REPAIRABILITY of 3rd GEN AHSS

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GREAT DESIGNS IN STEEL™

GDIS

Auto/Steel Partnership

Members

gm

NUCOR

Gestamp

posco

MARTINREA

STELLANTIS

MAGNA

Ternium

METALSA

TOYOTA

PROJECT TEAM MEMBERS AND PARTICIPANTS

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- Jackie Stachowski, Nucor
- Tim Rickard, Nucor
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- Lynn Rogers, Stellantis
- Juan Pablo Pedraza, Ternium

Project Participants:

- AET Integration
- I-Car

PROJECT OBJECTIVE

The objective of A/SP Repairability of AHSS projects is to obtain weld joint repair data to assist automotive OEMs and the collision repair industry in developing appropriate weld joint repair strategies for 3rd Gen AHSS. These steels have unique mechanical properties and weldability characteristics that may result in the need for updated weld repair strategies.

This presentation includes supplemental data to support the comprehensive work performed in previous A/SP Repairability of AHSS projects P#1 through P#6. The specific objectives of P#7 include the following:

- Evaluation of repairability methods for steel thickness near the lower limit of the commonly used 980 3rd Generation AHSS range.
- Investigation of manual laser welding feasibility for repair of 3rd Generation AHSS.

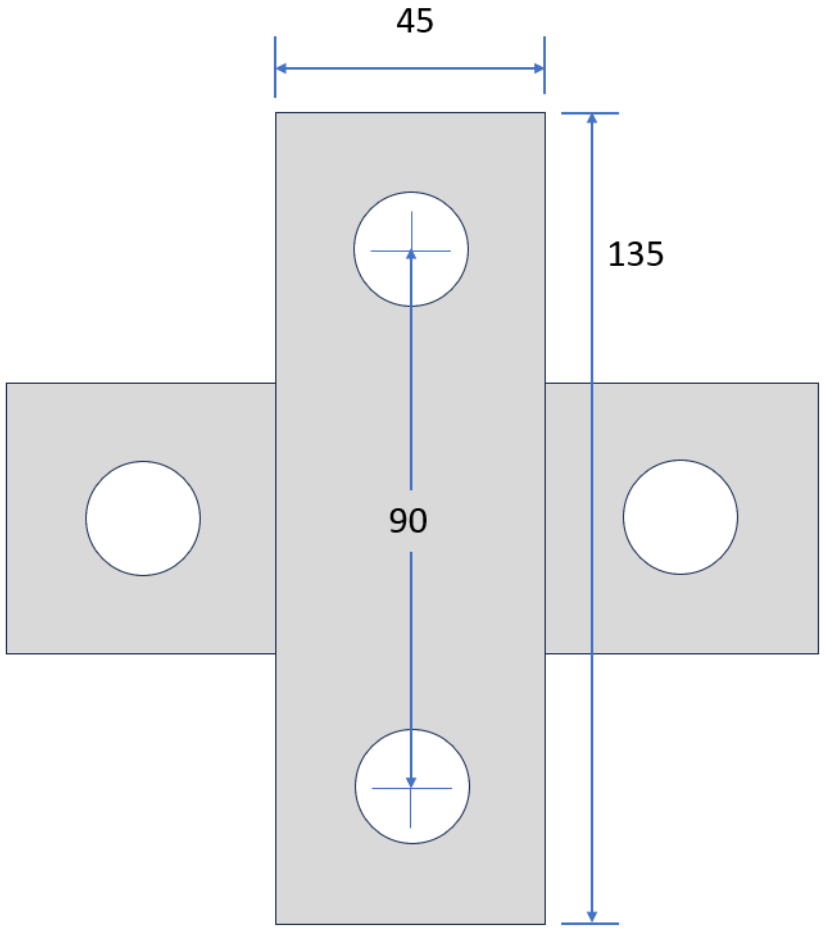
TEST MATRIX

Project P#7									
Material	Joining Process	Baked before Joining	Baked after Joining	ASTM E8 Tensile Test	Liquid Penetrant Inspection	Radiographic Inspection	Metallurgical Examination	Shear Tension (ST)	Cross Tension (CT)
1.0 mm CR600Y980T-RA-GI Lot #203	Base Metal			3			1		
	Base Metal Baked	X		3			1		
	RSW Production		X				1	3	3
	RSW Production with Henkel EP5089 Production Adhesive		X		X		1	3	3
	RSW Service	X					1	3	3
	RSW Service with Henkel EP5065 Service Adhesive	X			X		1	3	3
	GMAB 8 mm Plug (ERCuSi-A) (zinc coating removed)	X				X	1	3	3
	GMAW 8 mm Plug (ER70S-6) (zinc coating removed)	X				X	1	3	3
	Rivet	X					1	3	3
	Rivet with Henkel EP5089 Production Adhesive		X				1	3	3
	Rivet with Henkel EP5065 Service Adhesive	X					1	3	3
	Manual Laser - 20 mm Lap	X			X		1	3	3
	Manual Laser - 20 mm Lap Fillet	X			X		1	3	3
	Manual Laser - 45 mm Butt	X			X		1	3	3

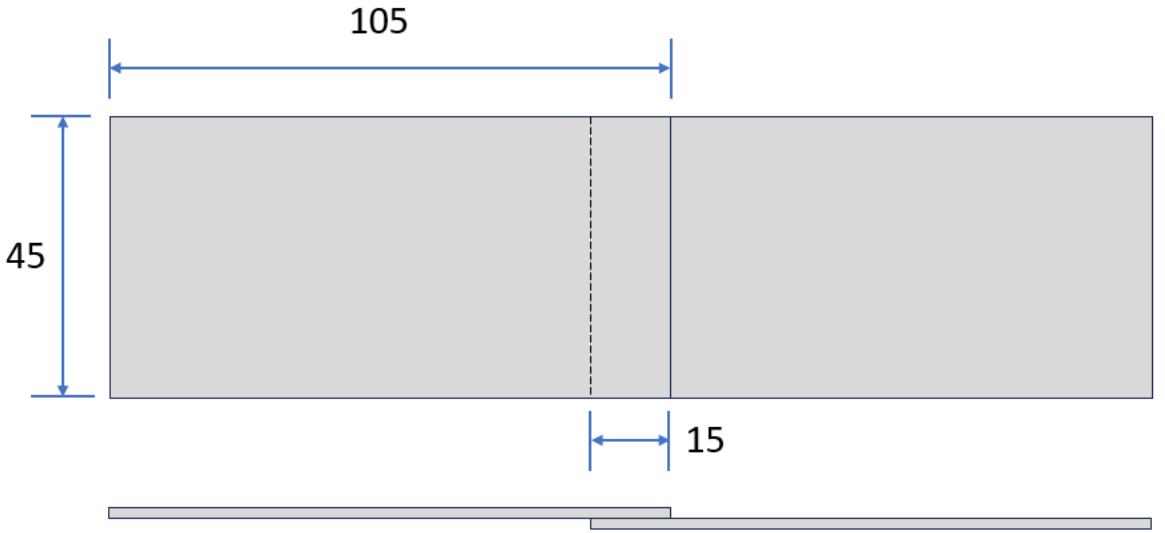
P#7 test matrix comparison to previous Repairability project phases

- 1.0 mm 980 3rd Gen steel was tested to evaluate thickness near the lower limit of the commonly used range.
- Zinc was removed from GMAB and GMAW joints prior to welding to prevent LME cracking.
- A manual laser process was tested with three different joint types.

