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SAW Enhancement Using TipMate™ Nozzles

Project Update – March 28, 2007

SP-7 Welding Panel Meeting
Fort Collins, CO

Presented by: R. Nick Kapustka

Acknowledgements

- Lee Kvidahl
  - NSRP Program Technical Representative
- Jim House
  - NSRP Program Technical Representative
- Dick Holdren
  - Former EWI Project Investigator

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Presentation Outline

- Background
- Project Objectives
- Technical Approach Overview
- Task 1
  - Deposition Rate Study
- Task 2
  - Quantification of Heat Input
- Task 3
  - Effect of TipMate™ Nozzles on SAW HSLA 100
- Conclusions

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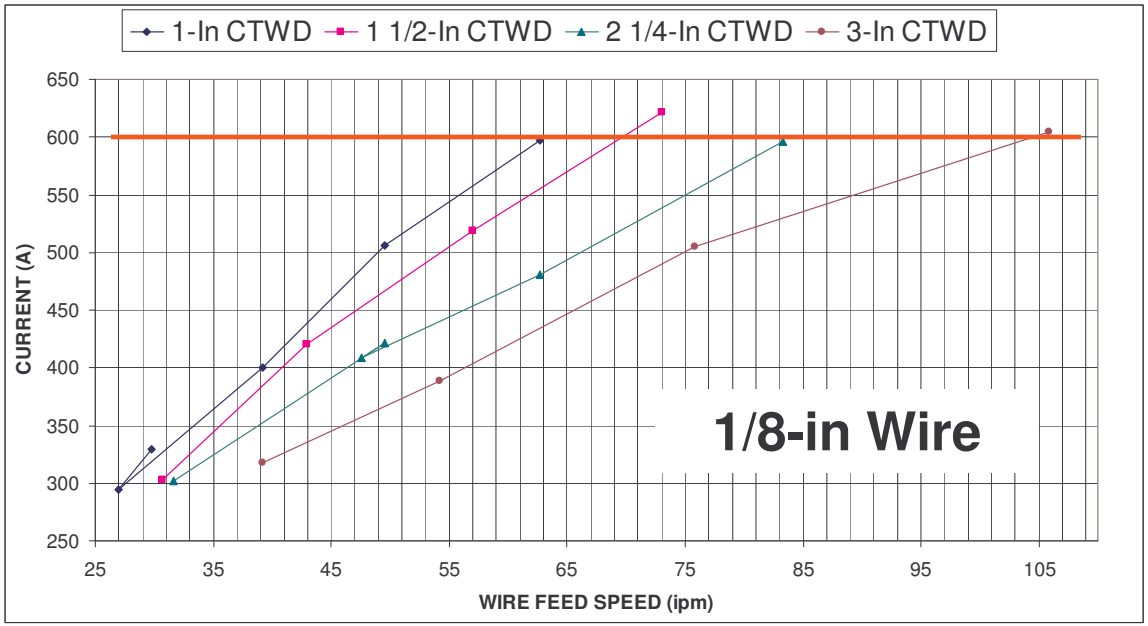
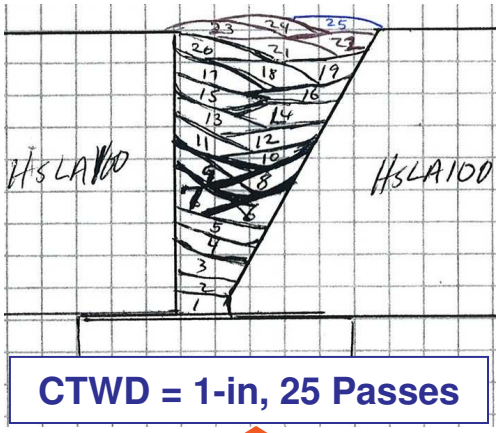
Background

