Heat Input and Shielding Gas Effects on Super Duplex Stainless Steel 2594 Microstructure

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BACKGROUND

- Super duplex stainless steels serve offshore, desalination, and chemical industries.
- Welding of SDSS 2594 may produce excess ferrite (>70%), lowering corrosion resistance and toughness.
- This work seeks weld conditions that restore phase balance to maintain the optimal microstructure and properties.

OBJECTIVE

Identify the optimal heat input (10 kJ/in vs. 20 kJ/in) and shielding gas (pure Ar vs. 95%Ar+5%N_2) that produces a ferrite/austenite ratio closest to 50/50 in 2507 SDSS multipass welds to maximize corrosion resistance for offshore, desalination, and chemical plant applications.

METHODOLOGY

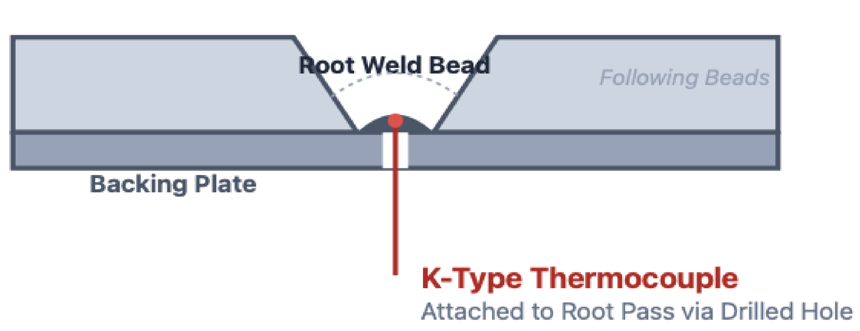
- **Materials**
  - Base metal SDSS 2507
  - Filler metal Lincoln BLUE MAX® MIG 2594

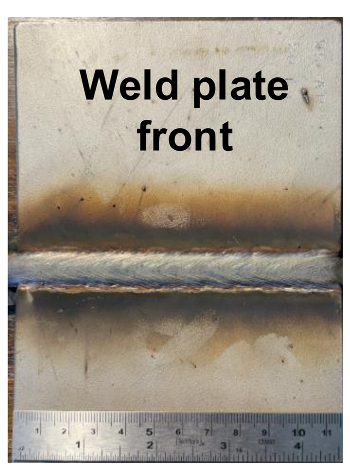
Alloy	C	Cr	Ni	Mo	Mn	Si	N	P	S	Cu	W	Fe
2507	≤0.03	24.0-26.0	6.0-8.0	3.0-5.0	≤1.20	≤0.80	0.24-0.32	≤0.035	≤0.020	≤0.50	-	Bal
ER2594	≤0.03	24.0-27.0	8.0-10.5	2.5-4.5	≤2.5	≤1.0	0.20-0.30	≤0.03	≤0.02	≤1.5	≤1.0	Bal

- **Welding Parameters**
  - Fronius TPS 400i with Flex Track
  - 4 multi-pass V-groove butt welds were performed:

Gas	100%Ar	100%Ar	95%Ar / 5%N_2	95%Ar / 5%N_2
Heat Input	10kJ	20kJ	10kJ	20kJ

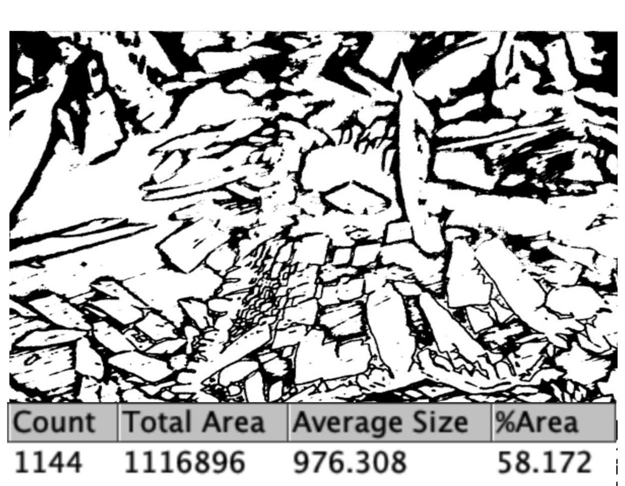
  - Time-temperature data was recorded via thermocouples placed in the root of the weld:



