Super Duplex Stainless Steel: Effects of Multi-Pass Welding Parameters on Microstructural Stability

Authors: Timothy Pickle, Peter Morriss, and Christian Von Qualen

Problem Statement

Super duplex stainless steel [SDSS] yield superior corrosion resistance and strength compared to standard 300-series SS. In multi-pass welding applications of oil and petrochemical pipelines, there have been reported failures for corrosion resistance of super duplex welds in corrosive environments.

Welding parameters in a fusion based welding process upset the internal base microstructure in the weld metal fusion zone [FZ] and heat affected zone [HAZ], which is ideally 50% ferrite - 50% austenite. Filler metal composition, base metal, shielding gas content, dilution, heat input, solidification rates, and cooling rates all influence the weld microstructure, whereby pitting and crevice corrosion resistance is affected.

This project seeks to:

- Study the effects of heat input and number of passes in multi-pass GTAW welds.
- Measure the volume fraction of austenite in the root and top pass weld metal and correlate volume fraction to process parameters.

Experimental Method

- Material: UNS S32750 (SDSS 2507) base metal & ER 2594 filler metal
- Machined 100 mm x 55 mm x 6 mm thick weld specimens with 75º single V groove, 2 mm root gap, and same metal backing plate.
- Employed 3-axis mechanized Arc Specialties equipment for consistency & repeatability.
- Perform multi-pass welds with CC DCEN-GTAW at varied heat inputs of 25, 30, 40, 60, and 75 kJ/in. per pass by increasing current (100-200 Amps) with constant travel speed (2 IPM), arc length (1/8"), and voltage (10.5-13.1 V) with 98% Ar- 2% N shielding gas.
- Calculated theoretical heat input as $HI = \frac{V*I}{v} * \frac{60}{1000}$ (kJ/in.)
- Maximum 120 ºC inter-pass temperature.
- Captured time vs. temperature of FZ and HAZ with IR imaging.
- Calculated volume fraction of austenite/ferrite via ASTM E562 manual point count method of optical micrographs.

