

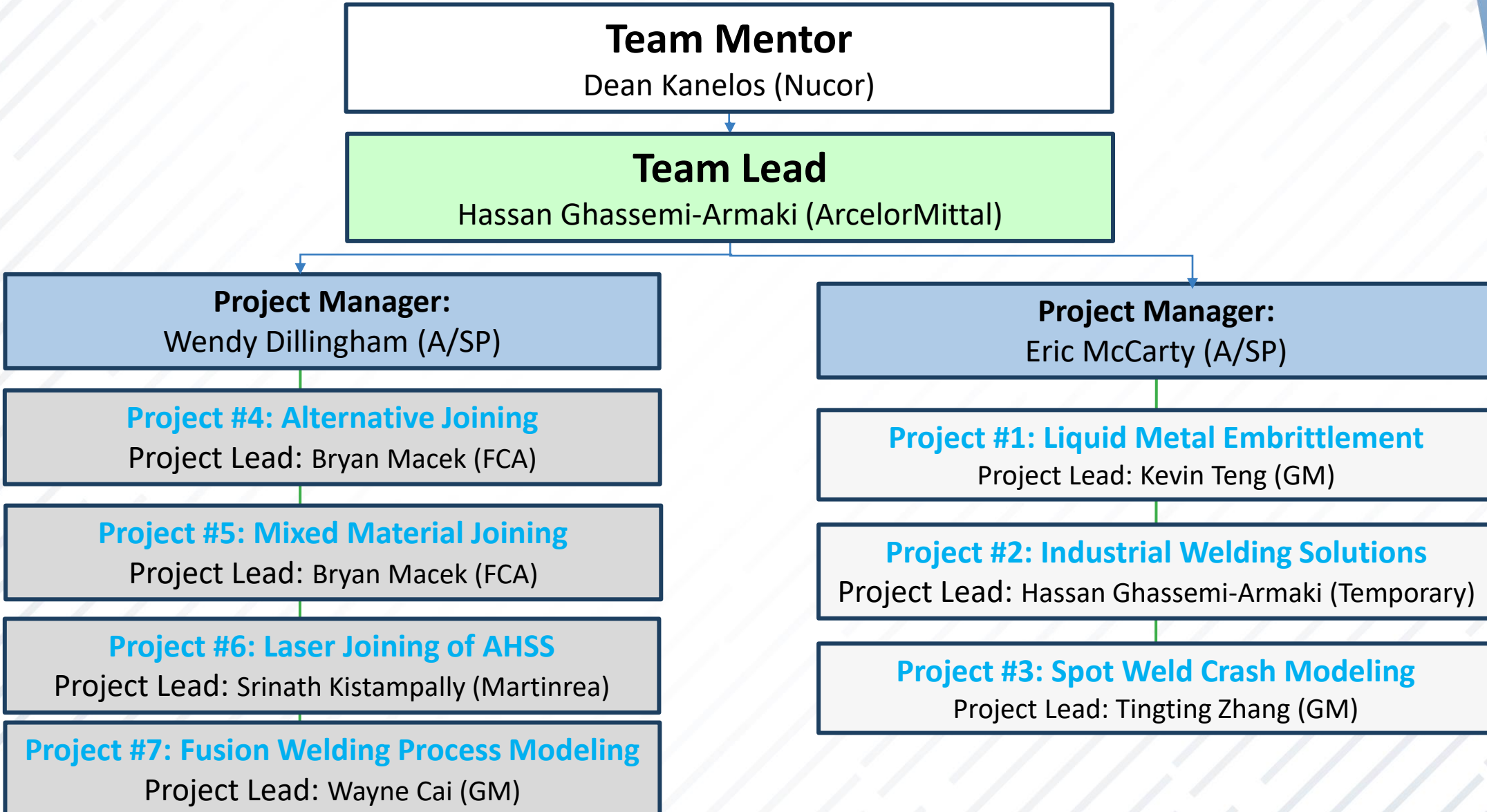
# GREAT DESIGNS IN **STEEL**

## **A/SP INVESTIGATION OF RESISTANCE SPOT- WELDING FOR 3RD GEN AHSS - WELD QUALITY & PERFORMANCE**

Hassan Ghassemi-Armaki, ArcelorMittal Global R&D

Kevin Teng, General Motors

# AUTO/STEEL PARTNERSHIP JOINING PROJECTS



# PUBLICLY AVAILABLE INFORMATION FROM A/SP JOINING TEAM

*A/SP LME Gleeble-Based Testing Procedure - OSU and A/SP*

*LME Evaluation of 3rd Gen. Advanced High Strength Sheet Steels, Hassan Ghassemi-Armaki et al.,  
Joining in Car Body Engineering,. Feb. 2020, MI, USA*

*Rapid Measurement of Liquid Metal Embrittlement, A/SP Research Results Webinar*

*A/SP Rapid LME Test Protocol – Version 2.0*

*Full Presentation Available : <https://www.steel.org/steel-markets/automotive/liquid-metal-research-webinar>*

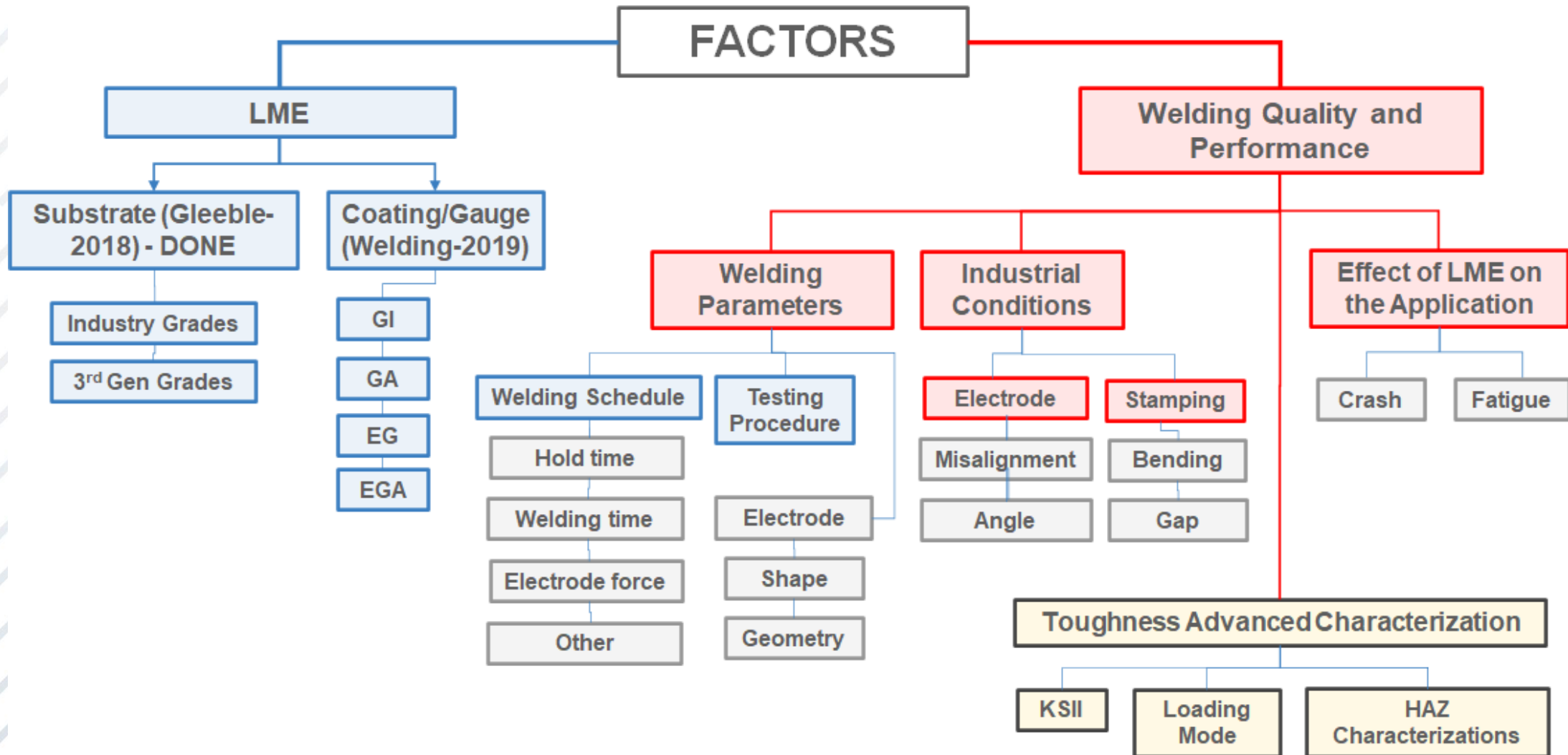
*Mixed Material Joining - A/SP Research Results Webinar*

