Buried Arc GMAW for Single Pass Single Sided Erection Joints Onboard Ships

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NSRP Project Number 2019-375-007

NSRP All Panel Meeting March 2023

Acknowledgements

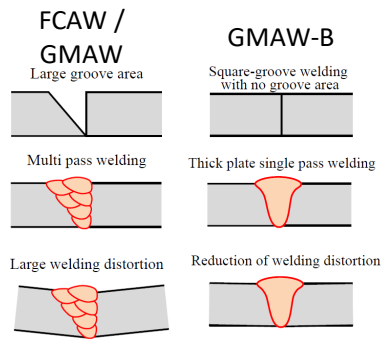
- This project was funded by the National Shipbuilding Research Program – Advanced Shipbuilding Enterprise.
- OTC DAIHEN provided the buried arc GMAW (GMAW-B) system used for this project.

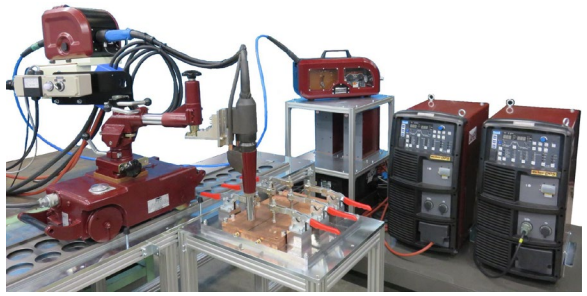
Project Team

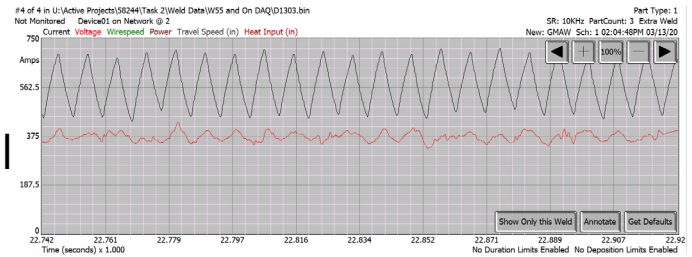
- EWI (prime)
  - Jim Hansen (PI), Elliot Ogles (Engineering support)
  - Katie Hardin (PM), Mark Schimming (VP Govt Business)
- ATI PM
  - Ryan Schneider
- NSRP Program Technical Representative (PTR)
  - Paul Herbert, NNS
- Participant
  - Ken Johnson – Vigor
  - Elmer Dickens – NNS
  - Shawn Wilber - Austal
  - Shawn Devoll, Ray Jackson, Pierre Samuels, Billy Stone – VT Halter Marine
  - Matt Sinfield – NSWCCD
  - Larry Barley – OTC Daihen

Introduction

- Shipyards have historically used submerged arc welding (SAW), flux cored arc welding (FCAW), and gas metal arc welding (GMAW) to fabricate butt-joints in thick steel plate.
- For butt-joints in ½ in. or thicker steel plate
  - Joint preparation is common.
  - Two-sided welding is common.
    - Plate flipping
    - Back gouging
  - SAW: 2+ passes, FCAW/GMAW: 5+ passes
- OTC DAIHEN has a GMAW variant that is designed for buried arc welding of thick steel plate.
  - Single-sided, single-pass welds in up to ¾-in. thick steel
  - Joint preparation can be reduced or eliminated.
  - Plate flipping and back gouging can be eliminated.
- Process and business case data were developed during NSRP Panel Project No. 2019-375-003.
  - This project focused on implementation for shipboard production.







Approach

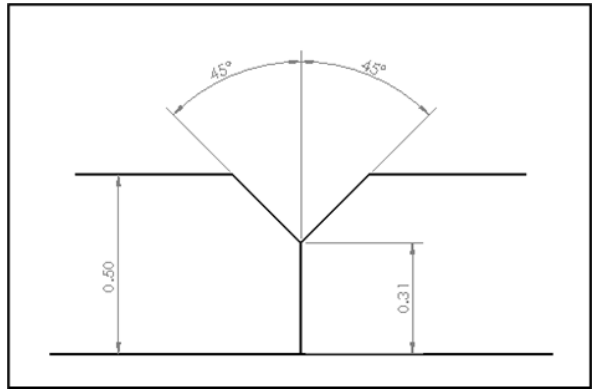
- Task 1 – Project Initiation and Kick-off Meeting
  - Discuss project and select candidate application
- Task 2 – Identification of Procedure Qualification Requirements
  - The procedure qualification requirements for the candidate application will be determined in this task.
- Task 3 – Development of Portable Mechanized GMAW-B Methods
  - Develop portable mechanized GMAW-B procedures for the candidate application
- Task 4 – Demonstration and Implementation
  - Portable mechanized GMAW-B system used at EWI will be shipped to Austal and set up in Austal's weld lab.
- Task 5 – Technology Transfer and Reporting

