

Great Designs in

# STEEL



## Gas Metal Arc Brazing and Welding of Advanced High Strength Steels

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Evaluate the effects of gas metal arc welding (GMAW) and gas metal arc brazing (GMAB) on AHSS and UHSS and to identify the impact of welding and brazing on joint strength.

# Test Matrix

Grade	Thickness (mm)	Coating	Process	Filler
BH210	0.67	HDGI	GMAW	ER70S-6
			GMAB	ERCuSi-A
BH240	0.65	HDGI	GMAW	ER70S-6
			GMAB	ERCuSi-A
DP490	0.69	HDGA	GMAW	ER70S-6
			GMAB	ERCuSi-A

Materials less than 0.7 mm thick were tested with both ER70S-6 (GMAW) and ERCuSi-A silicon bronze (GMAB) filler metals

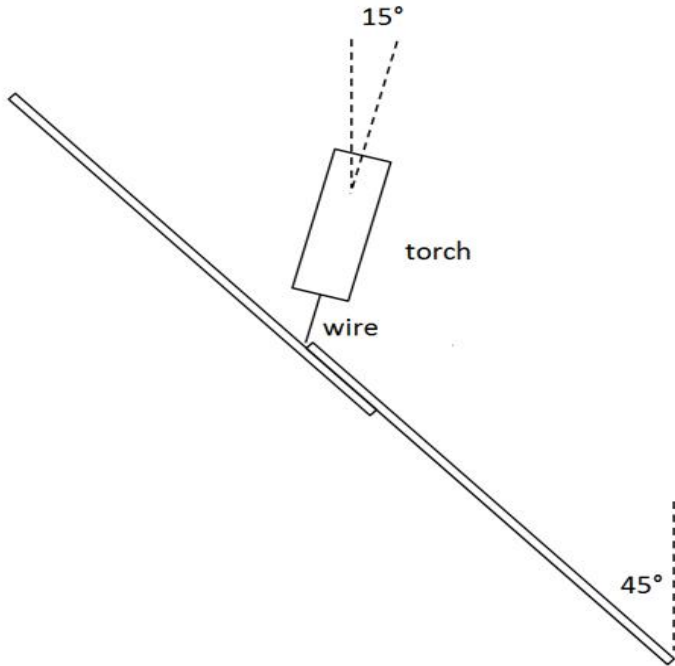
# Test Matrix (Cont'd)

Grade	Thickness (mm)	Coating	Process	Filler
DP780	2.0	HDGI	GMAW	ER70S-6
			GMAW	ER80S-D2
			GMAW	ER100S-G
CP780	2.53	HDGI	GMAW	ER70S-6
			GMAW	ER80S-D2
			GMAW	ER100S-G
780SF	2.7	uncoated	GMAW	ER70S-6
			GMAW	ER80S-D2
			GMAW	ER100S-G
DP1180	1.38	uncoated	GMAW	ER70S-6
			GMAW	ER100S-G
DP1180	1.4	EG	GMAW	ER70S-6
			GMAW	ER100S-G
DP980	1.95	HDGA	GMAW	ER70S-6
MS1700	1.4	uncoated	GMAW	ER70S-6
MP1180	1.2	uncoated	GMAW	ER70S-6
HSLA700	2.5	uncoated	GMAW	ER70S-6

Selected materials were tested with three different strength of filler metals:

- ER70S-6 (70 ksi)
- ER80S-D2 (80 ksi)
- ER100S-G (100 ksi)