*Full Presentation Available : <https://www.steel.org/steel-markets/automotive/joining-webinar>*

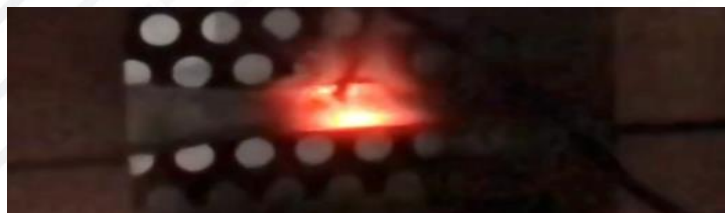
The above links and other resources can be found on the A/SP website:

<https://www.a-sp.org/publications-resources/joining-welding/>

# RSW FACTORS UNDER INVESTIGATION BY A/SP JOINING TEAM

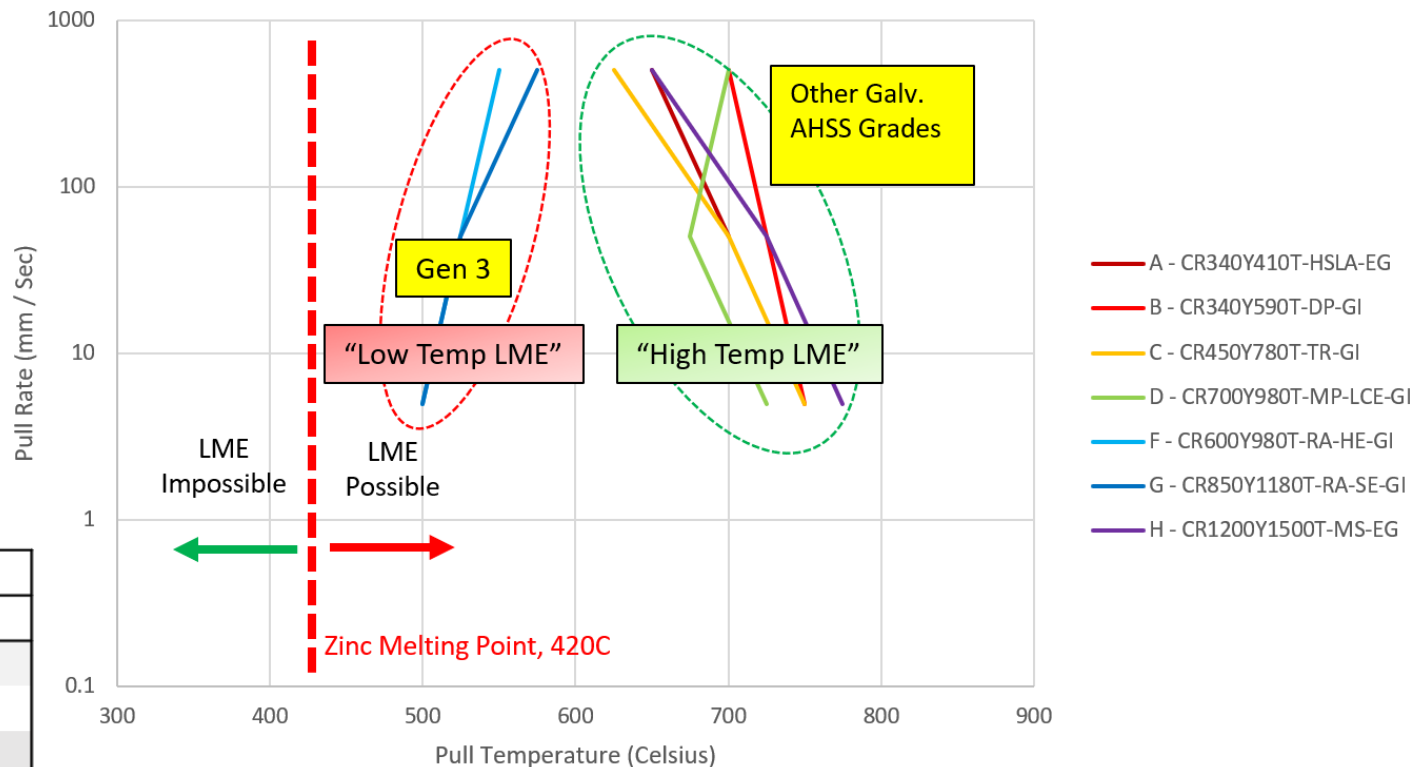


# GLEEBLE TEST DESIGN - LME UNDERSTANDING & SCREENING



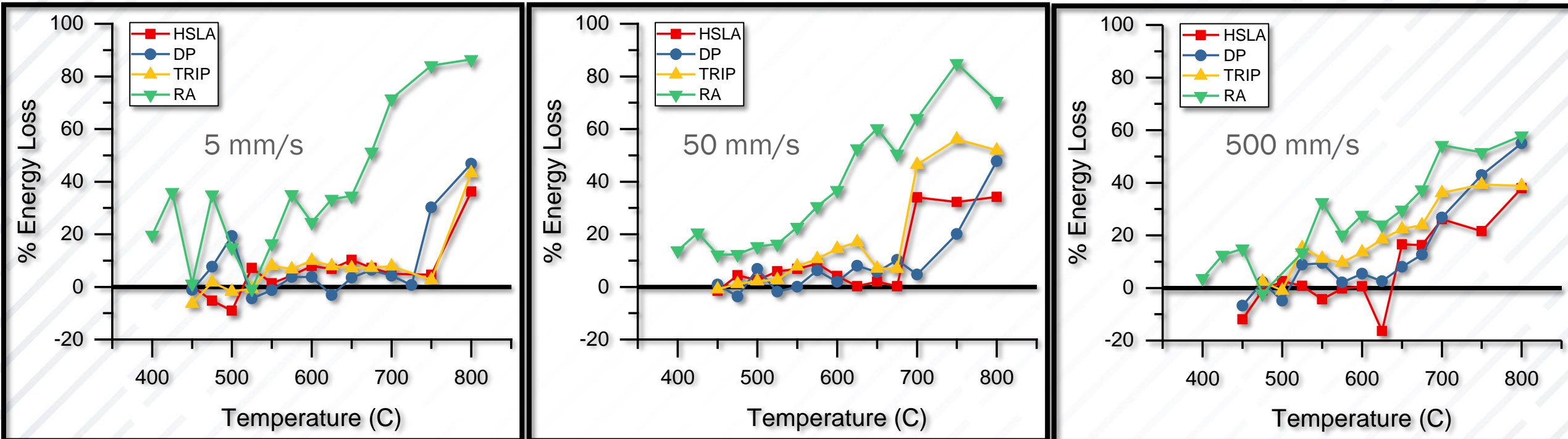
Liquid Metal Embrittlement Cracks

Transition Boundary for Deep LME Cracking  
Temperature vs Tensile Pull Rate for various AHSS grades



Result: Two kinds of LME in autobody steels were identified:  
Low Temperature versus High Temperature