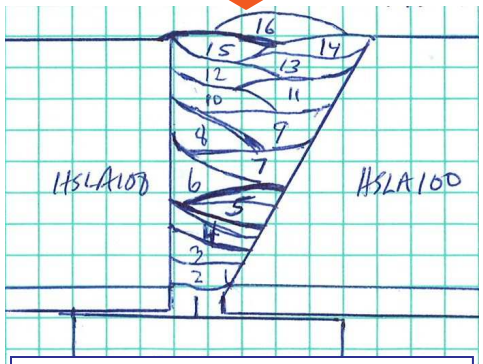
- To Maintain the Same Amperage, the WFS Must Be Increased With the CTWD
  - Higher deposition rates
  - Lower total HI into the base metal
    - Equivalent HAZ properties





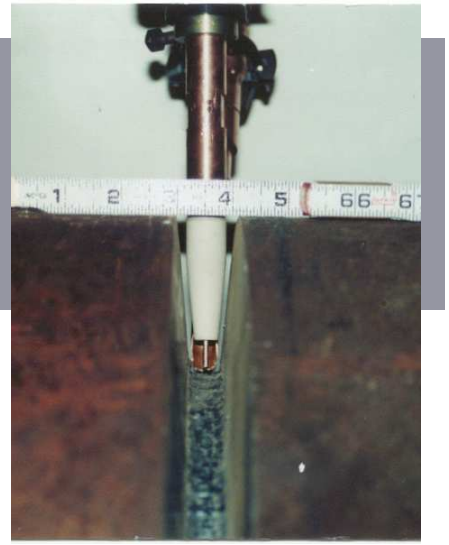
CTWD = 1-in, 25 Passes

HI ≈ 85 KJ / inch



CTWD = 3-in, 16 Passes

Background



- TipMate™ Nozzles
  - Ceramic contact tip extensions
  - Specific to wire size & extension length
    - Provides proper support for the preheated electrode extension
- Current Applications
  - Power generation industry
    - Pressure vessels & high pressure steam piping

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Project Objectives

- Quantify the Increase in Deposition Rate for Typical Shipyard Joint Configurations
- Quantify the Effective Heat Input Rate Using TipMate™ Nozzles and Compare It to the Heat Input Rate Using Conventional SAW
- Produce Welds in HSLA 100 and Perform Mechanical Testing to Determine the Degree of HAZ Property Improvement Resulting from the Reduced Effective Heat Input Rate

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Technical Approach

- Task 1 – Deposition Rate Study
  - Compare deposition rate and penetration with and without the use of TipMate™ nozzles
    - BOP welds (constant travel speed (TS))
    - Fillet welds (constant current level)
- Task 2 – Quantification of Heat Input
  - Compare the calculated HI to the measured HI at CTWDs of 1, 2 ¼, and 3 in
    - BOP welds (I ≈ 600A, TS ≈ 19 ipm)
- Task 3 – Effect of TipMate™ Nozzles on SAW HSLA 100
  - Evaluate the effect of CTWD on the mechanical properties and deposition rates
  - CTWDs: 1-in, 3-in
  - Single pass HI ≈ 85 KJ / in, TS ≈ 14 ipm

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Task 1 - Approach

Consumables	
Wire	3/32-in & 1/8-In. Lincoln L-61
Flux	Lincoln L-61
AWS Wire / Flux Spec	F7A2-EM12K-H8

- BOP & Fillet Welds
  - Wire Φ: 3/32-in, 1/8-in
  - **Determine current vs. WFS curves for each wire diameter & CTWD**
  - Voltage increased with CTWD
    - Arc voltage ≈ 3/4-in CTWD (3/32-in wire) or 1-in CTWD (1/8-in wire)
- BOP Welds
  - Constant TS: ≈ 19 ipm
  - CTWDs
    - 3/32-in wire: 3/4-in, 1 1/2-in, 2 1/4-in, 3-in
    - 1/8-in wire: 1-in, 1 1/2-in, 2 ¼-in, 3-in
  - Current levels
    - 3/32-in wire: 300A, 400A, 500A
    - 1/8-in wire: 300A, 400A, 500A, 600A
- Fillet Welds
  - Constant current: ≈ 450A +/- 5%
  - CTWDs
    - 3/32-in wire: 3/4-in, 1 1/2-in, 2 1/4-in
    - 1/8-in wire: 1-in, 2 1/4-in, 3-in
  - Nominal weld sizes: 3/16-in and 1/4-in leg lengths