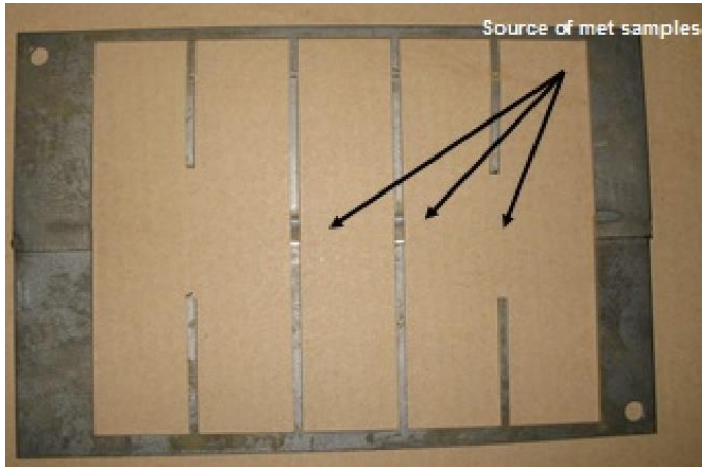
# Welding Setup



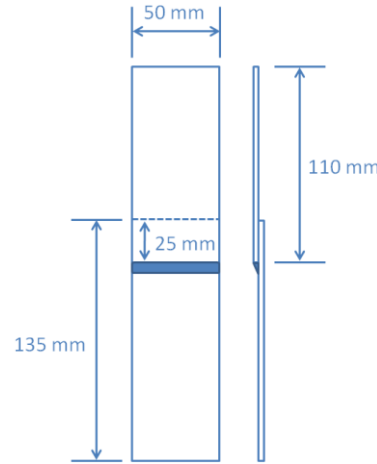
- Sheets sheared to 6" x 12" were robotically welded in 1F position
- 0.1 mm shims used on faying surfaces of sheet steels
- 0.035" diameter wire
- 90% Argon 10% CO<sub>2</sub> shielding gas (GMAW)
- 100% Argon shielding gas (GMAB)

- X-ray inspection (referencing ISO 17636-2 and ISO 5817)
  - for joints made with zinc coated steels
  - porosity percentage was measured
- Cross-section examination
- Microhardness traverse
- Quasi-static shear tension

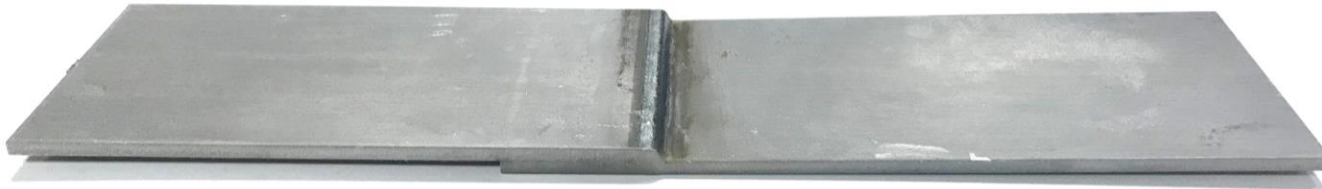
# Specimen Preparation



Example photo provided by A/SP

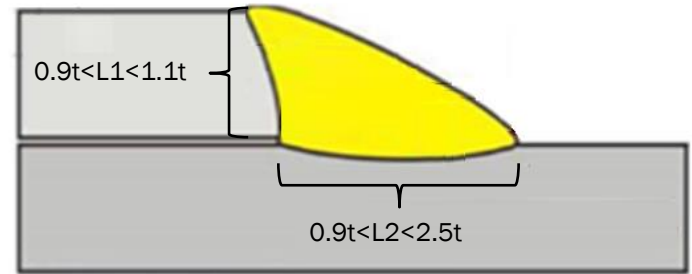


Test specimens were waterjet cut from continuous welded panels in order to eliminate the effects of weld starts and stops



