GREAT DESIGNS IN STEEL

Gas Metal Arc Brazing – LME Susceptibility

Justin Hunt

Materials Engineer - Welding

Stellantis

(Presenting for Auto/Steel Partnership)

A/S P

A/S P Auto/Steel Partnership

Members

gm

NUCOR

Gestamp

posco

MARTINREA

STELLANTIS

MAGNA

Ternium

METALSA

TOYOTA

PROJECT TEAM MEMBERS

GDIS

JPC Project Mentor: Dean Kanelos, Nucor
Project Leader: Justin Hunt, Stellantis
Project Manager: Michael White, A/SP

Project Team Members:

- Spyros Mellas, General Motors Company
- Cory Taulbert, General Motors Company
- Len Peschansky, General Motors Company
- Dean Kanelos, Nucor Corporation
- Weiping Sun, Nucor Corporation
- Jiwoong Ha, POSCO America
- Gyuyeal Bae, POSCO America
- Mark Fistler, Stellantis
- Joseph Beckham, Stellantis
- Jose Luis Galaviz, Stellantis
- Carlos Carballido, Ternium
- Ernesto DiLibero, Ternium
- Juan Pablo Pedraza, Ternium

Project Details

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Project Objective / Problem Statement:

- Assess the suitability of the GMAW of AHSS Team Ring Fillet Gas Metal Arc Brazing (GMAB) LME test method as a general liquid metal embrittlement (LME) susceptibility indicator.

Project Details

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Goals:

- Refine a previously conceived A/SP LME test method and conduct testing to determine LME susceptibility of selected HSLA steel, AHSS, and 3rd Generation AHSS. Determine the effect of LME cracking on quasi-static peak load and fatigue life of ring fillet GMAB joints.

Participants:

AET Integration

Project Approach

- Gas metal arc brazing is used in combination with a circular ring fillet (plug) joint geometry to produce extensive LME cracking for simple, quantitative determination of LME susceptibility.

- Correlation of A/SP Joining Team existing and future RSW Rapid LME to A/SP GMAW of AHSS Team Ring Fillet GMAB LME test data may allow a threshold GMAB LME cracking limit to be determined which, if exceeded, could indirectly indicate risk of RSW and GMAW LME crack susceptibility.

Project Approach – Test Matrix

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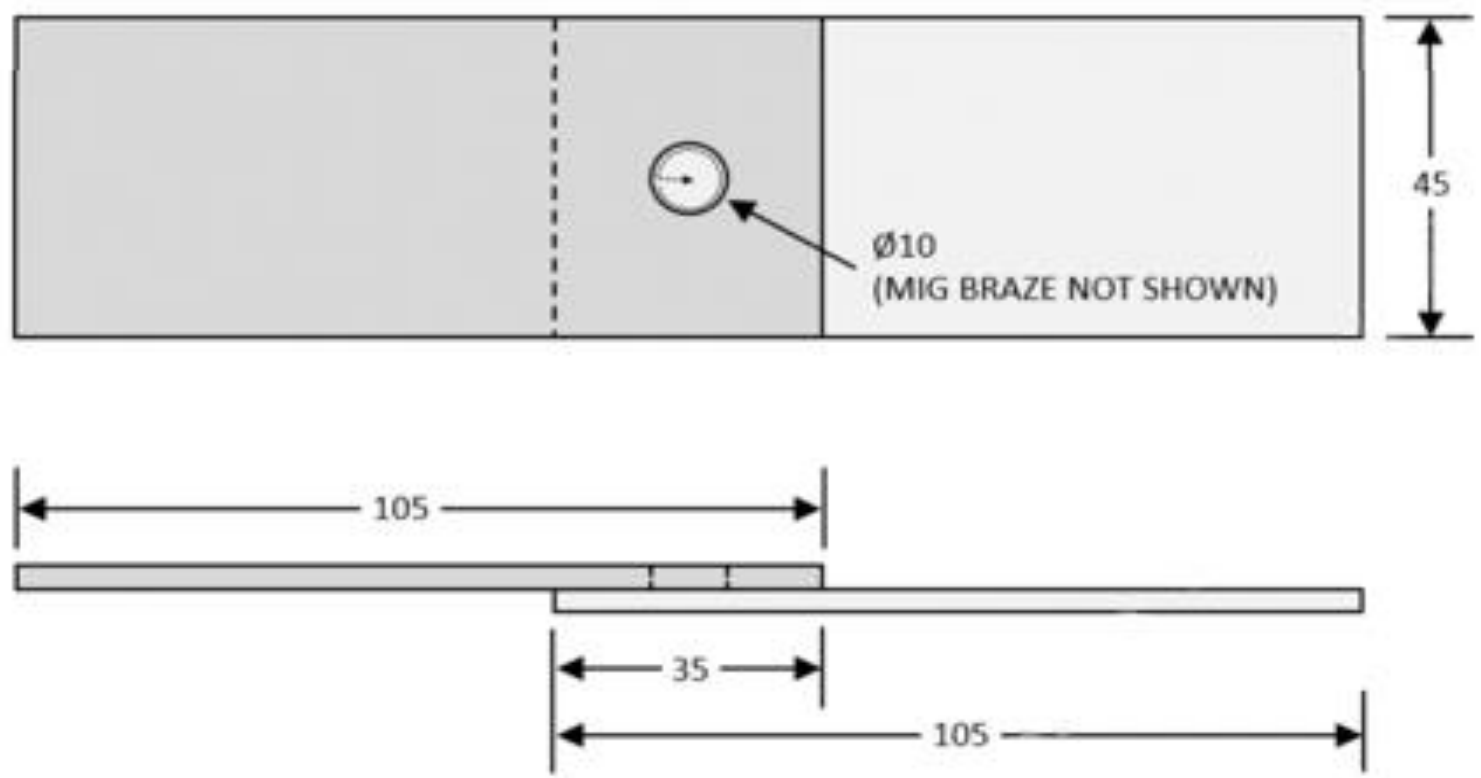
Lot #	Nominal Thickness (mm)	Steel Grade	Normalized Heat Input (kJ/mm)	LME Faying Surface Inspection	Metallurgical	Quasi-Static	1,000 - 10,000 Cycle Fatigue	200,000 - 1,000,000 Cycle Fatigue
184	1.5	CR400Y590T-DP-SE-GI	3	5	1	-	-	-
			7	5	1	-	-	-
212	1.2	CR340LA-SE-GI	3	5	1	-	-	-
			7	5	1	-	-	-
55	1.4	CR420Y780T-DP-SE-GI	3	5	1	-	-	-
			7	5	1	-	-	-
168	1.6	CR600Y980T-RA-HE-GI	3	5	1	3	5	5
			7	5	1	3	5	5
		CR600Y980T-RA-HE-UC*	3	5	1	3	5	5
			7	5	1	3	5	5
134	1.6	CR600Y980T-RA-HE-GI	3	5	1	-	-	-
			7	5	1	-	-	-
107	1.6	CR1000Y1200T-RA-SE-GI	3	5	1	-	-	-
			7	5	1	-	-	-

* Uncoated condition achieved through stripping of zinc coating prior to MIG brazing

LME susceptibility can be determined with five to ten test samples

Project Approach – Test Specimen Dimensions



Dimensions in mm

Normalized Heat Input Equation

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$$Qn = \frac{2.185X10^{-4}(VAD)}{St}$$

Where,
V = measured volts
A = measured amps
D = weld path diameter (8 mm)
S = travel speed (m/min)
t = sheet thickness (mm)

Qn represents the total heat input normalized to sheet thickness (kJ/mm)

Joining Process

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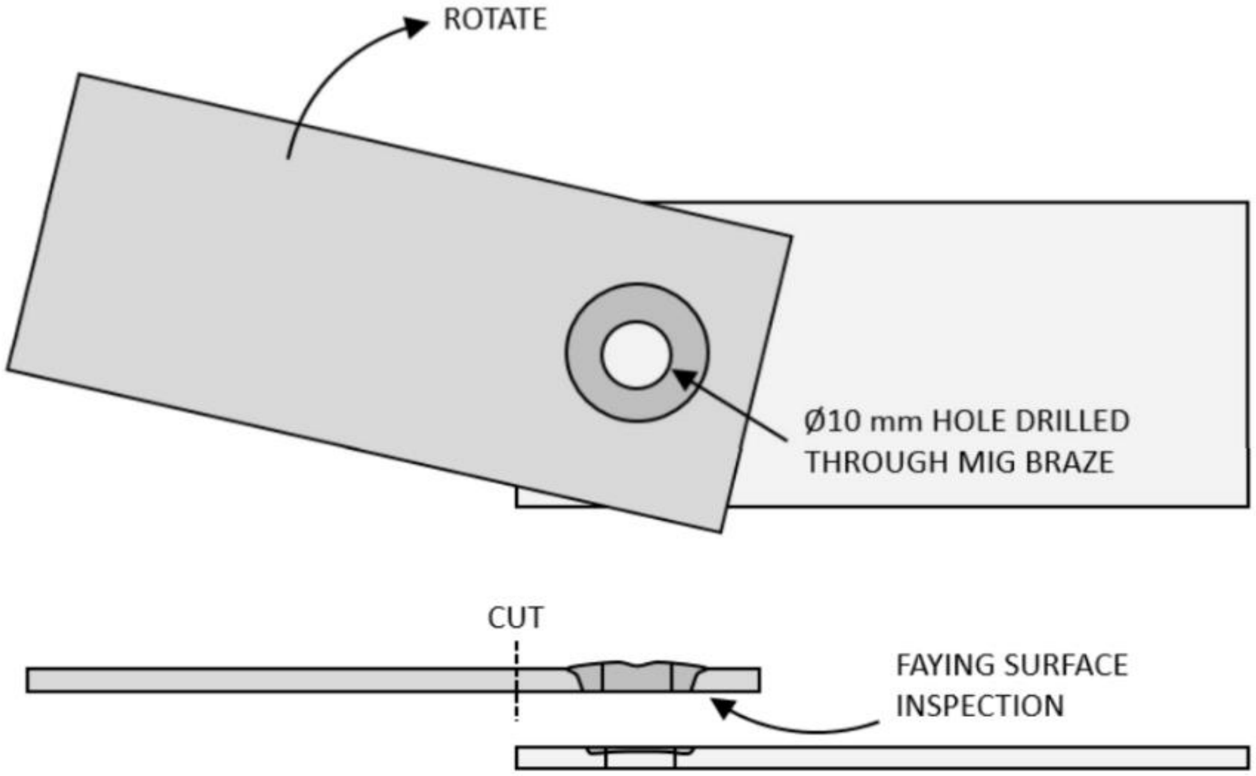
- Gas Metal Arc Brazing
  - 1.0 mm ER CuAl-A1 filler wire
  - 100% Argon Shielding gas
- Parameters