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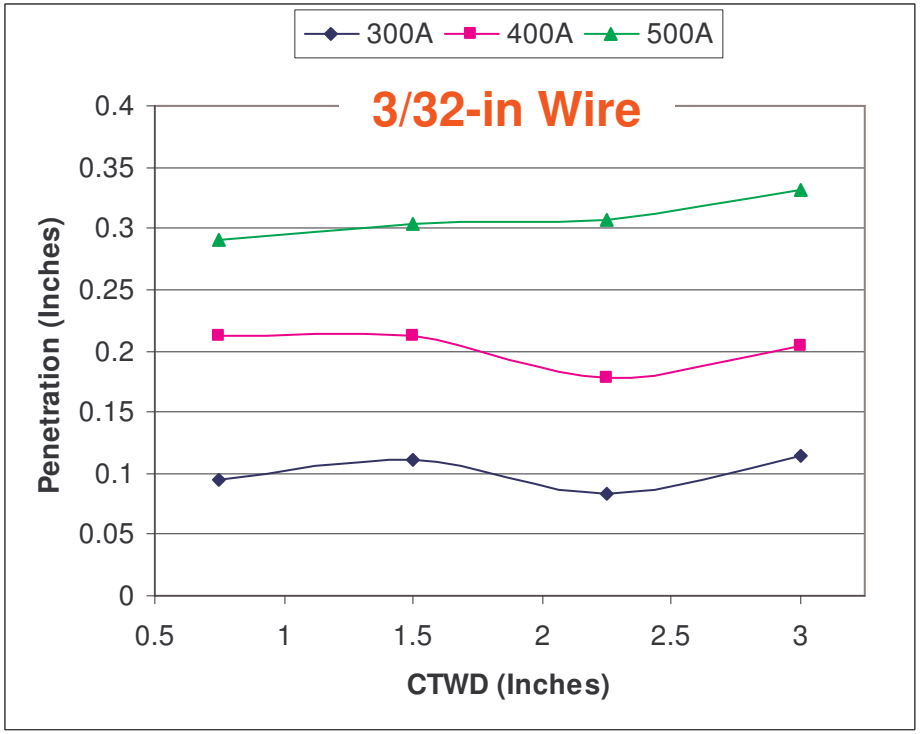
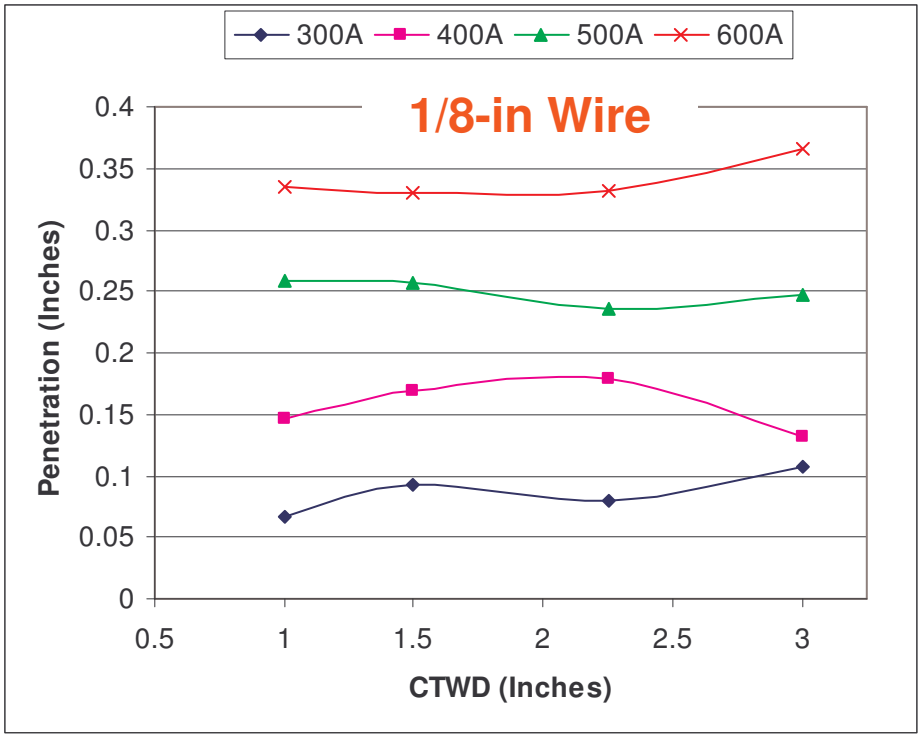
Task 1 – Penetration of BOP Welds