# Welding Parameters

Grade	Thickness (mm)	Coating	Process	Filler	Current (A)	Voltage (V)	Travel Speed (in/min)
BH210	0.67	HDGI	GMAW	ER70S-6	68	14.0	25
			GMAB	ERCuSi-A	70	15.4	30
BH240	0.65	HDGI	GMAW	ER70S-6	68	14.0	25
			GMAB	ERCuSi-A	125	11.2	30
DP490	0.69	HDGA	GMAW	ER70S-6	70	15.5	25
			GMAB	ERCuSi-A	85	18.0	30
DP780	2.0	HDGI	GMAW	ER70S-6	105	21.0	20
			GMAW	ER80S-D2	105	20.0	20
			GMAW	ER100S-G	105	20.0	20
CP780	2.53	HDGI	GMAW	ER70S-6	110	21.0	20
			GMAW	ER80S-D2	110	20.0	20
			GMAW	ER100S-G	110	20.0	20
780SF	2.7	uncoated	GMAW	ER70S-6	180	22.0	50
			GMAW	ER80S-D2	180	21.0	50
			GMAW	ER100S-G	180	21.0	50
DP1180	1.38	uncoated	GMAW	ER70S-6	105	15.0	50
			GMAW	ER100S-G	105	19.0	50
DP1180	1.4	EG	GMAW	ER70S-6	85	18.5	20
			GMAW	ER100S-G	78	20.0	20
DP980	1.95	HDGA	GMAW	ER70S-6	105	21.0	20
MS1700	1.4	uncoated	GMAW	ER70S-6	110	15.5	50
MP1180	1.2	uncoated	GMAW	ER70S-6	105	16.0	50
HSLA700	2.5	uncoated	GMAW	ER70S-6	160	21.0	50

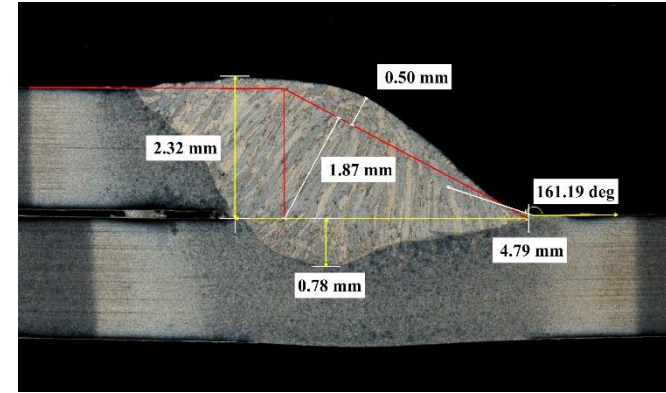


- $0.1t \leq \text{Penetration} \leq 0.3t$
- Theoretical throat  $0.7t$  minimum
- Convexity less than  $0.3t$

Welding parameters were developed to obtain the targeted weld size

# Weld and Braze Size

Grade	Thickness (mm)	Coating	Process	Filler	Leg Length L1 (mm)	Leg Length L2 (mm)	Penetration (mm)	Convexity (mm)	Toe Angle (degrees)
BH210	0.67	HDGI	GMAW	ER70S-6	1.05	2.65	1.06	0.46	143
			GMAB	ERCuSi-A	1.22	3.71	0.15	0.57	147
BH240	0.65	HDGI	GMAW	ER70S-6	1.13	2.54	0.74	0.63	136
			GMAB	ERCuSi-A	1.52	3.49	0.03	0.98	156
DP490	0.69	HDGA	GMAW	ER70S-6	0.97	2.99	1.00	0.55	150
			GMAB	ERCuSi-A	1.38	4.25	0.12	0.78	151
DP780	2.0	HDGI	GMAW	ER70S-6	2.60	4.39	0.81	0.41	160
			GMAW	ER80S-D2	2.23	4.34	0.62	0.37	164
			GMAW	ER100S-G	2.15	4.61	0.91	0.66	152
CP780	2.53	HDGI	GMAW	ER70S-6	2.60	4.39	0.81	0.41	167
			GMAW	ER80S-D2	2.56	4.00	0.74	0.29	158
			GMAW	ER100S-G	2.56	4.45	0.91	0.38	151
780SF	2.7	uncoated	GMAW	ER70S-6	2.57	3.70	0.74	0.60	152
			GMAW	ER80S-D2	2.60	3.65	0.55	0.51	147
			GMAW	ER100S-G	2.54	3.79	0.63	0.72	156
DP1180	1.38	uncoated	GMAW	ER70S-6	1.38	3.14	0.42	0.25	163
			GMAW	ER100S-G	1.52	3.17	0.47	0.49	144
DP1180	1.4	EG	GMAW	ER70S-6	1.49	3.99	0.76	0.46	167
			GMAW	ER100S-G	1.68	3.83	0.60	0.71	147
DP980	1.95	HDGA	GMAW	ER70S-6	2.36	4.57	0.90	0.53	151
MS1700	1.4	uncoated	GMAW	ER70S-6	1.55	2.96	0.30	0.43	149
MP1180	1.2	uncoated	GMAW	ER70S-6	1.37	2.87	0.30	0.40	153
HSLA700	2.5	uncoated	GMAW	ER70S-6	2.57	3.59	0.72	0.56	131