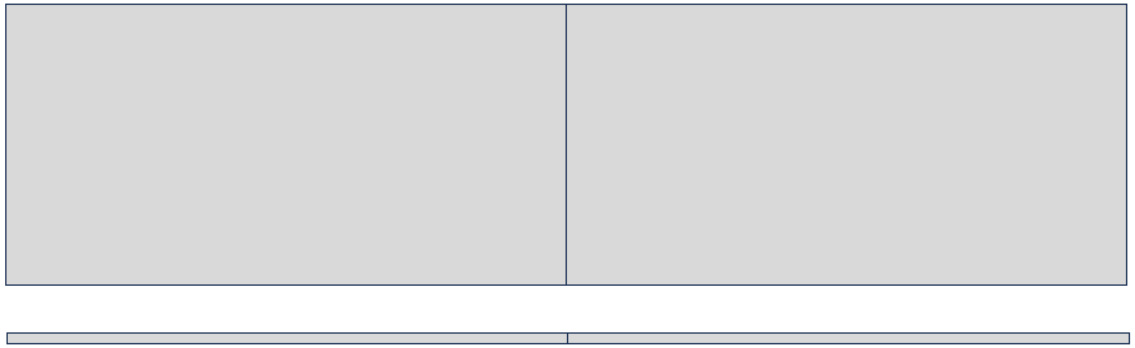
TEST SAMPLE DIMENSIONS



CROSS TENSION

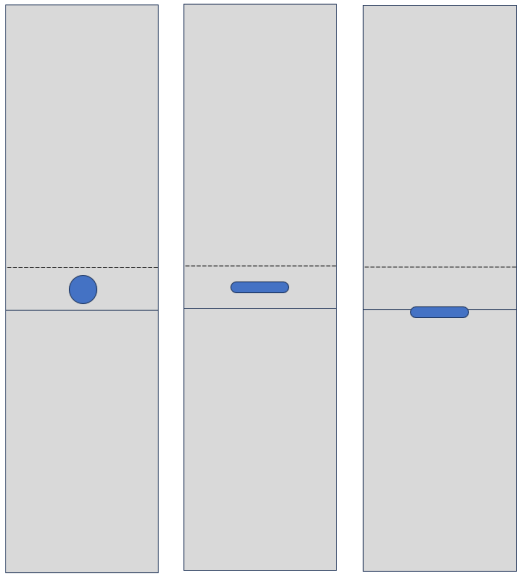


SHEAR TENSION



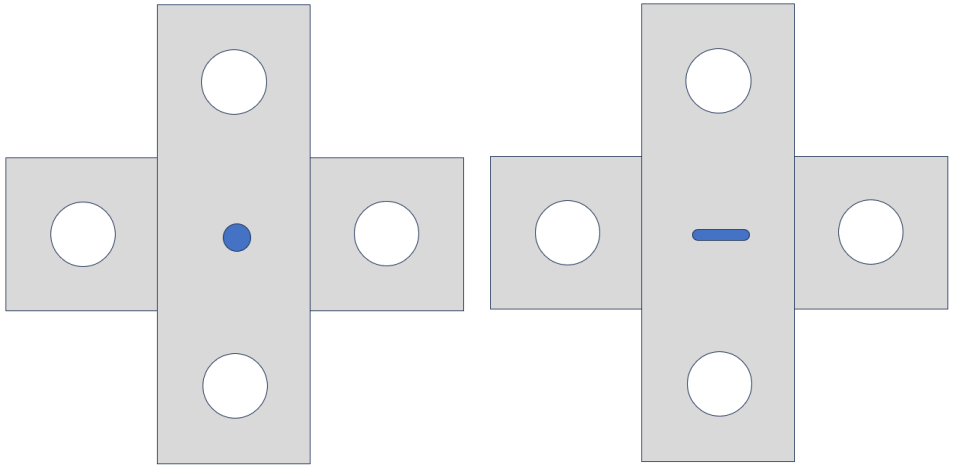
BUTT (TENSILE)

TEST SAMPLE TYPES



SHEAR TENSION

RSW (Production and Service)
GMAB Plug 8 mm Hole
GMAW Plug 8 mm Hole
Manual Laser - 20 mm Lap
Manual Laser - 20 mm Lap Fillet
Rivet



CROSS TENSION

RSW (Production and Service)
GMAB Plug 8 mm Hole
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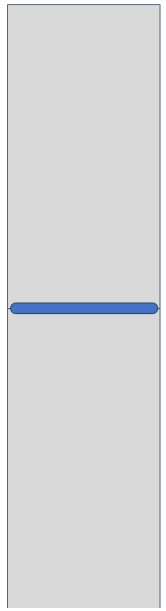
Manual Laser - 20 mm Lap
Rivet



TENSILE

Manual Laser - 45 mm Butt
Base Metal (ASTM E8)

JOINING PROCESSES

- **Resistance Spot Welding**
  - Production RSW joints referencing AWS D8.9M welding schedule
  - Service RSW joints were made using Pro Spot i5 welder, in automatic mode (no welding parameter adjustment)
  - Targeted weld size was 5.0 mm for RSW production joints

- **Gas Metal Arc Welding (GMAW Plug)**
  - 8 mm diameter hole, top sheet
  - 0.9 mm ER70S-6 filler wire with 90% Argon 10% CO_2 shielding gas
  - Zinc removed from both sides of top coupon and the faying surface of the bottom coupon prior to welding.

- **Gas Metal Arc Brazing (GMAB Plug)**
  - 8 mm diameter hole, top sheet
  - 1.0 mm ER CuSi-A filler with 100% argon shielding gas
  - Zinc removed from both sides of top coupon and the faying surface of the bottom coupon prior to brazing.

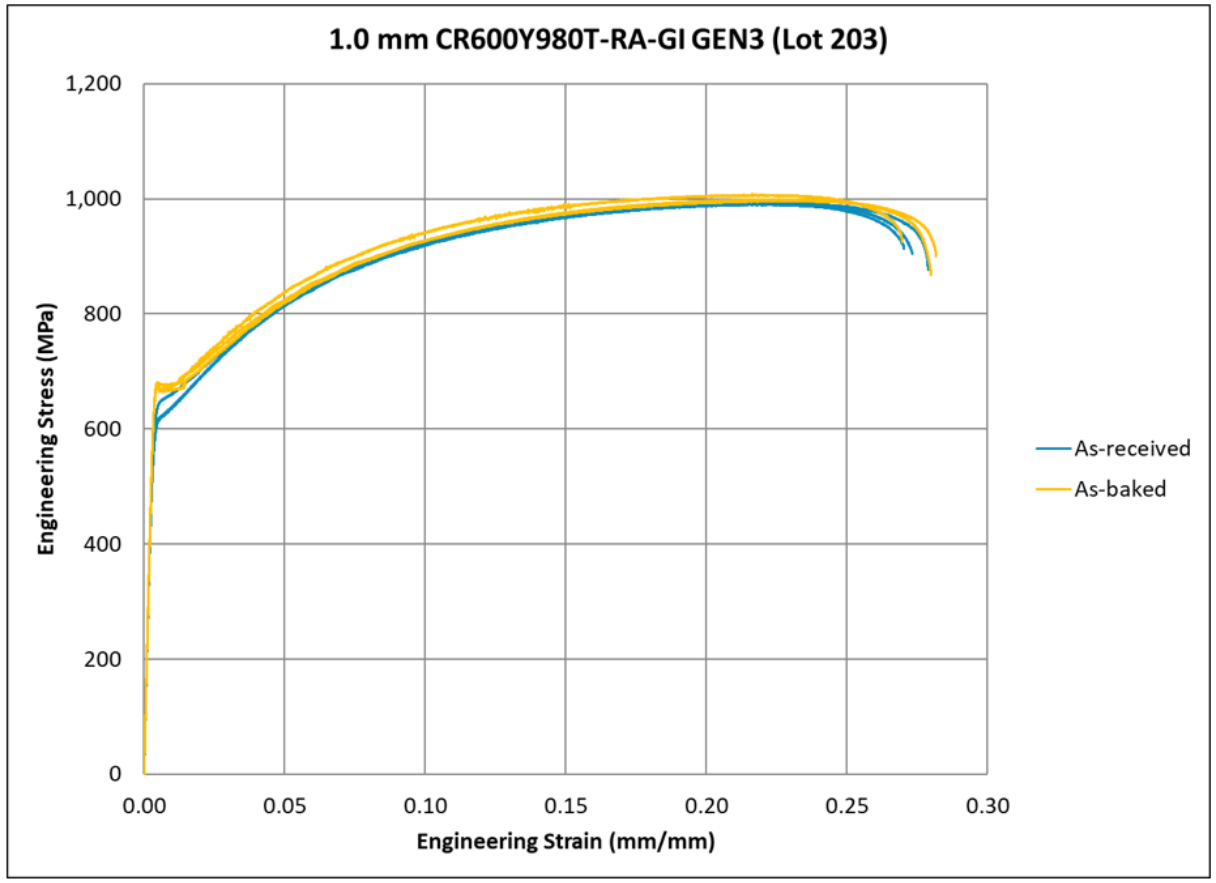
- **Mechanical Fastening**
  - 6.4 mm diameter Hemlok Rivet 02221-00812
  - 6.7mm diameter hole

