. displacement curve up to the peak force) than the current 1.5 GPa AISi-coated PHS

1.7GPa Coating-Free PHS – System Integration



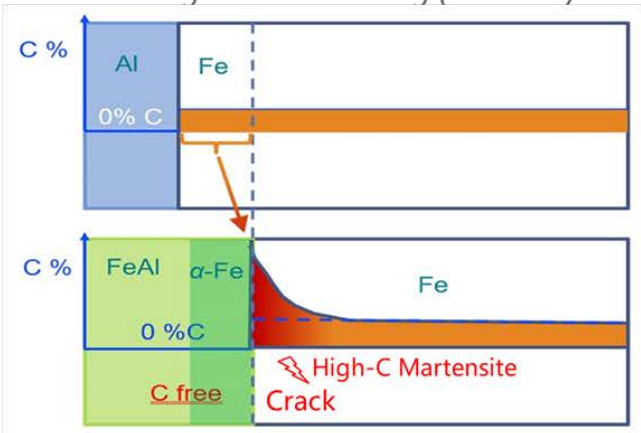
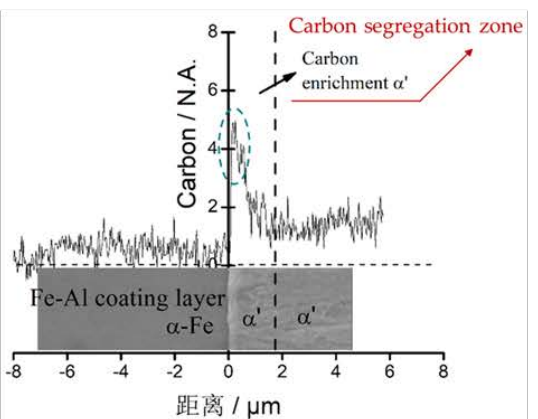
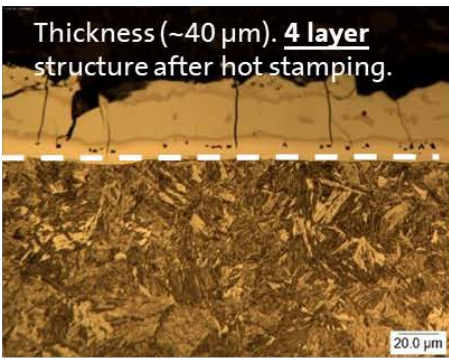
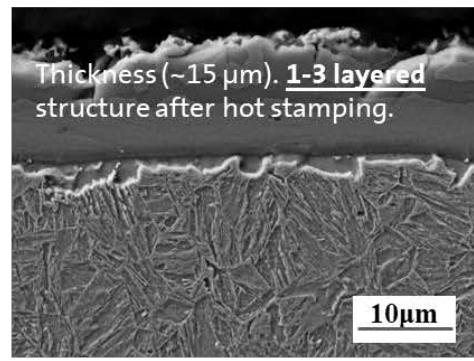
Tape adhesion test (GMW 14829): AlSi-coated PHS = Bare PHS = Oxidation free PHS



Stone chip test (GMW 14700): AlSi-coated PHS = Bare PHS = Oxidation free PHS

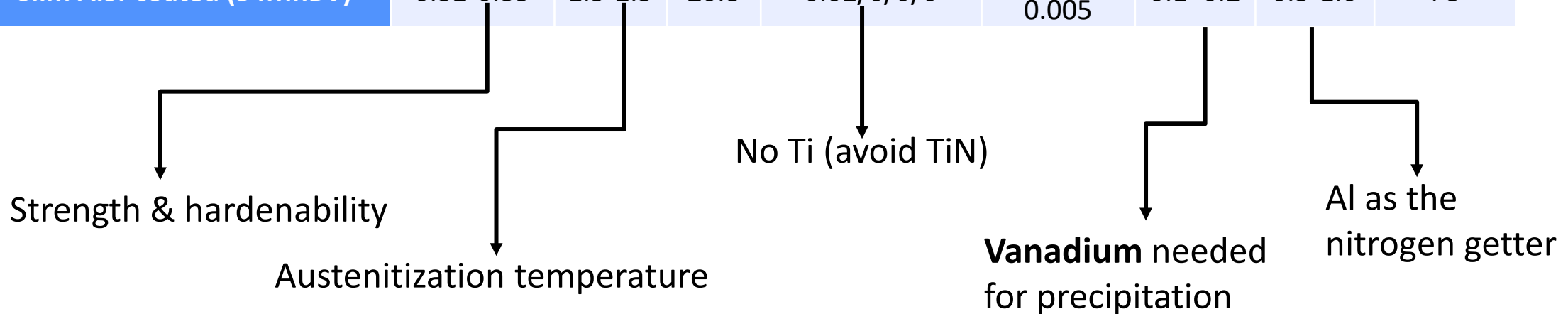
Same weld strength with existing AlSi-coated PHS (2.0mm PHS/ PHS stack-up).

2.0GPa PHS with Slim AlSi-Coating – Goal

<p>Surface Carbon Distribution</p>	<p><i>Regular AlSi coating (AS60/60)</i></p> 	<p><i>Slim AlSi coating (AS20/20) → less C-enrichment</i></p> 
<p>Coating morphology</p>	<p>Thickness (~40 μm). 4 layer structure after hot stamping.</p> 	<p>Thickness (~15 μm). 1-3 layered structure after hot stamping.</p> 
<p>Advantages & Drawbacks</p>	<p>Good oxidation resistance but limited supply base</p>	<p>Slim AlSi coating → better bendability; Different intermetallic layers → new IP;</p>