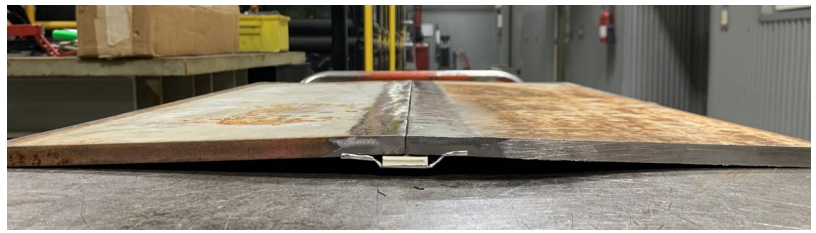
Buried Arc System Setup

- OTC Daihen GMAW-B system
  - "Welbee DPS" power sources (2)
    - Programs designed for 0.052-in. Ø and 0.062-in. Ø steel wire, CO_2 shielding gas, and steel base material
  - Servo wire feed controllers (2)
  - Push wire feeder
  - Pull wire feeder
  - Heavy duty torch, 2.5 m
- Bug-o weld tractor
- ArcAgent™ DAQ
- Water chiller

Candidate Application

- Target implementation opportunities
  - Shipboard production
- #1: Butt-joint in ½-in. thick DH 36 steel plate
  - 45-degree bevel with 5/16-in. land
- #2: Butt-joint in 3/8-in. thick EH 36 steel plate
  - Square groove butt-joint
- Constants
  - Flat (1G) position
  - ER70S-3 filler wire
  - 100% CO_2 shielding gas
  - Ceramic backing bar
  - Tape dogs used to hold ceramic backing to underside of plate





Qualification Requirements – Navy Work

- Tests required for evaluating GMAW-B procedures were discussed with NSWCCD.
  - Use of a high hz (5 khz) data acquisition unit is critical to understand heat input from the advanced waveform.
- Requirements specified in NAVSEA Tech Pub 248 for qualifying procedures of legacy processes will likely apply in addition to any other NAVSEA specified requirements (HAZ charpy v-notch testing).
  - Nondestructive evaluation
    - Visual testing, magnetic particle testing, radiographic testing, ultrasonic testing
  - Mechanical testing
    - Tensile specimens (2), face bend specimens (2), root bend specimens (2), macro specimen (1)
- Impact testing not required for selected applications but performed for select weldments for information

Heat Input & Productivity Comparison with a Legacy Process

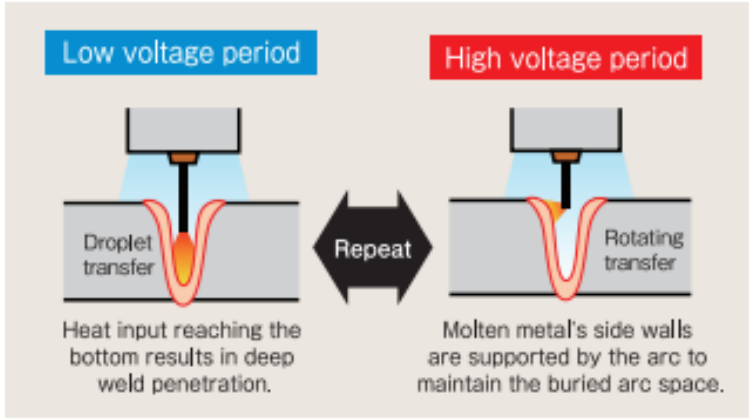
- Legacy process used at one shipyard is single wire SAW, two-sided procedure.
- Benefits of buried arc GMAW:
  - Plate flipping can be eliminated.
  - Arc-on-time per foot can be reduced.
  - Total heat input can be reduced which may result in lower distortion.
  - Back-gouging can be eliminated for plates ½-in. thick and above.
  - Flux is eliminated.

