GREAT DESIGNS IN STEEL

GAS METAL ARC WELDING OF ADVANCED HIGH STRENGTH STEELS

AUTO/STEEL PARTNERSHIP

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ArcelorMittal
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- Mike Palko, Ford

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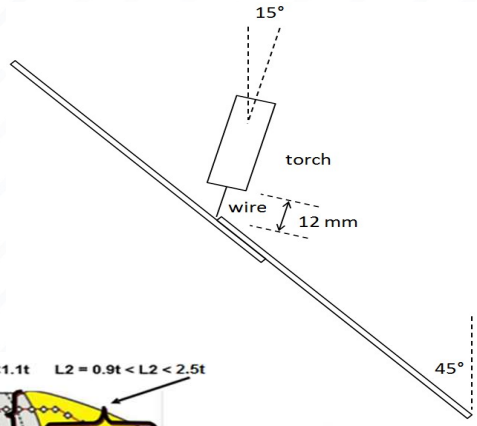
PROJECT OBJECTIVE

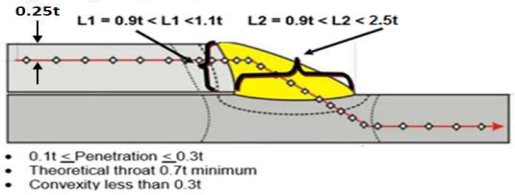
The purpose of this project is to evaluate the effects of gas metal arc welding (GMAW) on AHSS and to identify the impact of filler metal type on joint strength. The results of this investigation may be used as a basis to further develop appropriate welding parameters and processes for AHSS to meet design requirements and may allow for the development of a common test procedure for OEMs, Suppliers and the Steel Company members to establish gas metal arc weldability.

PROJECT APPROACH - TEST MATRIX

Grade	Thickness (mm)	Coating	Filler Metal	ASTM E-8 Tensile	X-ray Inspection	Quasi-static Shear Tension	Cross-section	Microhardness Traverse
HR700Y750T-LA-UC	2.5	uncoated	ER80S-D2	0	0	3	3	1
			ER100S-G	0	0	3	3	1
CR600Y980T-RA-HE-UC	1.4	uncoated	ER70S-6	3	0	3	3	1
CR600Y980T-RA-HE-GI	1.4	GI	ER70S-6	3	3	3	3	1
CR600Y980T-RA-HE-UC	2.0	uncoated	ER70S-6	3	0	3	3	1
CR1000Y1200T-RA-SE-GI	1.6	GI	ER70S-6	3	3	3	3	1

APPROACH - WELDING SETUP





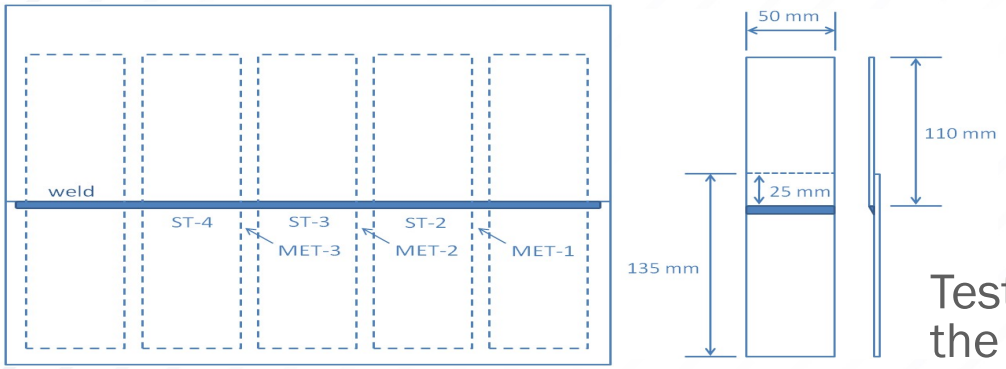
- Welds were made in the 1F position
- 0.1 mm shims were used to produce controlled sheet gaps for zinc coated materials
- 0.035" wire was used
- 90% Argon 10% CO_2 shielding gas was used
- Targeted weld sizes are shown

	Minimum Tensile Strength (MPa)	%C	%Mn	%Si	%Cr	%Ni	%Mo	%S	%P	%Cu	%Al	%V
ER70S-6	485	0.06-0.15	1.40-1.85	0.80-1.15	0.15 (max)	-	0.15 (max)	0.035 (max)	0.025 (max)	0.50 (max)	-	0.03 (max)
ER80S-D2	550	0.07-0.12	1.60-2.10	0.50-0.80	-	-	0.40 (max)	0.025 (max)	0.025 (max)	0.50 (max)	-	-
ER100S-G*	690	0.10	1.55	0.57	0.27	0.88	0.48	<0.005	0.01	0.09	0.00	<0.003

*typical composition shown

Source: www.lincolnelectric.com

APPROACH - TEST SPECIMENS

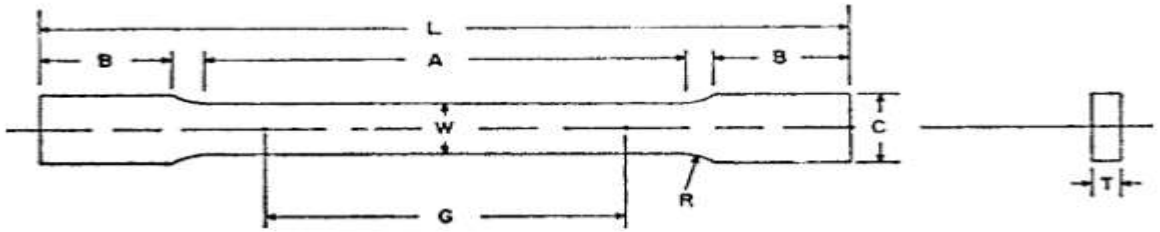


Test specimens were taken from the center of the welded plates to avoid the weld starts and stops

X-ray images correspond to the locations of the shear tension (ST) specimens.