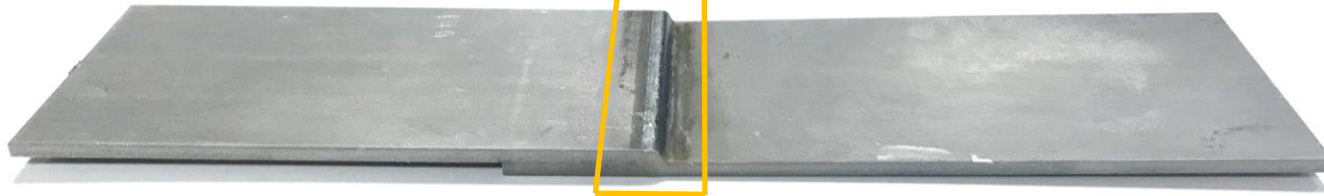
Average weld and braze size for each joint

# X-ray Results: 0.67 mm BH210 HDGI

ER70S-6 filler metal



ERCuSi-A filler metal

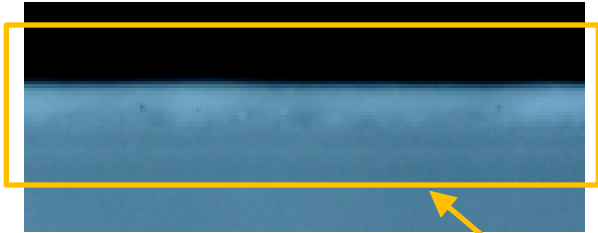


Example specimen shown

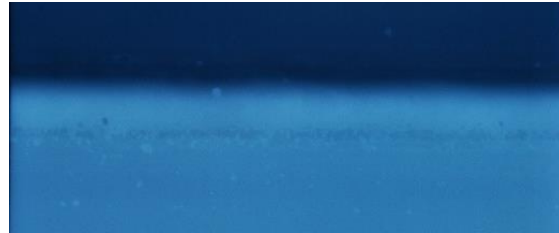
X-ray inspections were performed to detect imperfections in weld and braze metals