# MATERIAL & STRAIN RATE EFFECT ON DUCTILITY LOST IN GLEEBLE TEST

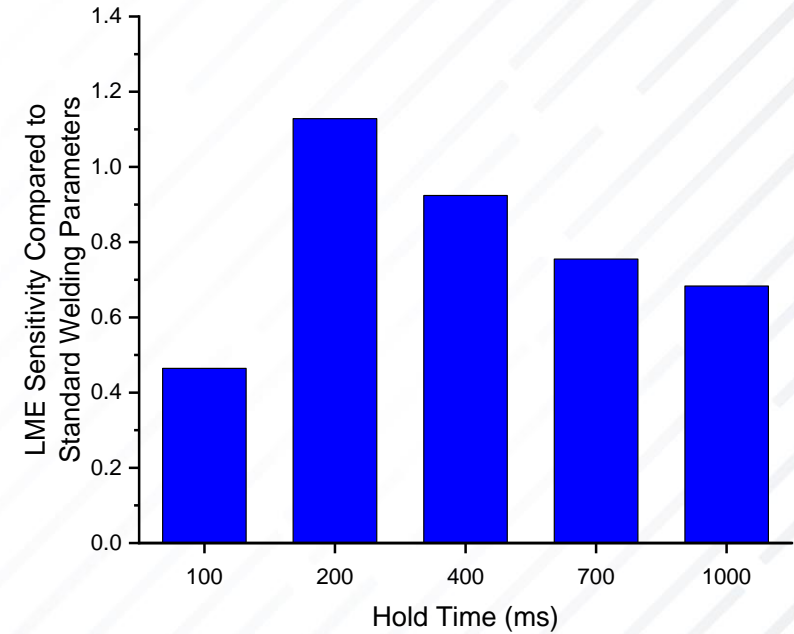
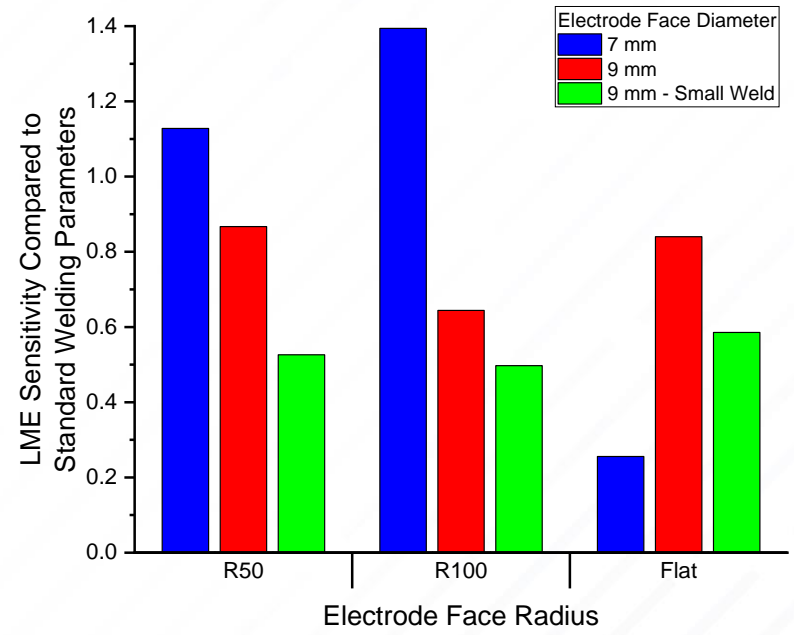
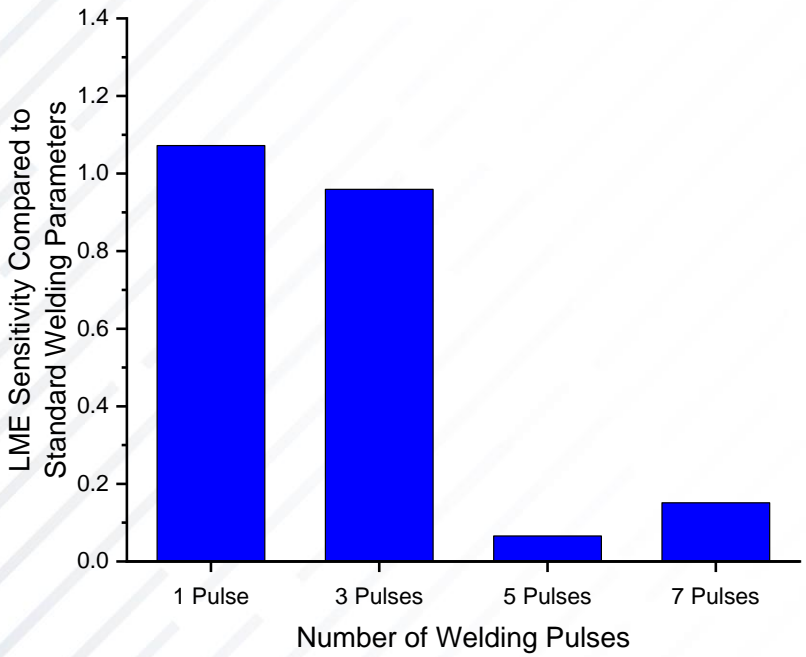


- LME start temperature decreases from Dual Phase (DP) to Transformation Induced Plasticity (TRIP) and Retained Austenite (RA) steels.
- In lower strain rate different between LME between different materials design is more pronounced as compared to when strain rate is higher!
  - Which strain rate is more representative of Resistance Spot-Weld?

# INDUSTRIAL WELDING CONDITIONS

Effect of Welding Parameters on LME - All data for High LME susceptible steel

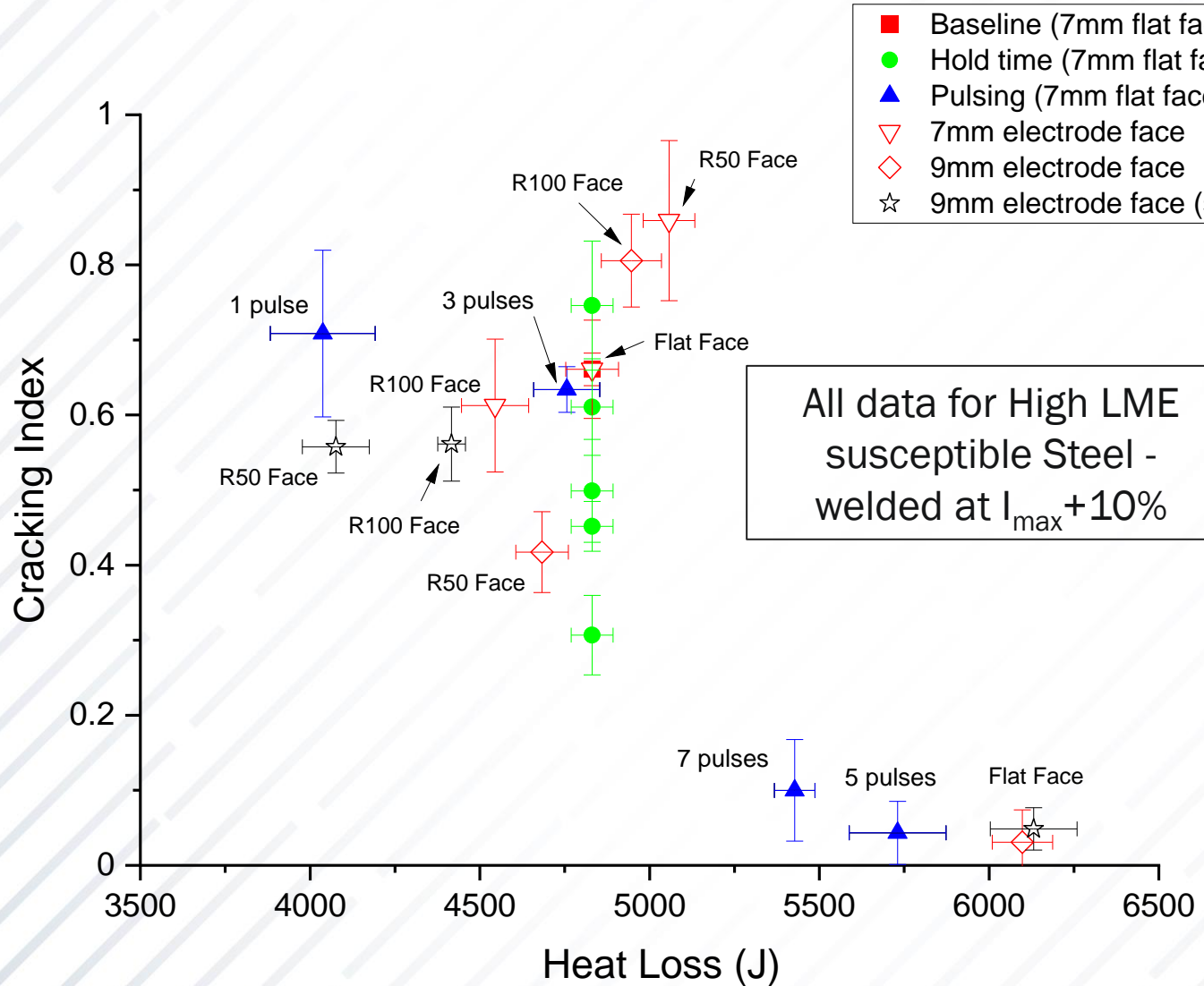
Welded at  $I_{max} + 10\%$



- Increase in number of pulses decreases LME
- Increase in electrode face diameter decreases LME
- Increase in holding time decreases LME slightly