2.0GPa PHS with Slim AlSi-Coating – Composition

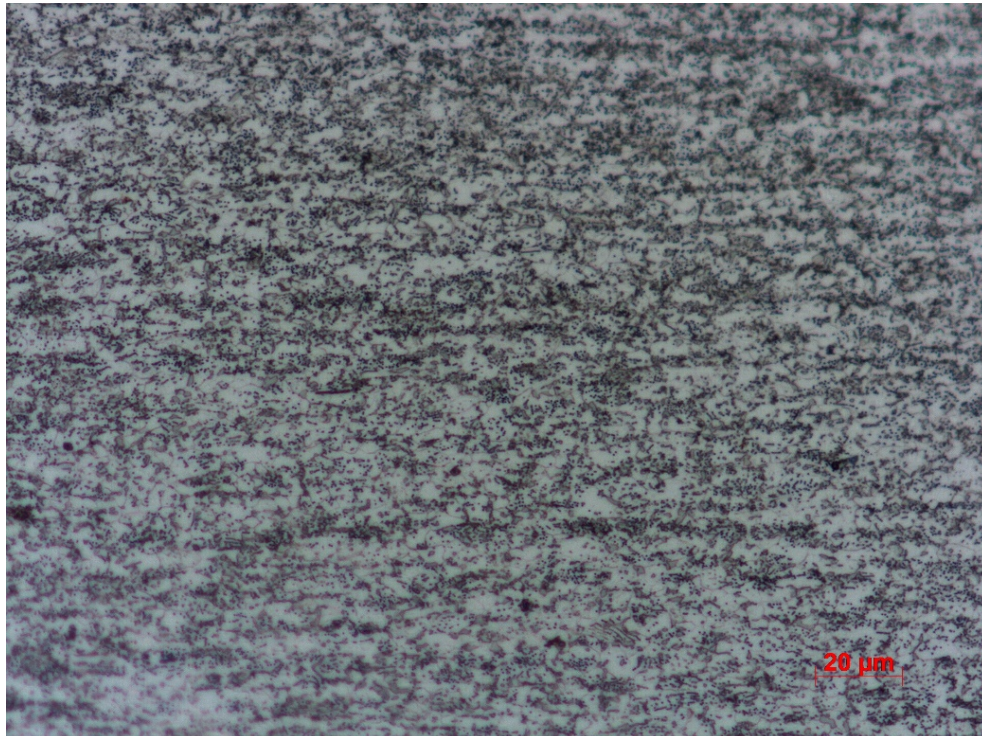
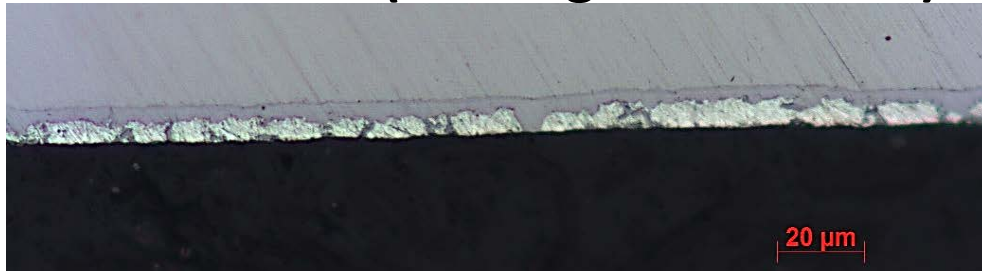
	C	Mn	Si	Nb/Ti/Mo/Cr	B	V	Al	Balance
AlSi-coated PHS/1.5GPa (22MnB5)	0.19-0.25	≤1.4	≤1.0	Nb+Ti≤0.12; Cr+Mo≤1.0;	0.0008- 0.005	-	-	Fe
AlSi-coated PHS/1.8GPa (34MnB5)	0.37max	1.4	≤0.7	Nb+Ti≤0.12; Cr+Mo≤1.4;	0.0008- 0.005	-	-	Fe
Slim AlSi-coated (34MnBV)	0.32-0.35	1.5-2.5	≤0.8	0.02/0/0/0	0.0008- 0.005	0.1~0.2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



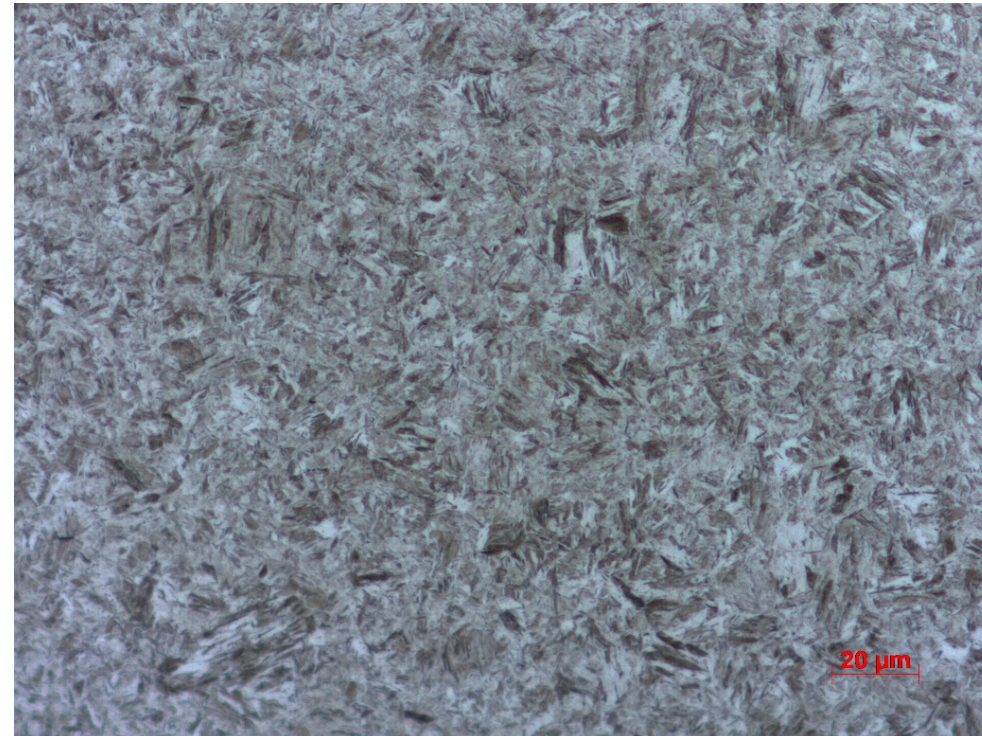
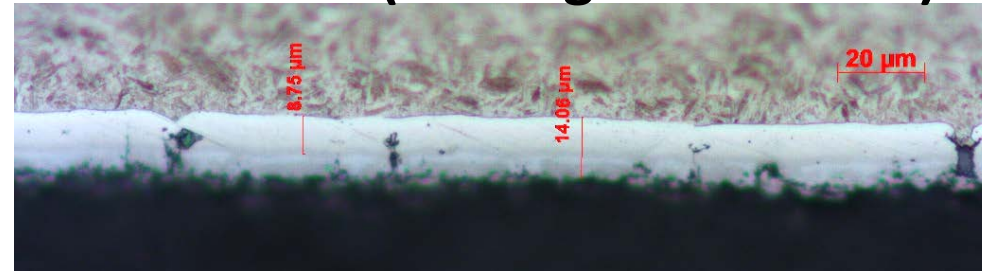
- **Steel production:** manufacturable by existing process;
- **Component production:** seamless adoption to current hot stamping line;
- **Performance:** higher strength than AlSi-coated 34MnB5, with better bendability;
- **Assembly and system integration:** weldable.