JOINING PROCESSES

- **Adhesive Bonding (RSW and Rivet)**
  - Production adhesive: Henkel Teroson EP 5089 (Cured for 20 minutes at 170°C)
  - Service adhesive: Henkel Teroson EP 5065 (cured for 48 hours at room temperature)
  - 3.0 mm diameter adhesive bead applied across the width of coupons

- **Manual Laser Welding**
  - Manual laser welded samples were provided by I-Car
  - 100% penetration was targeted with visual indication of melt-through on the back side of bottom coupon
  - Joints were welded autogenously, without addition of filler metal. Filler metal addition is possible with this process
  - 100% nitrogen shielding gas

BASE METAL STRESS-STRAIN CURVES



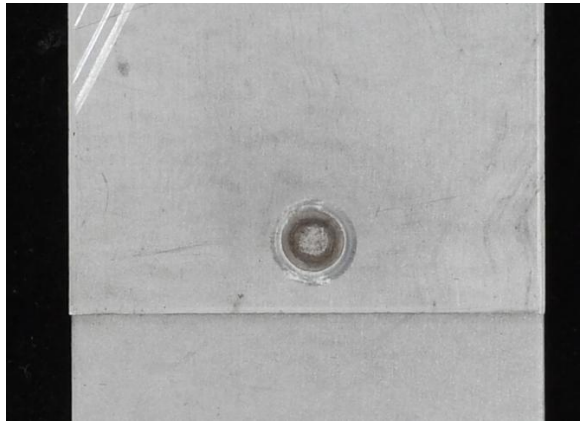
- The material tested meets minimum mechanical property requirements.
- A 7% increase in yield strength was observed after paint bake cycle.

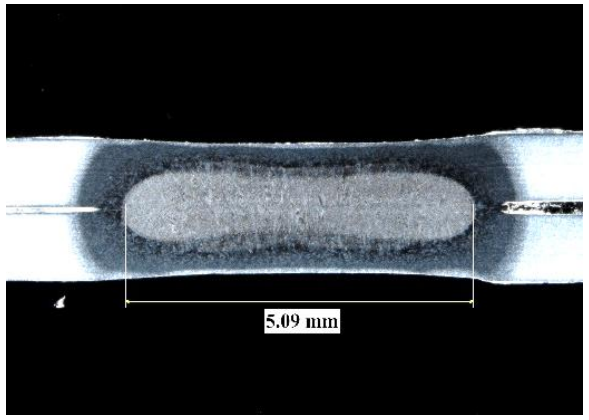
Specimen ID	Ultimate Tensile Strength (MPa)	Yield Strength 0.2% offset (MPa)	Elongation (%)
As-received 1	991	618	27.1
As-received 2	994	615	27.9
As-received 3	992	645	28.4
As-baked 1	1008	669	28.4
As-baked 2	997	676	28.8
As-baked 3	1000	667	28.2