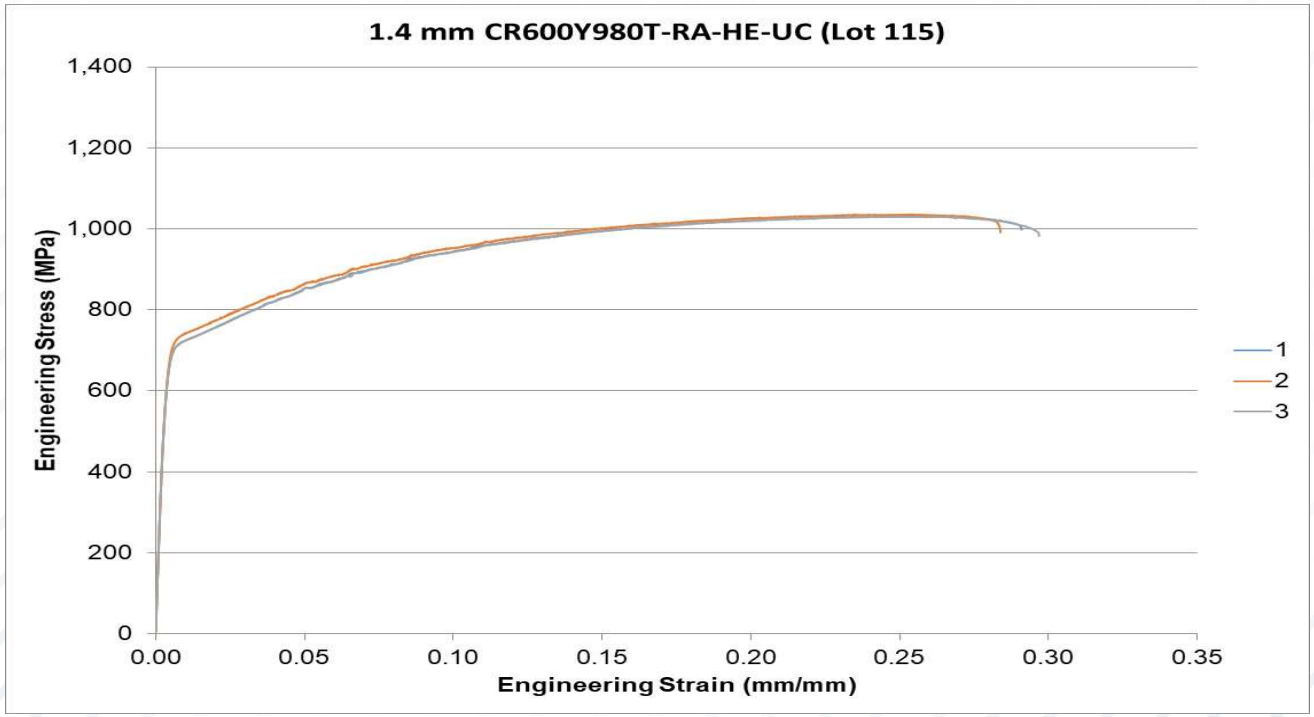
Metallurgical (MET) specimens were taken from the locations shown.