2.0GPa PHS with Slim AlSi-Coating – Microstructure

As-received (coating & substrate)

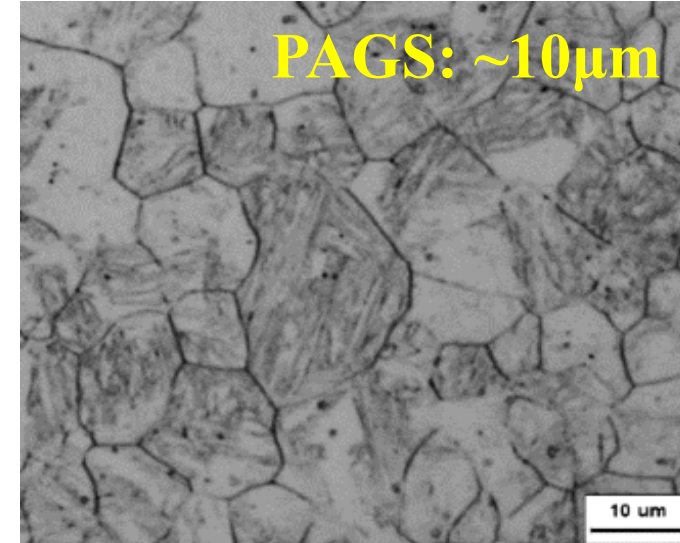
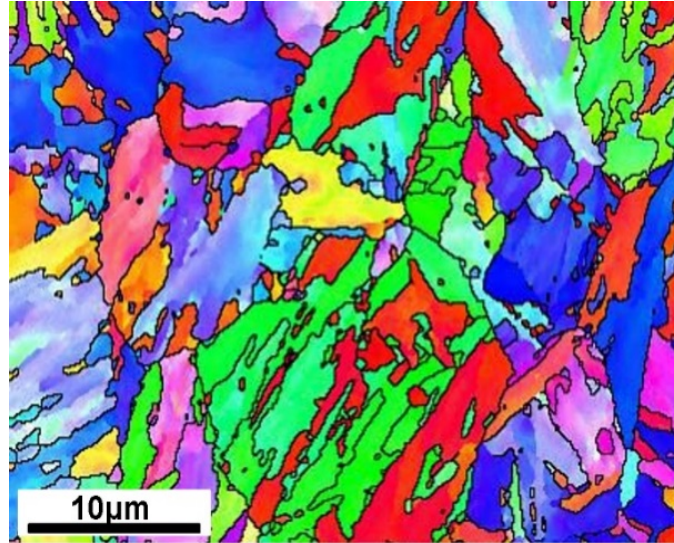


Hot Formed (coating & substrate)

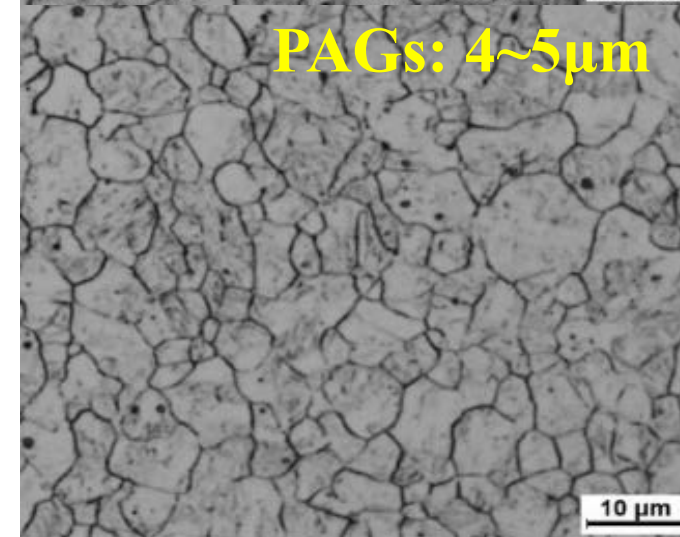
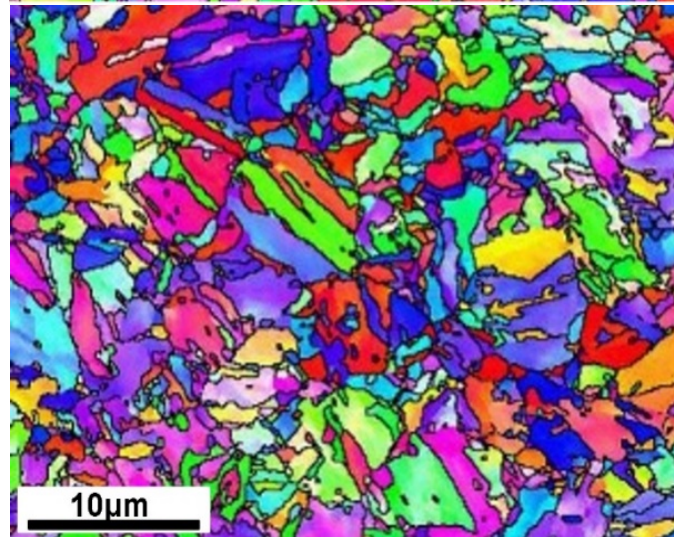