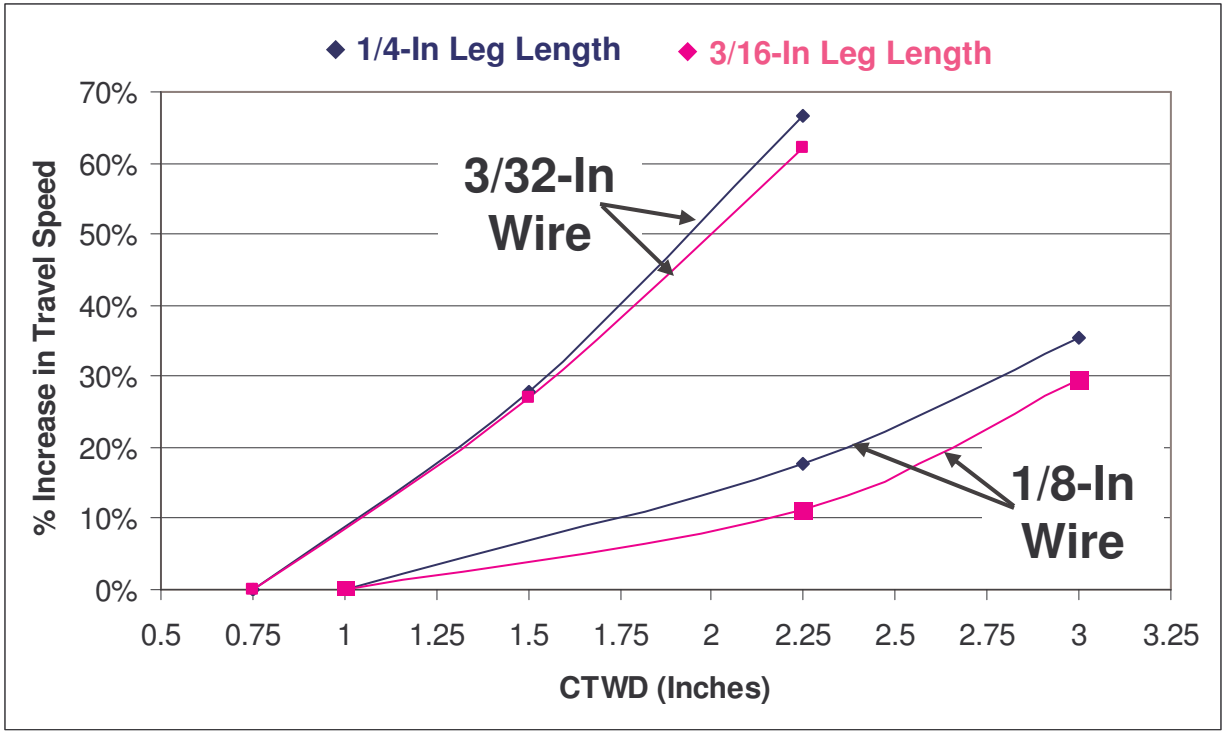
- At a Given Current Level, No Consistent Trend Relating Penetration to CTWD
- Regardless of the CTWD, Penetration Increased w / the Current Level





Task 1 – Deposition Rate of Fillets

- To Maintain the Same Fillet Weld Size, TS Must be Increased with the CTWD
  - 3/32-In Wire: ≈ 60% when CTWD was increased from 3/4 – 2 1/4-in
  - 1/8-In Wire: ≈ 30% when CTWD was increased from 1 – 3-in