APPROACH - BASE METAL TENSILE TEST SPECIMEN DIMENSIONS

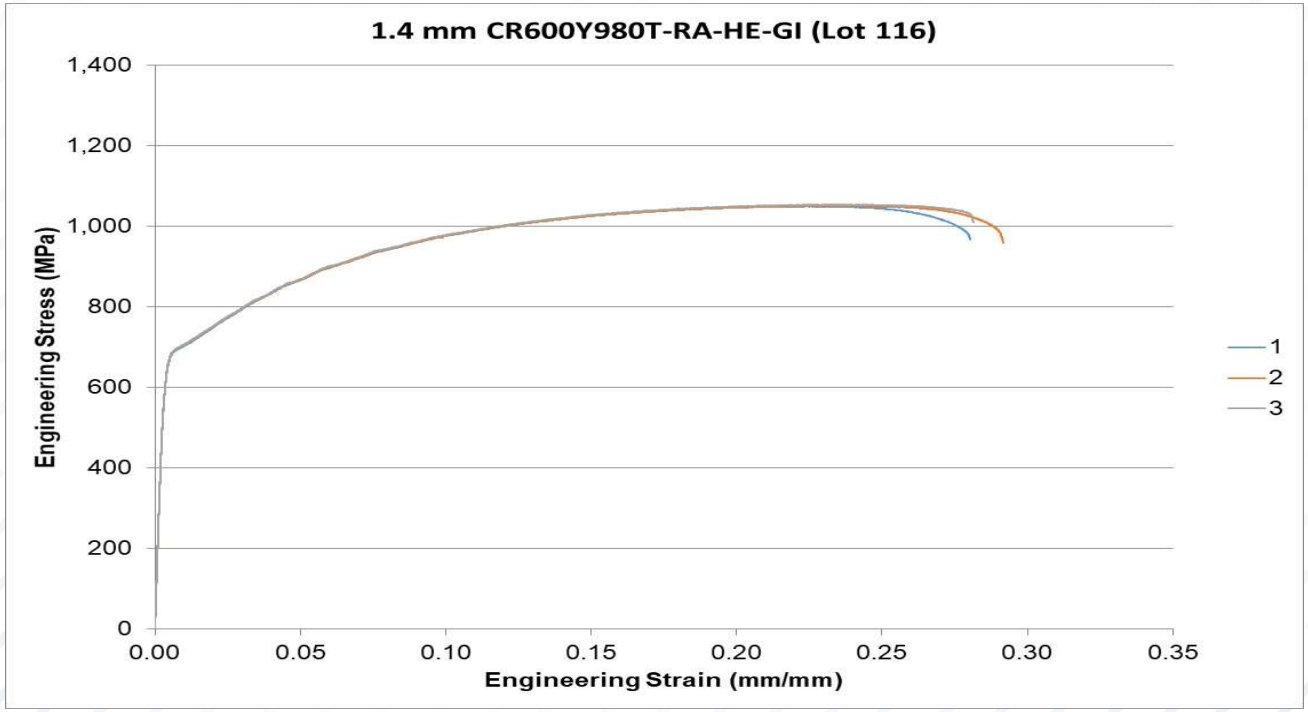


	Sheet-Type, 12.5 mm [0.500 in.] Wide
	mm [in.]
G—Gage length	50.0 ± 0.1 [2.000 ± 0.005]
W—Width	12.5 ± 0.2 [0.500 ± 0.010]
T—Thickness	thickness of material
R—Radius of fillet, min	12.5 [0.500]
L—Overall length, min	200 [8]
A—Length of reduced section, min	57 [2.25]
B—Length of grip section, min	50 [2]
C—Width of grip section, approximate	20 [0.750]