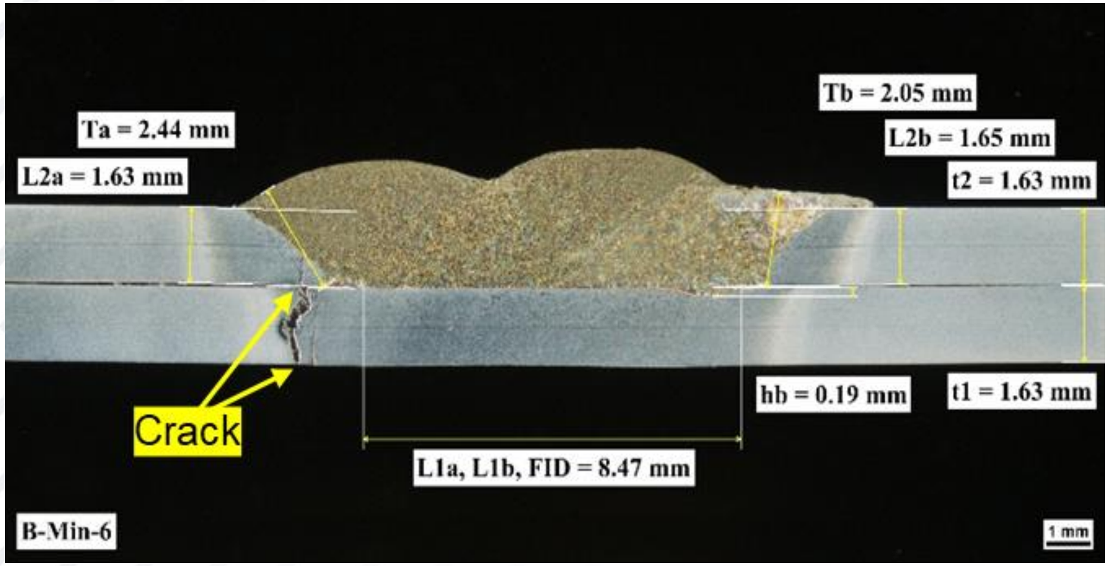
Material	Brazing Current (A)		Voltage (V)		Travel Speed (m/min)
	MIN	MAX	MIN	MAX	
1.2 mm CR340LA-SE-GI (Lot 212)	79	138	13.4	17.4	0.5
1.5 mm CR400Y590T-DP-SE-GI (Lot 184)	88	177	14.6	17.0	0.5
1.4 mm C420Y780T-DP-SE-GI (Lot 55)	88	158	13.7	17.7	0.5
1.6 mm CR600Y980T-RA-HE-GI (Lot 168)	98	179	14.1	17.9	0.5
1.6 mm CR600Y980T-RA-HE-UC* (Lot 168)	95	180	14.2	17.9	0.5
1.6 mm CR600Y980T-RA-HE-GI (Lot 134)	97	178	14.5	17.8	0.5
1.6 mm CR1000Y1200T-RA-SE-GI (Lot 107)	97	180	14.4	17.9	0.5
Normalized Heat Input (kJ/mm)	3	7	3	7	

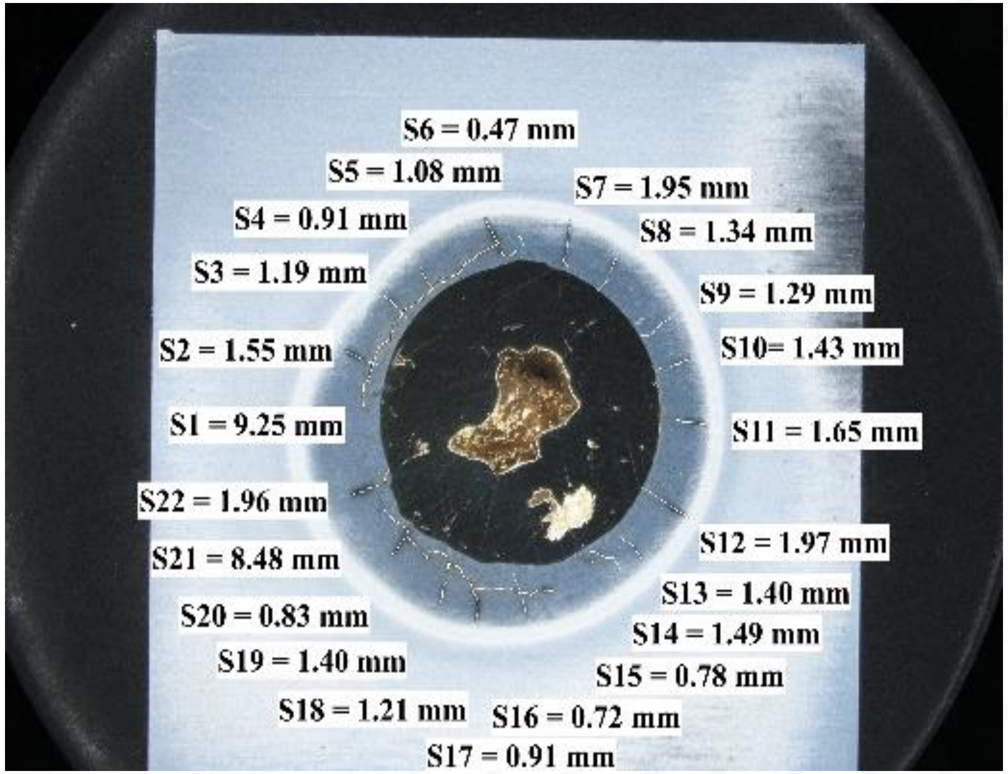
Schematic of Faying Surface Inspection



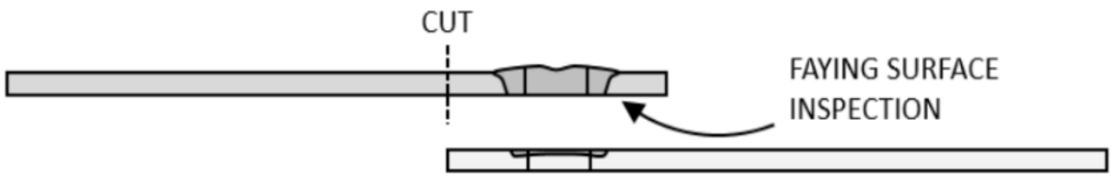
Samples are separated to expose cracks visible in the heat affected zone on the faying surface of the top sheet. Cracks on the entire faying surface of the sample are completely exposed and easily measurable. This eliminates the risk of non-detection inherent to other methods that rely on a single cross-section inspection plane.