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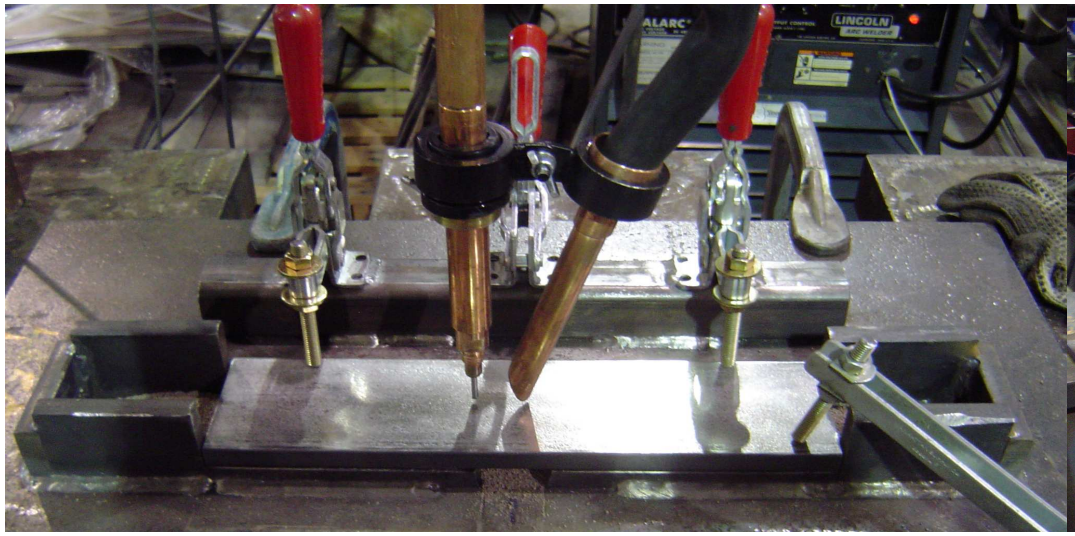
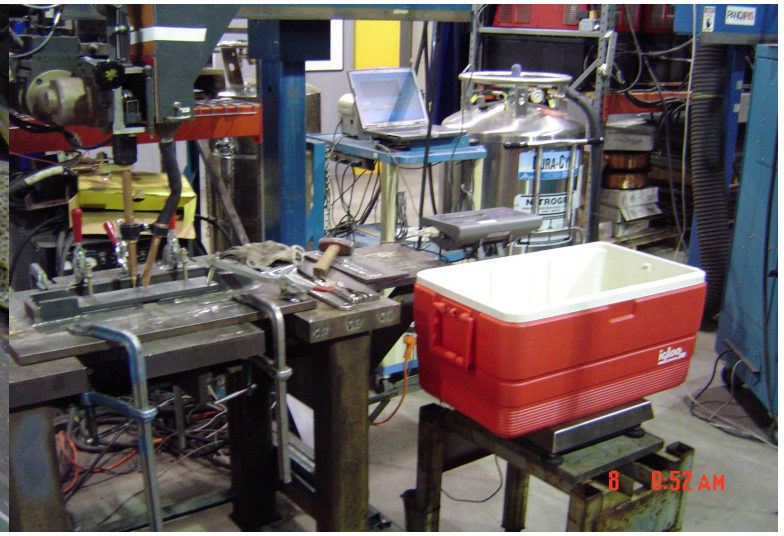
Task 2 - Approach

- Same Consumables Were Used In Task 2 & Task 3
  - Determine current vs. WFS curve at each CTWD
- Calorimetric Measurement of the Heat Input
  - Current ≈ 600A
  - TS = 19 ipm
  - CTWDs: 1-in, 2 1/4-in, and 3-in
  - Arc voltage ≈ 1-in CTWD (32V)