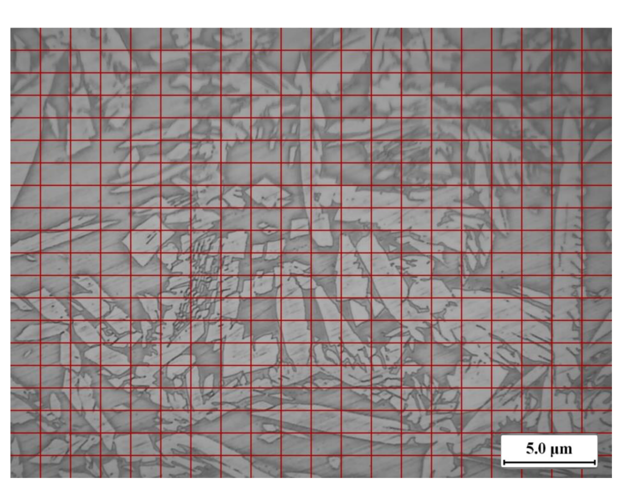


Heat Input	Voltage	Current	Travel Speed	Gas Flow	Weave
10 kJ	26.7 V	237 A	38.5 ipm	25 CFH	Triangle
20 kJ	26.7 V	216 A	17.2 ipm	25 CFH	Triangle

- **Metallographic Preparation and Microhardness Testing**
  - Samples were cold mounted, ground, polished, and electrolytically etched with 40% NaOH at 3V
  - Vickers microhardness (0.98 N load) was measured from the weld centerline to the base metal in 0.050″ steps.