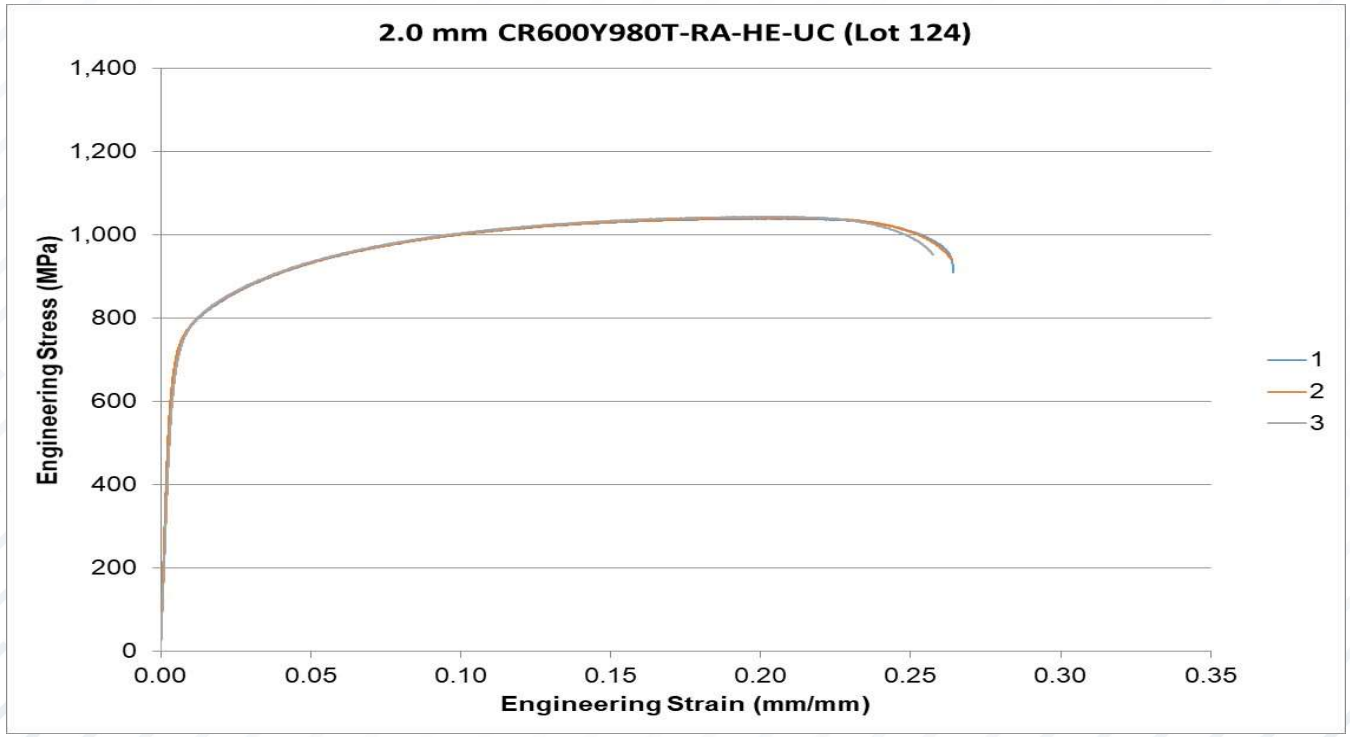
BASE METAL TENSILE TEST



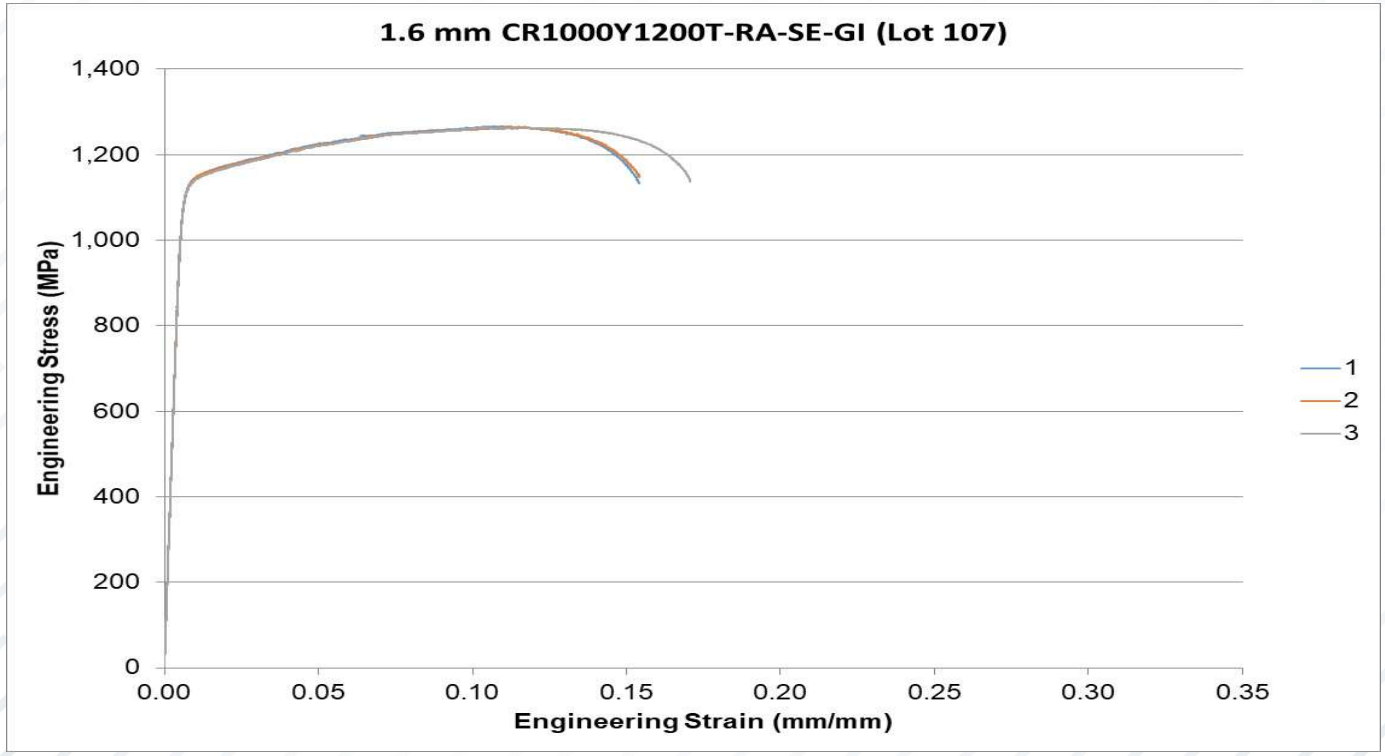
BASE METAL TENSILE TEST



BASE METAL TENSILE TEST



BASE METAL TENSILE TEST



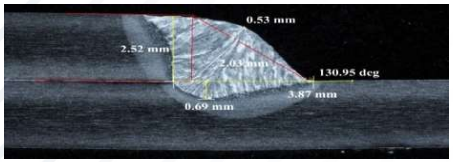
WELDING PARAMETERS

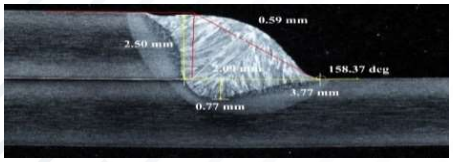
Grade	Thickness (mm)	Coating	Process	Filler Metal	Current (A)	Voltage (V)	Travel Speed (in/min)
HR700Y750T-LA-UC	2.5	uncoated	GMAW	ER80S-D2	150	19.0	40
			GMAW	ER100S-G	150	20.0	40
CR600Y980T-RA-HE-UC	1.4	uncoated	GMAW	ER70S-6	105	15.0	50
CR600Y980T-RA-HE-GI	1.4	GI	GMAW	ER70S-6	80	18.0	20
CR600Y980T-RA-HE-UC	2.0	uncoated	GMAW	ER70S-6	120	20.0	50