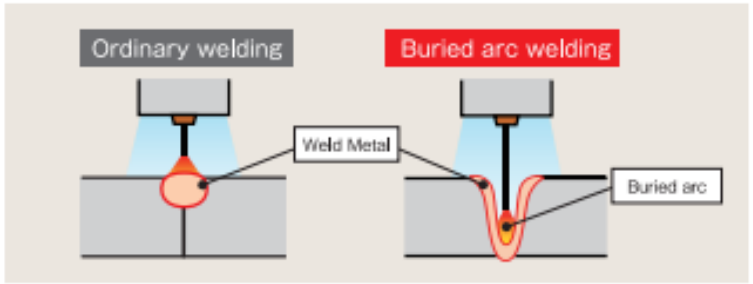
3/8-in. EH 36 Steel Plate								
Process	Joint Prep	Pass 1		Additional Processes	Pass 2		Total Arc-on-Time per Foot of Weld	Total Heat Input
		Travel Speed	Heat Input		Travel Speed	Heat Input		
SAW	Square Groove	32-ipm	30.9-kJ/in.	Plate Flipping	32-ipm	55.8-kJ/in.	1.50-min.	86.7-kJ/in.
GMAW-B (W64)		18-ipm	74.2-kJ/in.	None	N/A	N/A	1.33-min.	74.2-kJ/in.
						% Change	11% Reduction	14% Reduction

½-in. DH 36 Steel Plate								
Process	Joint Prep	Pass 1		Additional Processes	Pass 2		Total Arc-on-Time per Foot of Weld	Total Heat Input
		Travel Speed	Heat Input		Travel Speed	Heat Input		
SAW	Square Groove	25-ipm	58.8-kJ/in.	Plate Flipping Back-Gouging	25-ipm	82.1-kJ/in.	1.92-min.	140.1-kJ/in.
GMAW-B (W65)	Square Groove	18-ipm	71.1-kJ/in.	Plate Bevel	N/A	N/A	1.33-min.	71.1-kJ/in.
						% Change	31% Reduction	49% Reduction

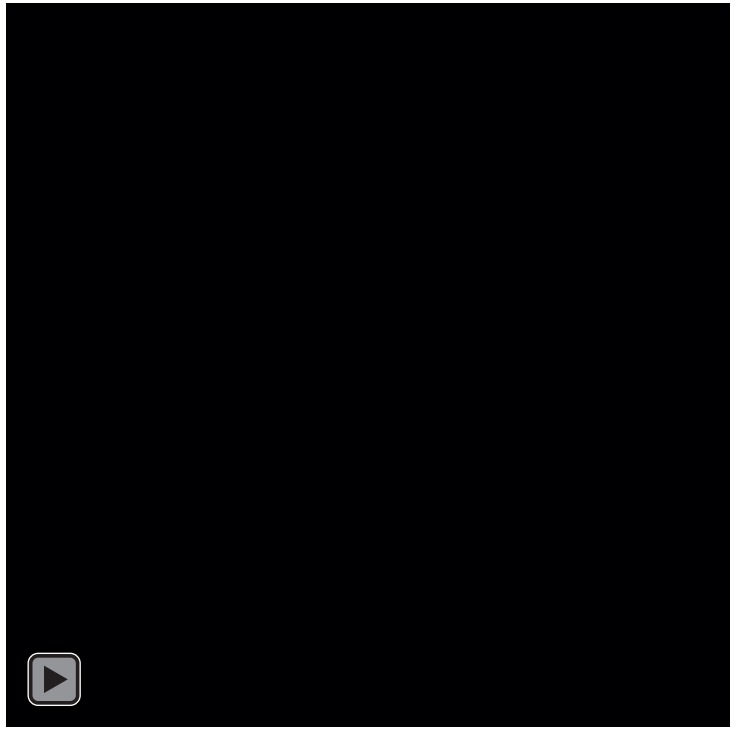
High Speed Video Analysis

- High speed video used to document change in transfer modes during the GMAW-B process
  - Through precise waveform control the transfer modes changes from a deep penetrating spray to rotary spray.