# X-ray Results: GMAW 2.0 mm DP780 HDGI

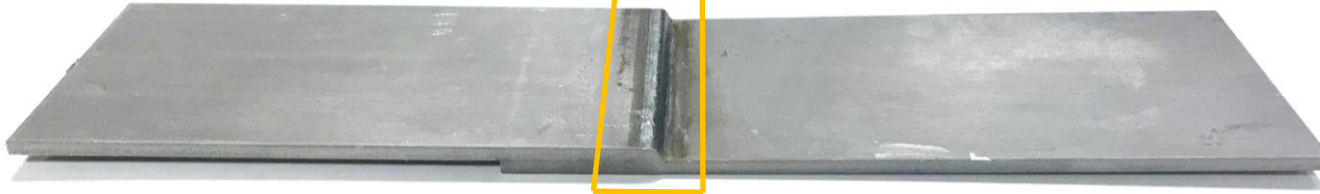
ER70S-6 filler metal



ER80S-D2 filler metal



ER100S-G filler metal

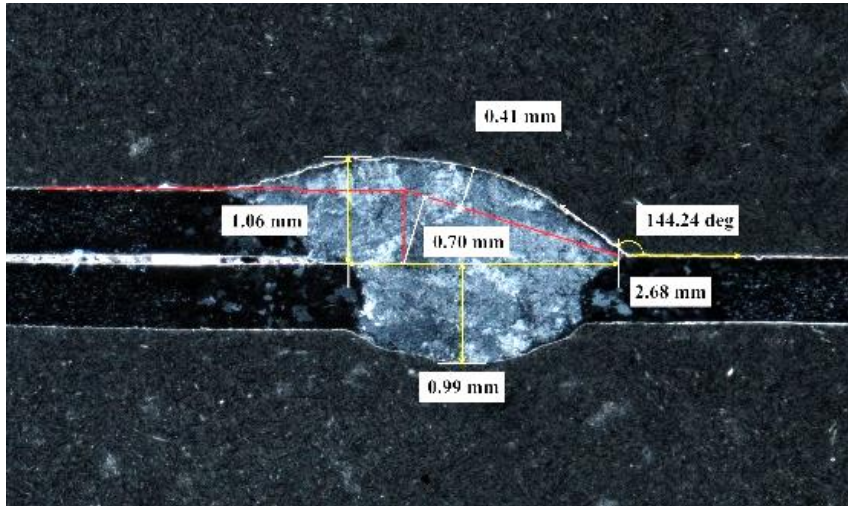


Example specimen shown

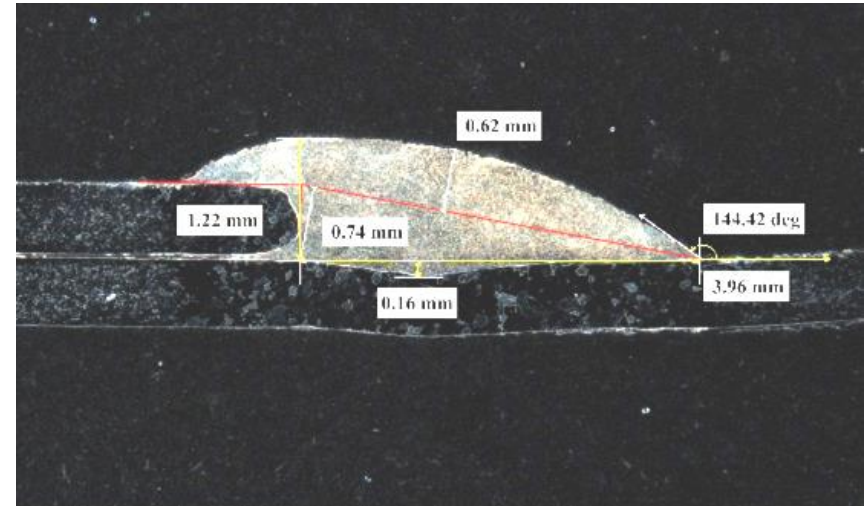
Porosity percentage values are tabulated in the report

# Cross-sections: 0.67 BH210 HDGI Joints

ER70S-6 filler metal



ERCuSi-A filler metal



# Microhardness Traverse vs. Fracture Location

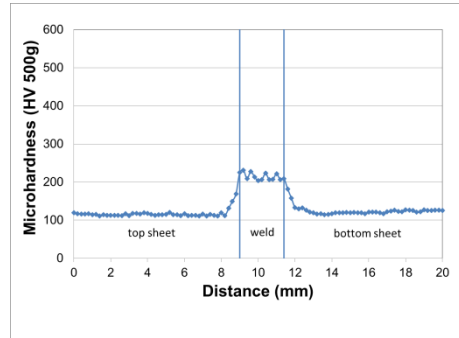
0.67 mm BH210 HDGI

Microhardness  
Traverse

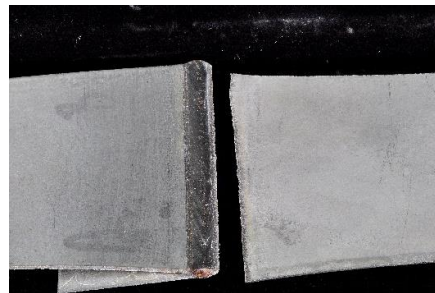
Average Peak  
Load and (Joint  
Efficiency)