CR1000Y1200T-RA-SE-GI	1.6	GI	GMAW	ER70S-6	85	18.5	20

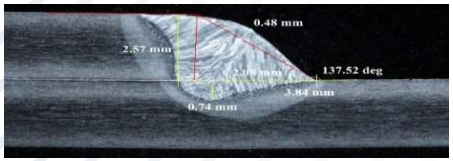
WELD SIZE

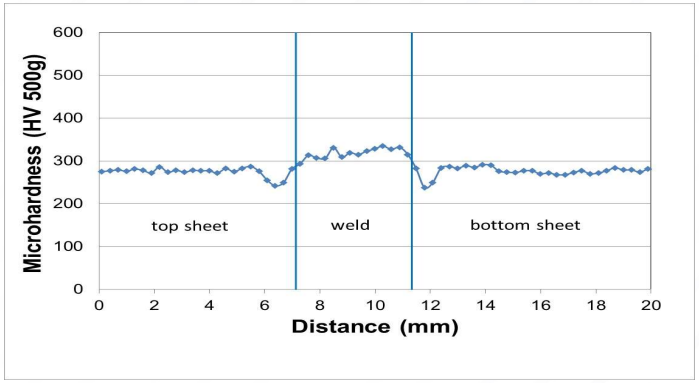
Grade	Thickness (mm)	Coating	Process	Filler Metal	Leg Length L1 (mm)	Leg Length L2 (mm)	Penetration (mm)	Theoretical Throat (mm)	Convexity (mm)	Toe Angle (degrees)
HR700Y750T-LA-UC	2.5	uncoated	GMAW	ER80S-D2	2.5	3.8	0.7	2.1	0.5	142
			GMAW	ER100S-G	2.5	3.9	0.9	2.1	0.9	150
CR600Y980T-RA-HE-UC	1.4	uncoated	GMAW	ER70S-6	1.4	3.2	0.6	1.3	0.4	166
CR600Y980T-RA-HE-GI	1.4	GI	GMAW	ER70S-6	2.1	3.9	0.6	1.5	0.7	148
CR600Y980T-RA-HE-UC	2.0	uncoated	GMAW	ER70S-6	1.9	3.5	0.5	1.7	0.5	162
CR1000Y1200T-RA-SE-GI	1.6	GI	GMAW	ER70S-6	2.1	4.3	0.7	1.6	0.7	157