OTC Buried Arc Specification Sheet



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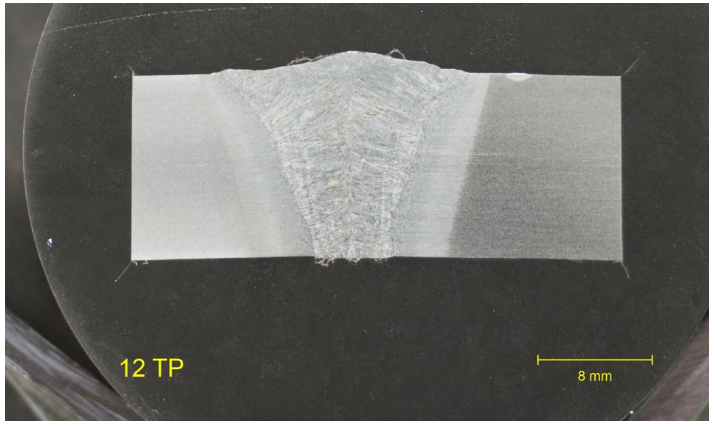
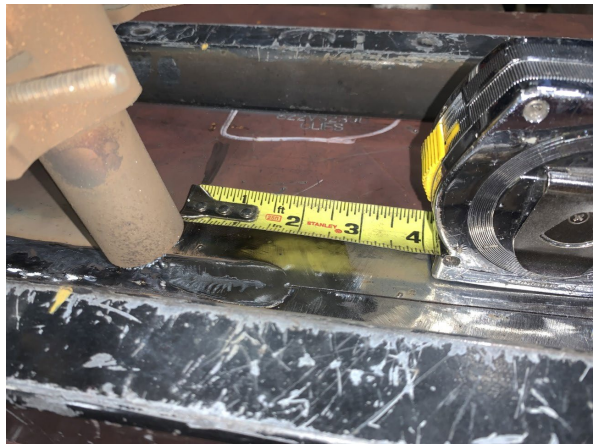
½–in. DH36 Steel trials



Procedures (Main)							
Travel Speed (ipm)	CTWD (in)	Travel Angle (deg)	Work Angle (deg)	Main		Buried Arc Char. (-20 to +20)	Arc Control (-10 to +10)
				Current (A)	Trim (-30 to +30)		
18.0	5/8	10° Push	0°	508	-10	0	0