Inspection Example – 3 kJ/mm



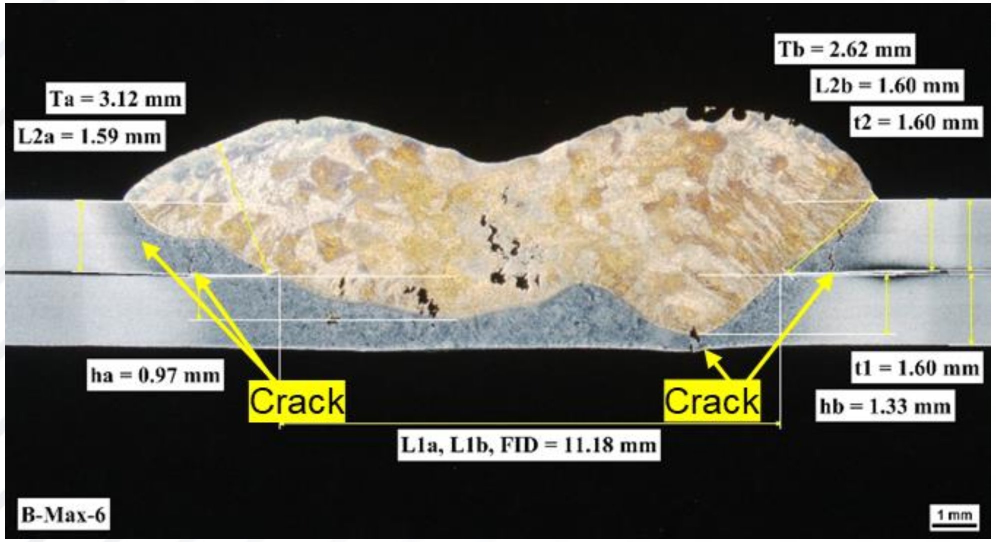


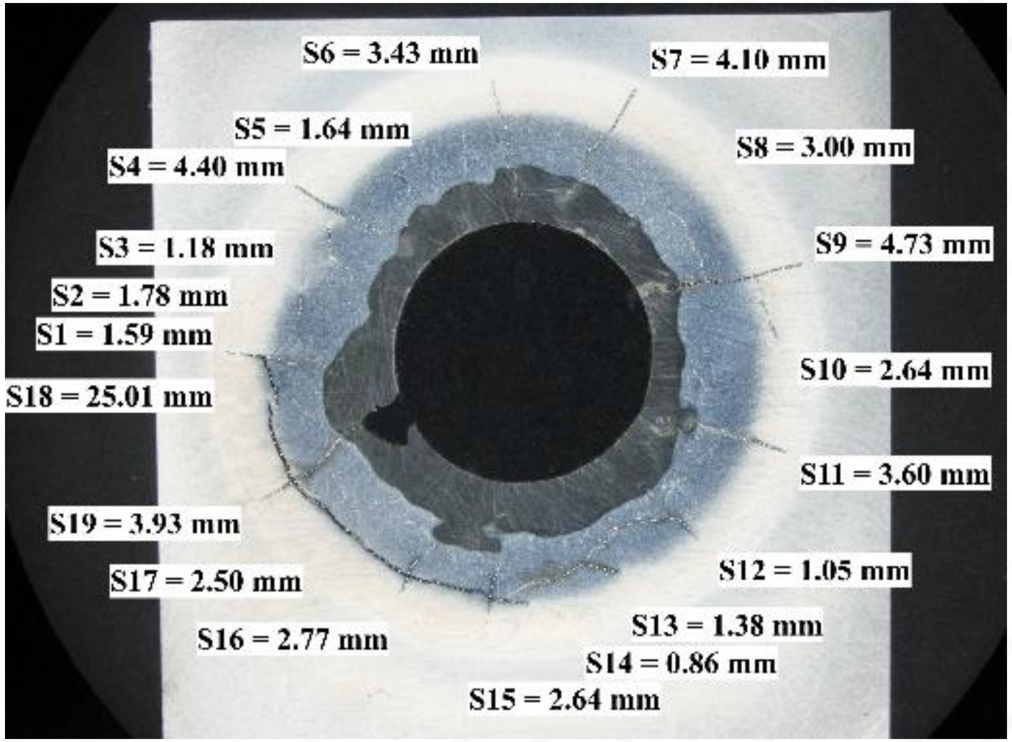
1.6 mm CR1000Y1200T-RA-SE-GI (Lot 107)

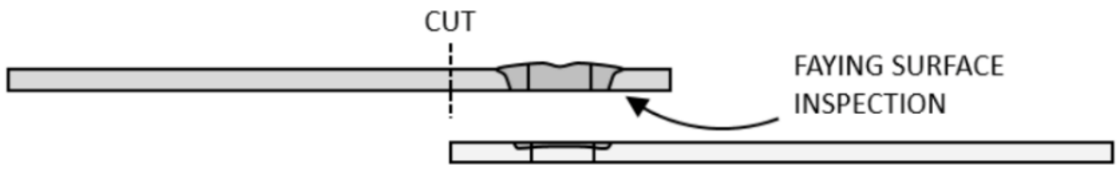


Faying surfaces are polished and etched. Total crack length is measured.

Inspection Example – 7 kJ/mm







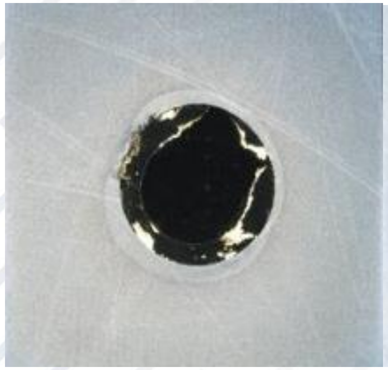
1.6 mm CR600Y980T-RA-SE-GI (Lot 134)

Faying surfaces are polished and etched. Total crack length is measured.

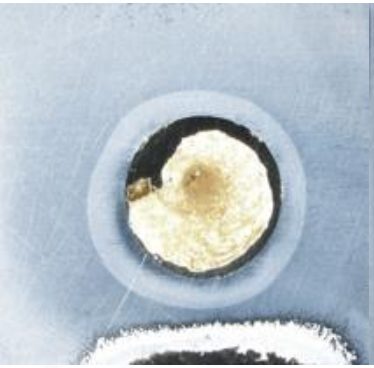
Faying Surface Inspection Examples – 3 kJ/mm

GDIS

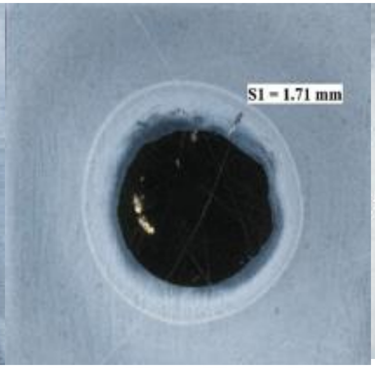
1.2 mm
CR340LA-SE-GI
(Lot 212)



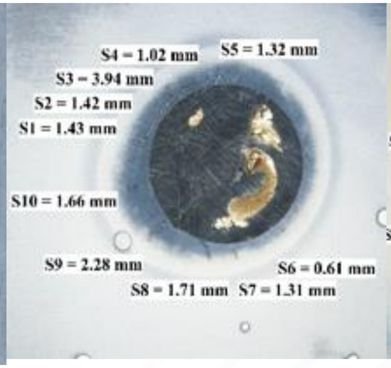
1.5 mm
CR400Y590T-DP-SE-GI
(Lot 184)



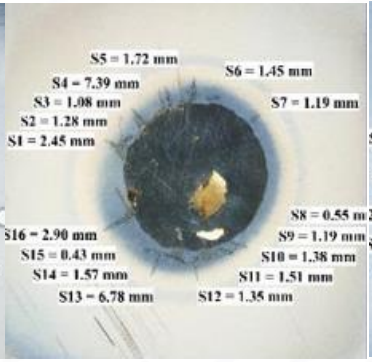
1.4 mm
CR420Y780T-DP-SE-GI
(Lot 55)



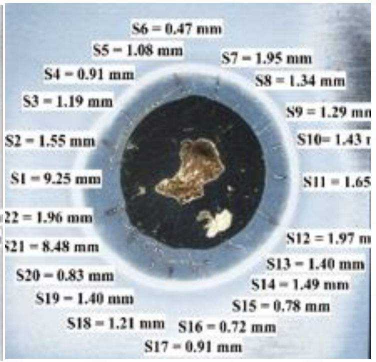
1.6 mm
CR600Y980T-RA-HE-GI
(Lot 168)



1.6 mm
CR600Y980T-RA-HE-GI
(Lot 134)



1.6 mm
CR1000Y1200T-RAHE-GI
(Lot 107)

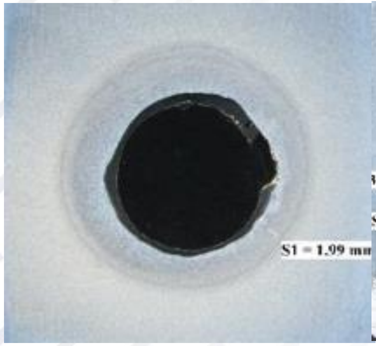


- At the low heat input level of 3 kJ/mm, LME cracking was observed in the 3rd Generation steels tested.
- Minor LME cracking was observed in the CR420Y780T-DP-SE-GI steel.

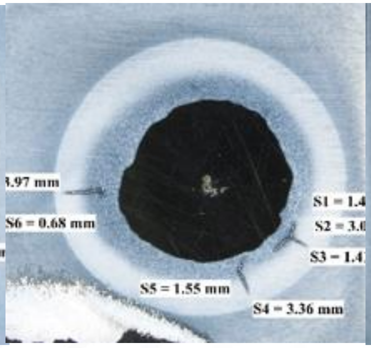
Faying Surface Inspection Examples – 7 kJ/mm

GDIS

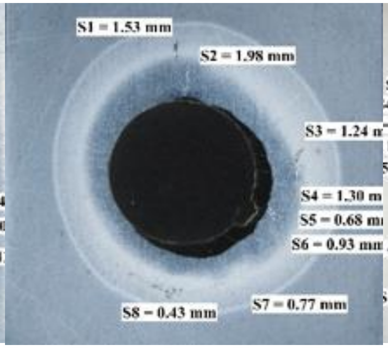
1.2 mm
CR340LA-SE-GI
(Lot 212)



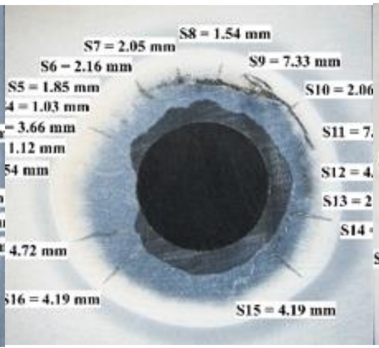
1.5 mm
CR400Y590T-DP-SE-GI
(Lot 184)



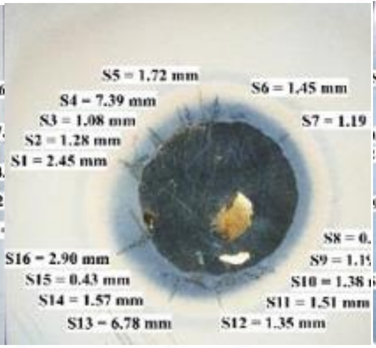
1.4 mm
CR420Y780T-DP-SE-GI
(Lot 55)



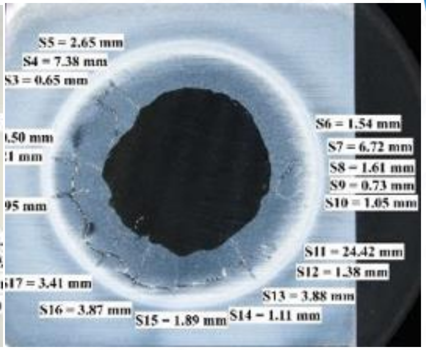
1.6 mm
CR600Y980T-RA-HE-GI
(Lot 168)



1.6 mm
CR600Y980T-RA-HE-GI
(Lot 134)