# INDUSTRIAL WELDING CONDITIONS

## Summary of Effect of Welding Parameters on LME



All data for High LME susceptible Steel - welded at  $I_{max} + 10\%$

$$Crack\ Index = \frac{\text{Average Number Of Cracks} \times \text{Lognormal Median Crack Length}}{t}$$

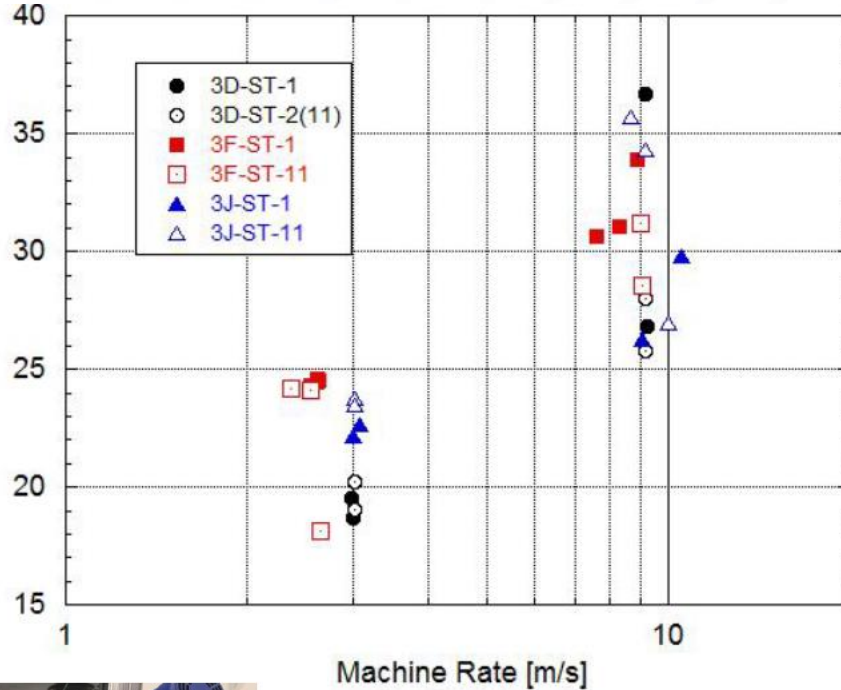
Thickness

E. Wintjes, et al., "Quantifying the Link Between Crack Distribution and Resistance Spot Weld Strength Reduction in Liquid Metal Embrittlement Susceptible Steels," Weld. World, vol. 63, pp. 807-814, 2019.

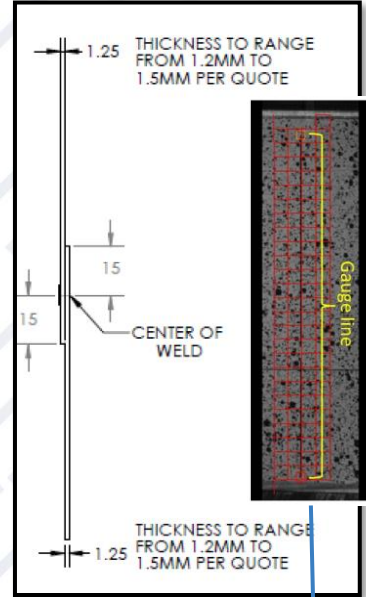
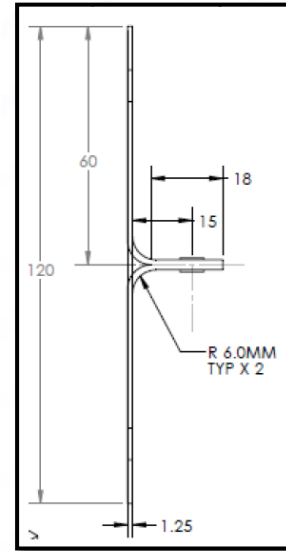
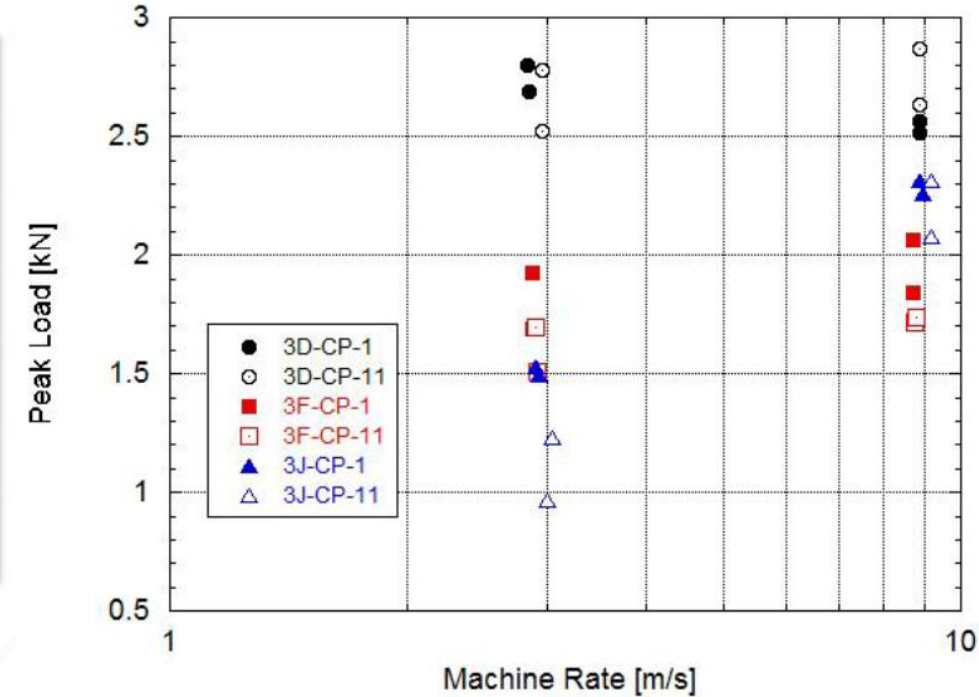
- LME cracking is reduced with higher heat loss
- Lowest cracking was observed with pulsing and large electrodes, which had higher heat loss

# SPOT-WELD CRASH RESPONSE: EFFECT OF HIGH STRAIN RATE

Shear-Tension



Coach-Peel



Machine Rate [m/s]

Machine Rate [m/s]

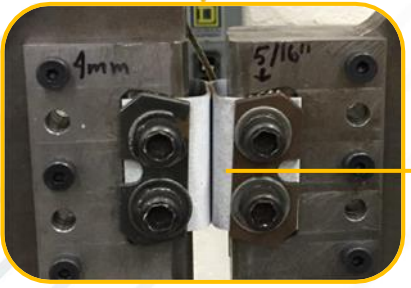
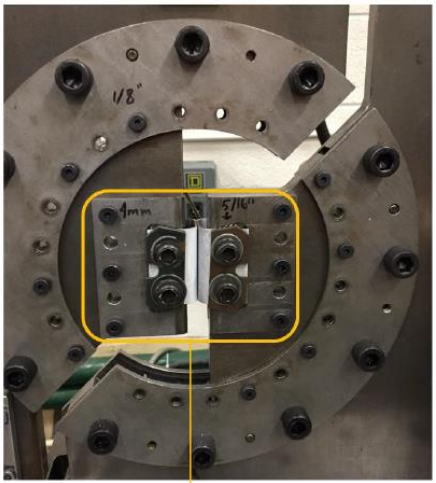
- A gauge length of ~45 mm for the ST-1 and CP-1 specimens, and a gauge length of ~80 mm for ST-2 (11) and CP-2 (11) specimens
- For Shear-Tension (ST), peak loads increased by at least 30% for all three materials between 2.6 m/s and 9 m/s
- For Coach-Peel (CP), the peak loads for 3D and 3F remained the same; 3J showed an increase of 50% in the peak load