Consumables

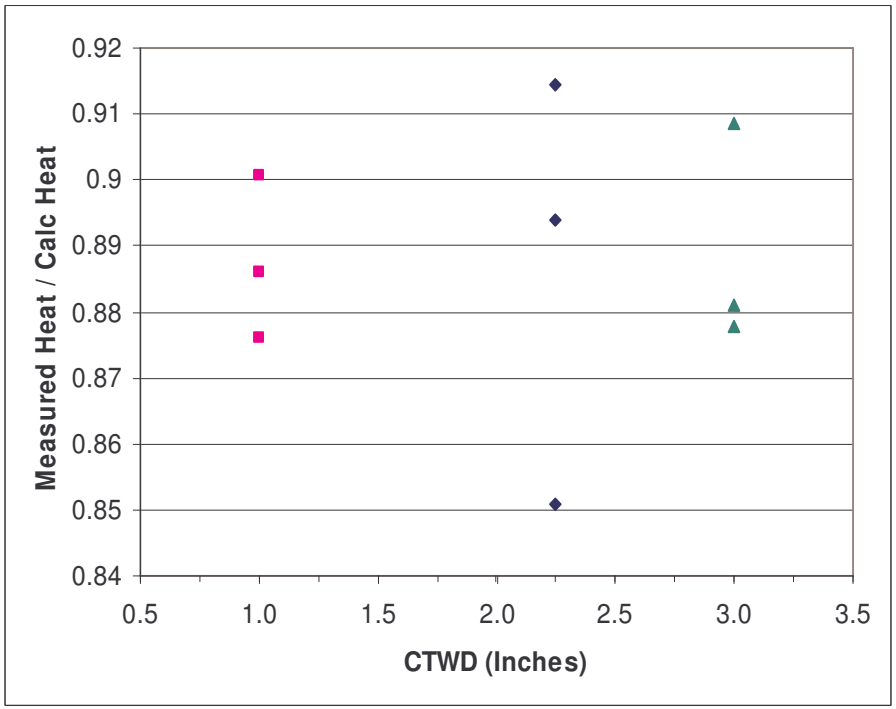
Wire	1/8-In. ESAB SpoolArc™ 95
Flux	ESAB 10.62
AWS Wire/Flux Spec.	EM2 / F11A6-EM4-M4

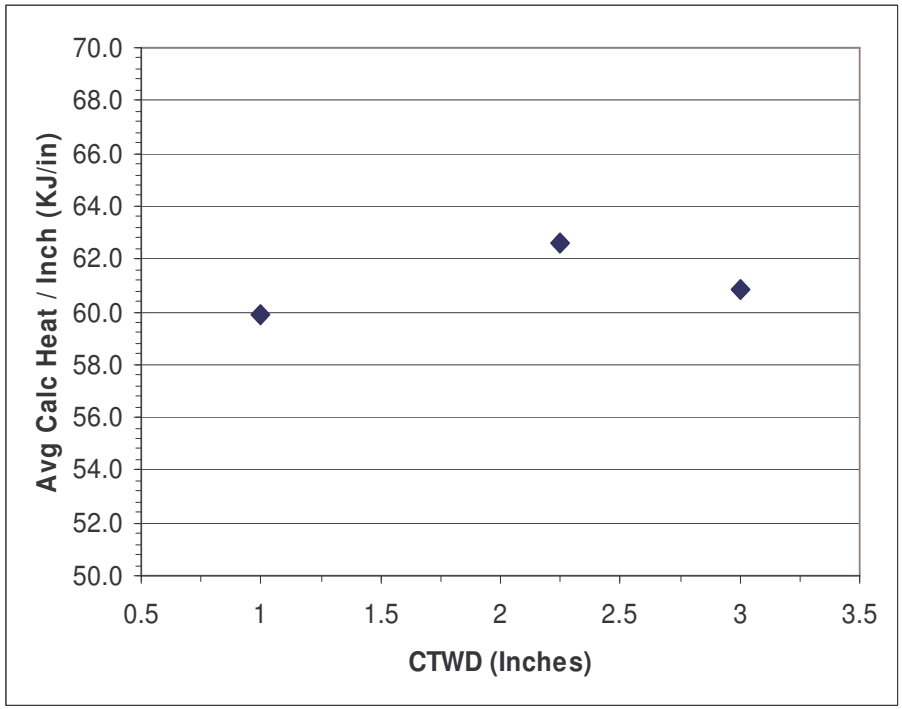




Task 2 – Calorimetric Results

- Regardless of the CTWD ≈ 85 – 91% of the Calculated Heat is Present in the Welded Coupon
  - All welds had approximately the same calculated heat input
  - Increasing the CTWD results in higher deposition rates without increasing the single-pass heat input