Typical Fracture  
Location

ER70S-6 weld

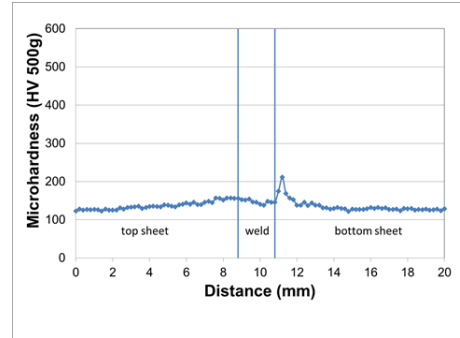


11.95 kN (100%)



heat-affected zone

ERCuSi-A braze



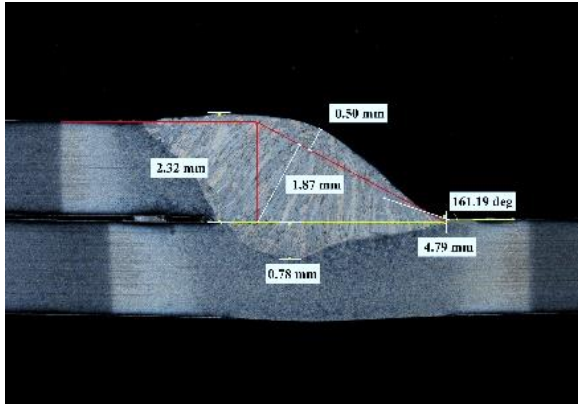
12.04 kN (101%)