D: MP980 -CR700Y980T-MP-LCE-GI  
 F: 3rd Gen 980 -CR600Y980T-RA-HE-GI  
 J: 3rd Gen 1180 - CR850Y1180T-RA-HE-GI

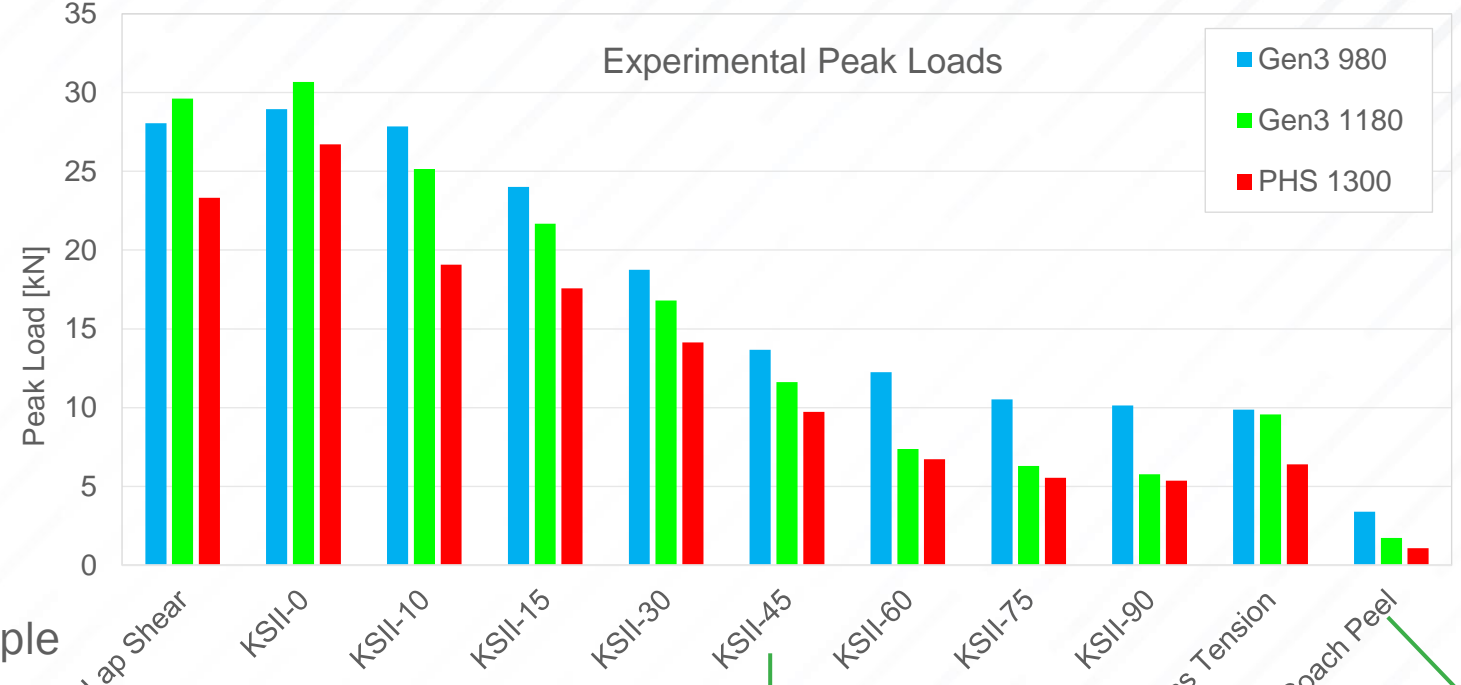


Figure 2. Tension shear test setup

# SPOT-WELD CRASH EXPERIMENTS

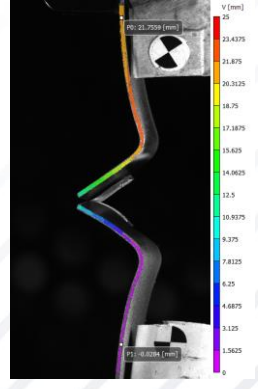
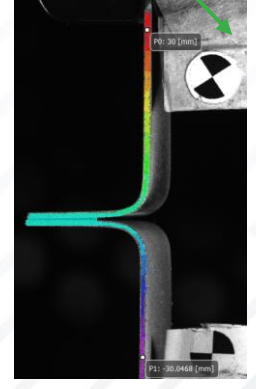
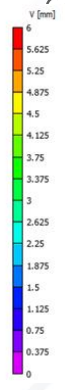
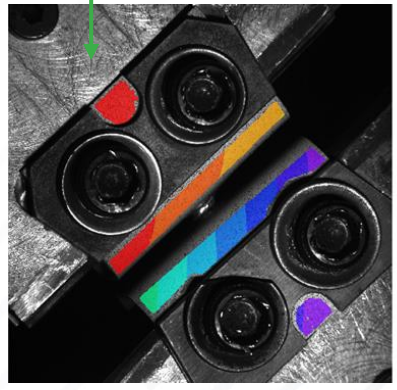
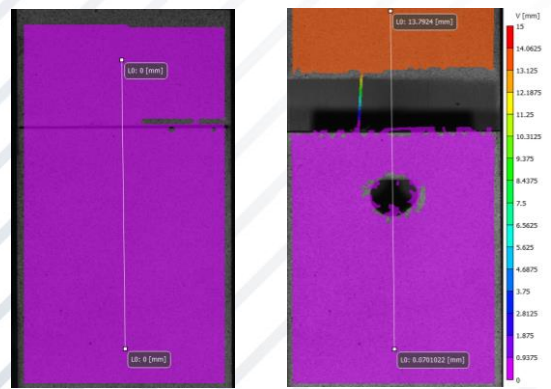