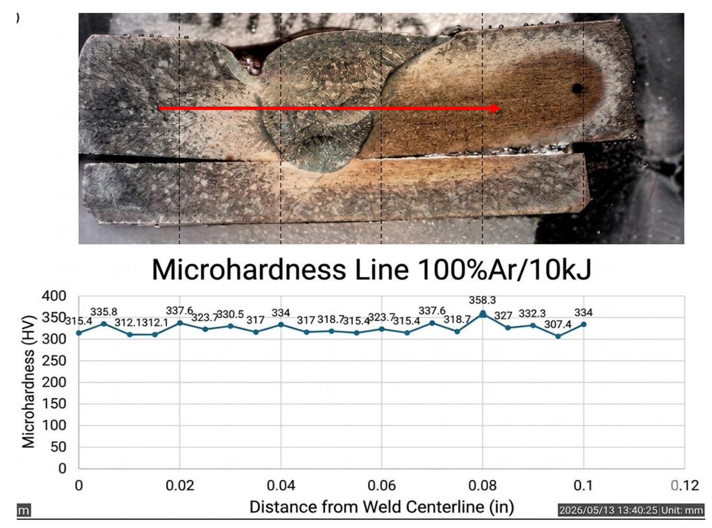


IMAGEJ Microstructure 100% Ar 10 kJ



Point Counting Microstructure 100% Ar 10 kJ

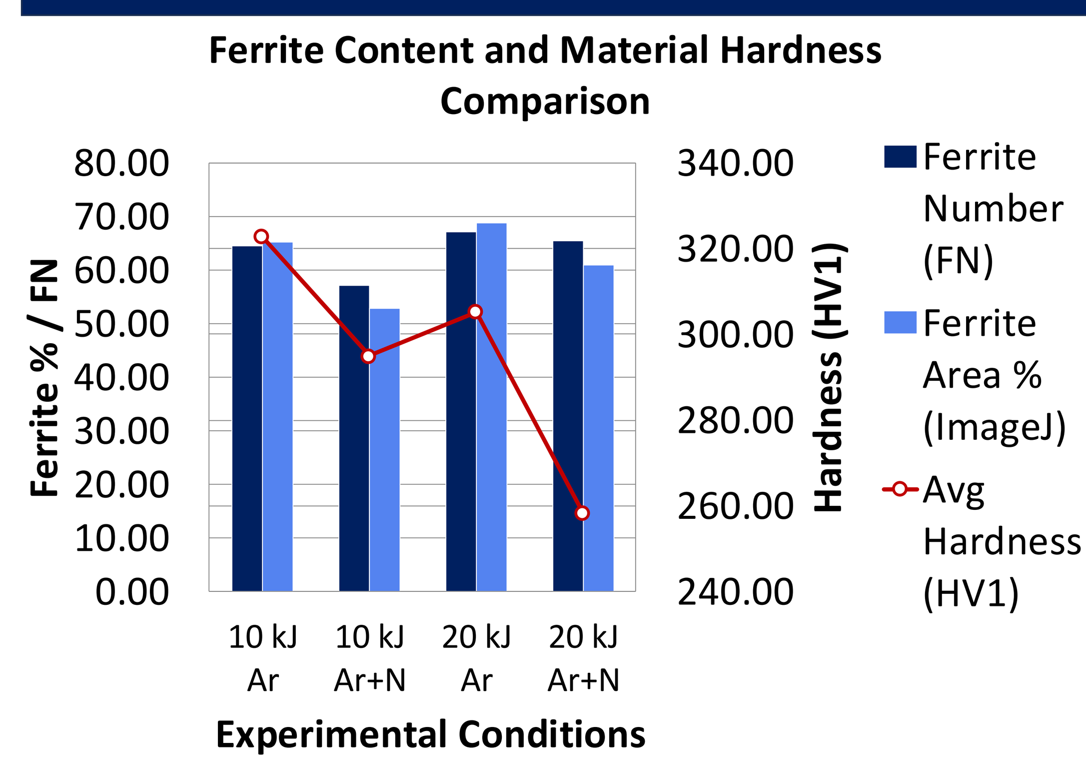
RESULTS & DISCUSSION



Hardness remained relatively uniform across the base metal, HAZ, and fusion zone for all welds. The 95%Ar + 5%N_2 welds averaged 240-320 HV, while the 100%Ar welds were slightly higher (300-340 HV) neither increasing heat input from 10 kJ to 20 kJ nor adding nitrogen caused substantial hardness changes.

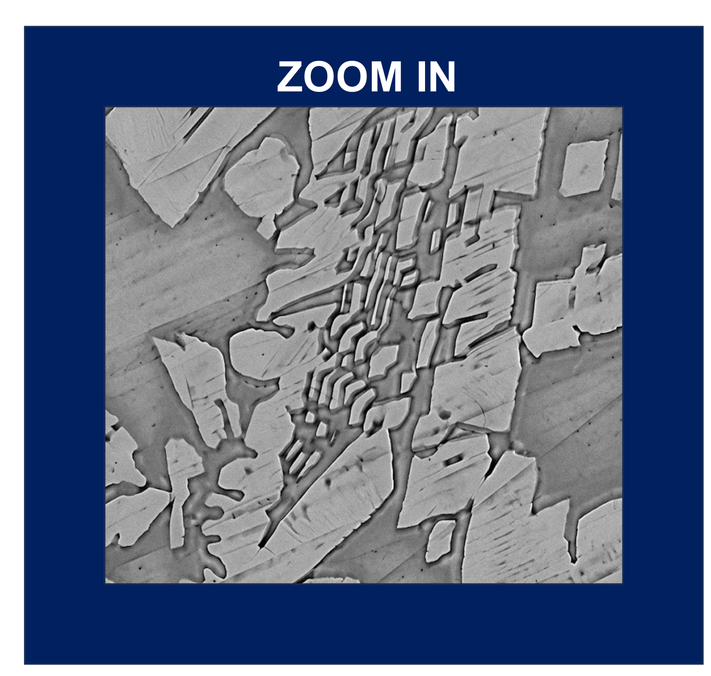
EXPERIMENTAL DATA SUMMARY: CONDITIONS					
CONDITION	GAS	HEAT INPUT	PASSES	AVG.FERRITE # (FN)	FERRITE VOLUME %
10 kJ Ar	Pure Argon	10 kJ/in	γ+δ	64.50	65.23%
10 kJ Ar+N	95% Ar+ 5% N_2	10 kJ/in	γ+δ	57.02	52.88%
20 kJ Ar	Pure Argon	20 kJ/in	γ+δ	67.08	68.68%
20 kJ Ar+N	95% Ar+ 5% N_2	20 kJ/in	γ+δ	65.34	60.85%