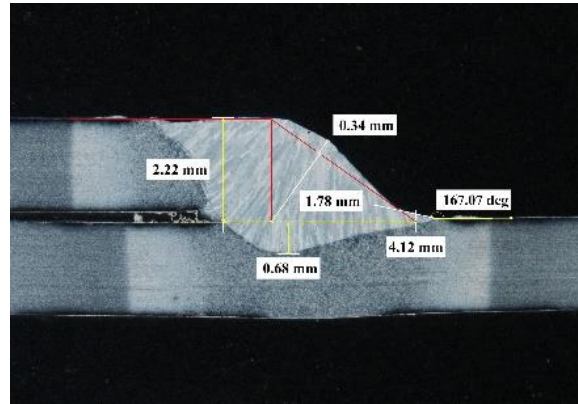
base metal

# Cross-sections: 2.0 mm DP780 HDGI Joints

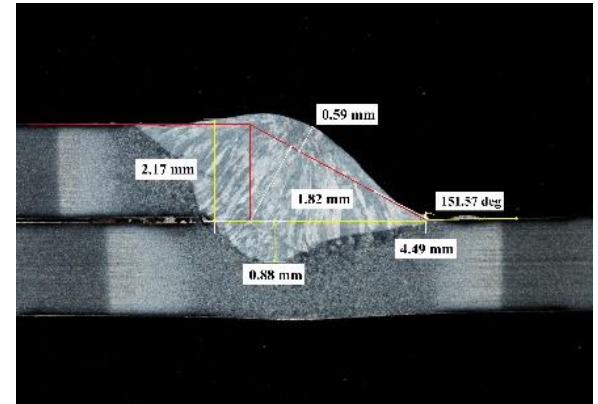
ER70S-6 filler metal



ER80S-D2 filler metal



ER100S-G filler metal



# Microhardness Traverse vs. Fracture Location (Cont'd)

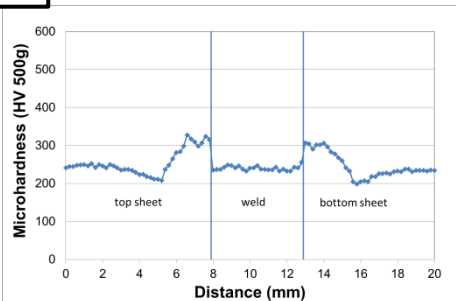
2.0 mm DP780 HDGI

Microhardness Traverse

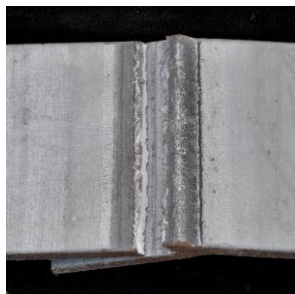
Average Peak Load and Joint Efficiency

Typical Fracture Location

ER70S-6 weld

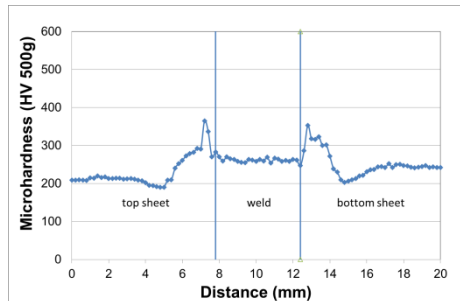


73.4 kN (91%)

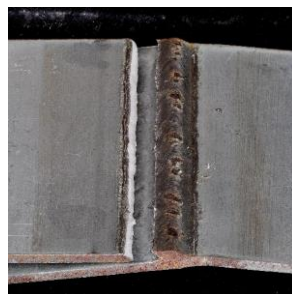


weld metal

ER80S-D2 weld

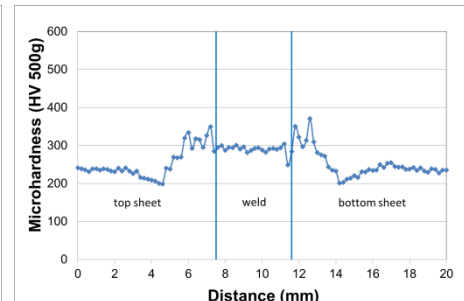


71.9 kN (89%)



weld metal

ER100S-G weld



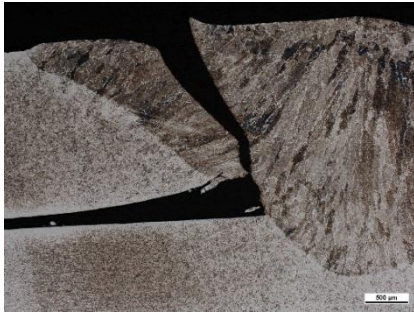
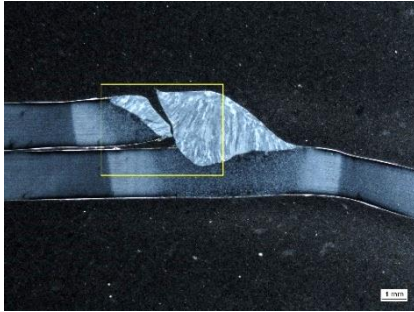
76.0 kN (94%)



heat-affected zone

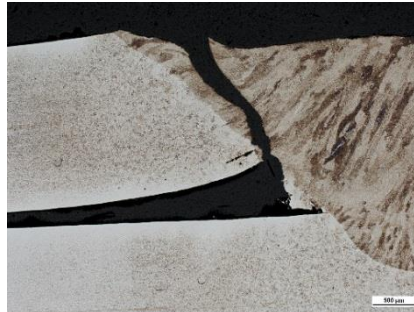
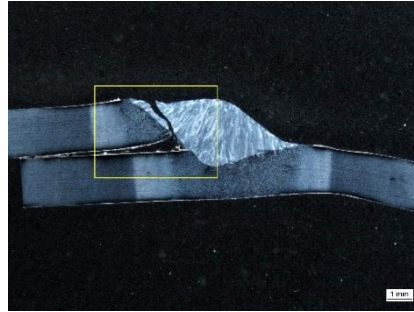
# Fracture Location: 2.0 mm DP780 HDGI