KS-II Sample



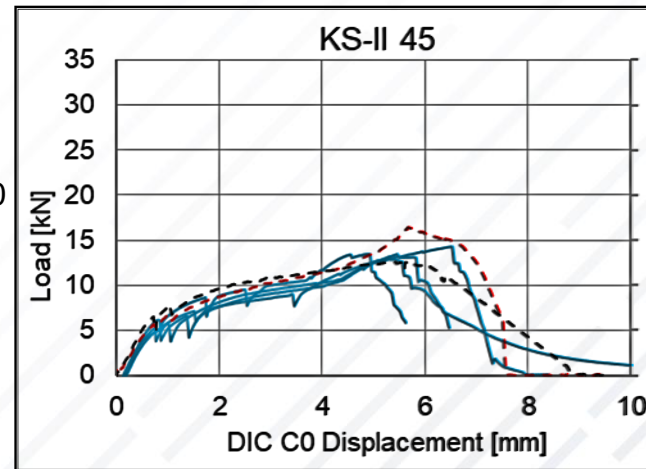
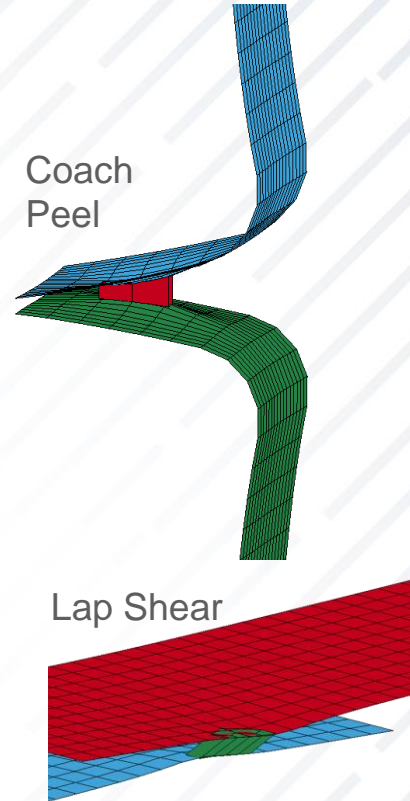
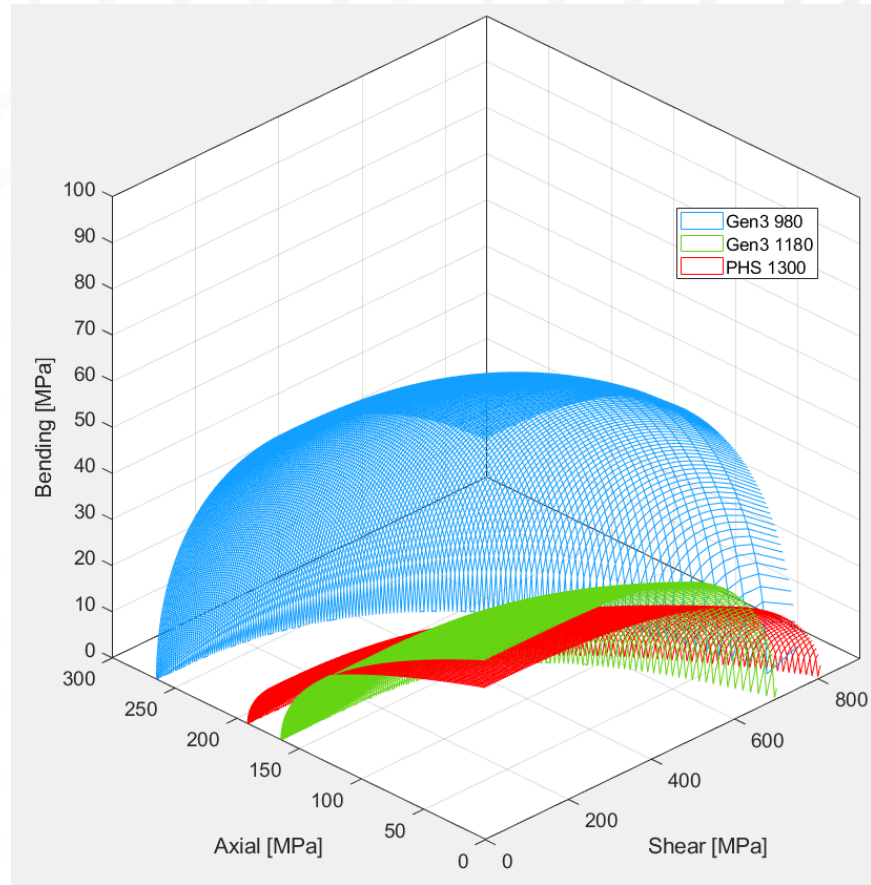
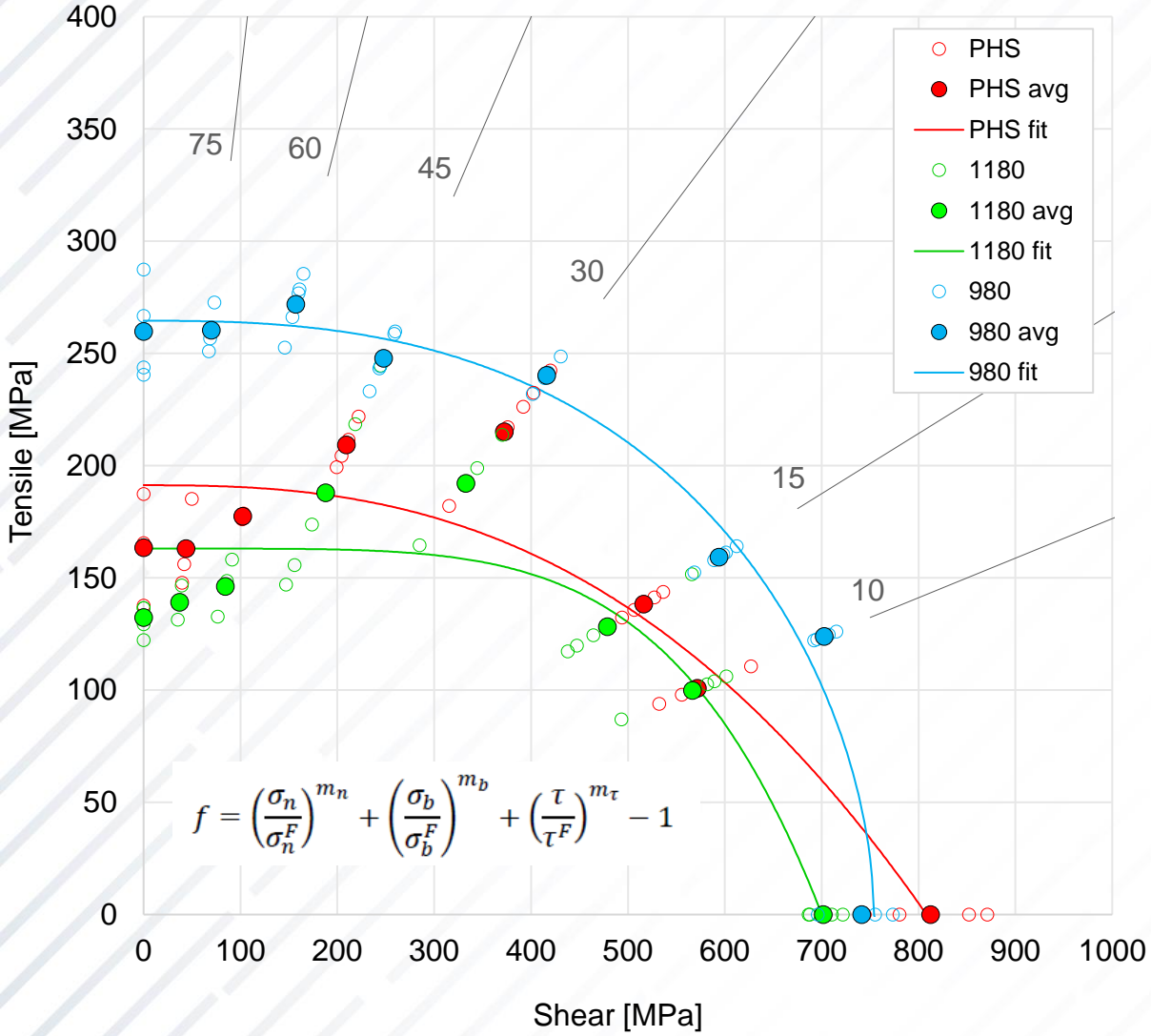
Average Nugget Diameter

PHS 1300	6.47 mm
3rd Gen 980	7.05 mm
3rd Gen 1180	7.46 mm

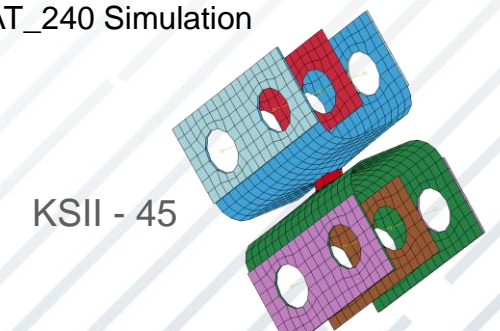


KSII Geometries with different angles and Coach-peel have been designed and tested for three materials; 3rd Gen and Press Hardened Steel (PHS)

# SPOT-WELD CRASH MODELING

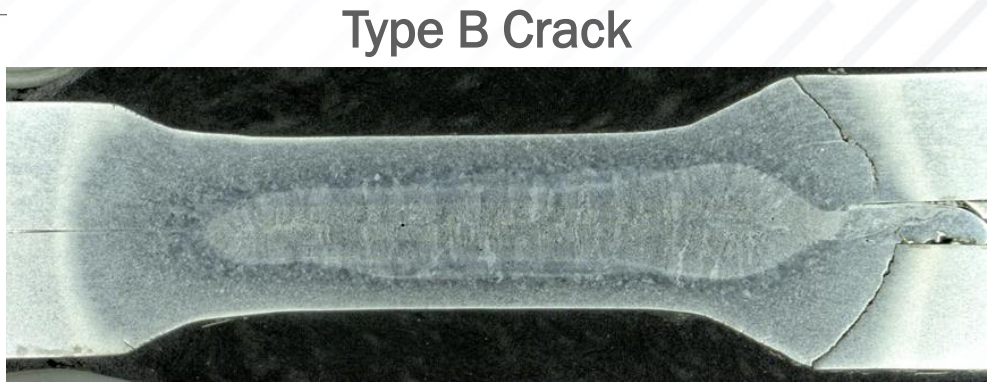
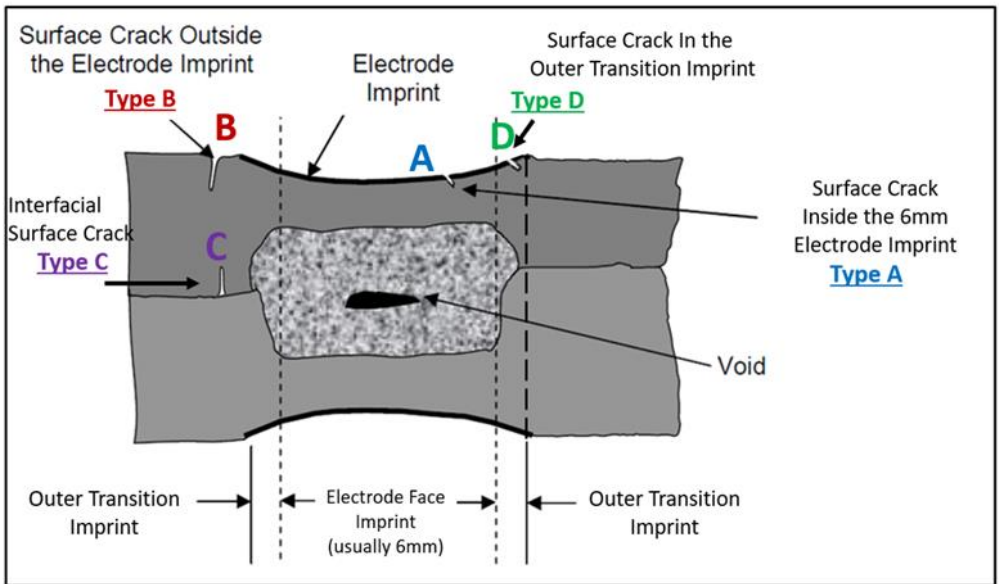