Task 3 - Background

- Previous ManTech Project No. S1054 Evaluated SAW of HSLA 100
  - Minimum weld mechanical properties established by NAVSEA and NGSS
  - Maximum single pass heat input of ≈ 85 KJ/in to consistently meet minimum weld metal properties
- Same Consumables, Welding Parameters, & Minimum Weld Mechanical Properties Used in Task 3
  - Same consumables as Task 2
- Single-Pass Heat Input of ≈ 85 KJ/in Used in Task 3

Minimum Weld Metal Mechanical Properties

Yield Strength	Elongation	Weld CVN (0°F)	Weld CVN (-60°F)
88 ksi	16% min	60 ft-lb	35 ft-lb

Consumables & Parameters

Wire	1/8-In. ESAB SpoolArc 95
Flux	ESAB 10.62
Current	600A
Arc Voltage	≈ 1-in CTWD
Travel Speed	14 ipm

Task 3 – Approach

- Two 2-in Thick HSLA 100 Weldments Produced With 1-in CTWD and 3-in CTWD
  - Single bevel joint design
    - 30° bevel, 3/8-in root opening, backing bars

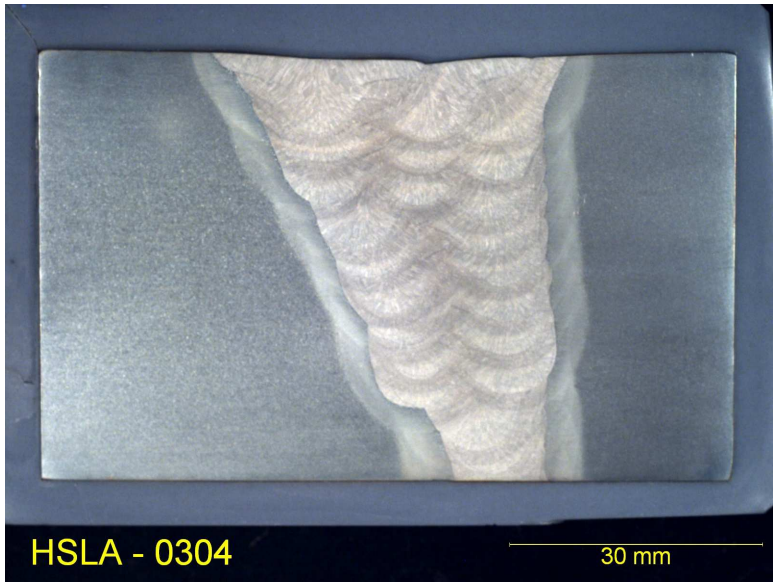
- HSLA-03 & HSLA-04
  - CTWD = 1-in
  - No TipMate™ nozzle
  - Set Voltage ≈ 32.1V
  - HI of 1st and 2nd pass
    - ≈ 63 KJ/in
  - HI of fill passes
    - 80.5 – 88.7 KJ/in

- HSLA-01 & HSLA-02
  - CTWD = 3-in
  - 2 ¼-in TipMate™ nozzle
  - Set Voltage ≈ 34.1V
  - HI of 1st and 2nd pass
    - ≈ 53 KJ/in
  - HI of fill passes
    - 83.7 – 87.8 KJ/in