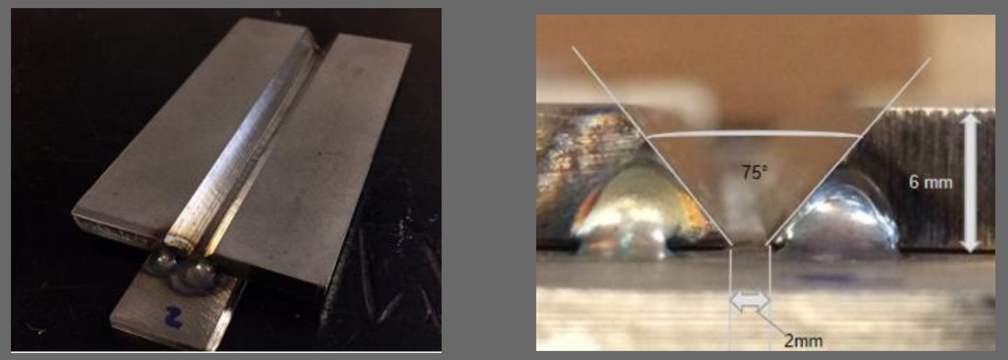


Figure 1: Multi-pass weld sample and side geometry

Results

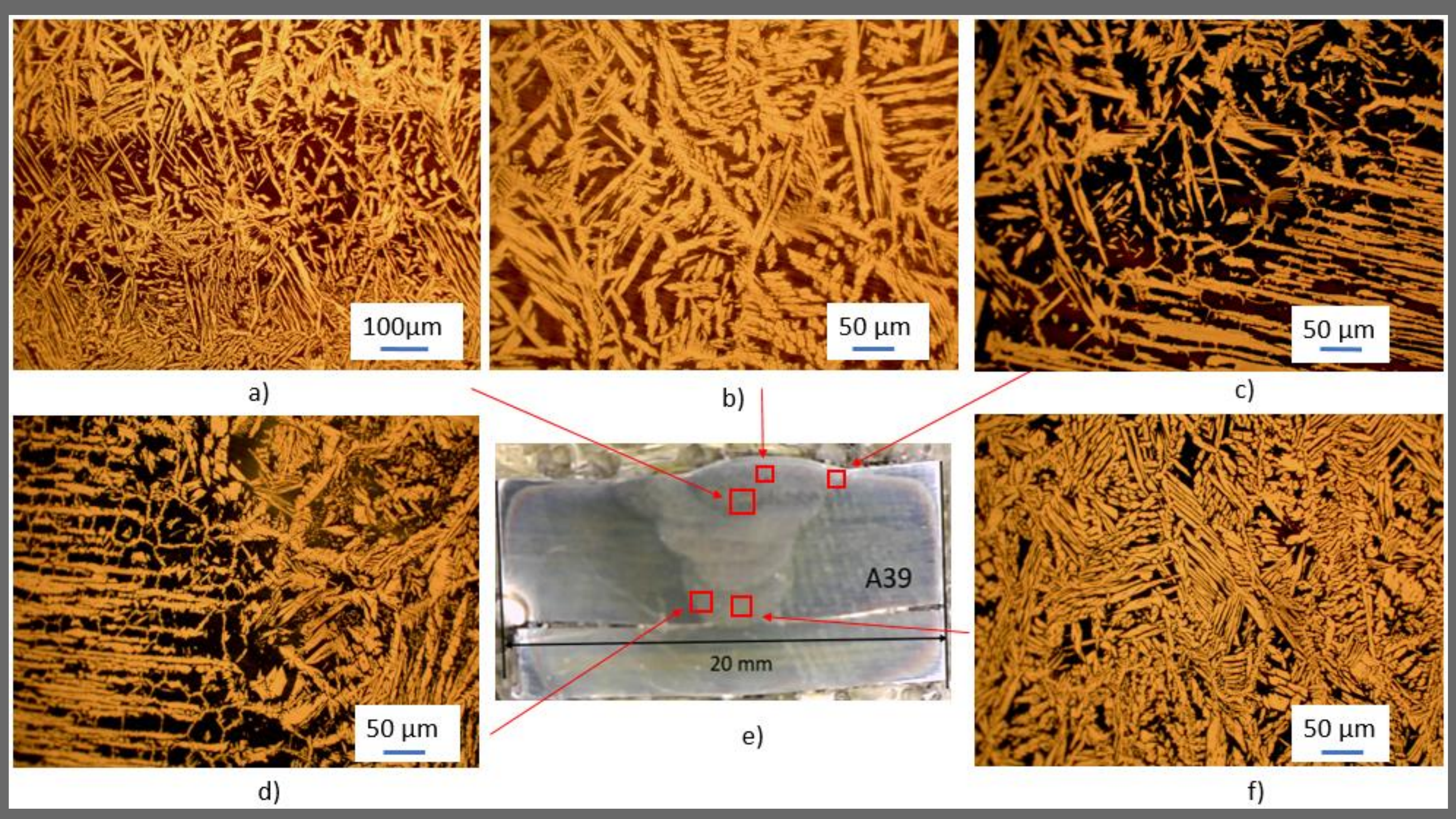
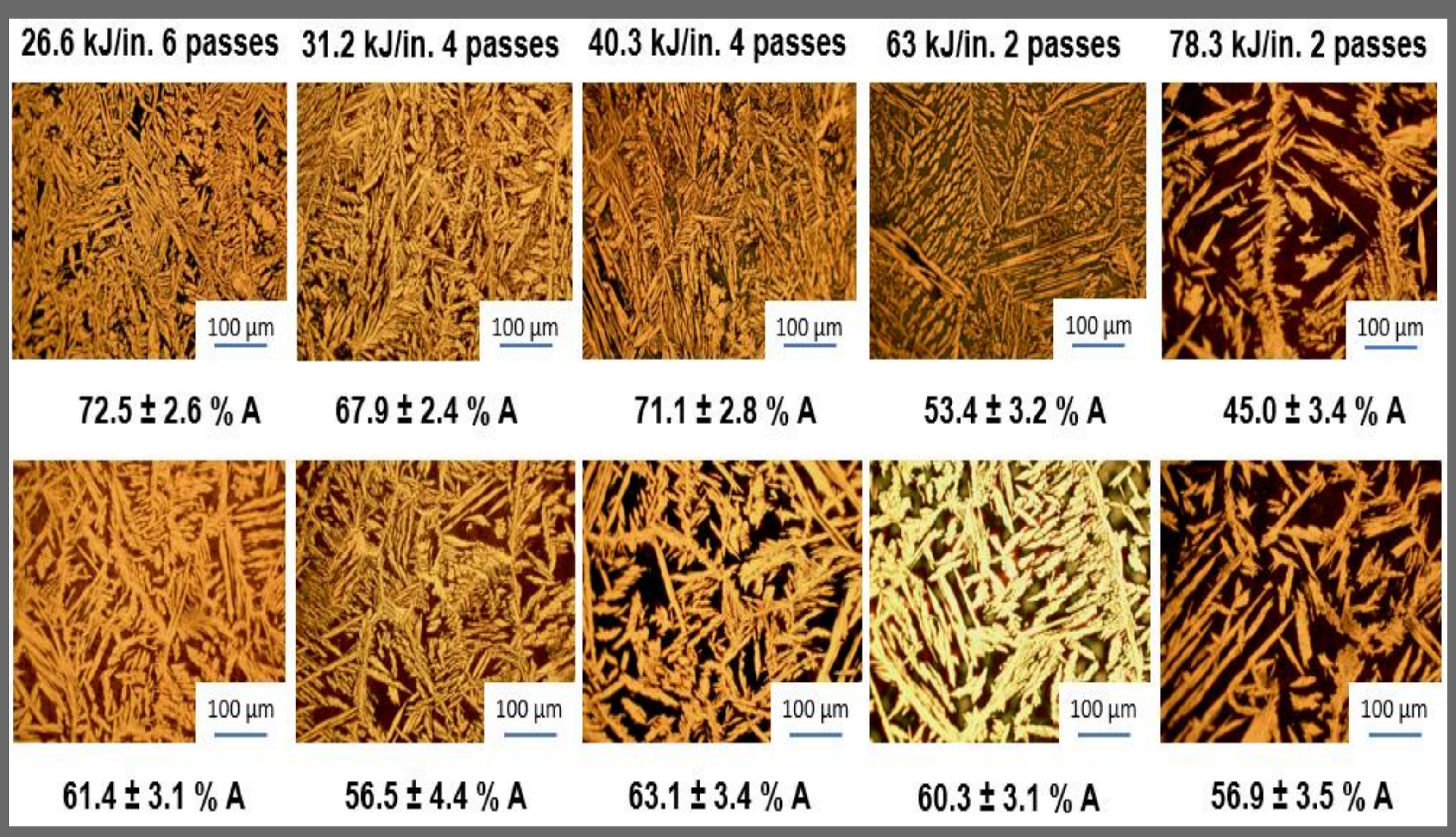