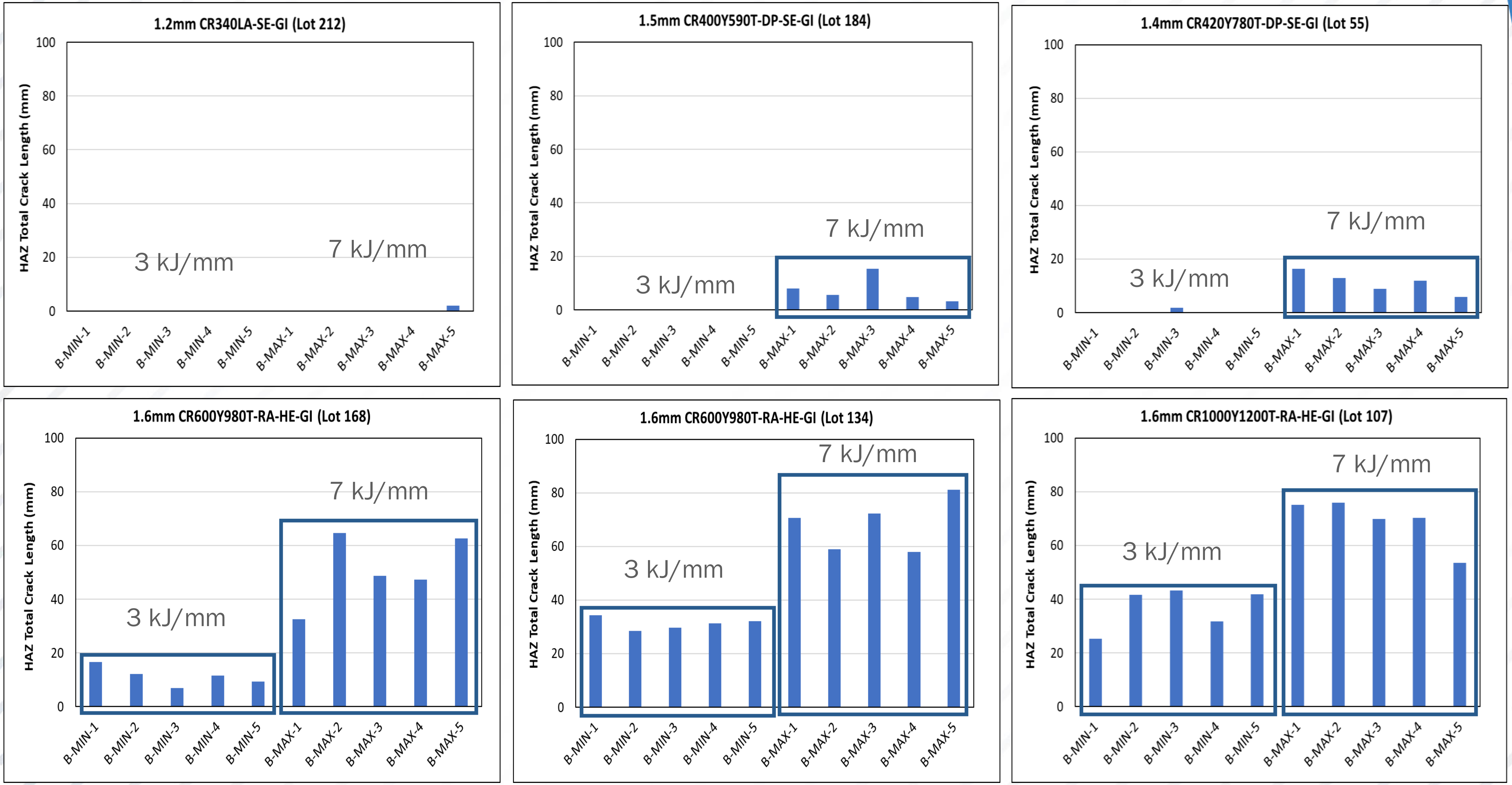
1.6 mm
CR1000Y1200T-RA-HE-GI
(Lot 107)



- At the high heat input level of 7 kJ/mm, LME cracking occurred to varying degrees in all tested steels.
- The test method appears to produce data with sufficient resolution to quantitatively rate LME susceptibility by total crack length for all sheet steel grades studied.

LME Crack Data

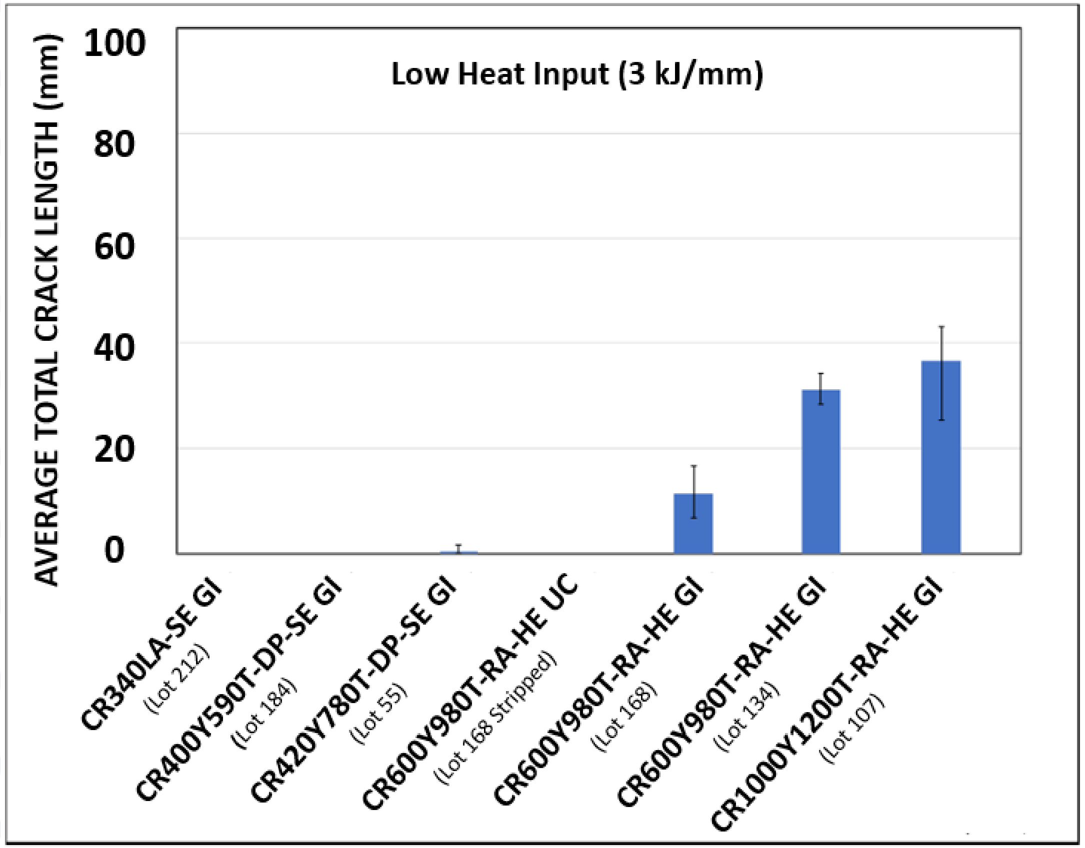
GDIS

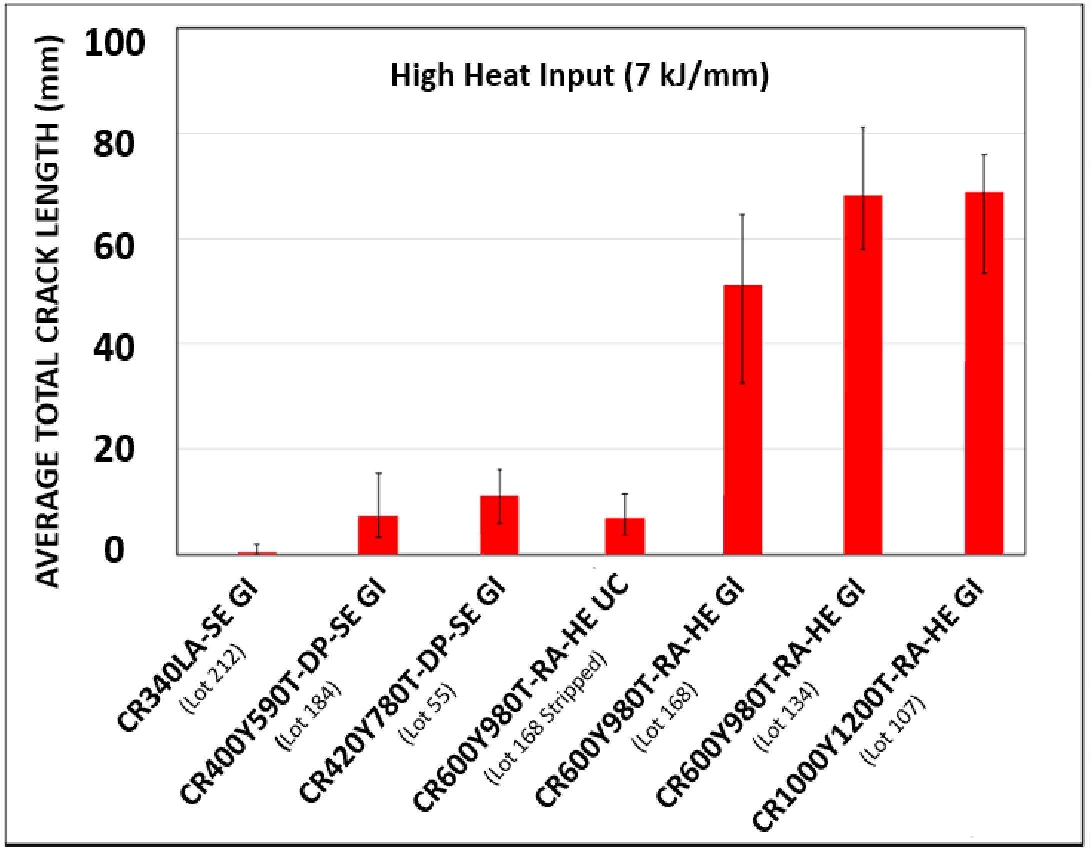


For each material, cracking was fairly consistent within five sample replicate groups.