2.0GPa PHS with Slim AlSi-Coating – Microstructure

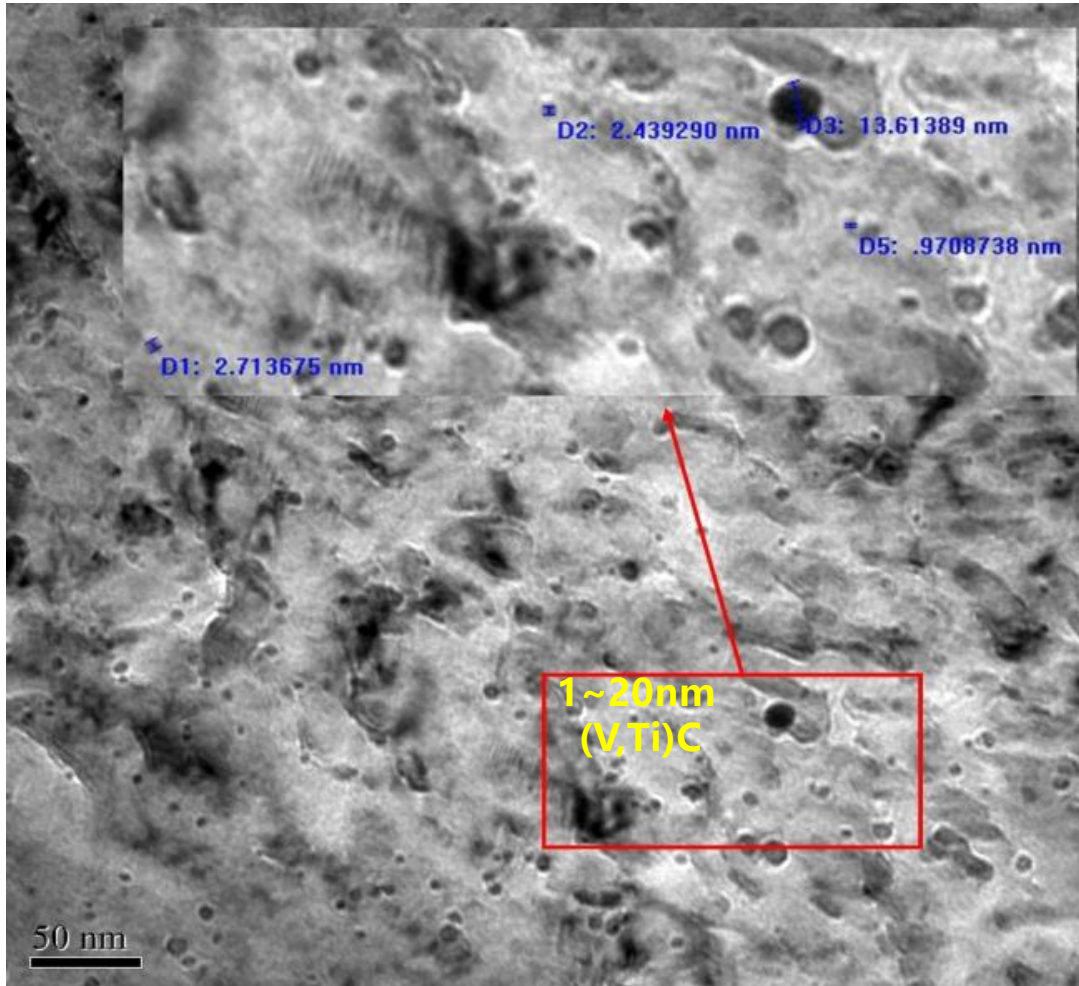
22MnB5



34MnBV

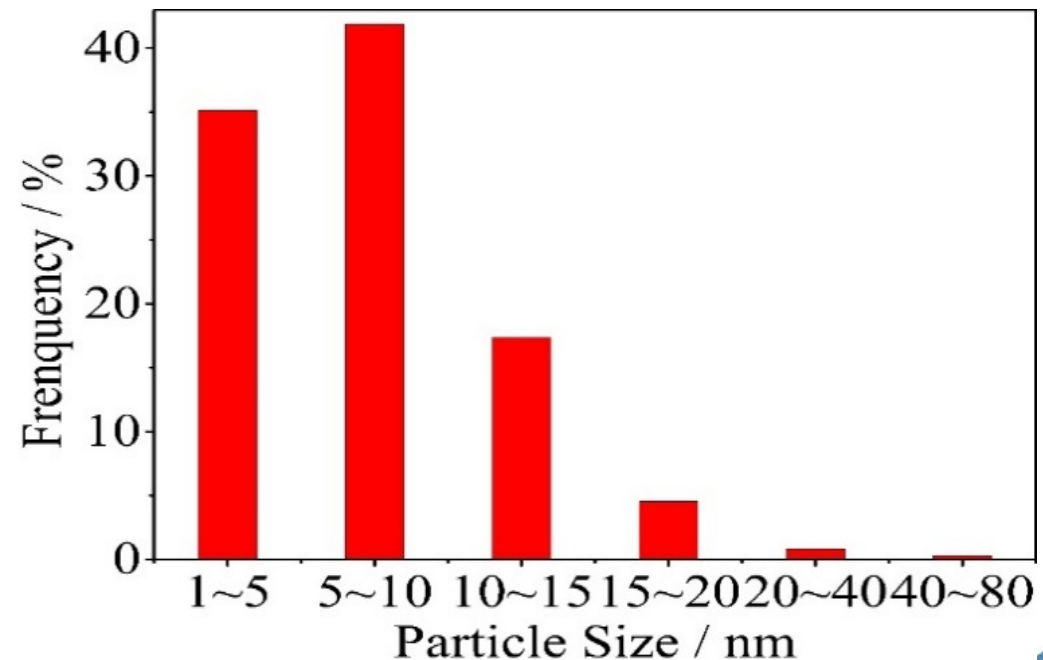


2.0GPa PHS with Slim AlSi-Coating – Microstructure

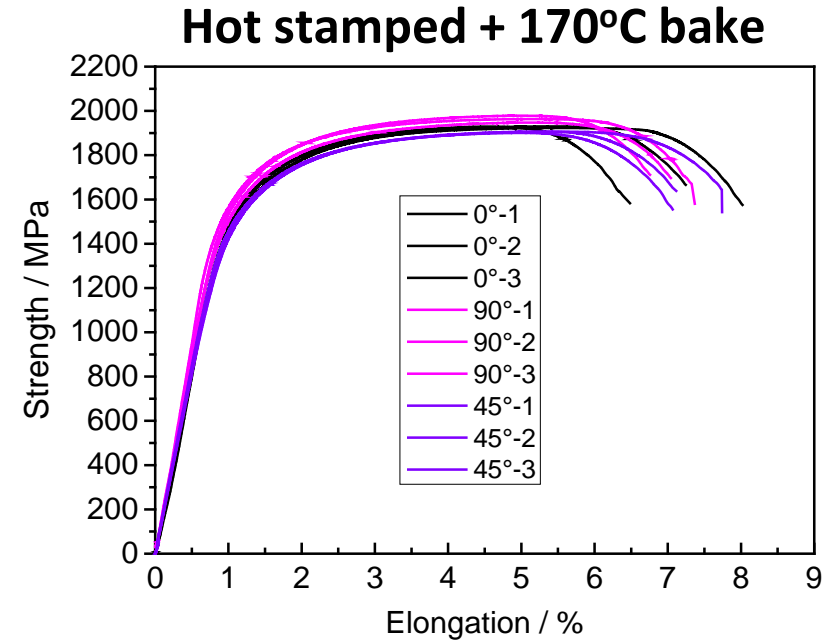
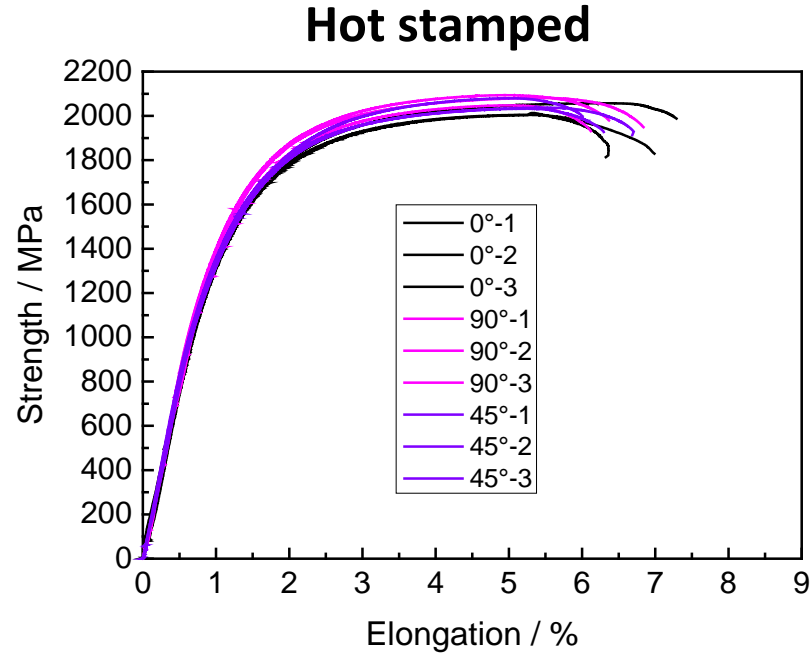