Phase Balance & Hardness Trends

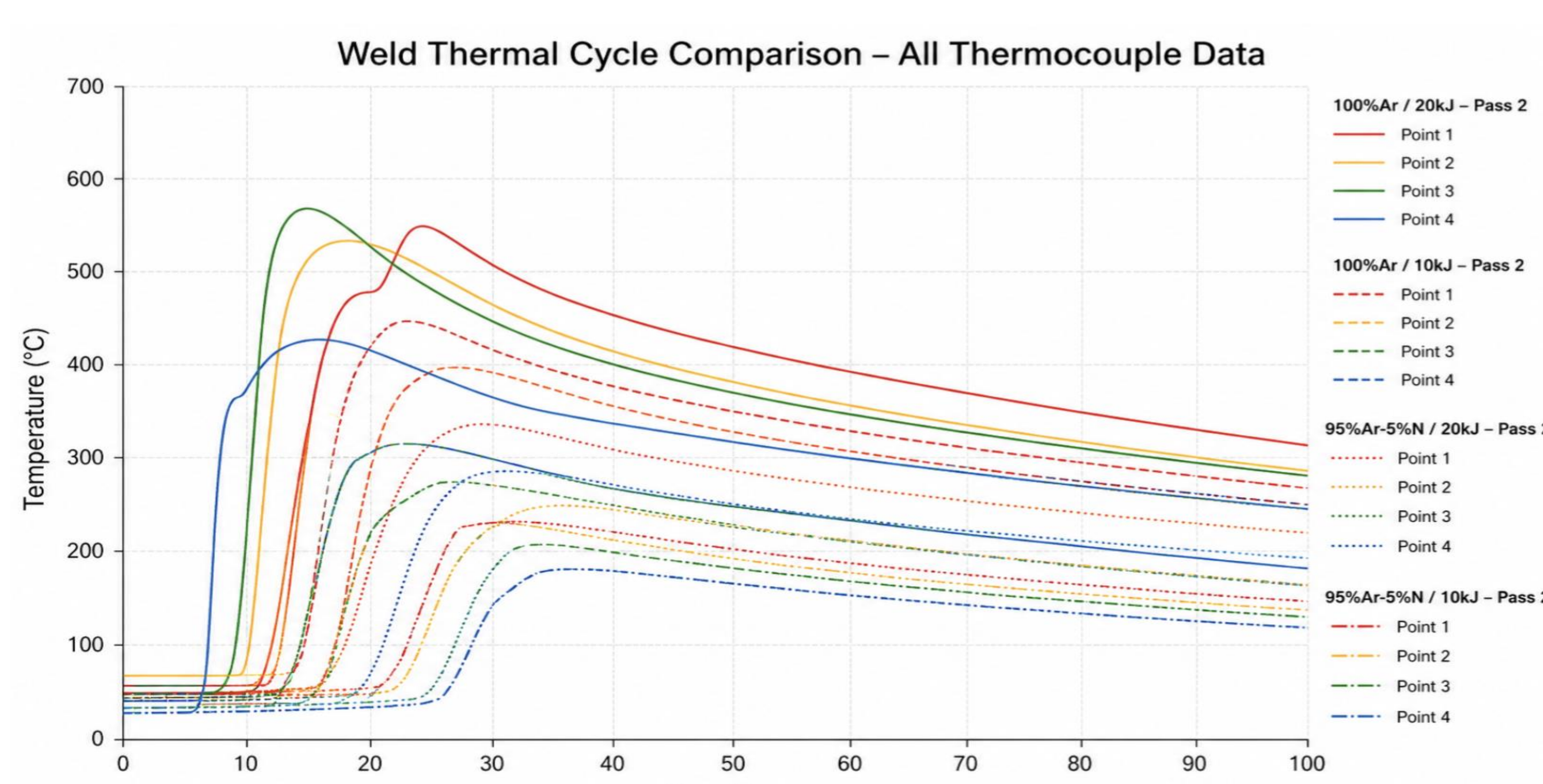


Key Finding: Nitrogen addition to the shielding gas is the dominant factor for restoring austenite balance, increasing it by approximately 15%. Higher heat input (20 kJ) slightly reduces hardness due to grain growth.

Microstructural Analysis: Fusion Zone



The magnified view reveals fine secondary austenite (γ_2) laths precipitated within ferrite grains during the thermal cycles of passes 2 and 3. A higher concentration of these laths is observed in the 10 kJ Ar+N_2 condition, attributed to nitrogen addition and reheating peak approaching 600°C.



CONCLUSIONS

Objectives achieved? Yes, the optimal welding condition for near 50/50 ferrite/austenite was identified.

Recommended condition: Low heat input (10 kJ/in) + 95% Ar / 5% N_2 shielding gas achieved 52.88% ferrite (57.02 FN), which is optimal for corrosion resistance in offshore and chemical plant service.

CONDITION	FERRITE FRACTION
20 kJ/in +pure Ar	Highest
20 kJ/in + 5% N_2	2nd highest
10 kJ/in + pure Ar	3rd highest
10kJ/in +5% N_2	Lowest

Major findings:

- No dendrite structure remains in the fusion zone after solid-state phase transformation.
- Nitrogen enriched gas (5% N_2) promotes austenite formation.
- The number of weld passes has stronger effect on decreasing ferrite fraction than the heat input.
- Secondary austenite forms in the root pass from reheating, decreasing the ferrite fraction

ACKNOWLEDGEMENT

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