LME Crack Data Summary

GDIS

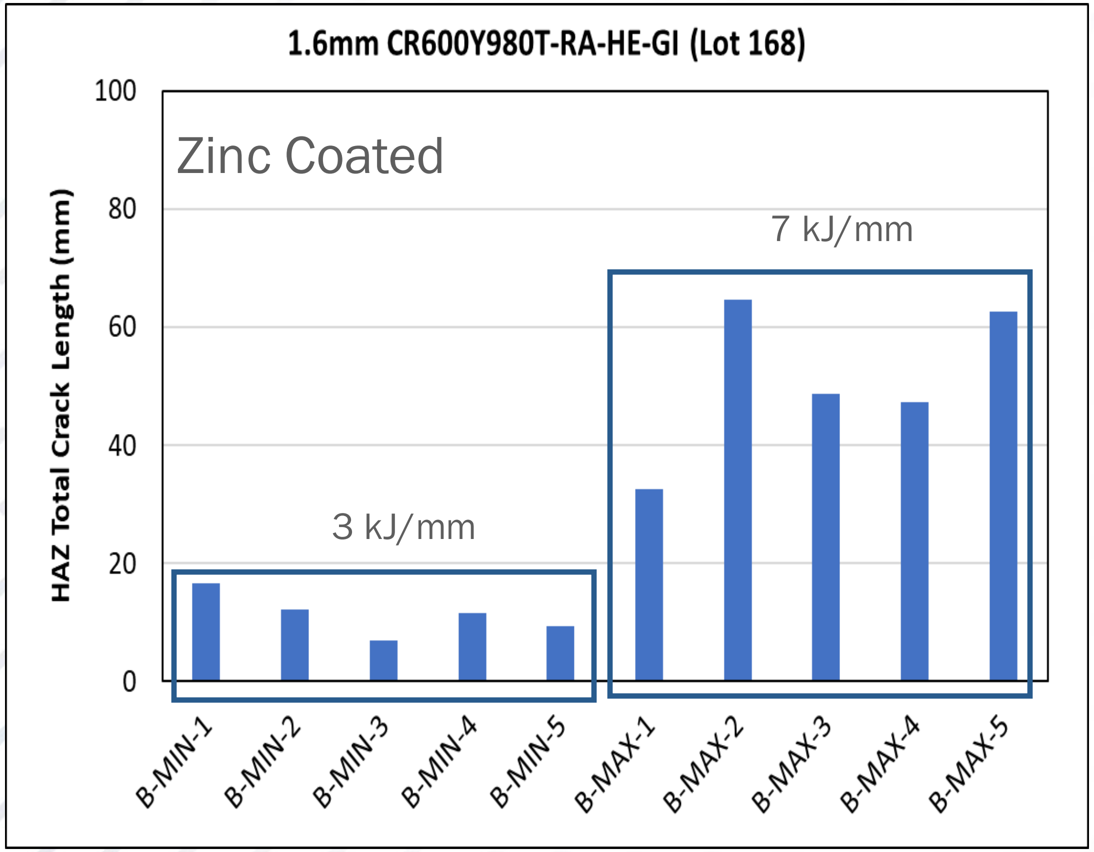


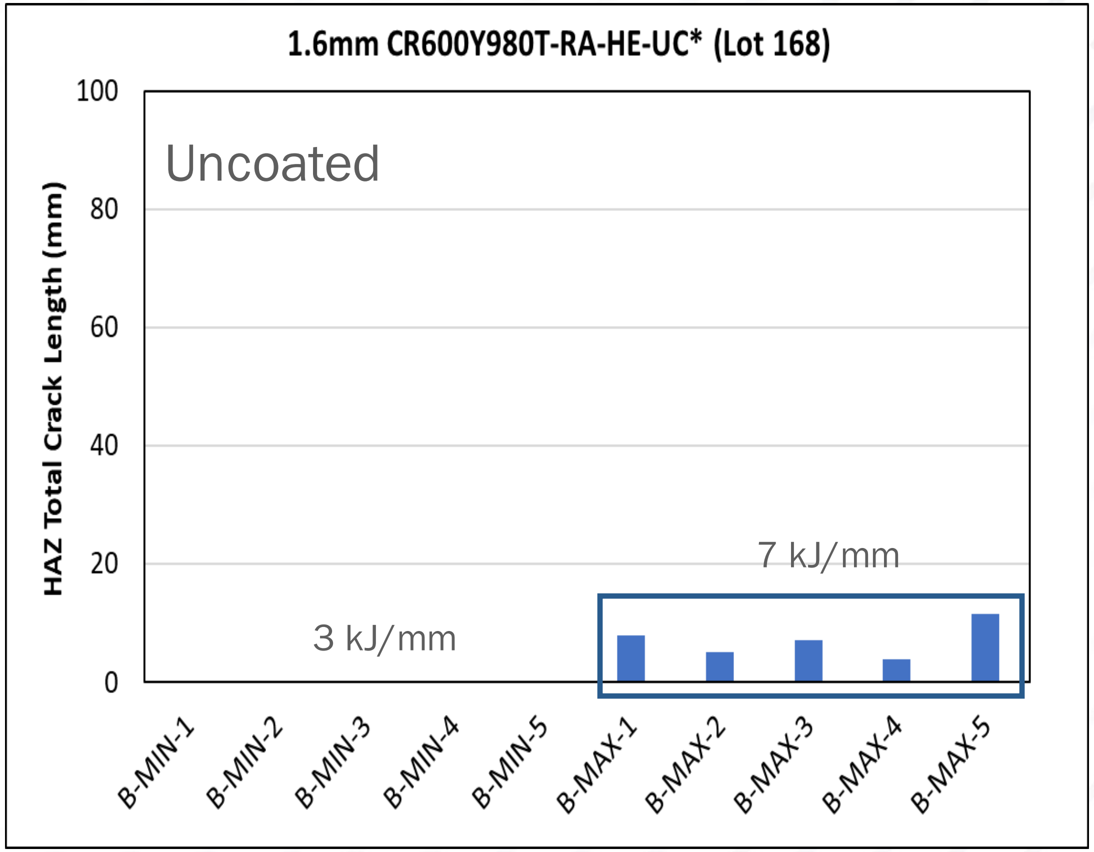


If correlation to RSW LME data can be made, it may be possible to determine a Ring Fillet GMAB LME total crack length threshold for rating of general LME susceptibility.

LME Crack Data – Effect of Zinc Coating

GDIS



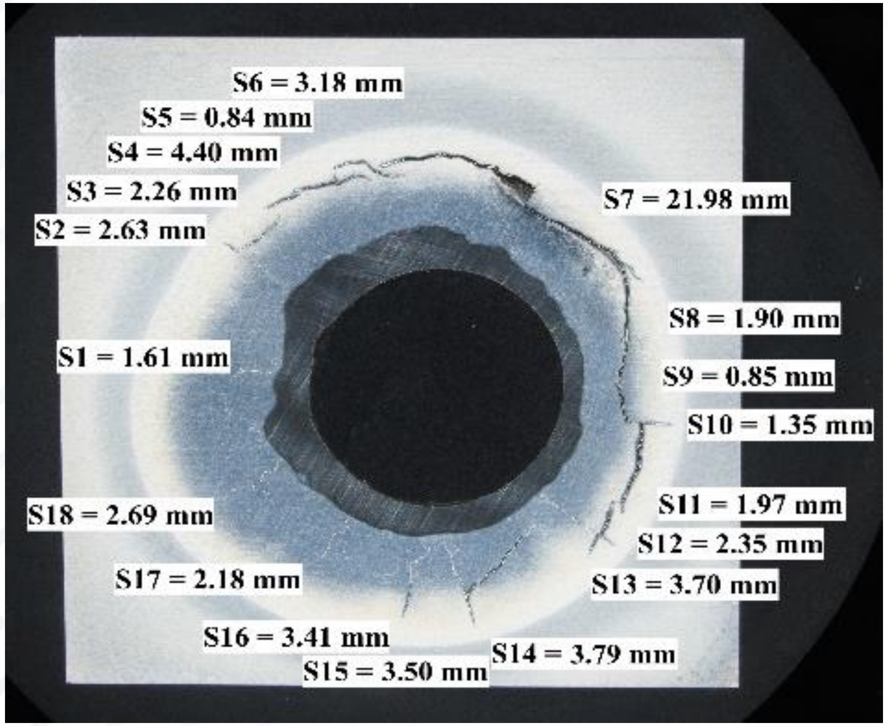


In this study, zinc coating was acid stripped to evaluate the same substrate in the coated and uncoated conditions. LME cracking was eliminated or significantly reduced in uncoated steel, depending on GMAB heat input.