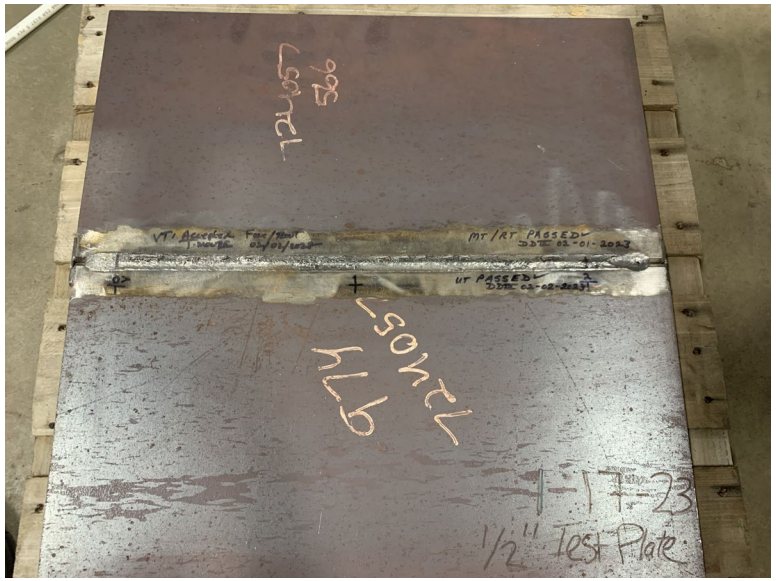
½-in. DH36 Start/Stop Development

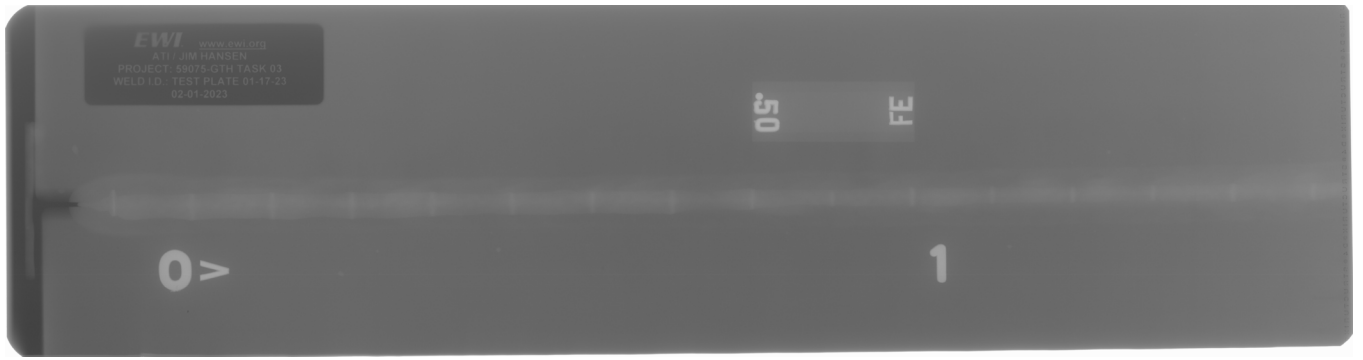


- Weld stop area feathered 2-in. back from termination of weld prior to welding re-start
- Face and root bends taken from start/stop regions to validate soundness

½-in. DH36 NDE

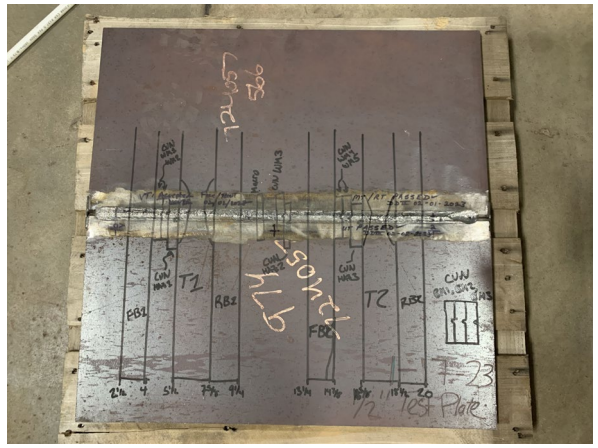
- Weldment inspected to MIL-STD 2035, Class 1
  - VT – Pass
  - MT – Pass
  - UT – Pass
  - RT – Pass

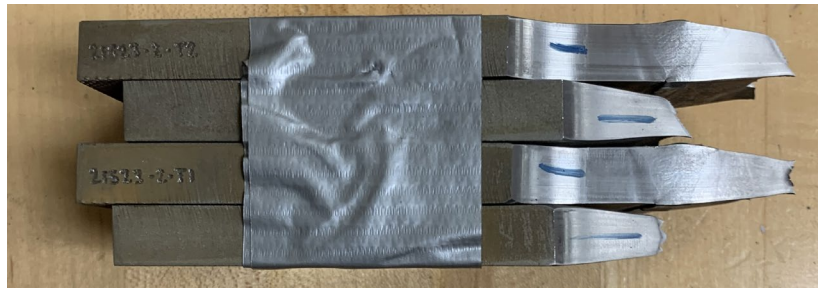




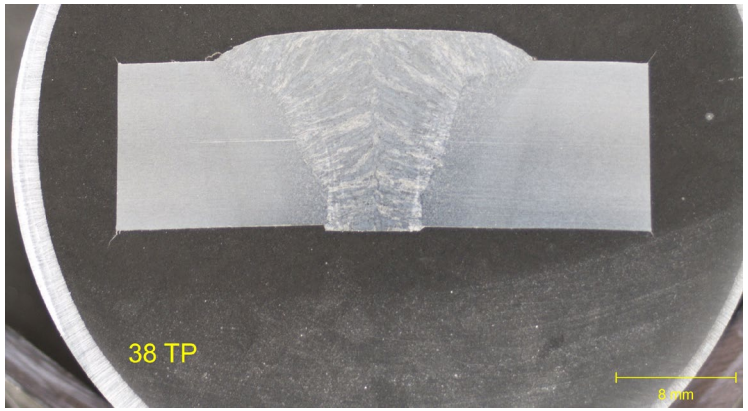
½-in. DH36 Mechanical Testing

- 2 Tensile Tests – Pass
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – Not required per Tech Pub 248. AWS A5.18 requirements used
  - 4 Weld Centerline – Fail
    - Average Impact: 9 J
  - 3 HAZ – Pass
    - Average Impact: 337 J
  - 3 Base Metal – Pass
    - Average Impact: 339 J
- Macro Specimen – Pass