3rd Gen 980 Experimental Data  
 \*MAT\_100DA Simulation  
 \*MAT\_240 Simulation

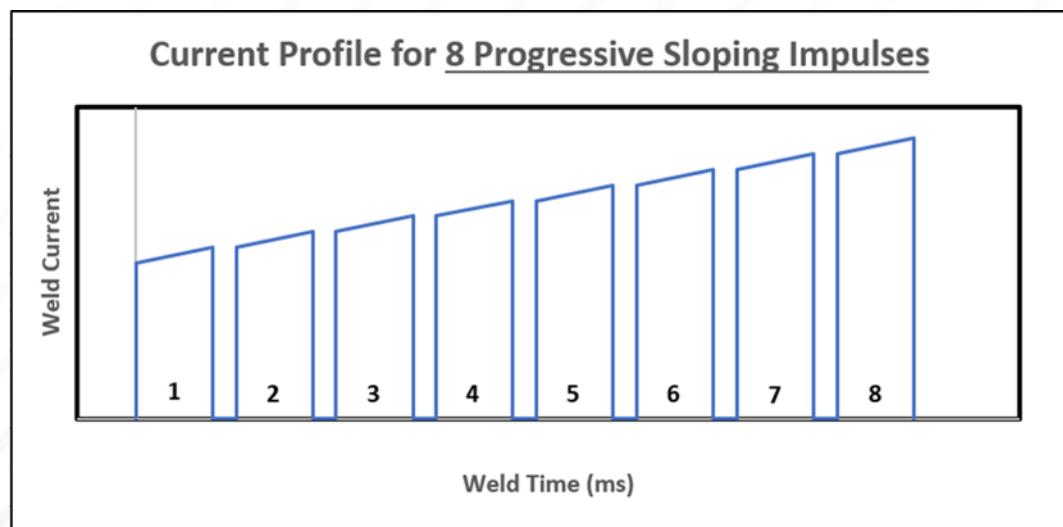
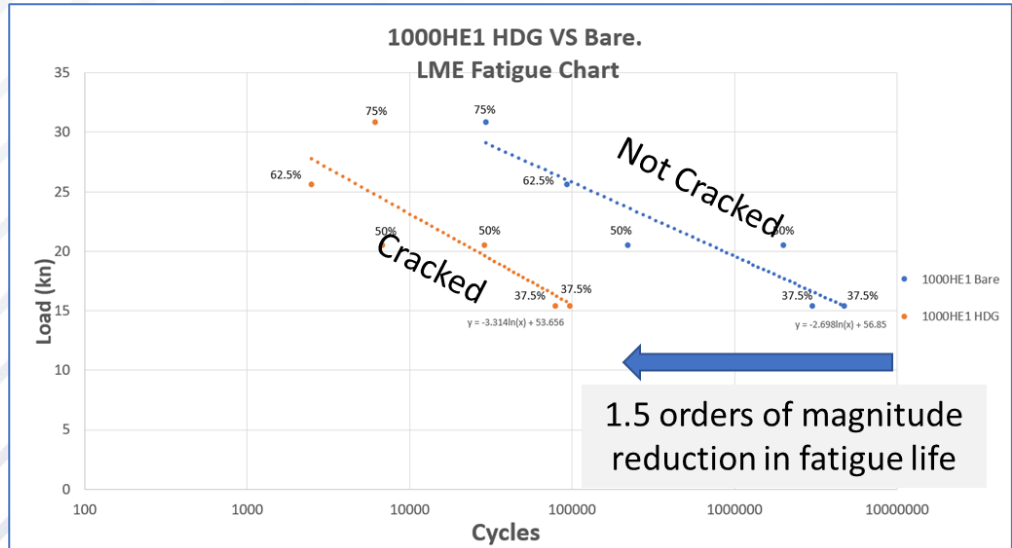


From multi-coupon testing, the 3D failure surface for axial, shear and bending is determined which gives parameters for FEA failure prediction modeling.

# RAPID LME TEST PROCEDURE



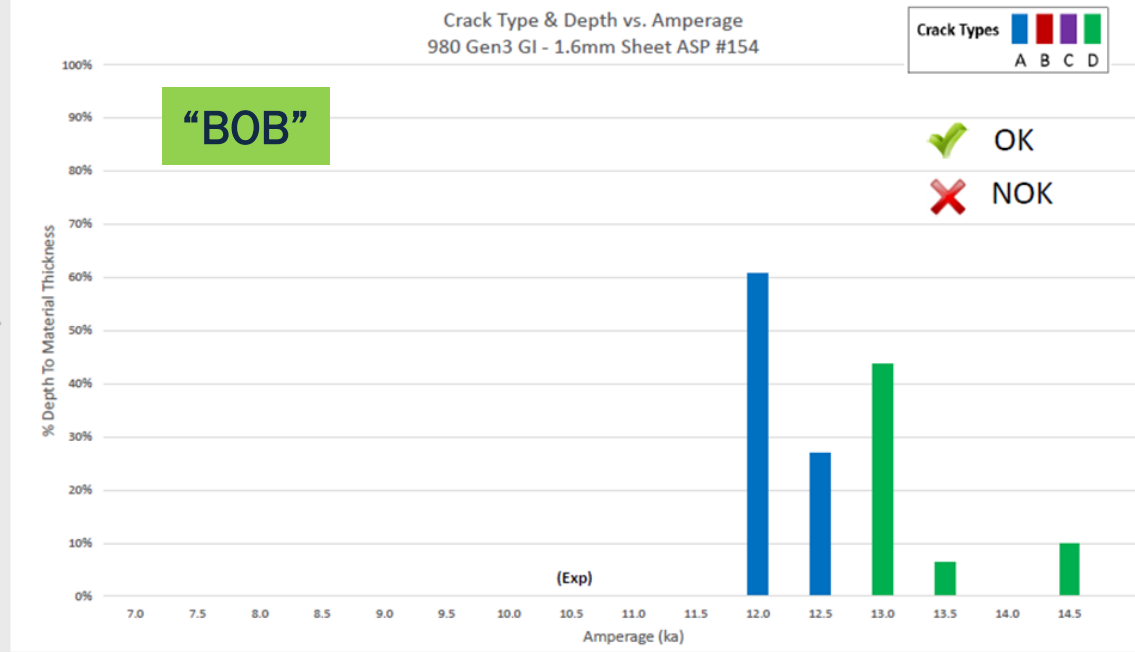
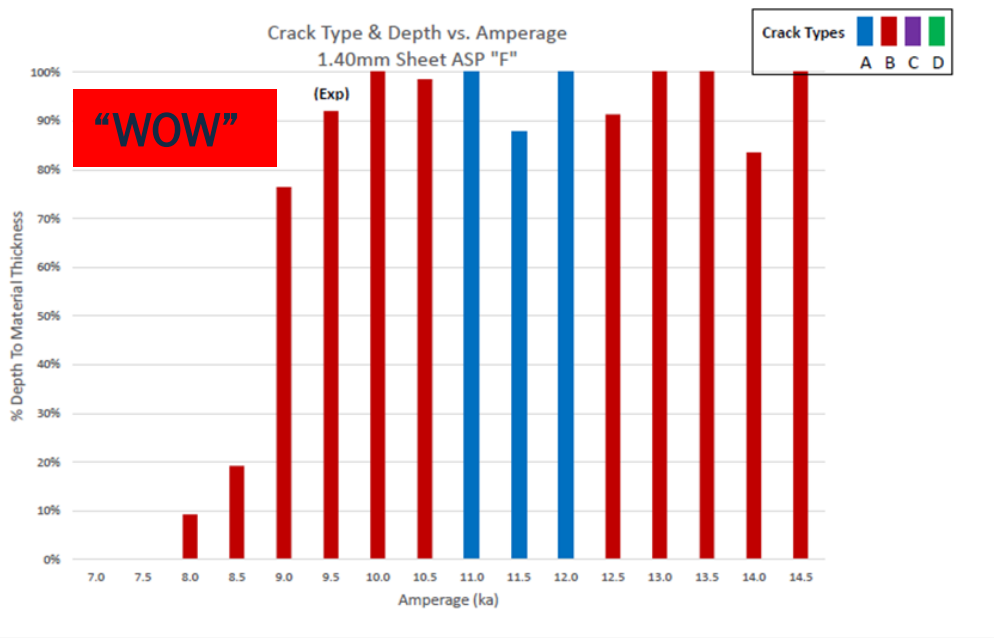
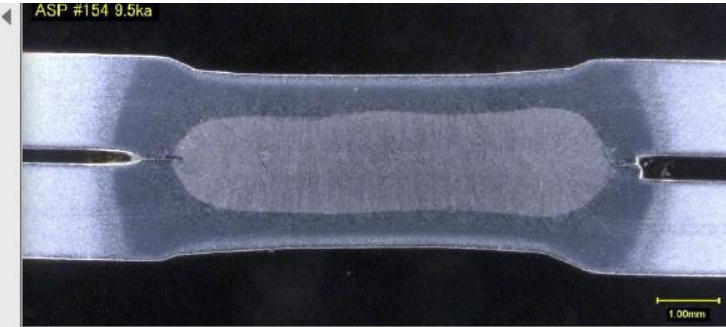
- Four types of LME cracks
- Type B Degrades Weld Strength the Most**
- Progressive sloping pulses to produce type B crack while suppressing expulsion