ER70S-6 filler metal



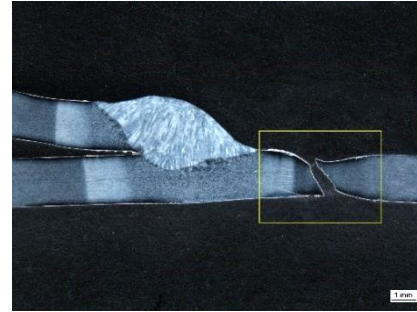
weld metal

ER80S-D2 filler metal



weld metal

ER100S-G filler metal



heat-affected zone

# Summary of Test Results

Grade	Thickness (mm)	Coating	Process	Filler	Basemetal Microhardness (HV <sub>500g</sub> )	Minimum Microhardness (HV <sub>500g</sub> )	Minimum Microhardness Location	Joint Peak Load (kN)	Nominal Joint Strength (MPa)	Joint Efficiency (%)	Percent Porosity (X-ray)	Fracture Location
BH210	0.67	HDGI	GMAW	ER70S-6	119	111	base metal	12.0	357	100	0.12	heat-affected zone
			GMAB	ERCuSi-A	129	122	base metal	12.0	359	101	0.15	base metal
BH240	0.65	HDGI	GMAW	ER70S-6	135	130	base metal	12.1	371	105	1.98	heat-affected zone
			GMAB	ERCuSi-A	128	110	base metal	12.1	372	105	0.11	base metal
DP490	0.69	HDGA	GMAW	ER70S-6	180	167	base metal	19.9	576	100	0.20	heat-affected zone
			GMAB	ERCuSi-A	173	111	braze	18.2	527	91	1.51	braze
DP780	2.0	HDGI	GMAW	ER70S-6	232	199	heat-affected zone	73.4	735	91	0.10	weld metal
			GMAW	ER80S-D2	229	190	heat-affected zone	71.9	720	89	0.37	weld metal
			GMAW	ER100S-G	237	199	heat-affected zone	76.0	760	94	0.10	heat-affected zone
CP780	2.53	HDGI	GMAW	ER70S-6	284	211	heat-affected zone	85.7	683	78	0.70	weld metal
			GMAW	ER80S-D2	276	239	heat-affected zone	80.5	637	73	0.44	weld metal
			GMAW	ER100S-G	279	239	heat-affected zone	97.5	771	88	0.32	near fusion line
780SF	2.7	uncoated	GMAW	ER70S-6	269	233	heat-affected zone	90.1	648	85	n/a	near fusion line
			GMAW	ER80S-D2	267	222	heat-affected zone	90.6	664	86	n/a	heat-affected zone
			GMAW	ER100S-G	261	228	heat-affected zone	88.3	647	83	n/a	heat-affected zone
DP1180	1.38	uncoated	GMAW	ER70S-6	378	264	heat-affected zone	55.2	788	61	n/a	weld metal
			GMAW	ER100S-G	391	277	heat-affected zone	68.2	989	77	n/a	heat-affected zone
DP1180	1.4	EG	GMAW	ER70S-6	370	218	weld	48.8	696	55	0.97	weld metal
			GMAW	ER100S-G	379	260	heat-affected zone	68.6	980	78	n/a	heat-affected zone
DP980	1.95	HDGA	GMAW	ER70S-6	299	232	heat-affected zone	76.1	780	75	1.73	weld metal
MS1700	1.4	uncoated	GMAW	ER70S-6	545	205	heat-affected zone	51.1	714	41	n/a	heat-affected zone
MP1180	1.2	uncoated	GMAW	ER70S-6	359	219	heat-affected zone	53.2	840	69	n/a	weld metal
HSLA700	2.5	uncoated	GMAW	ER70S-6	285	247	heat-affected zone	86.4	691	80	n/a	near fusion line

- Quality welded and brazed joints were achieved for all test materials.
- A targeted gap of 0.1 mm between faying surfaces was effective in providing a consistent gap and at minimizing porosity in weld metal for coated materials.
- Fracture locations can be in the base metal, HAZ, weld metal, or near the weld fusion line, depending on material grade and thickness.
- For the thin gauge coated steels tested, GMAW and GMAB resulted in similar joint strength.
- Compared to ER70S-6 filler metal, ER100S-G appears to slightly increase the joint strength for the CP780, DP780, and DP1180 materials tested.
- Joint efficiency ranged from 40% (MS1700 Uncoated GMAW) to 105% (BH240 HDGI GMAB) and generally decreased as steel strength increased.
- The test methods used in this study may be used as a basis for developing gas metal arc welding and gas metal arc brazing qualification procedures.

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