RSW

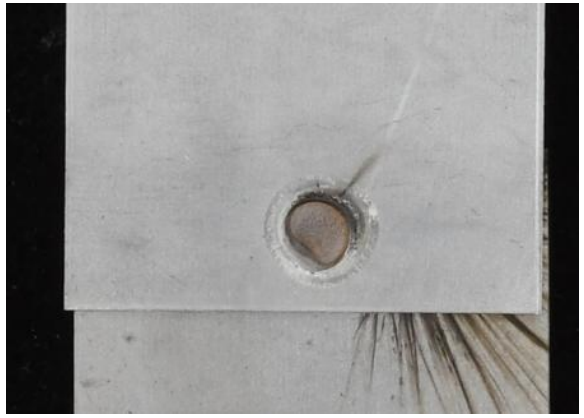
METALLOGRAPHIC

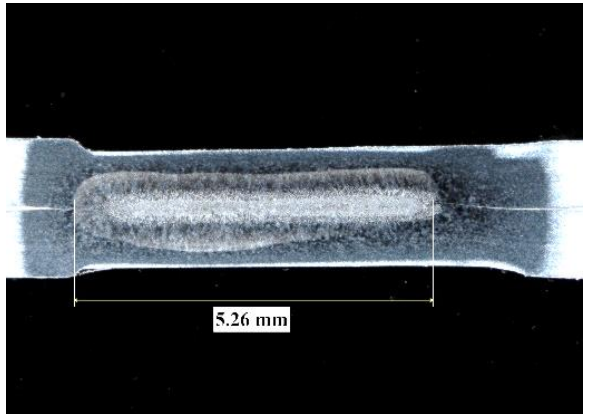
FRACTURE

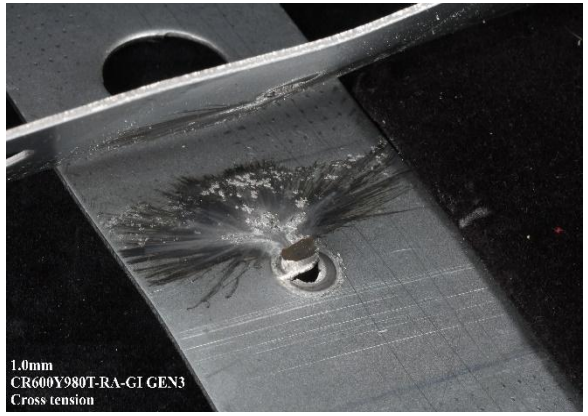




RSW PRODUCTION



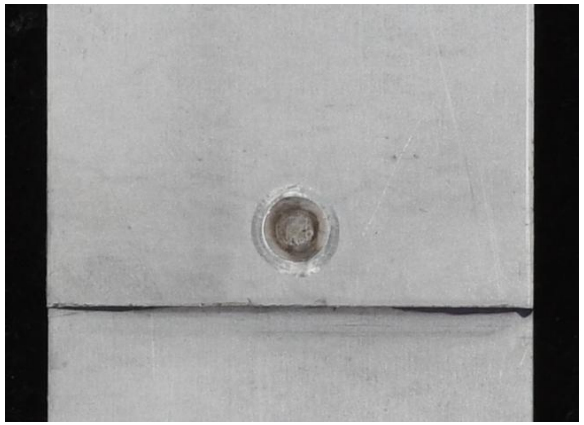
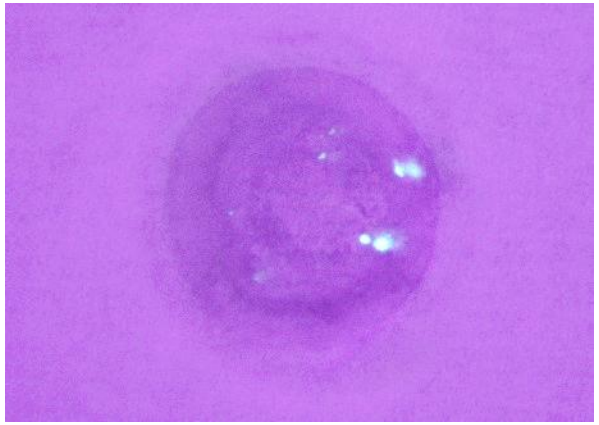
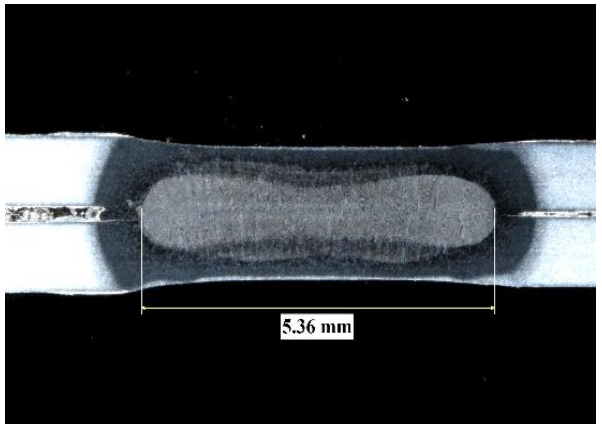
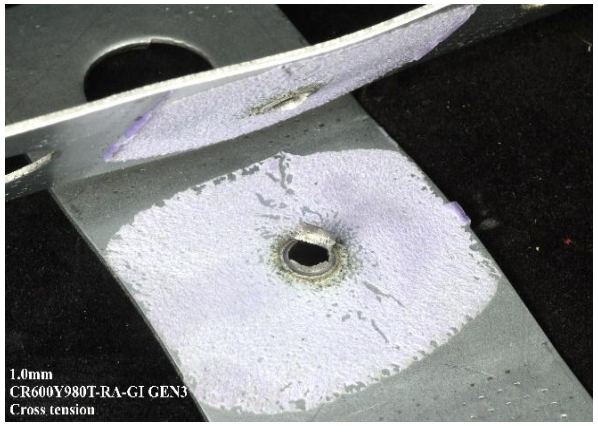
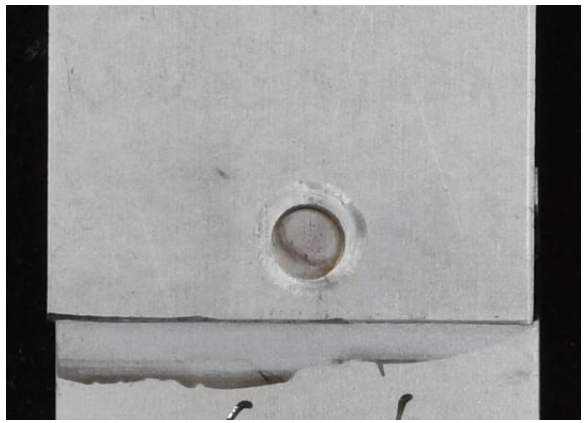
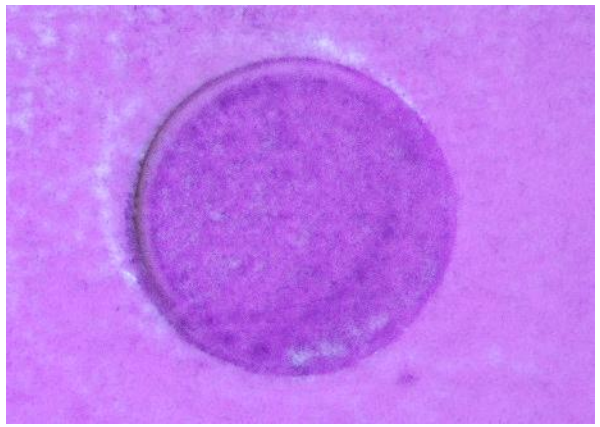
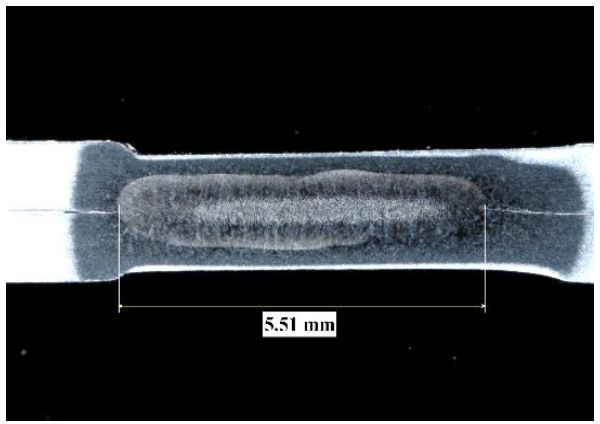




RSW SERVICE

RSW WITH ADHESIVE

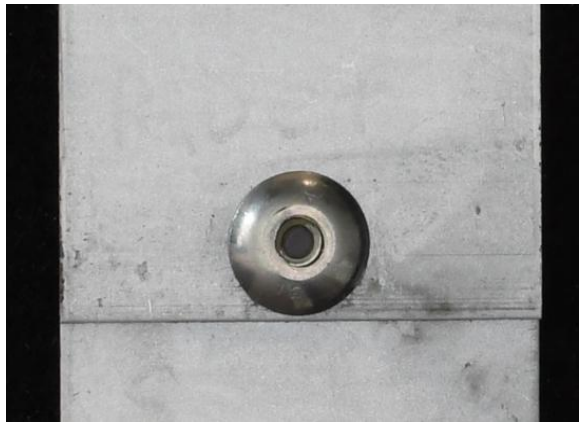
GDIS

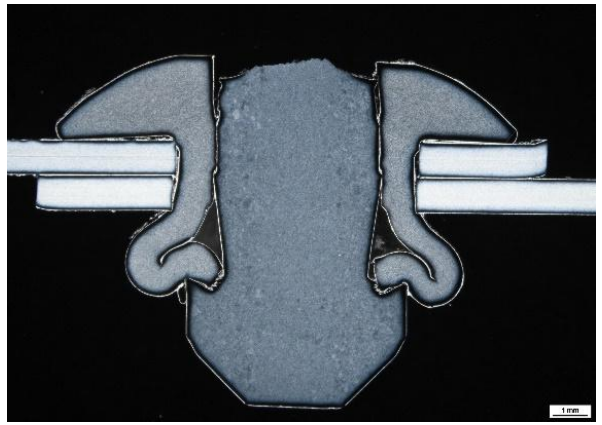
	LIQUID PENETRANT	METALLOGRAPHIC	FRACTURE
			
RSW PRODUCTION WITH ADHESIVE	FLPI indications were not attributed to LME cracking.		Button pull with cohesive separation
			