# TEST RESULTS FOR "WOW" & "BOB" 3RD GEN 980

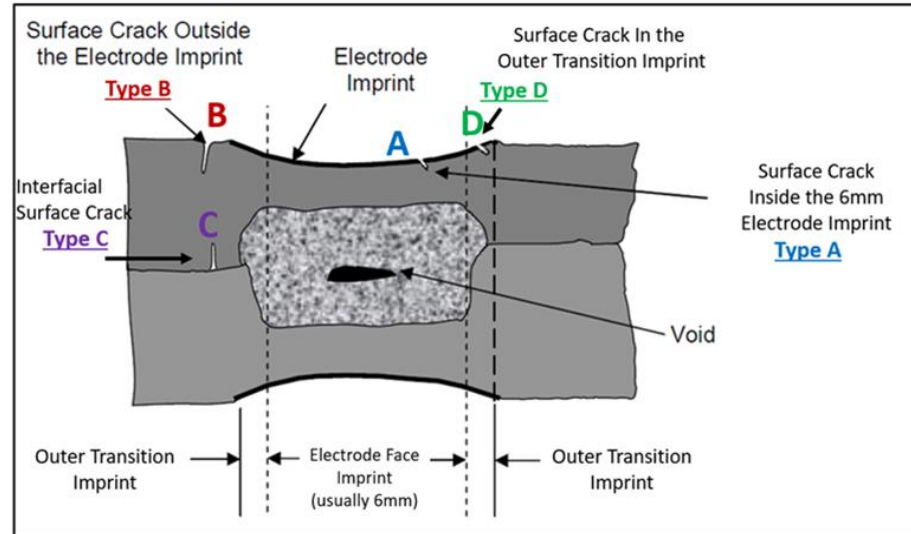


9.5 kA



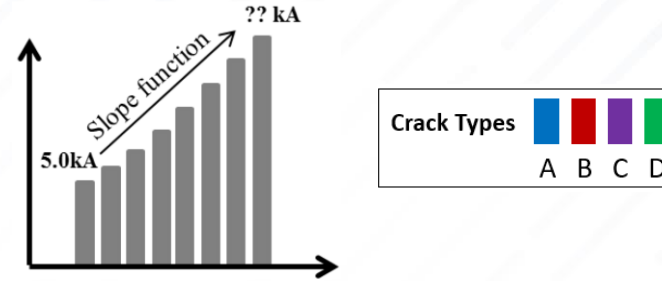
Compare crack depth and type at each current level

# ACCEPTANCE CRITERIA



4 Crack Types by Relative Temperature:				
	Type A	Type B	Type C	Type D
<b>Relative Test Current</b>	<b>High Temp LME (&gt;650C)</b>	<b>Low Temp LME (&lt;650C)</b>	<b>Interfacial LME (? rare)</b>	<b>Threshold Temp LME (~650C)</b>
Below Expulsion	> 10% NOK	> 5% NOK	> 5% NOK	> 5% NOK
At (or above) Expulsion	OK	> 5% NOK	> 5% NOK	> 10% NOK

# RAPID LME: 3RD GEN AHSS EVALUATION



## LME Test Log Sheet

As of September 25, 2019

Test Amperage (ka)

Grade	Thick	Coat	Lot #	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	LME ka Rating		
CR980T/600Y-RA-HE	1.0	EG	161					EXP	50%	5%	30%	30%	30%	20%	40%	50%	40%	50%		0.5 D		
	1.6	EG	163				5%	10%	EXP 80%	40%	20%	10%	10%	40%	60%	100%	60%	60%	100%	-1.0 D		
	1.0	GI	155								EXP 20%						5%	40%			0.0 D	
	1.6	GI	154								EXP				60%	30%	40%	5%		10%	2.5 D	
	1.4	GI	116 "F"				10%	20%	80%	EXP 90%	100%	100%	100%	90%	100%	90%	100%	100%	90%	100%	-1.5 B	
	1.0	GA	tbd 3																			
	1.6	GA	tbd 4																			

CR1180T/850Y-RA-SE	1.0	EG	tbd 1							EXP 70%	10%	10%	70%	40%	20%	60%	20%		40%		0.0 B	
	1.6	EG	tbd 2									EXP 70%	30%	90%	80%	40%	40%	70%	10%		0.0 B	
	1.0	GI	166			20%	60%	60%	60%	60%	60%	EXP 10%	80%	20%	40%	20%	40%	60%	50%	50%	-3.5 B	
	1.6	GI	107	10%	20%	40%	50%	50%	60%	100%	80%	EXP 4%	100%	60%	70%						-4.0 B	
	1.5	GI	"G"				10%			EXP 40%	70%	80%	30%	10%	60%	60%	20%	10%	50%	60%	-1.0 B	
	1.0	GA	tbd 5																			
	1.6	GA	tbd 6																			

# RAPID LME STUDY SUMMARY

- ❑ The rapid LME susceptibility screening test was successfully developed for two-thickness (2t) homogenous joints:
  - Improved alignment with the spot-welding process
  - Lower cost
  - Reduced test time
  - Validated across a variety of 3rd Gen AHSS
  - Correlated well with Gleeble test results for the same steels
  - A/SP Rapid LME Test Protocol – Version 2.0 [Available Here](#)
  
- ❑ The Results indicate a wide spectrum of LME sensitivity currently exists in the 3rd Gen AHSS supply base
  
- ❑ Phase 3: Industrial stackup LME study
  - Future work will focus on expanding the Rapid LME Test to include heterogeneous joints, 3t joints, and eventually industrial welding factors.

# ACKNOWLEDGMENT

The Auto/Steel Partnership gratefully acknowledges the contributions of the University of Waterloo and Ohio State University.

# FOR MORE INFORMATION



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