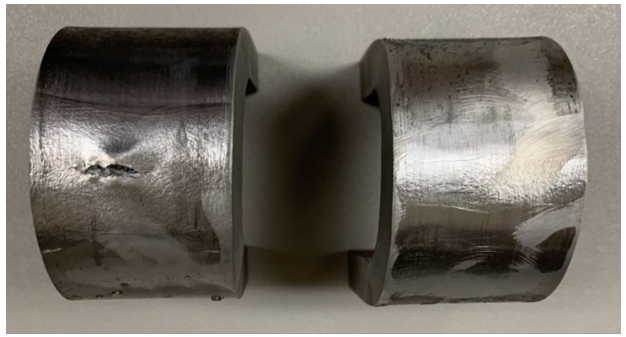


3/8-in. EH36 Steel Trials



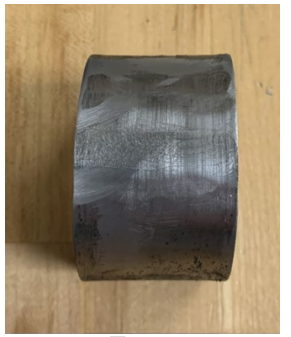
Procedures (Main)							
Travel Speed (ipm)	CTWD (in)	Travel Angle (deg)	Work Angle (deg)	Main		Buried Arc Char. (-20 to +20)	Arc Control (-10 to +10)
				Current (A)	Trim (-30 to +30)		
18.0	5/8	10° Push	0°	529	-10	0	0

3/8–in. EH36 Start/Stop Development



Face Bend

Root Bend

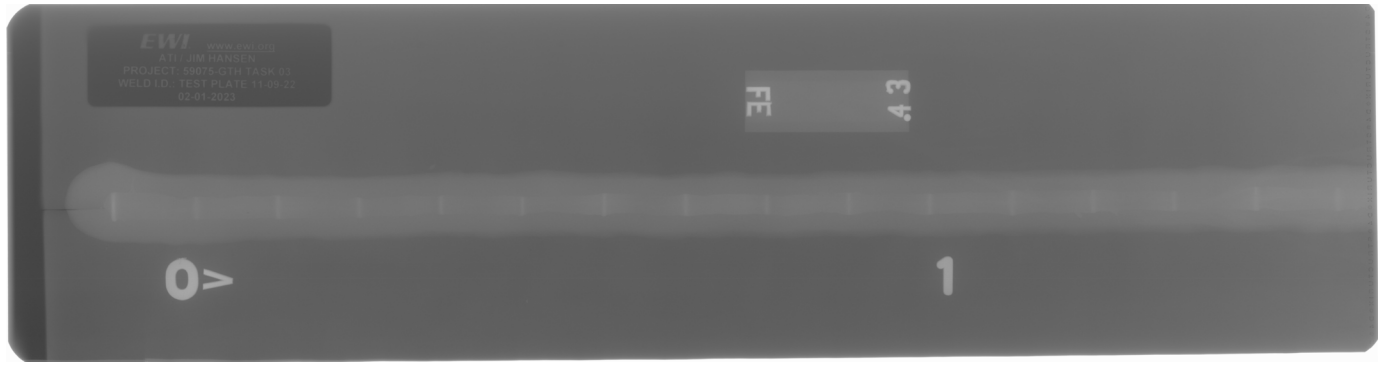


Face Bend

- Weld stop area feathered 2-in. back from termination of weld prior to welding re-start
- Face and root bends taken from start/stop regions to validate soundness
- Trials with no feathering at the weld stop area resulted in failed face bends.