Nano-VC precipitates: 0.21 vol.%

- Toughening by grain refinement
- Toughening by reducing carbon in the martensite (hence less brittle matrix)
- Precipitate strengthening



2.0GPa PHS with Slim AlSi-Coating – Tensile Property



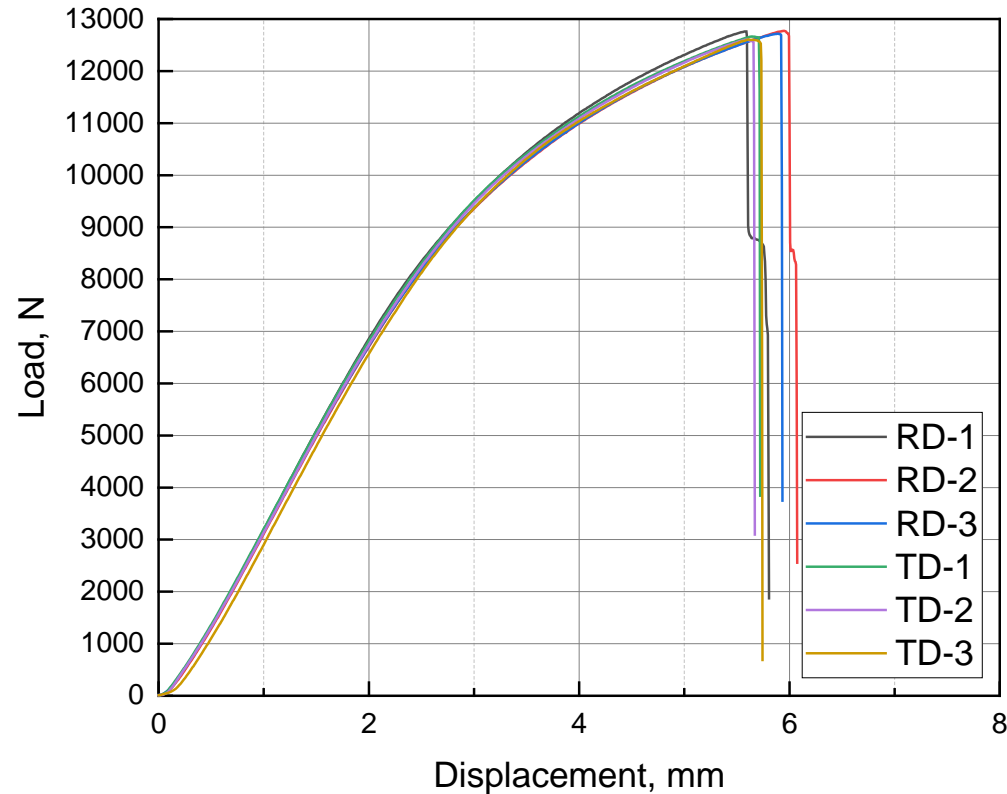
Orientation	Yield/MPa	UTS/MPa	TEL/%	UEL/%
0-deg (RD)	1403±2	2025±26	7.4±0.4	6.0±0.2
45-deg	1361±2	2050±26	6.3±0.4	5.2±0.2
90-deg (TD)	1430±52	2074±24	6.5±0.3	5.1±0.3

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

34MnBV: decent ductility before baking with 2.0 GPa UTS (drop to 1.9 GPa post baking)

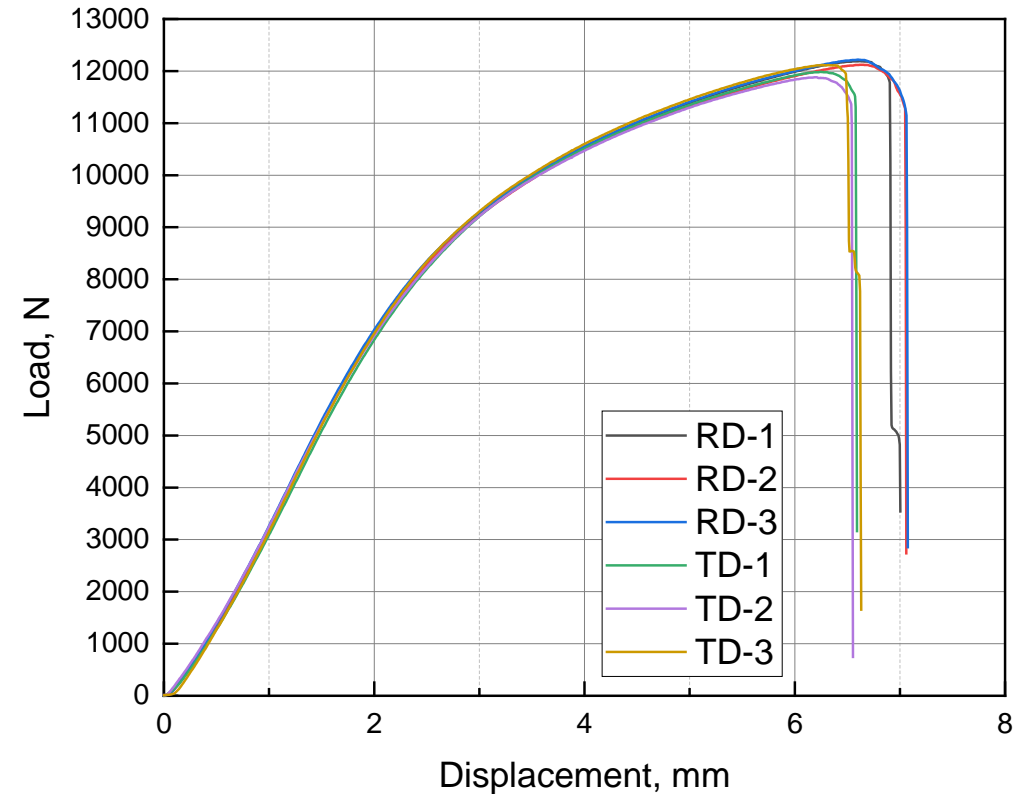
2.0GPa PHS with Slim AlSi-Coating – Bendability