RSW SERVICE WITH ADHESIVE			Button pull with adhesive separation

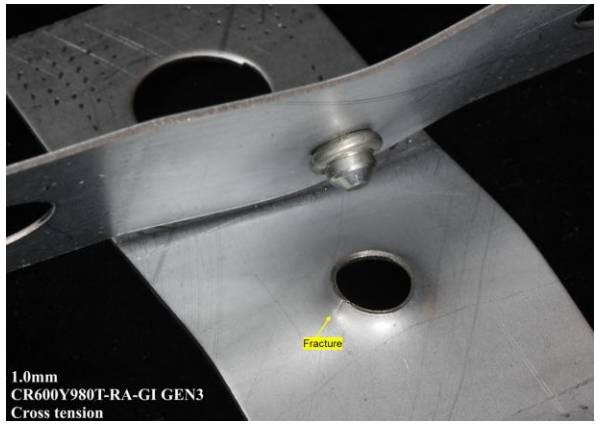
RIVET

METALLOGRAPHIC

FRACTURE





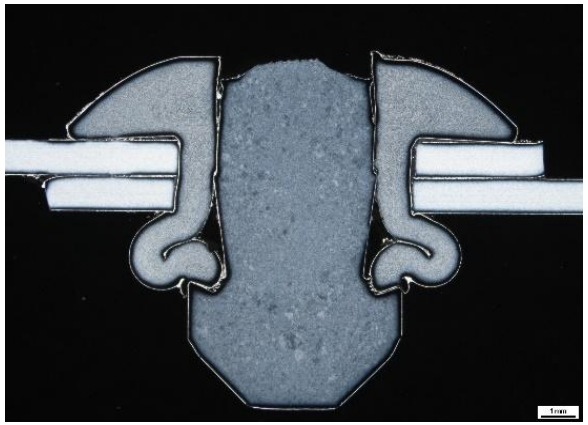


RIVET

RIVET WITH ADHESIVE

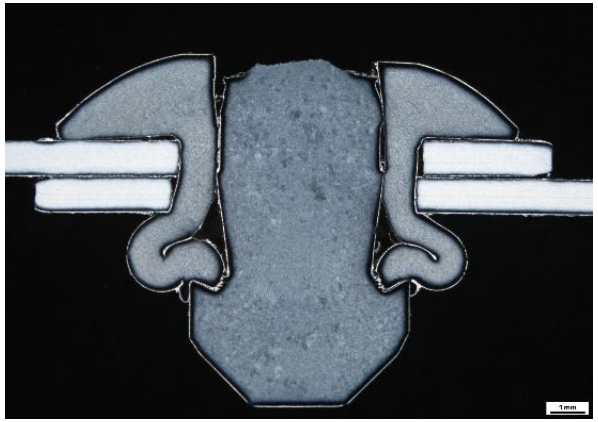
METALLOGRAPHIC

FRACTURE



RIVET WITH PRODUCTION ADHESIVE

Rivet pull-out with cohesive fracture

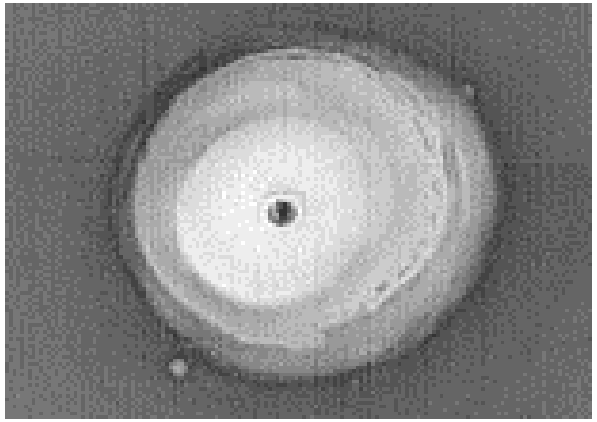
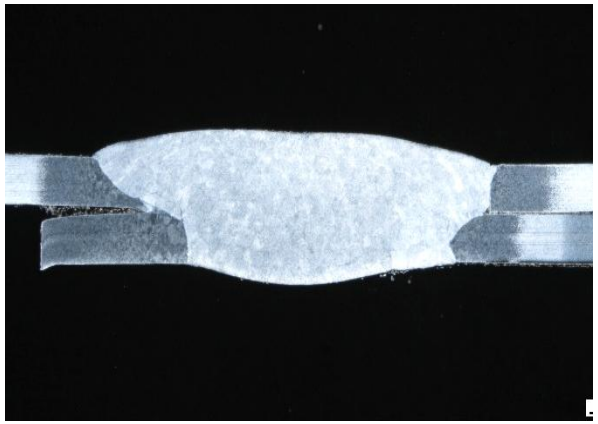
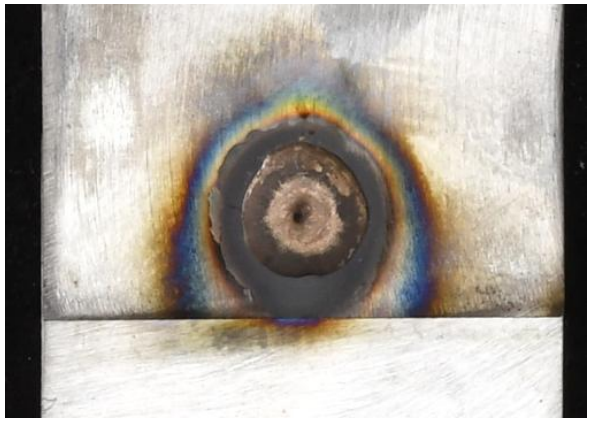
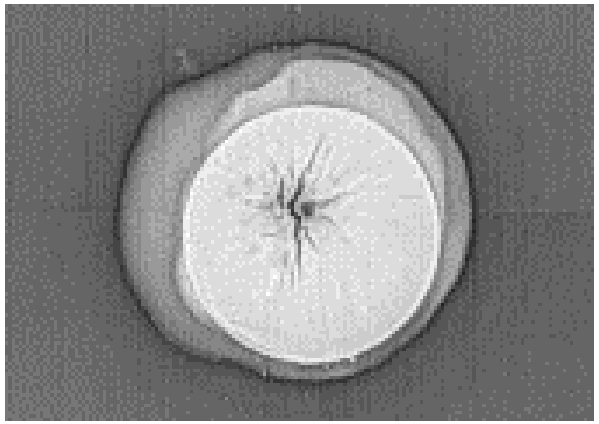
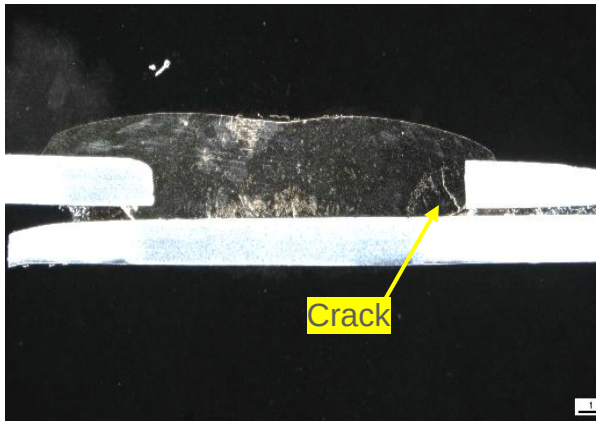


RIVET WITH SERVICE ADHESIVE

Rivet pull-out with adhesive fracture

GMAW PLUG AND GMAB PLUG

GDIS

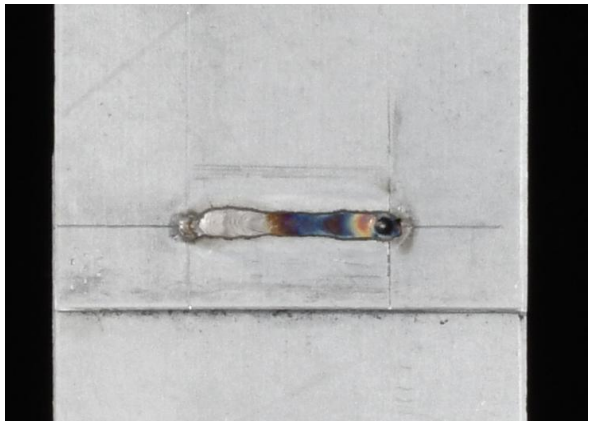
	RADIOGRAPHIC	METALLOGRAPHIC	FRACTURE
			
GMAW PLUG			
			
GMAB PLUG	GMAB Plug joint cracking was contained within the braze metal.		