LME Crack Data – Effect of Zinc Coating -7kJ/mm

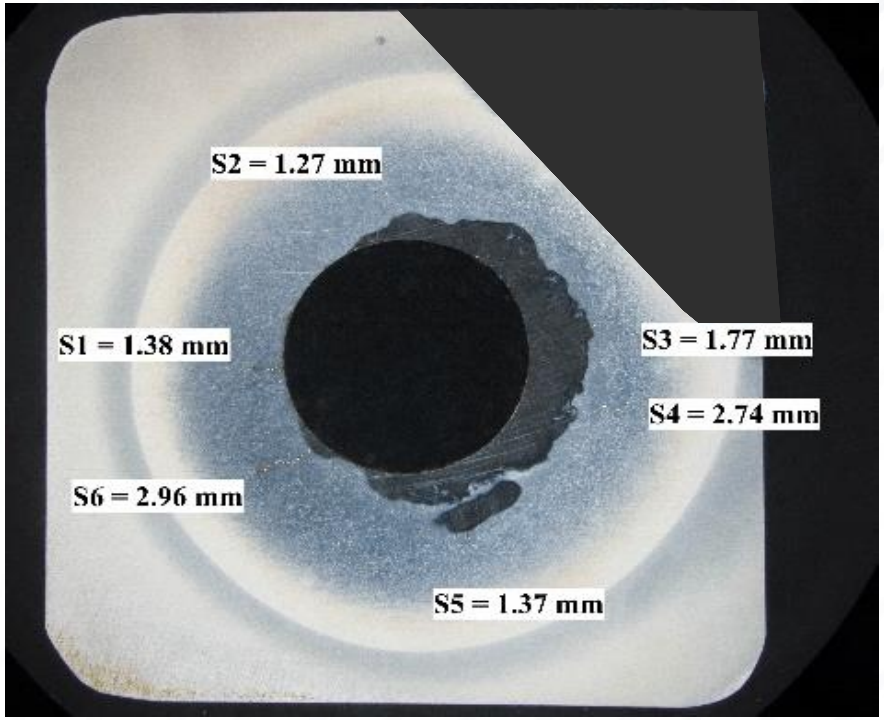
GDIS

1.6 mm
CR600Y980T-RA-HE-GI
(Lot 168)



TOTAL CRACK LENGTH = 65 mm
(Average of five samples = 51 mm)

1.6 mm
CR600Y980T-RA-HE-UC
(Lot 168) Coating Stripped

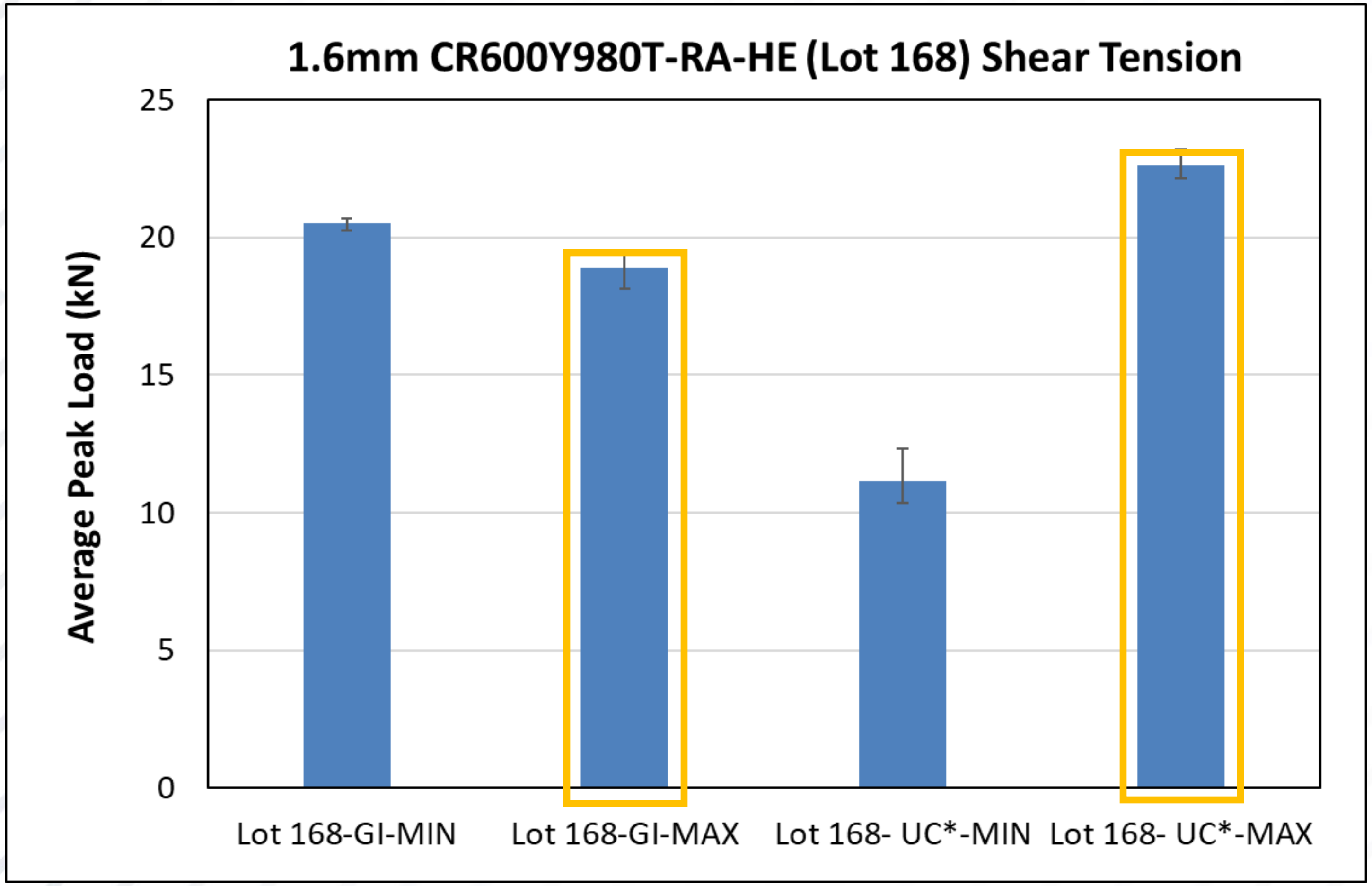


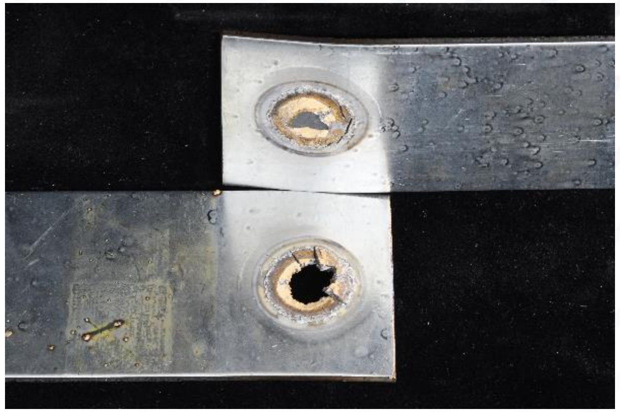
TOTAL CRACK LENGTH = 12 mm
(Average of five samples = 7 mm)

- Removal of the zinc from CR600Y980T-RA-HE-GI (Lot 168) steel significantly reduced LME cracking.