Hot stamped



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

Hot stamped + 170°C bake

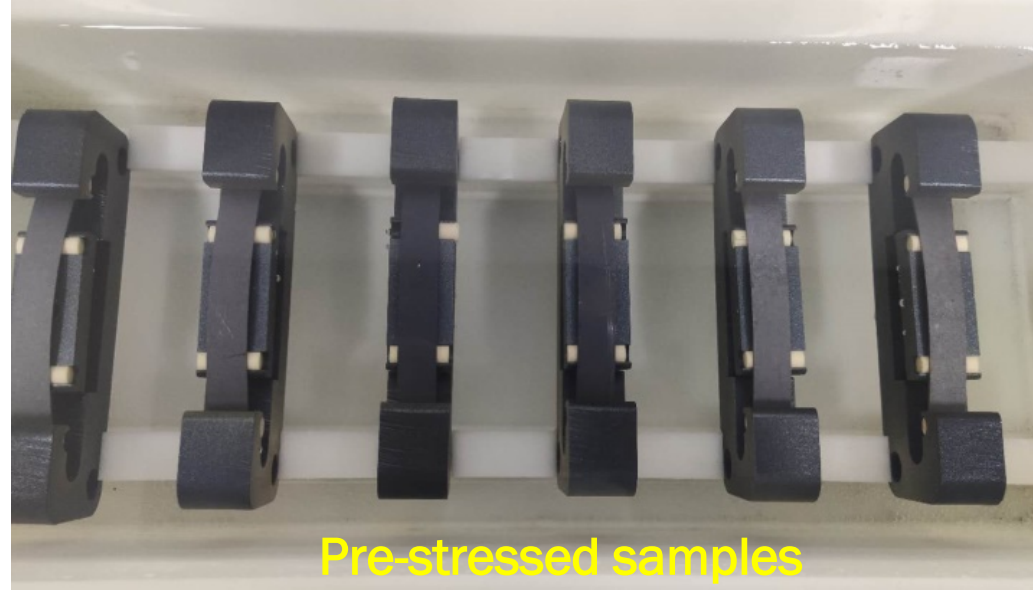


Bending angle:
RD: 55.4 ± 0.2 / TD: 51.6 ± 0.2

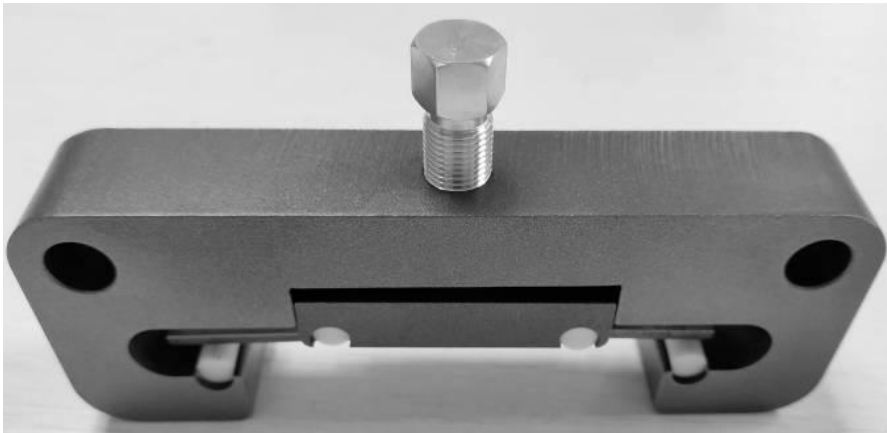
2.0GPa PHS with Slim AlSi-Coating – Performance



PH Monitor



Pre-stressed samples

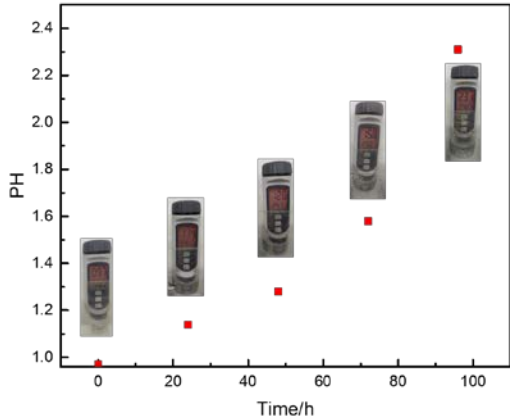


4-point bending fixture



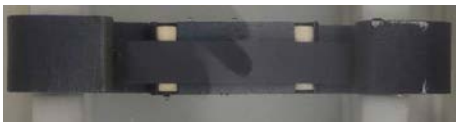

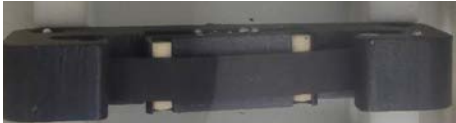



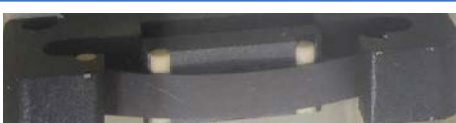

Test conditions

- 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



PH value changes from 1 at the start of testing to 2.3 when test ends.