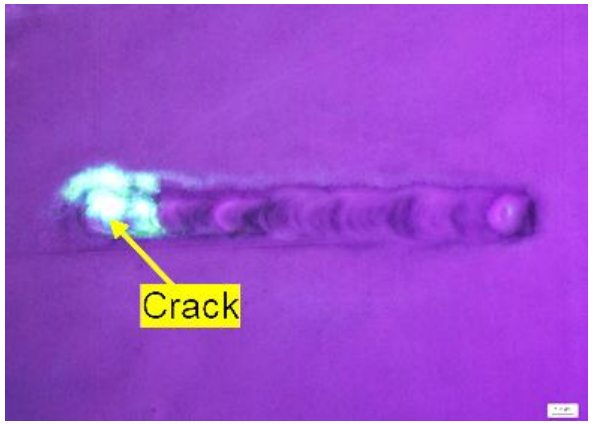
MANUAL LASER

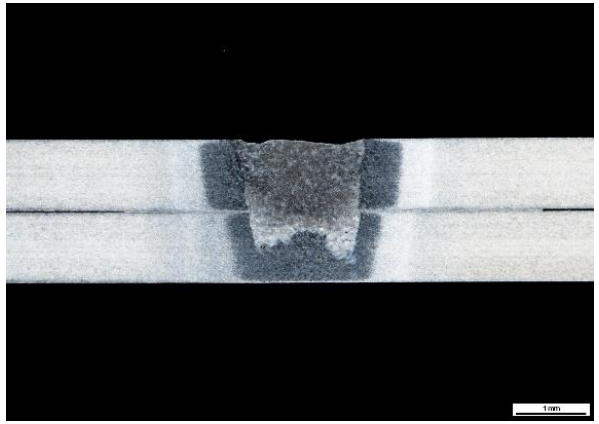
LIQUID PENETRANT

METALLOGRAPHIC

FRACTURE

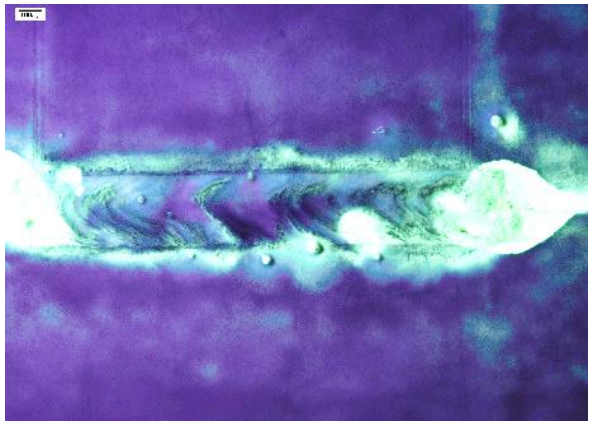


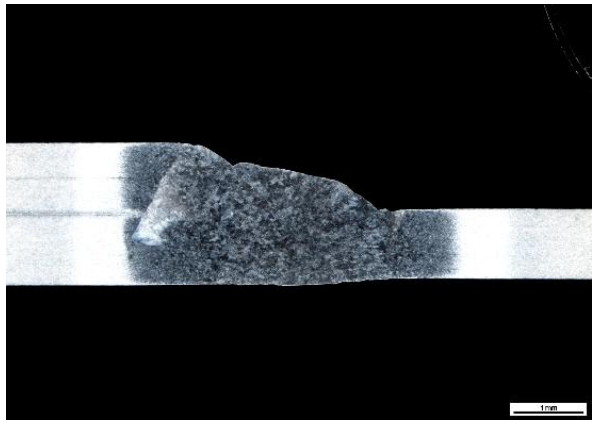


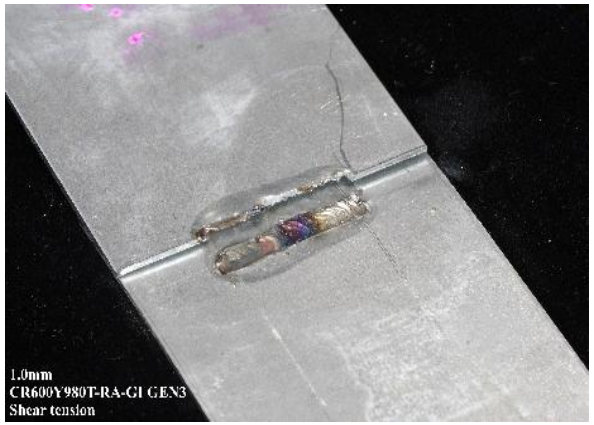


MANUAL LASER
20 mm LAP

Weld metal crack mitigation may be possible through welding process adjustment or filler metal addition.