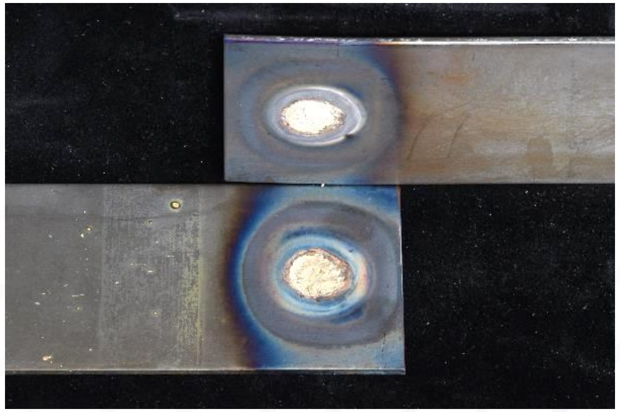
Shear Tension Quasi-Static Data Summary

GDIS





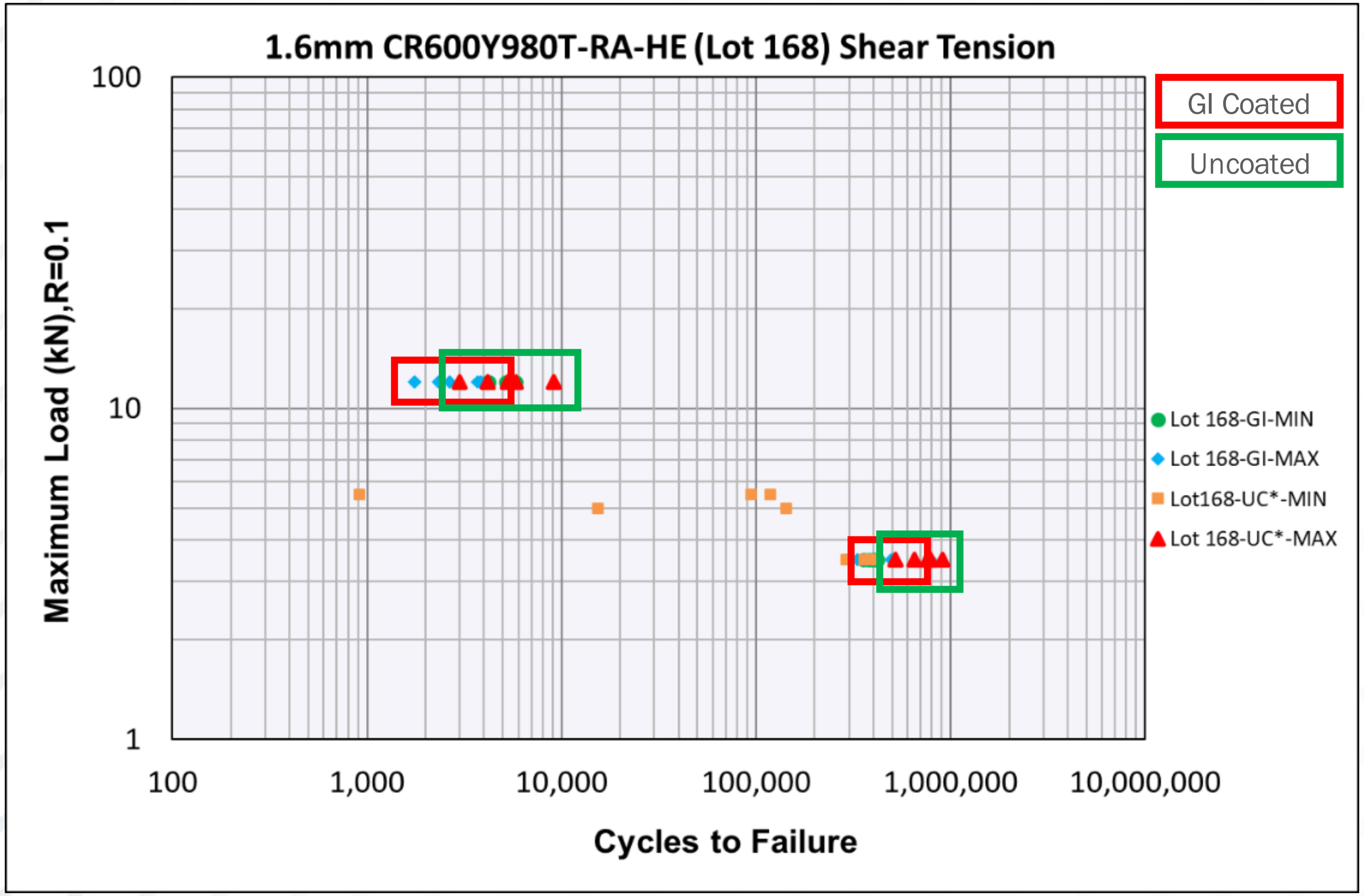
Typical fracture - GI coated

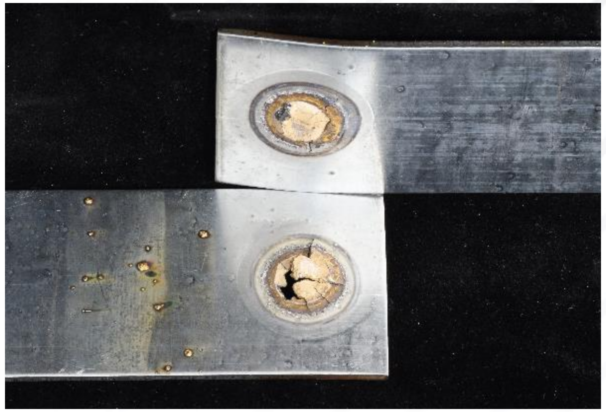


Typical fracture - uncoated

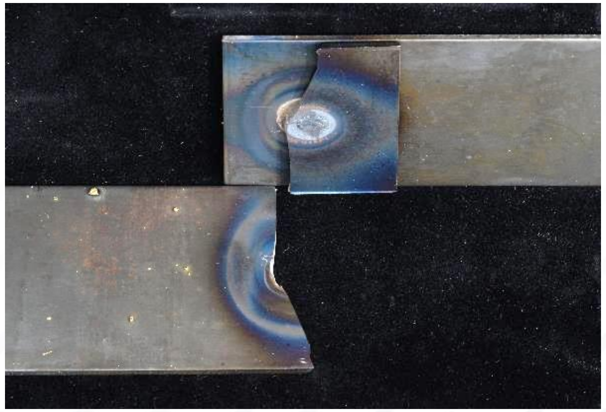
The GI coated 7 kJ/mm (MAX) samples with a high degree of LME cracking exhibited slightly lower peak loads and a different typical fracture mode than the uncoated (UC) 7 kJ/mm (MAX) samples that had minor LME cracking.

Shear Tension Fatigue Data Summary





Typical fracture – GI coated



Typical fracture - uncoated

The GI coated 7 kJ/mm (MAX) samples with a high degree of LME cracking exhibited slightly lower fatigue life and a different typical fracture mode than the uncoated (UC) 7 kJ/mm (MAX) samples that had minor LME cracking.

Ring Fillet GMAB – RSW Rapid LME (CR600Y980T-RA-HE-GI Lot 168)

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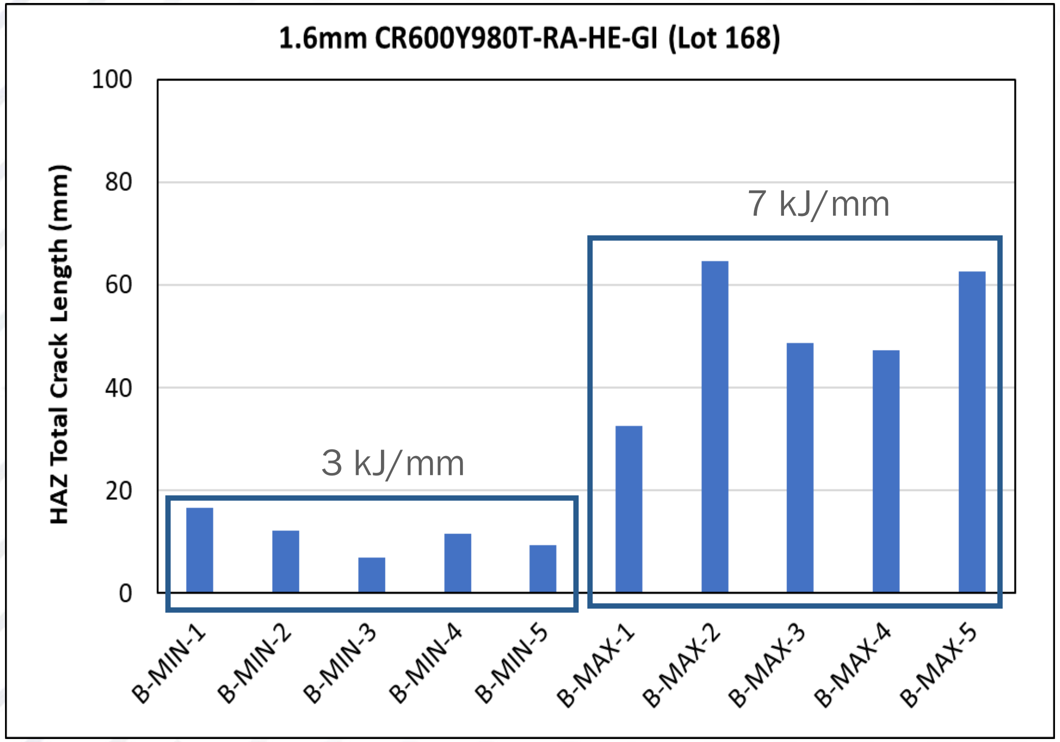
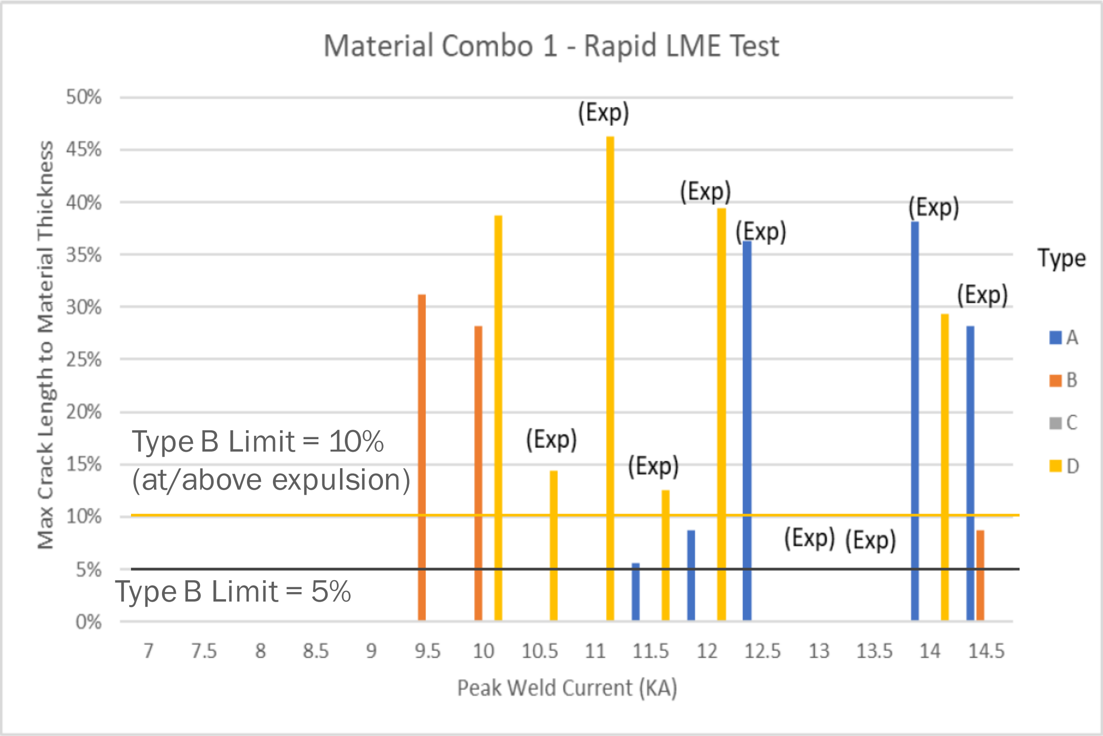
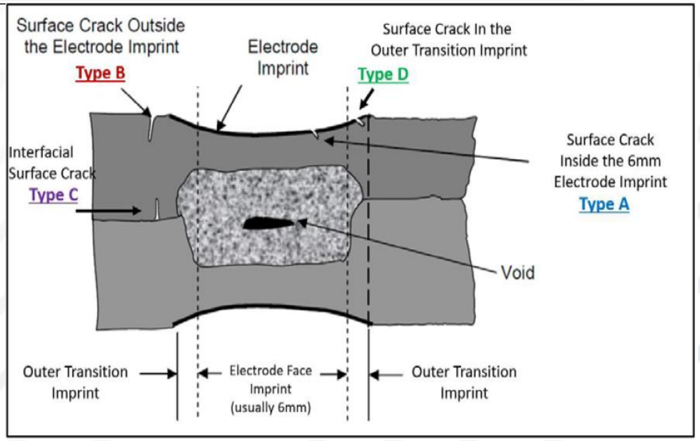