SN	Thickness (mm)	Pre-stress (MPa)	Fracture	Time to Fracture	Photos before test	Photos after test
1-1	1.407	1213.3 (0.8*YS)	N	/		
1-2	1.406		N	/		
2-1	1.415	1364.9 (0.9*YS)	N	/		
2-2	1.416		N	/		
3-1	1.414	1516.6 (1.0*YS)	N	/		
3-2	1.399		N	/		

2.0GPa PHS with Slim AlSi-Coating – Performance

Reg AlSi 1.5 GPa:

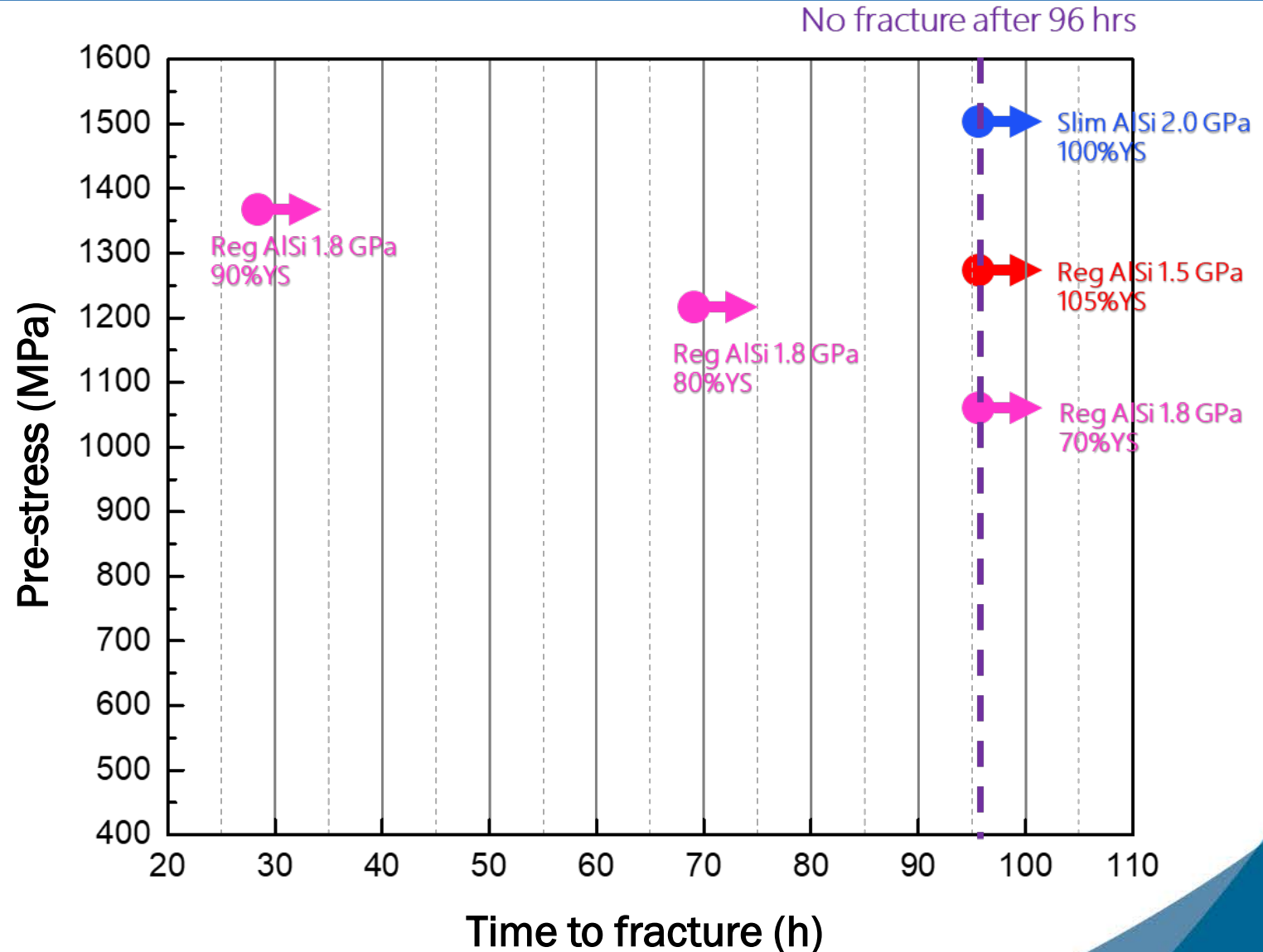
commercial product of 22MnB5 chemistry with 60g/m² coating;

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;

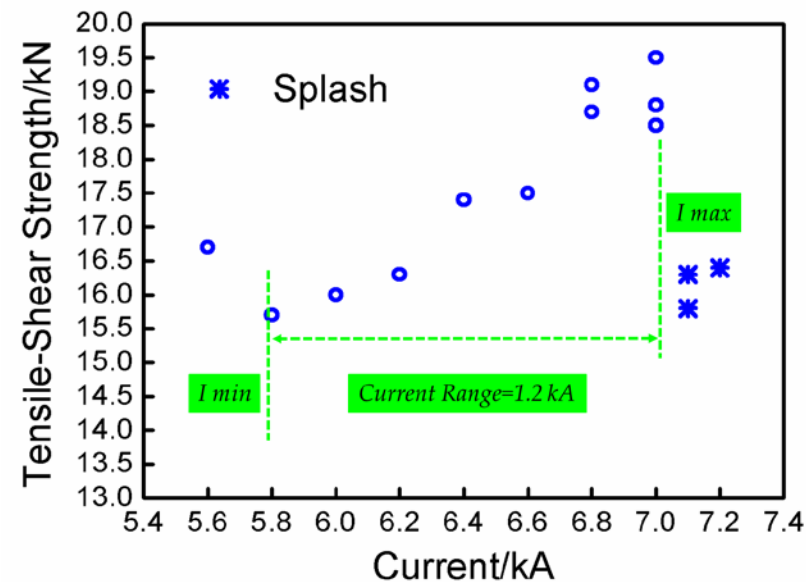
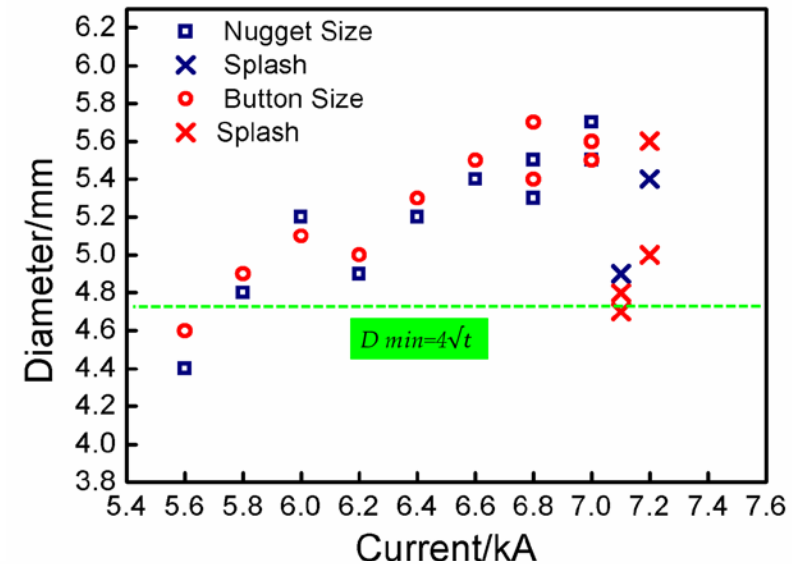