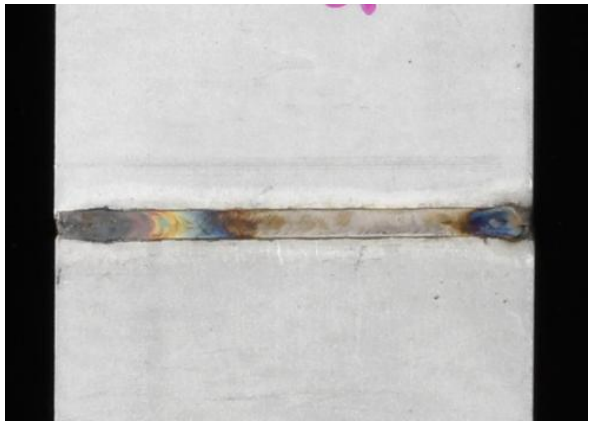
MANUAL LASER
20 mm LAP FILLET

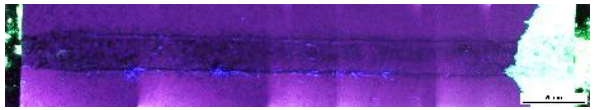
MANUAL LASER

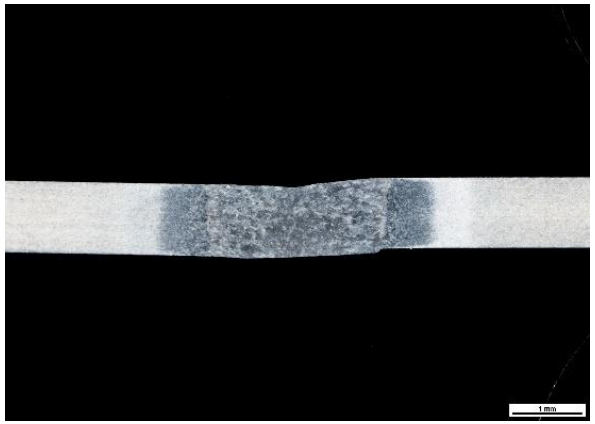
LIQUID PENETRANT

METALLOGRAPHIC

FRACTURE

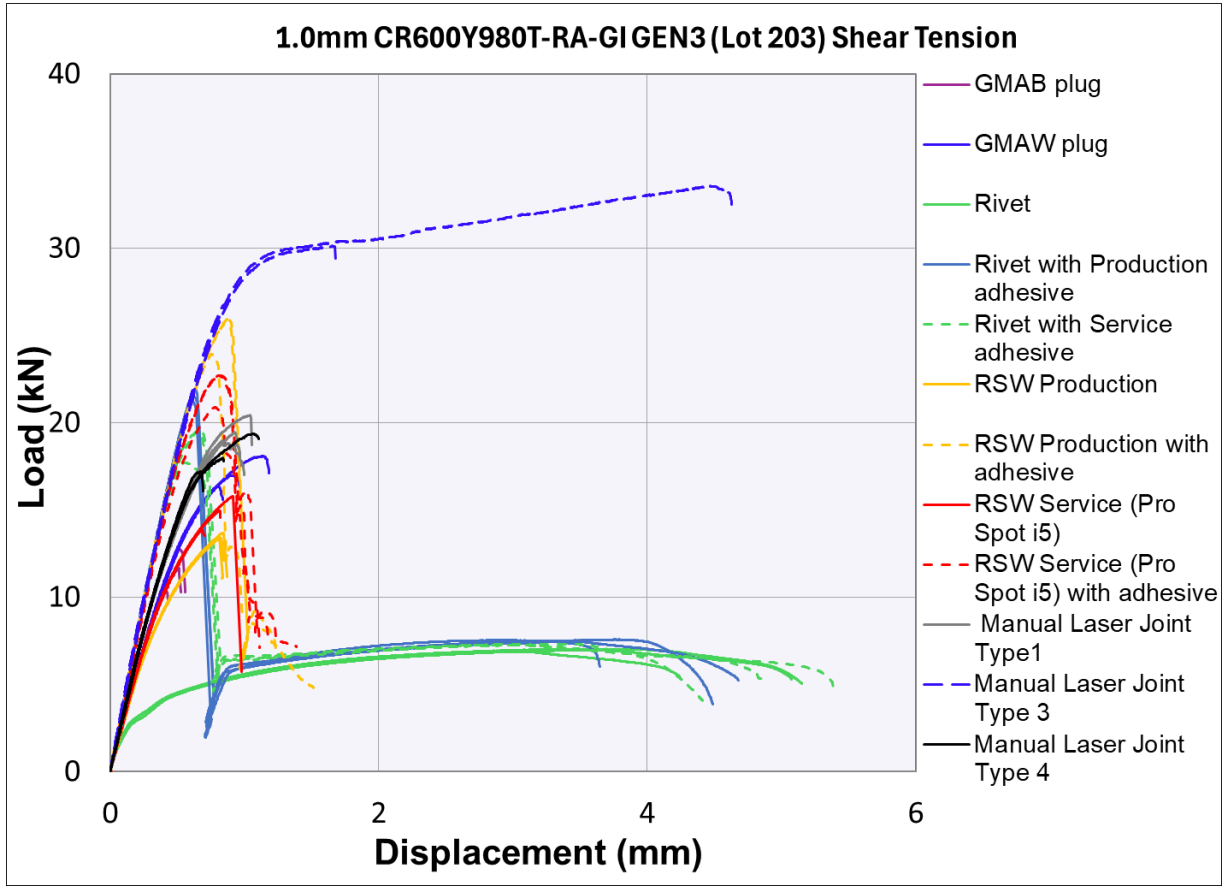


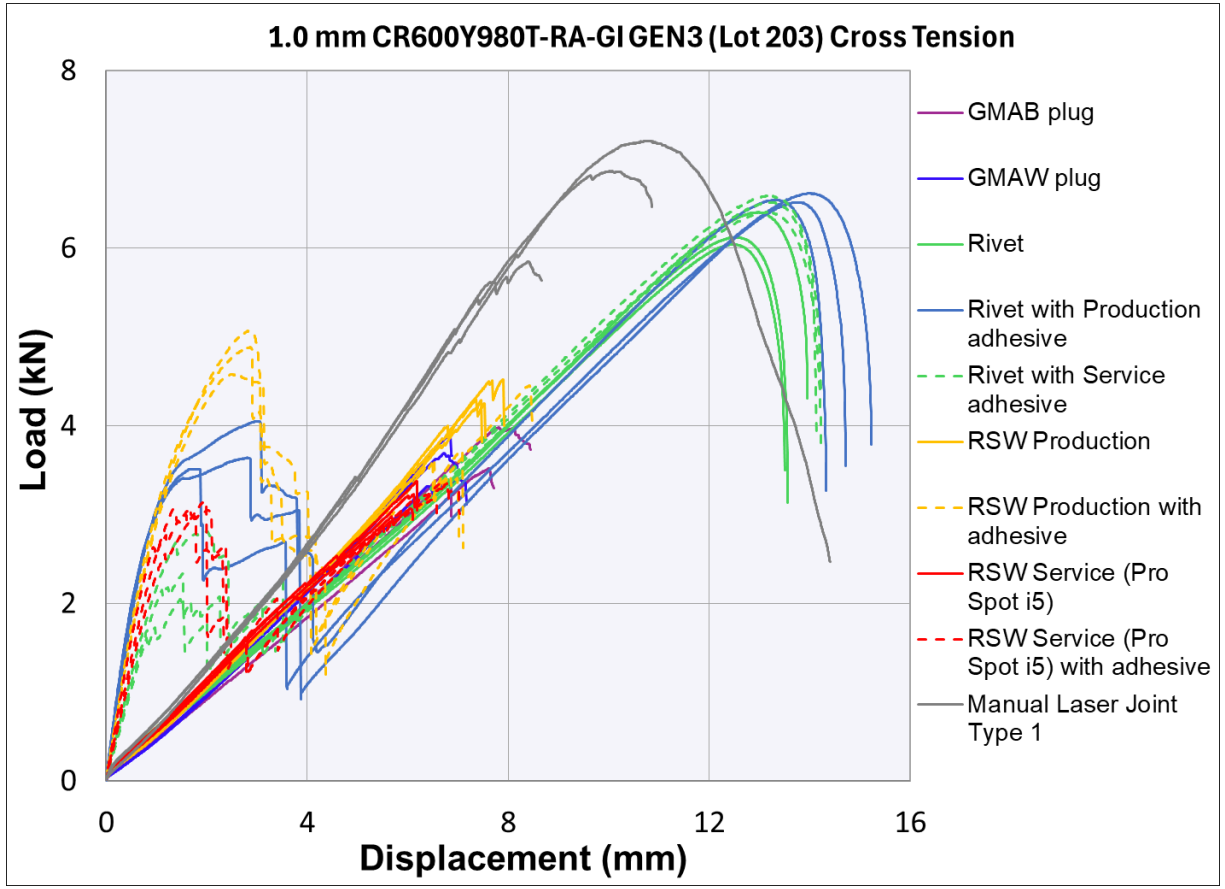




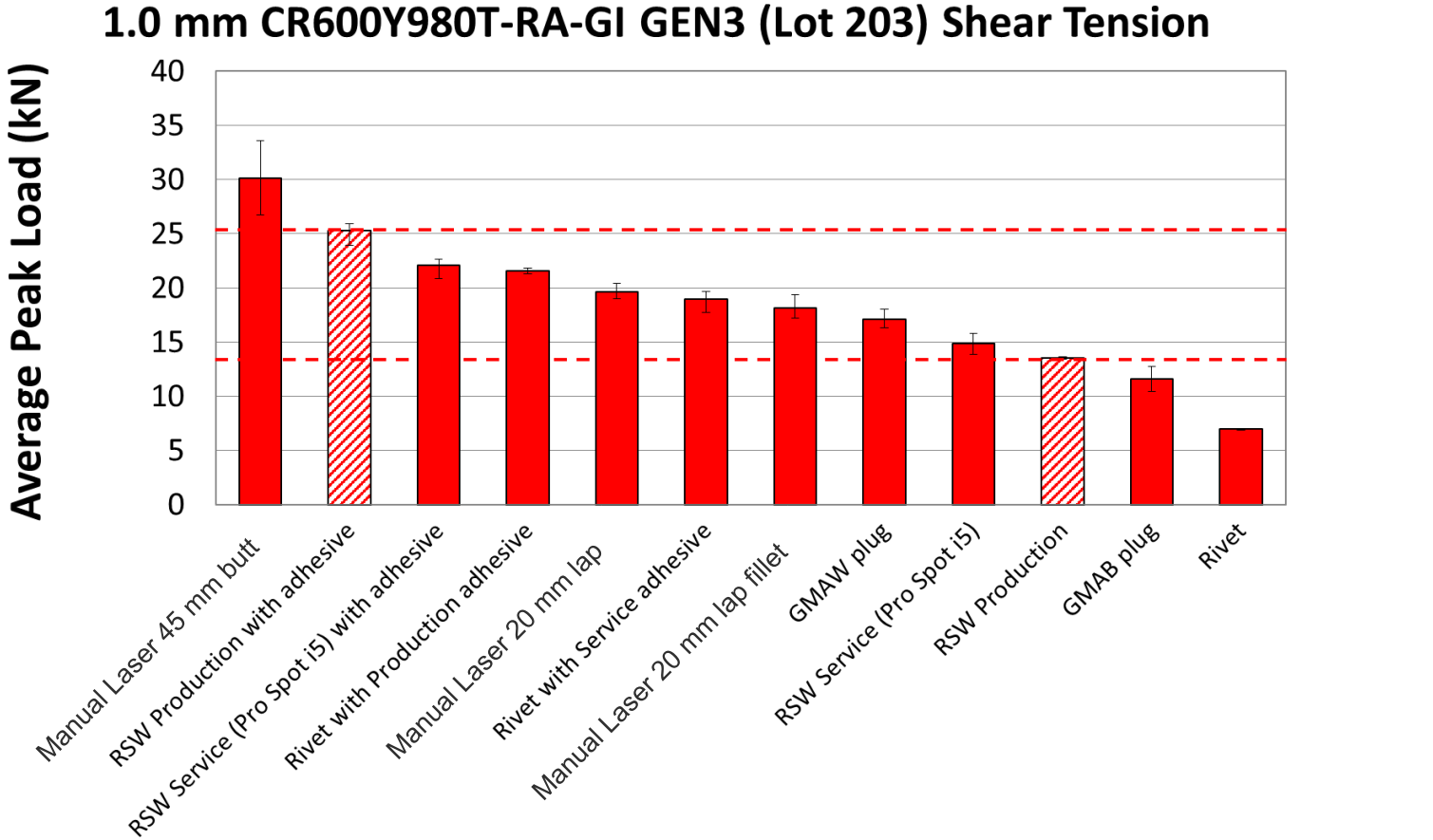
MANUAL LASER
45 mm BUTT

SHEAR TENSION AND CROSS TENSION DATA



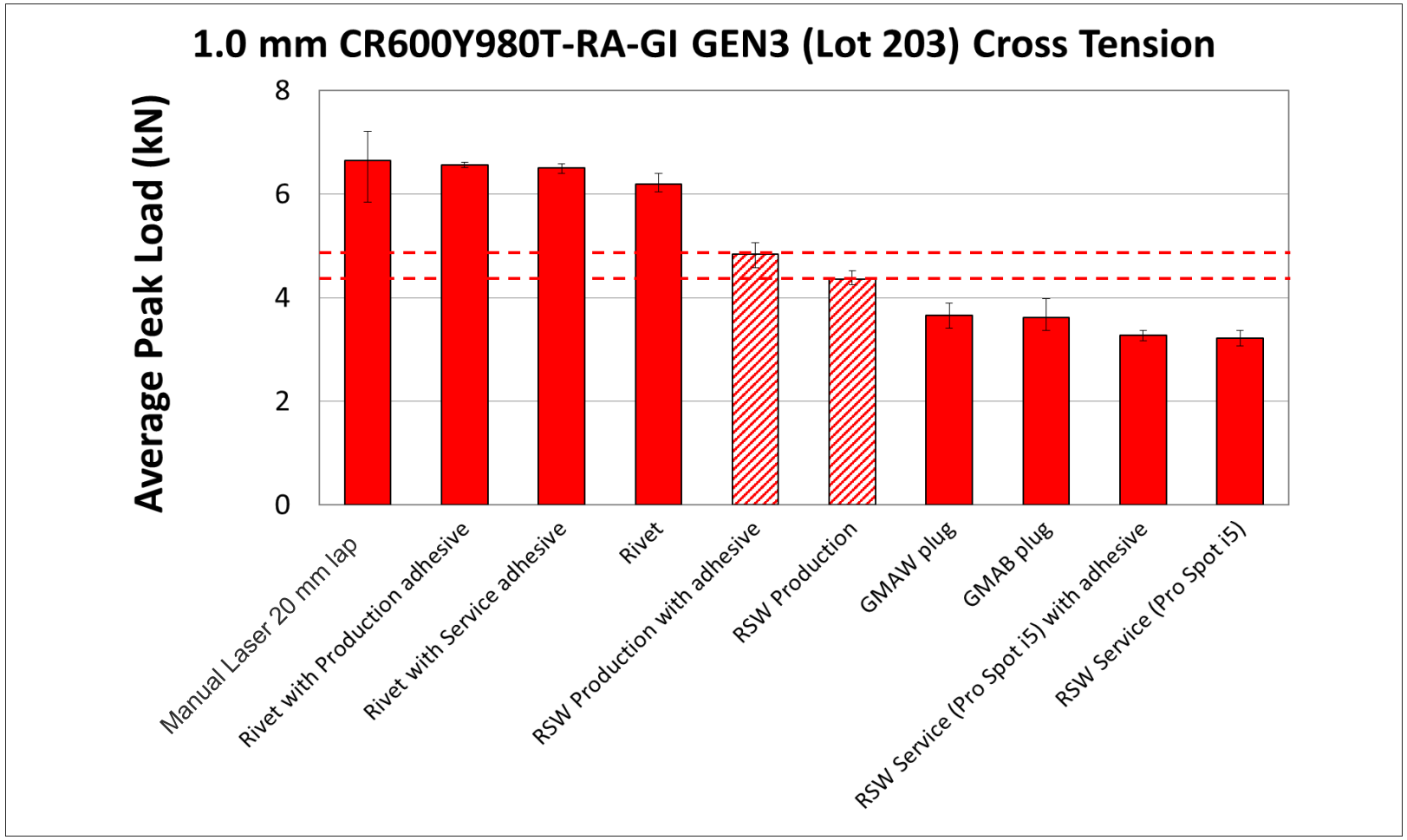


SHEAR TENSION DATA



- Several repair process options exist that are capable of meeting or exceeding joint strength of the baseline RSW production process.
- The RSW production with adhesive process produced the highest lap joint strength.
- The RSW service with adhesive process produced shear tension joint strength approximately 88% of the RSW production with adhesive process.

CROSS TENSION DATA



- Repair process options exist that are capable of meeting or exceeding joint strength of the RSW production process.
- The RSW service with adhesive process produced cross tension joint strength approximately 68% of the RSW production with adhesive process.

MANUAL LASER BUTT JOINT STRENGTH

Specimen	Ultimate Tensile Strength (MPa)	Yield Strength 0.2% Offset (MPa)	Elongation (%)
Base Metal - Baked (ASTM E8)	1002	670	28.4
Manual Laser Butt Joint	593 - 746	N/A	N/A

- Manual laser butt joint tensile strength was approximately 60% to 75% of the base metal tensile strength.
- Process optimization or filler metal addition may be necessary to increase joint strength.

REPAIR PROCESS COMPARISON TO RSW

Repair Process	1.0 mm CR600Y980T-RA-GI (P#7 Lot#203)	
	Repair Process Meets or Exceeds RSW Production Quasi-static Peak Load?	
	Shear Tension	Cross Tension
Rivet with Service Adhesive	YES	YES
Manual Laser 20 mm Lap	YES	YES
Manual Laser 20 mm Lap Fillet	YES	N/A
GMAW Plug 10 mm Hole	Not tested	Not tested
GMAW Plug 8 mm Hole	YES	NO
RSW Service with Adhesive	YES	NO
RSW Service	YES	NO
Rivet	NO	YES