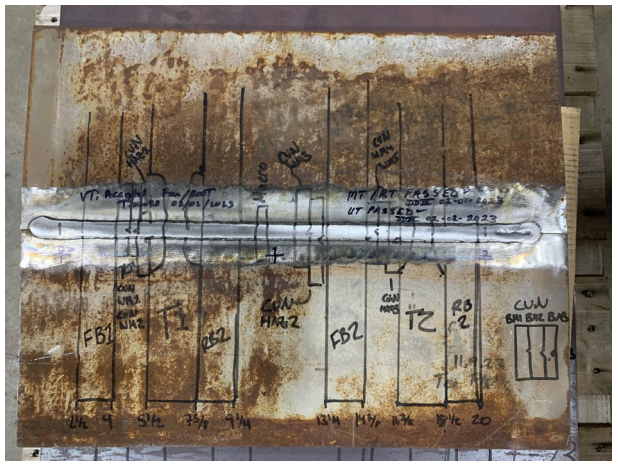
3/8–in. EH36 NDE

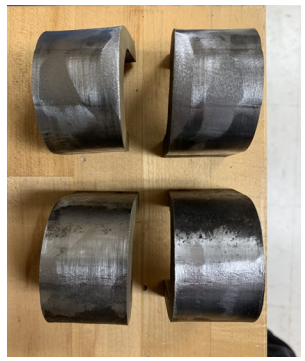
- Weldment inspected to MIL-STD 2035, Class 1
  - VT – Pass
  - MT – Pass
  - UT – Pass
  - RT – Pass



3/8–in. EH36 Mechanical Testing

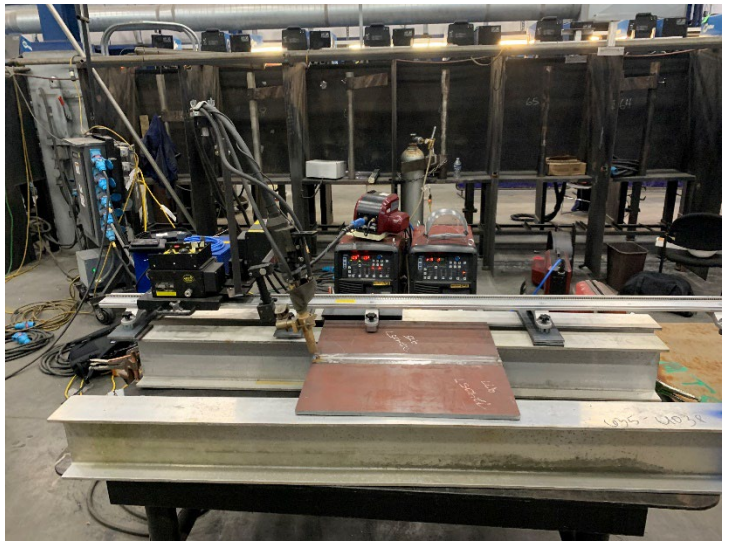
- 2 Tensile Tests – Pass
- 2 Face Bends – Pass
- 2 Root Bends – Pass
- Charpy V-Notch – Not required per Tech Pub 248. AWS A5.18 used
  - 4 Weld Centerline
    - Average Impact: 5 J
      - Full Size Equivalent: 7 J
  - 3 HAZ
    - Average Impact: 8 J
      - Full Size Equivalent: 11 J
  - Base Metal
    - Average Impact: 276 J
      - Full Size Equivalent: 364 J
- Macro Specimen – Pass





Technology Transfer at Austal

- ½-in. DH36 Tests
  - Maximum root opening of 1/8 in.
  - Minimum root opening of 0 in.
  - Start/Stop test
- 3/8-in. EH36 Tests
  - Maximum root opening of 1/8 in.
  - Minimum root opening of 0 in.
  - Start/Stop test
- 8-ft long 3/8-in. ABS Grade A Test



Summary

- Buried arc GMAW procedures were developed for producing single pass welds in ½-in. DH 36 steel plate.
- Buried arc GMAW procedures were developed for producing single pass welds in 3/8-in. EH 36 steel plate.
  - Feasibility of root opening tolerance of 0.0 to 0.16 in. was demonstrated with similar procedures.
- Start/Stop procedures developed for both material thicknesses allowed for minimal weld dressing.

Questions?

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