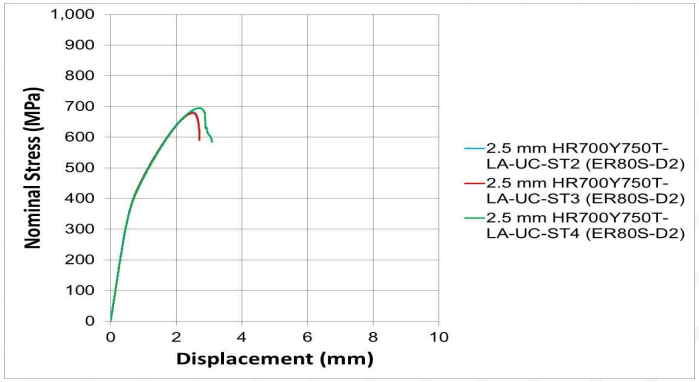
RESULTS - 2.5 MM HR700Y750T-LA-UC ER80S-D2 FILLER METAL

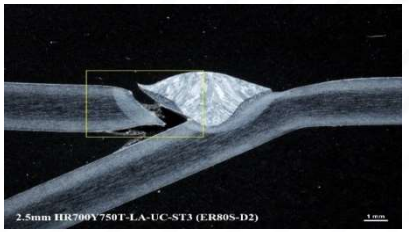




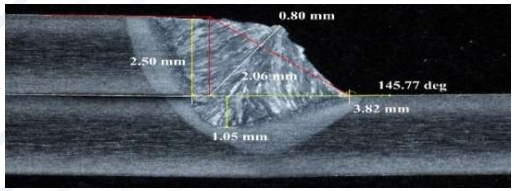


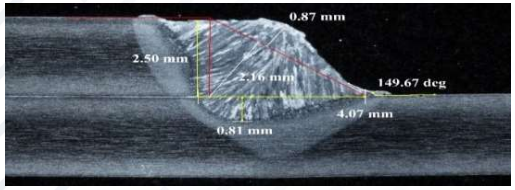


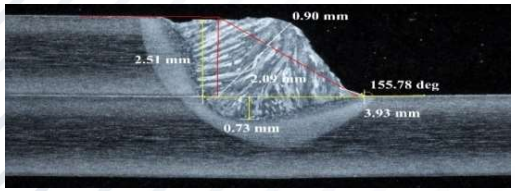


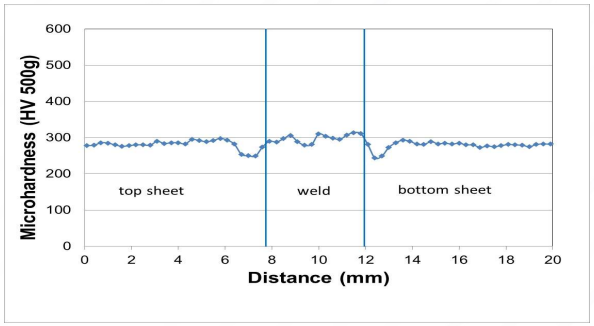


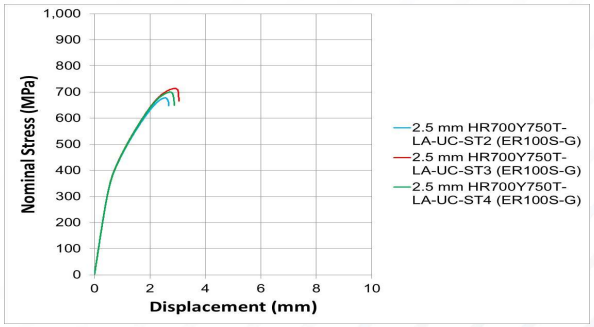
RESULTS - 2.5 MM HR700Y750T-LA-UC ER100S-G FILLER METAL

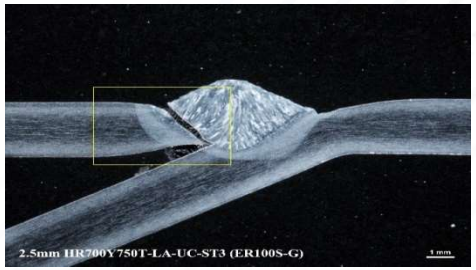




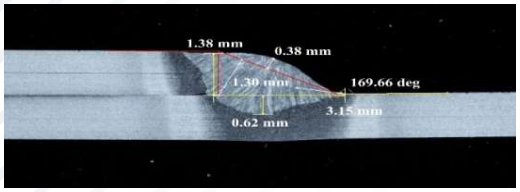


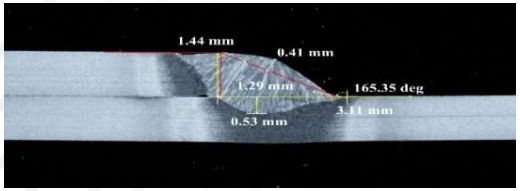


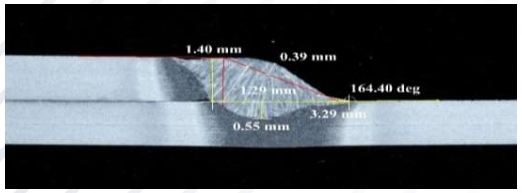


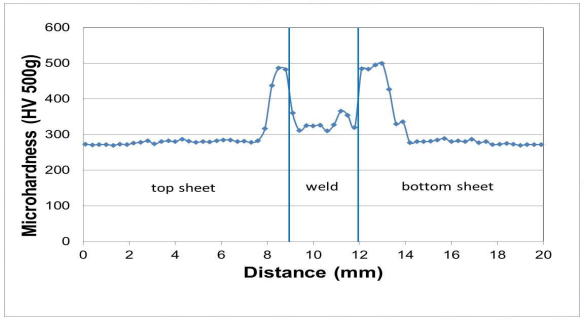


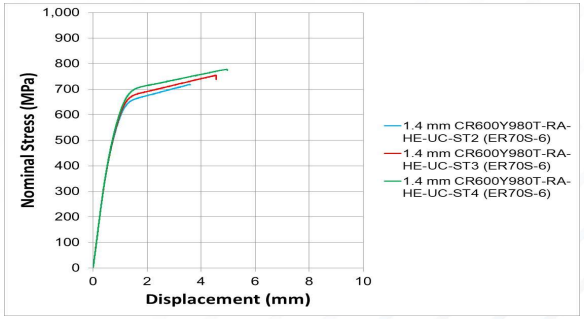
RESULTS - 1.4 MM CR600Y980T-RA-HE-UC ER70S-6 FILLER METAL