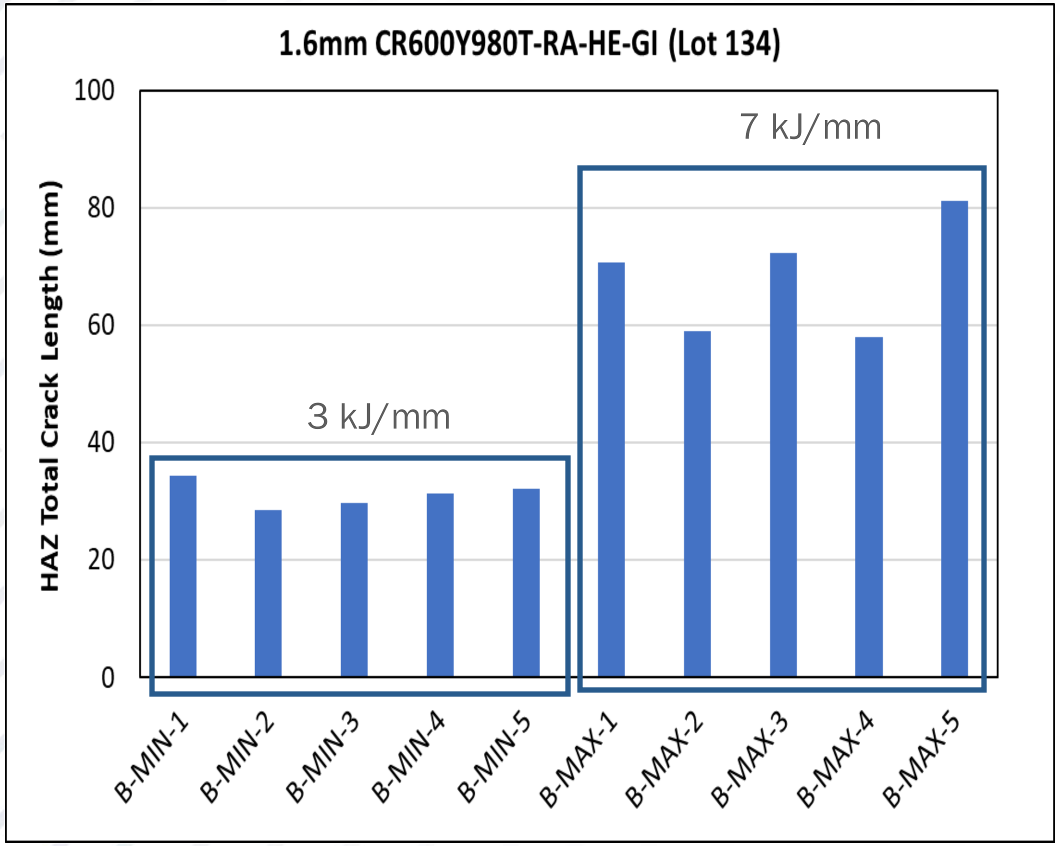


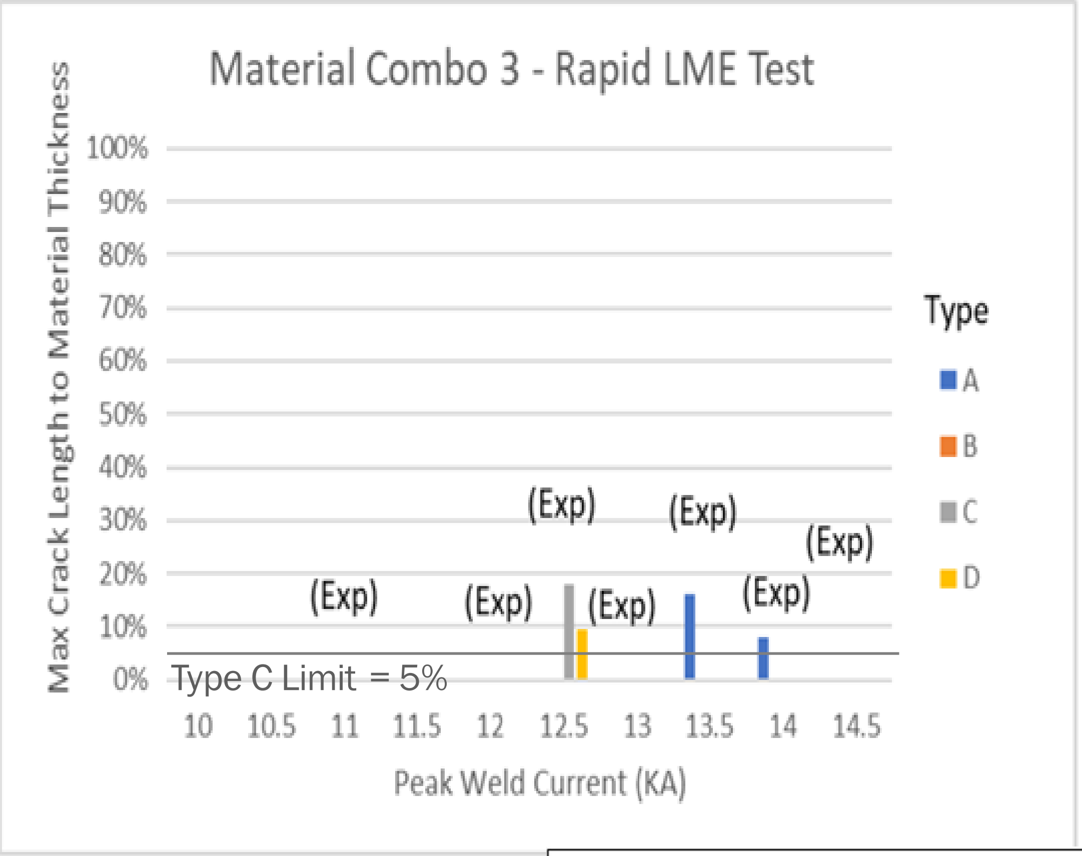
- This steel appears to fail the RSW Rapid LME test suggested criteria for Type B and Type D crack length relative to material thickness.
- The ring fillet GMAB test shows high LME susceptibility.
- A Ring Fillet GMAB total crack length threshold value could be proposed that would correlate to RSW Rapid LME test failure criteria.



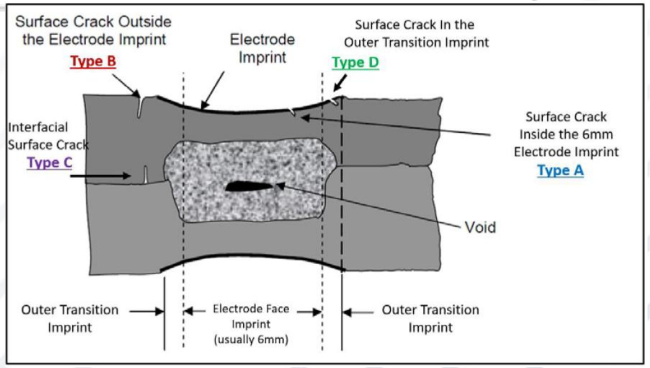
Ring Fillet GMAB – RSW Rapid LME (CR600Y980T-RA-HE-GI Lot 134)

GDIS





- This steel appears to fail the RSW Rapid LME test suggested criteria for Type C crack length relative to material thickness.
- The ring fillet GMAB test shows high LME susceptibility.
- A Ring Fillet GMAB total crack length threshold value could be proposed that would correlate to RSW Rapid LME test failure criteria.



Project Summary / Conclusion

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- The removal of zinc resulted in elimination or substantial reduction in LME cracking for the steel tested, depending on GMAB heat input.
- The GI coated samples with a high degree of LME cracking exhibited slightly lower shear tension quasi-static peak load, slightly lower fatigue life, and different fracture modes than the uncoated (UC) samples that had minor LME cracking.
- The Ring Fillet GMAB test method was capable of producing LME cracking to varying degrees in all test materials, including HSLA, AHSS, and 3rd Generation steels.
- Cracks on the entire faying surface of the sample are completely exposed and easily measurable.
- The test method appears to produce data with sufficient resolution and reproducibility to quantitatively rate LME susceptibility by total crack length for all sheet steel grades.
- Correlation of A/SP Joining Team RSW Rapid LME test data to A/SP GMAW of AHSS Team Ring Fillet GMAB LME test data may allow a threshold GMAB total crack length limit to be determined which, if exceeded, could indirectly indicate risk of RSW and GMAW LME cracking with a simple, highly discriminating test method.

Pros and Cons

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Advantages:

- The Ring Fillet GMAB LME test method is capable of generating extensive, reproducible LME cracking for conclusive determination of LME susceptibility. Cracks on the entire faying surface of the sample are completely exposed and easily measurable. This eliminates the risk of non-detection inherent to other methods that rely on a single cross-section inspection plane. LME susceptibility can be determined with only five to ten test samples.

Disadvantages:

- The Ring Fillet GMAB LME test method has only been proven to reliably produce cracking with copper based brazing filler metals. Direct application to GMAW may only produce cracking in highly susceptible steels. The use of this method as a general LME susceptibility indicator will require one-time generation of an RSW correlation data set to define a threshold value of total crack length.

Next Steps

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- The team is currently scoping the GMAW of AHSS - LME, G#7, Correlation Testing for RSW Rapid LME, Ring Fillet GMAB

  - Project Purpose
    - Obtain RSW Rapid LME & GMAW test data for conventional steel and AHSS.
    - Correlate Ring Fillet GMAB LME test data to RSW Rapid LME test data.
    - Determine the suitability of the GMAW of AHSS team Ring Fillet GMAB test procedure as a general LME susceptibility indicator.

For more information

GDIS

Justin Hunt, Project Lead
Stellantis
justin.hunt1@stellantis.com
248.410.1513

Michael White, Project Manager
Auto/Steel Partnership
mwhite@a-sp.org
313.378.8958