Figure 2: 26.6 kJ/in. heat input per pass (6 passes) **a)** Reheated zone between 5th and top pass **b)** Top pass FZ **c)** Top pass HAZ **d)** Root pass HAZ **e)** Macrograph **f)** Root pass FZ

- Shows the morphology for different regions in the multi-pass weld.
- Demonstrates noticeable HAZ with predominantly ferrite and a significant growth of secondary austenite in the root pass FZ & HAZ.



Root pass

Top pass

Figure 3: Morphology of root and top passes (all same scale. A=Austenite)

- After all completed passes, root pass austenite content decreases with increasing heat input.
- Top pass austenite content is statistically invariant for all heat input variations (Figure 4).
- Cooling rates in the fusion zone decrease with increasing heat input.

Discussion

- Increasing heat input results in slower solid state cooling rates, which was confirmed with IR data.
- Surprisingly, higher heat inputs (slower cooling rates) do not correlate to higher austenite contents in the fusion zone. (Figure 4)
- With increasing number of passes in the root pass fusion zone there is a direct increase in austenite content. (Figure 5)
- In contrast to the top pass, there is observed secondary austenite formation and primary austenite growth in the root pass FZ and HAZ.
- Additional welds have been completed and show similar trends with austenite content versus heat input in FZ according to Figures 4 & 5. However, we do observe a statistically significant decrease of austenite content with increasing heat input in the FZ of the top pass

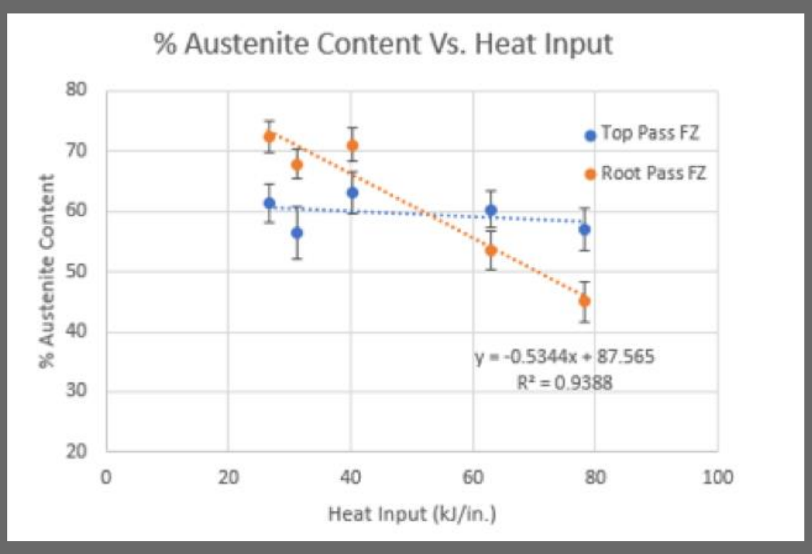


Figure 4: Austenite content Vs. heat input

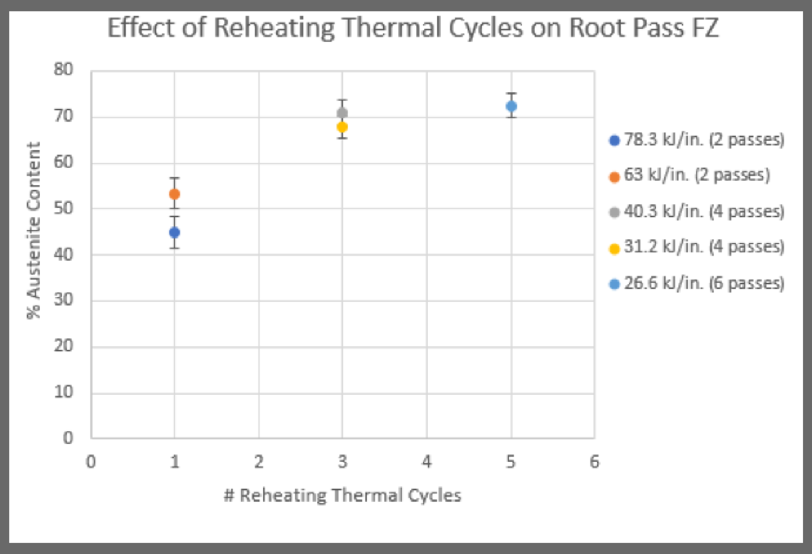


Figure 5: Austenite content Vs. Thermal cycles

Conclusions

- With increasing heat input, austenite content decreases in the root pass FZ, while the top pass austenite content is statistically consistent with decreasing trends observed in a second set of experiments.
- Reheating thermal cycles, rather than cooling rates, have more influence in microstructural stability in FZ of multi-pass welds.
- Root austenitic ratios undergo elevated austenite percentage when welded with traditionally-accepted 98% Ar – 2% N and subjected to multiple thermal cycles from subsequent passes.

Areas for Future Research

- Given surprising results, additional work will be focused on root cause and results will be correlated with corrosion and impact properties via ASTM G48 pitting/crevice corrosion testing and Charpy impact testing.

Acknowledgments

Thanks to Bechtel Global Corporation and Dr. Ben Pletcher for sponsorship. Thanks to Dr. Richard Baumer, Dr. Yoni Adonyi, Balazs Varbai, and Wes Downing for supervision and direction.