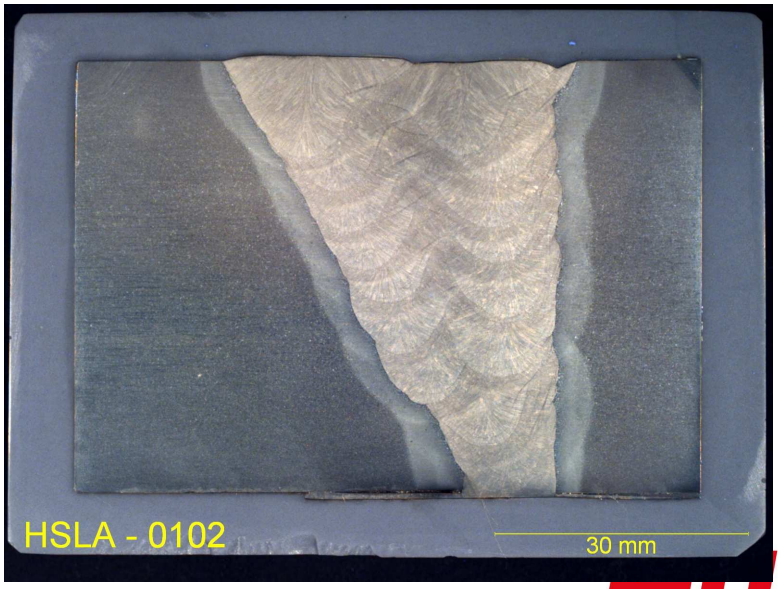
Task 3 – Deposition Rate Results

- Increasing the CTWD From 1-in to 3-in Resulted In a 40% Reduction in the Number of Passes
  - 1-in CTWD: 25 passes
  - 3-in CTWD: 16 – 17 passes

1-in CTWD



3-in CTWD



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Task 3 – Mechanical Properties

- 2-in Thick HSLA 100 Weldments Made With CTWDs of 1 and 3-in Met the Mechanical Property Requirements
  - UTS: 103.5 – 105.3 ksi
  - 0.2% offset yield strength: 89.9 – 92.9 ksi
  - Elongation: 20.5 – 25.0%

Weldment ID	CTWD (in.)	TipMate™ Nozzle (in.)	UTS (ksi)	0.2% Offset Yield Strength (ksi)	Elongation (%)	Reduction in Area (%)
Requirement	---	---	---	88	16	---
HSLA - 03	1	None	103.5	91.6	25.0	68.3
HSLA - 04	1	None	104.7	92.9	20.5	52.7
HSLA - 01	3	1¾	105.3	89.9	23.8	65.7
HSLA - 02	3	1¾	103.8	90.7	24.6	67.9

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Task 3 – Mechanical Properties

- Weldments Produced With 3-in CTWD Had Greater HAZ Toughness But Lower Weld Metal Toughness
  - Higher HAZ toughness probably due to lower total HI into the base metal
  - Weld CVN requirement: 60 ft-lbs @ 0 °F, 35 ft-lbs @ - 60 °F

	1-in CTWD / No TipMate™ Nozzle			3-in CTWD / 2 1/4-in TipMate™ Nozzle		
	Absorbed Energy Range (ft-lb)	**Average Absorbed Energy (ft-lb)**	**Shear (%)**	**Absorbed Energy Range (ft-lb)**	**Average Absorbed Energy (ft-lb)**	**Shear (%)**
	Test Temperature = 0 °F			**Test Temperature = 0 °F**		
Weld Metal	160 – 295	253	4 @ 100%	86 – 123	102	4 @ 100%
HAZ	190 – 213	198	4 @ 100%	210 – 244	227	4 @ 100%
	Test Temperature = - 60 °F			**Test Temperature = - 60 °F**		
Weld Metal	156 – 246	199	4 @ 100%	47 – 54	51	35 – 43%
HAZ	142 – 164	151.3	3 @ 100% 1 @ 76%	158 – 274	223	4 @ 100%

Conclusions

- Deposition Rate Study
  - 3/16-in and 1/4-in Fillet Welds
    - To maintain the same weld size, TS must be increased w / the CTWD
    - 3/32-in Wire: ≈ 60% when CTWD increased from 3/4 – 2 1/4 in
    - 1/8-in Wire: ≈ 30% when CTWD increased from 1 – 3 in
  - 2-in Thick HSLA 100 Weldments
    - Increasing the CTWD from 1 to 3 in resulted in a 40% reduction in the number of passes

- Heat Input Rate Study
  - Regardless of the CTWD, ≈ 85 – 91% of the calculated heat was measured in the welded coupon
  - Increasing the CTWD results in higher deposition rates w/o increasing the single pass heat input rate

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Conclusions

- Effect of TipMate™ Nozzles on Mechanical Properties of SAW HSLA-100
  - Weldments made with 1 and 3-in CTWDs met the weld metal mechanical property requirements
    - Yield strength > 88 ksi
    - Elongation > 16%
    - CVN toughness @ 0 °F > 60 ft-lbs
    - CVN toughness @ -60 °F > 35 ft-lbs
  - Weldments produced with 3-in CTWD had greater HAZ toughness but lower weld metal toughness
    - Higher HAZ toughness maybe due to lower total HI

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Questions

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