2.0GPa PHS with Slim AlSi-Coating – Integration

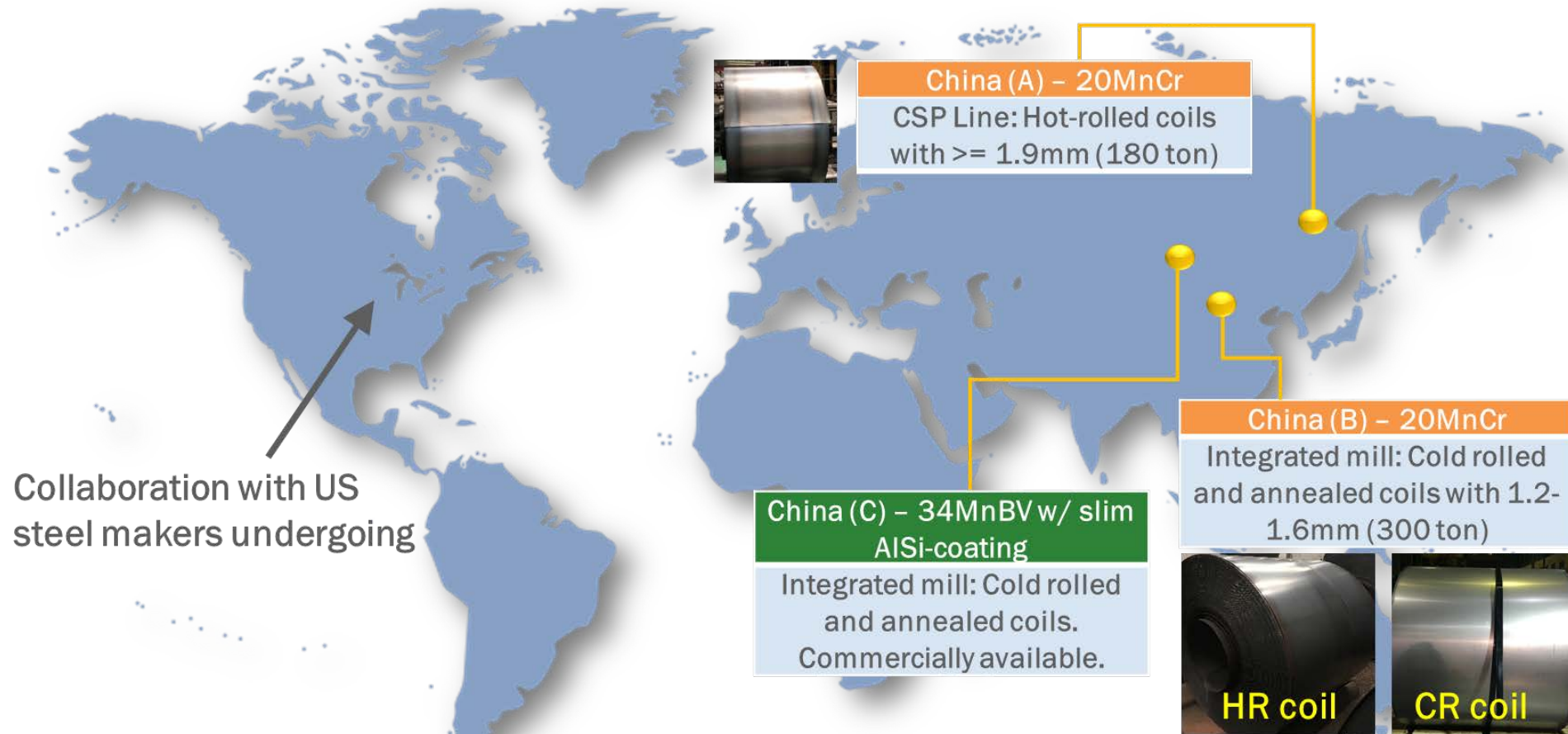
Materials	Thickness	Electrode Diameter	Welding Time	electrode force
34MnBV	1.4mm	5.5mm	380ms	4500N



All specimens were pull-out failure mode



Status of Commercialization – Steel Production

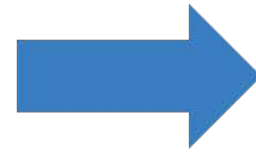


Both the 1.7 and 2.0 GPa steels have been successfully produced via conventional steel making processes.

Status of Commercialization – Component

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

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



Coating-Free PHS 20MnCr



Conventional bare PHS 22MnB5



Summary

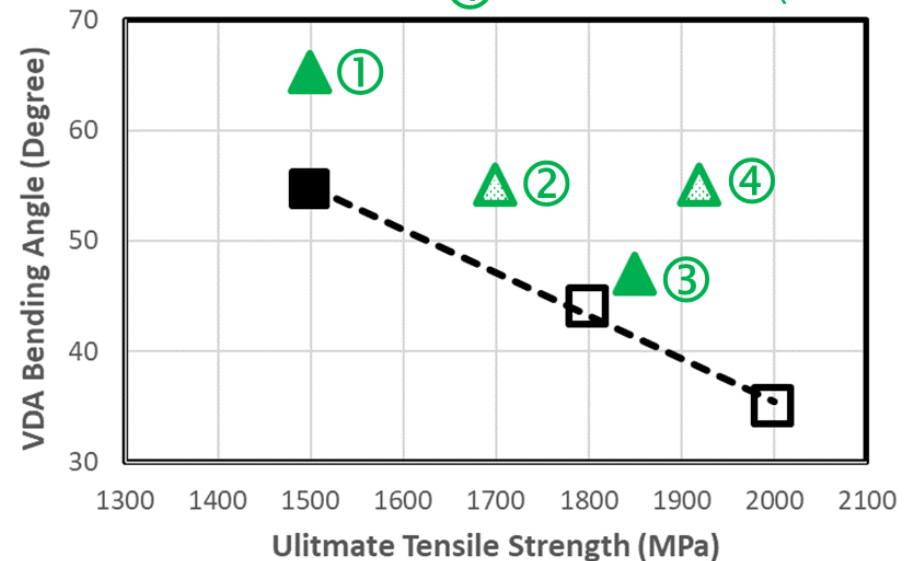
- Novel alloy design concept enables next generation PHS with strength and bendability better than existing commercial grades;
- Combination of higher strength and adequate bendability gives **BETTER energy absorption** of component;
- Enhanced bendability results in higher resistance to delayed fracture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

① Slim ALSi 1.5 GPa (22MnB5)

② Coating-free 1.7 GPa

③ Reg. ALSi 1.8 GPa

④ Slim ALSi 2.0 GPa (34MnBV)



Commercially available and in mass production



Commercially available



Commercially available and in mass production



Development grade



American
Iron and Steel
Institute

THANK YOU

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