Alloy 800 HT Extruded-Pipe Cracking

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Background

- Alloy 800HT is a solid-solution strengthened nickel-iron-chromium alloy designed for applications requiring high temperature corrosion and creep resistance, making it an ideal choice for hydro-processing equipment [1].
- Cracking was identified after welding the reduced end of an Alloy 800HT pipe extrusion onto the furnace quench chamber, and after cutting the pipe extrusion off the chamber, dye penetrant testing revealed cracking around the entirety of the inner circumference.
- The proposed cracking mechanism was stress relaxation cracking (SRC) which is indicated in Alloy 800HT by grain boundaries exhibiting chromium-rich oxides, nickel-rich metallic filaments and small isolated cavities, hardnesses exceeding 200 HV, and extended exposure to temperatures between 550°C and 750°C [2].

Motivation

To mitigate future cracks on the furnace quench chamber assembly that could potentially lead to failure of the Alloy 800HT pipe extrusion.

Objectives & Approach

Task 1: Crack Evaluation

- 1.1 Dye penetrant testing to identify crack locations
- 1.2 Machine and prepare samples for metallography and fracture surface analysis
- 1.3 Characterize cracking phenomenon using optical microscopy and fracture surface analysis
- 1.4 Vickers microhardness testing to support determination of cracking phenomenon

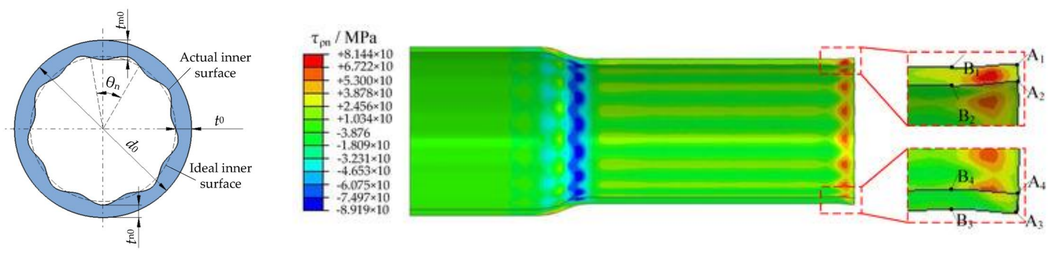
Task 2: Weldability Testing

- 2.1 Conduct manual GTAW 1G weldability test
- 2.2 Dye penetrant testing to determine test pass/fail
- 2.3 Machine and prepare samples for metallography
- 2.4 Analyze cross sections by optical microscopy

Conclusions

Case 1: Cracking occurred from Extrusion Process

- Existing literature on reduced diameter cracking of a pipe's inner circumference from extrusion suggests a theory that "wrinkles" on the ID caused by reduction creates regions of stress concentration, leading to stress-induced cracking [3].
- The spacing, location, and orientation of cracking revealed by PT in Task 1 supports the "wrinkle" theory.

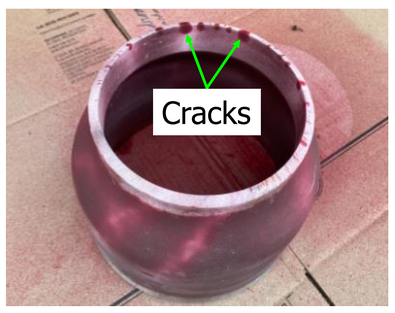


Case 2: Cracking occurred from Welding Process

- For SRC
  - Intergranular cracking in HAZ and weld metal
  - Fine, intragranular chromium carbide precipitates
  - Large degree of strain on grain boundaries
- Against SRC
  - No chromium-rich oxides or nickel-rich filaments on grain boundaries
  - No extended high temperature exposure
  - Hardness values < 200 HV
  - Cracking perpendicular to fusion boundary

Results & Discussion

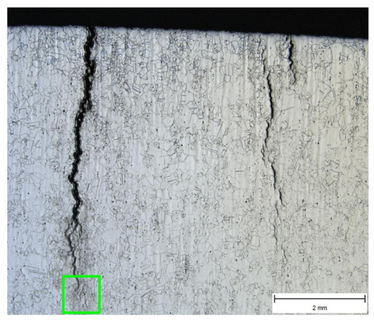
Task 1.1

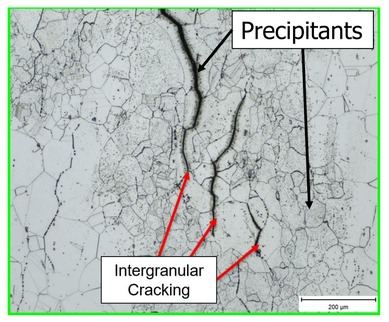


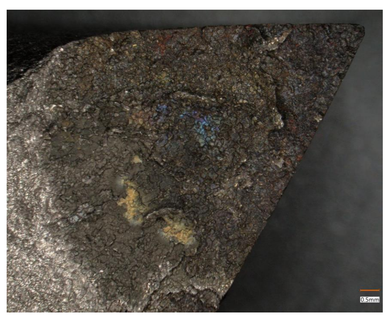
Task 1.2

1) The pipe to the left was wire EDM cut to isolate sections containing the cracks.
2) The samples were ground to a mirror surface finish, mounted in Bakelite and electrolytically etched with 10g of oxalic acid mixed with 100 mL of hot water at 3 volts and 0.5 amps.
3) One cracked sample was placed under a hydraulic press to reveal the fracture surface.

Task 1.3 Microscopy & Fracture Surface Analysis







- No Cr-rich oxides or Ni-filament
- No cracks found in low-precipitate density areas
- Heavy oxidation
- Intergranular structure

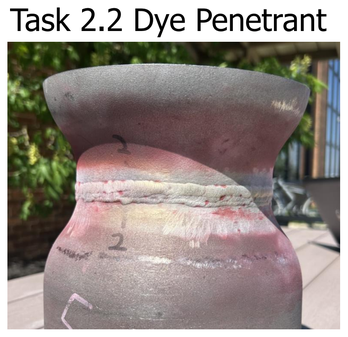
Task 1.4 Microhardness

Pipe Cracked Base Metal
- Max. 191 HV

Non-Cracked Base Metal
- Max. 181 HV

Task 2.1 Manual GTAW Weldability Test
- Pass: No cracking occurred in area of interest

Task 2.2 Dye Penetrant



Pass: No cracking occurred in area of interest

Task 2.3 Machine and Sample Preparation

1) The samples were rough cut with a bandsaw and isolated with a chop saw.
2) The samples were prepped in the same manner as Task 1.2 but etched longer to expose the filler metal grain structure.

Task 2.4 Cross Section

- No discontinuities
- Little precipitants
- Out of plane of previous 1.3 microscopy

Future Work

- Obtain detailed report of the extrusion process and heat treatment procedure and run finite-element analysis simulation to evaluate areas of stress concentration.
- Redesign weldability test to more accurately assess SRC.
- Perform hardness testing on large sample size and expand to different locations of the pipe extrusion.
- Perform SEM analysis to identify potential compositional effects caused by the extrusion process.

References

[1] https://www.specialmetals.com/documents/technical-bulletins/incoloy/incoloy-alloy-800h-800ht.pdf
[2] https://www.bondvoormaterialenkennis.nl/wp-content/uploads/2021/05/Down-Control-of-relaxation-cracking-in-austenitic-high-temperature-components-Van-Wortel.pdf
[3] https://www.mdpi.com/2075-4701/11/9/1438