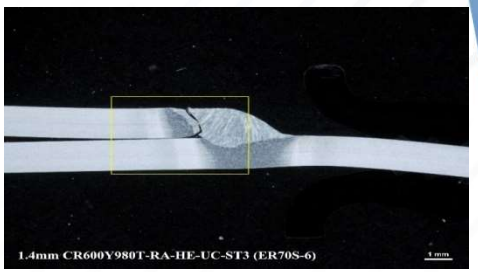


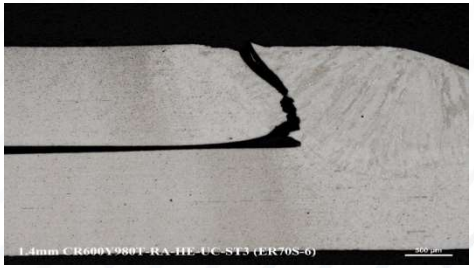




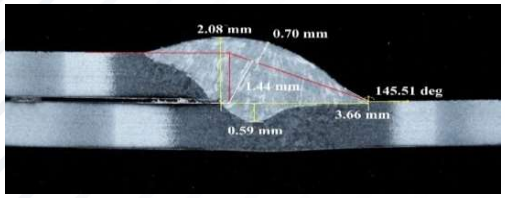


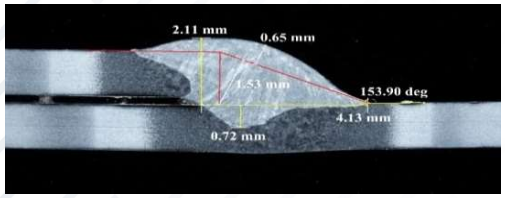


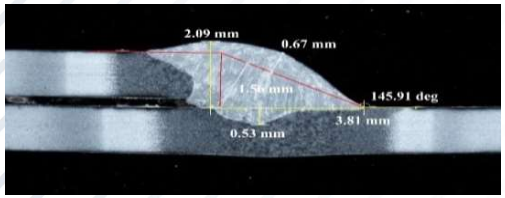


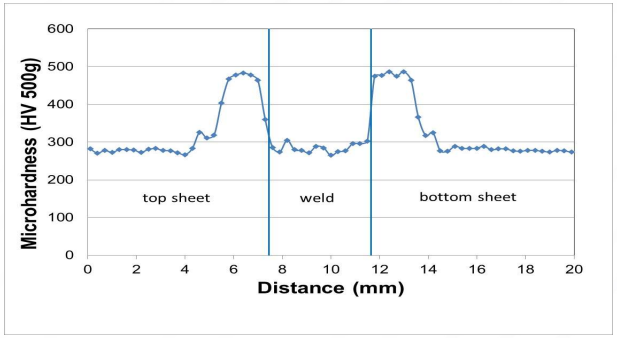


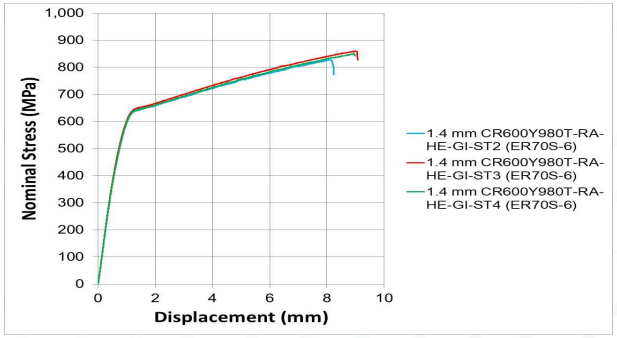
RESULTS - 1.4 MM CR600Y980T-RA-HE-GI ER70S-6 FILLER METAL

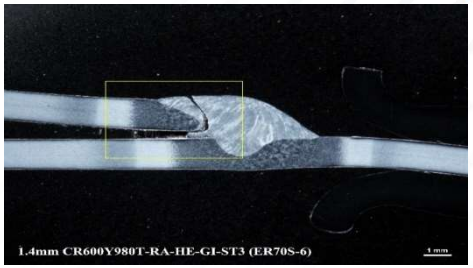


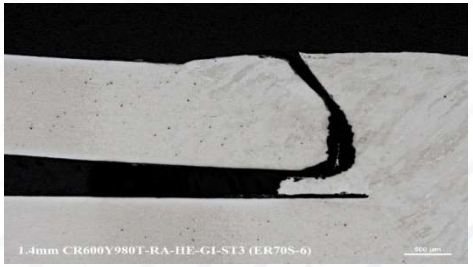




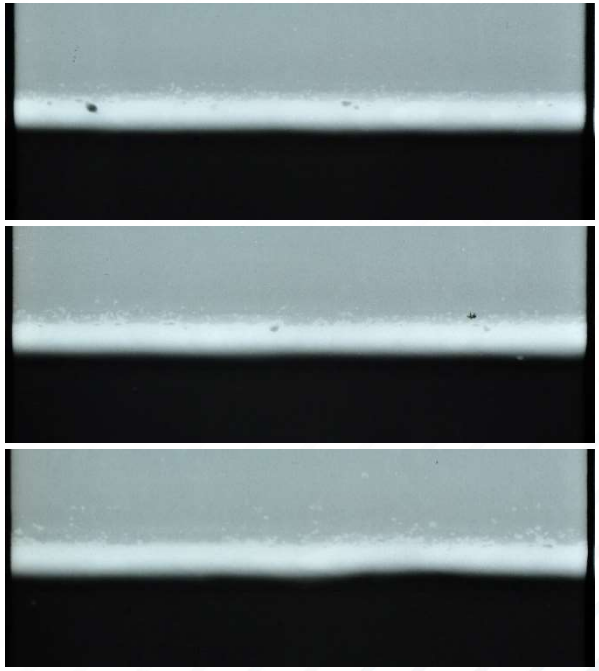




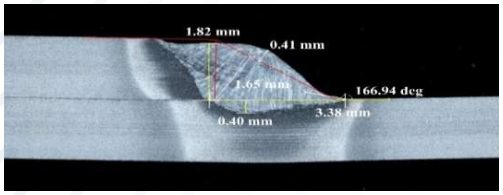


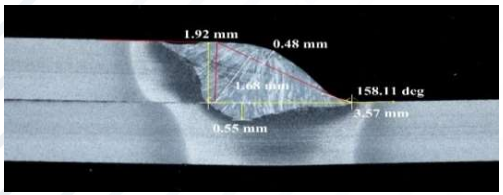


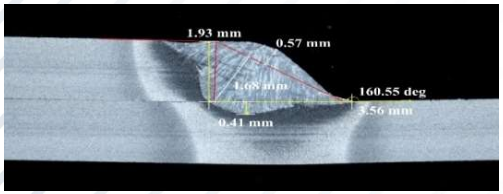
RESULTS – X-RAY IMAGES
1.4 MM CR600Y980T-RA-HE-GI, ER70S-6 FILLER METAL

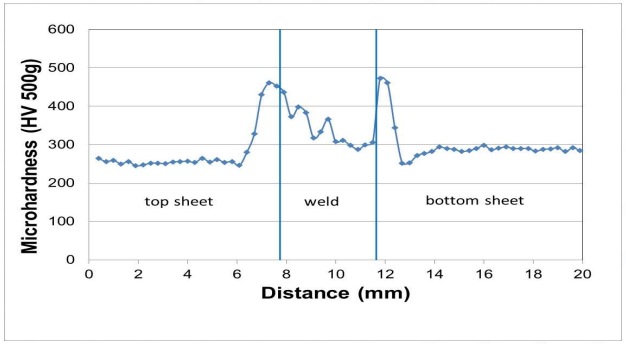


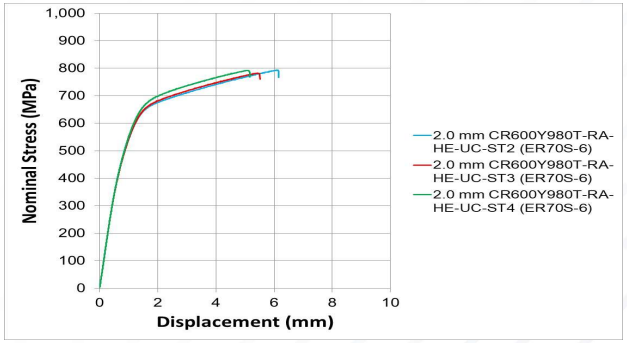
RESULTS - 2.0 MM CR600Y980T-RA-HE-UC ER70S-6 FILLER METAL