GMAB Plug 8 mm Hole	NO	NO

Repair Process	1.3 mm CR600Y980T-RA-GI (P#5, P#6 Lot#192)	
	Repair Process Meets or Exceeds RSW Production Quasi-static Peak Load?	
	Shear Tension	Cross Tension
Rivet with Service Adhesive	YES	YES
Manual Laser 20 mm Lap	Not tested	Not tested
Manual Laser 20 mm Lap Fillet	Not tested	N/A
GMAW Plug 10 mm Hole	YES	YES
GMAW Plug 8 mm Hole	YES	YES
RSW Service with Adhesive	YES	YES
RSW Service	NO	YES
Rivet	NO	YES
GMAB Plug 8 mm Hole	NO	NO

REPAIR PROCESS COMPARISON TO RSW W/ADHESIVE

Repair Process	1.0 mm CR600Y980T-RA-GI (P#7 Lot#203)	
	Repair Process Meets or Exceeds RSW Production with Adhesive Quasi-static Peak Load?	
	Shear Tension	Cross Tension
Rivet with Service Adhesive	NO	YES
RSW Service with Adhesive	NO	NO

Repair Process	1.3 mm CR600Y980T-RA-GI (P#5, P#6 Lot#192)	
	Repair Process Meets or Exceeds RSW Production with Adhesive Quasi-static Peak Load?	
	Shear Tension	Cross Tension
Rivet with Service Adhesive	NO	YES
RSW Service with Adhesive	NO	NO

PROJECT SUMMARY / CONCLUSION

- Manual removal of zinc coating at the GMAW plug and GMAB plug joints prior to welding appeared to mitigate LME cracking.
- LME cracking was not detected in any of the test samples.
- The RSW production with adhesive process produced higher joint strength than the RSW or rivet processes with service adhesive.
- Manual laser process produced the highest joint strengths of all processes without adhesive.
- For the material evaluated in this project, repair processes can be selected that meet or exceed the joint strength of the baseline RSW production process.
- Project results can be used to assist OEMs in defining appropriate weld joint repair strategies for 980 3rd GEN AHSS.
- Common procedures used in this study allow for comparison to other A/SP Joining projects and with prior Repairability Team testing of other AHSS grades and thicknesses.

FOR MORE INFORMATION

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