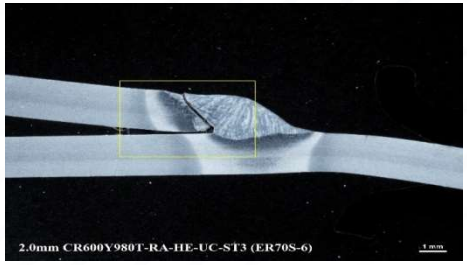


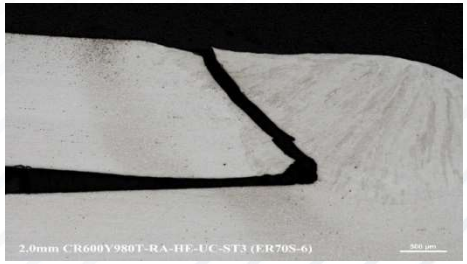




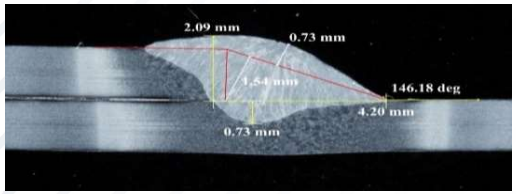


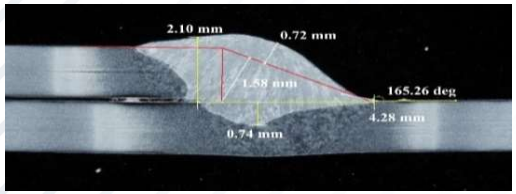


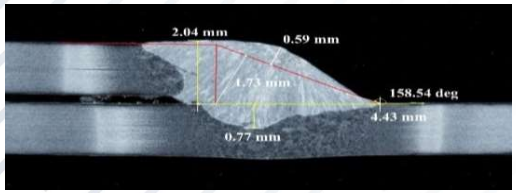


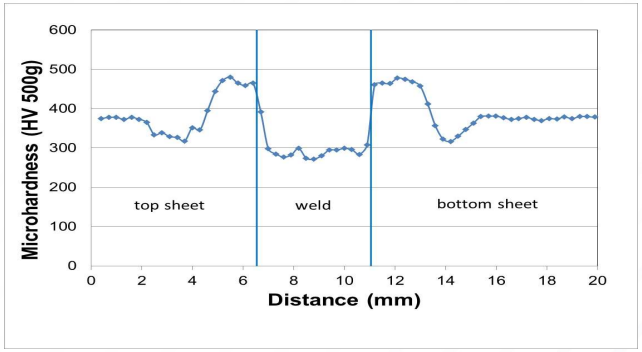


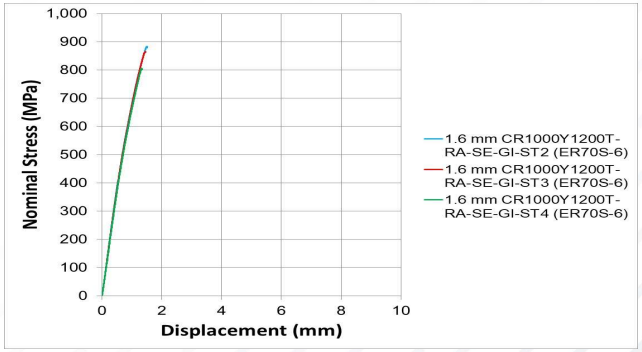
RESULTS - 1.6 MM CR1000Y1200T-RA-SE-GI ER70S-6 FILLER METAL



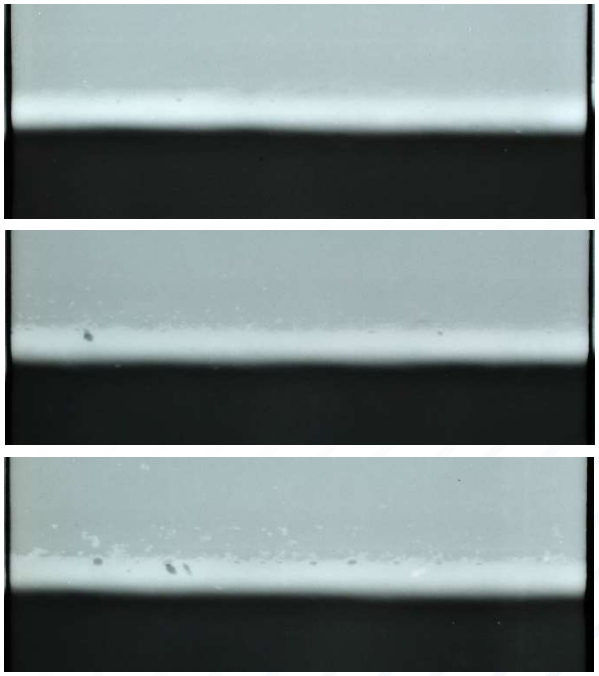








RESULTS – X-RAY IMAGES
1.6 MM CR1000Y1200T-RA-SE-GI, ER70S-6 FILLER METAL



PROJECT RESULTS - SUMMARY

Grade	Thickness (mm)	Coating	Process	Filler Metal	Base Metal Microhardness (HV_{500g})	Minimum Microhardness (HV_{500g})	Minimum Microhardness Location	Joint Peak Load (kN)	Nominal Joint Strength (MPa)	Joint Efficiency (%)	Porosity (X-ray) (%)	Fracture Location
HR700Y750T-LA-UC	2.5	uncoated	GMAW	ER80S-D2	278	238	heat-affected zone	89.0	685	0.83	n/a	heat-affected zone
			GMAW	ER100S-G	284	244	heat-affected zone	90.9	698	0.84	n/a	weld metal near fusion line
CR600Y980T-RA-HE-UC	1.4	uncoated	GMAW	ER70S-6	273	270	base metal	53.6	750	0.73	n/a	weld metal
CR600Y980T-RA-HE-GI	1.4	GI	GMAW	ER70S-6	277	265	weld metal	60.3	846	0.80	0.53	weld metal
CR600Y980T-RA-HE-UC	2.0	uncoated	GMAW	ER70S-6	274	245	base metal	76.9	789	0.76	n/a	weld metal
CR1000Y1200T-RA-SE-GI	1.6	GI	GMAW	ER70S-6	379	272	weld metal	69.6	852	0.67	0.77	weld metal

Nominal joint strength was calculated using the steel sheet cross-section dimensions.

Joint efficiency was calculated as the nominal joint strength divided by parent metal tensile strength, expressed as a percentage.

ER70S-6 minimum tensile strength: 485 MPa
ER80S-D2 minimum tensile strength: 550 MPa
ER100S-G minimum tensile strength: 690 MPa

PROJECT RESULTS - SUMMARY

- Quality welds were achieved with all test materials.
- Zinc coated steels were able to be welded with average area percent porosity less than 1% using appropriate welding schedules and the test conditions used.
- Fractures occurred in the heat affected zone, weld metal, or near the weld fusion line.
- Fracture location did not necessarily correspond to the areas with the lowest microhardness.
- Joint efficiency ranged from 67% (CR1000Y1200T-RA-SE-GI with ER70S-6 filler metal) to 84% (HR700Y750T-LA-UC with ER100S-G filler metal).
- Nominal joint strength ranged from 685 MPa (HR700Y750T-LA-UC with ER80S-D2 filler) to 852 MPa (CR1000Y1200T-RA-SE-GI with ER70S-6 filler metal).
- The data obtained using the test procedure defined in this project quantifies joint characteristics and could be used as a basis for developing a GMAW qualification procedure.

FOR MORE INFORMATION

GDIS

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GREAT DESIGNS IN STEEL

Presentations will be available for download on SMDI's website on Wednesday, May 22