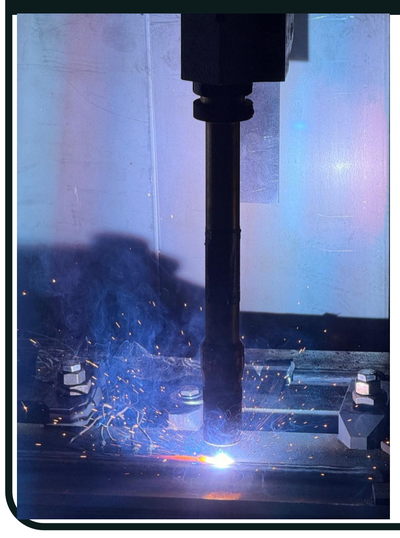
Nicolas Gonzalez

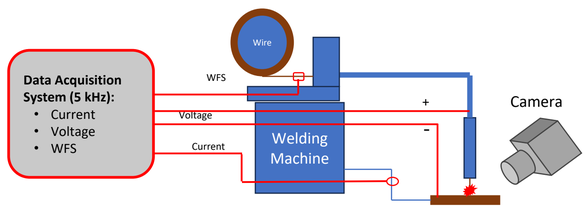
Upper Arlington High School
Wire Arc Additive Manufacturing of High Strength Steels
Ruslan Kim and Dr. Antonio Ramirez

HIGH SCHOOL INTERNSHIP PROGRAM

Background

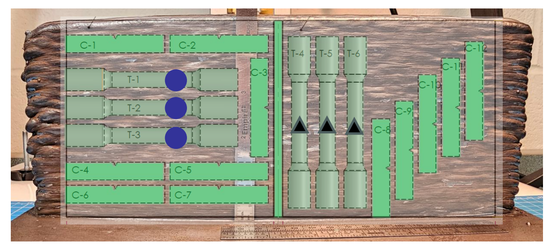


GMAW/MIG Welding is a standard welding process that uses the oppositely charged work plate and wire tip to create an arc between them when close to contact, melting the wire and depositing it onto the workpiece in the form of liquid metal. WAAM is the process of using an arc-based welding process to 3d print layer upon layer to get the desired output build



IPT: 100
Water Gap: N/A
Productivity: Low, 20hr (0.26 kg/h)
Result: acceptable properties, but low productivity

Baseline Reference



	UTS	YS	CVN
Longitudinal	899	867	79
Transverse	907	870	67

Sample	Joules
C1	61
C2	66
C4	69
C5	62
C6	65
C7	79
C8	76
C9	68
C10	77
C11	96

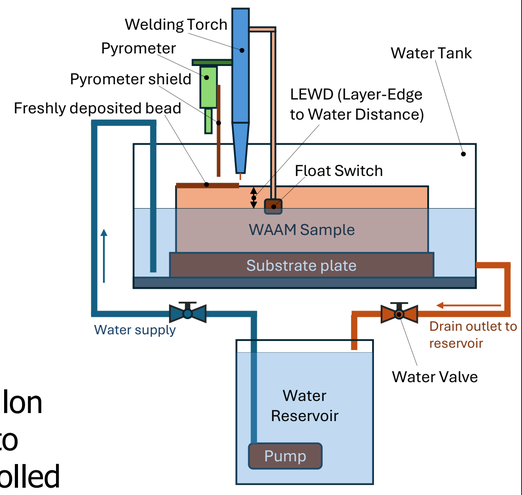
C3 & C12 are invalid

Motivation

The Baseline build yields acceptable properties. Forced cooling turned out to be needed to increase productivity, leading us to investigate water methods even though carbon steel is susceptible to Hydrogen cracking.

Objectives & Approach

Target properties	
Min. YS	100-120 KSI (690 – 827 MPa)
Min. Elong.	15%
Area Red	35%
Max. HBW*	321
CVN Energy	42 J @ -30 °C
Production Rate	>2.5kg/h



Cooling is needed to increase productivity without sacrificing properties. Using a 45-gallon reservoir tank equipped with a water pump to supply the water coolant. The pump is controlled by a float switch that is fixed to the welding torch creating the water to weld gap variable. The water is continually drained back into the reservoir to create a water cycle.

- **HS Metal-cored wire**
  C-0.08, Mn-1.50, Si-.50, Ni-1.84, Cr-0.24, Mo-0.46

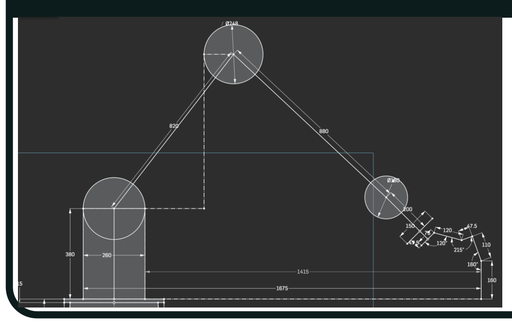
Conclusions

1. Printing HSLA Carbon Steel at high deposition rates is made possible with forced cooling

3. Water cooling approach can be used when stress distribution, geometry, IPT, and water gap are properly managed together

4. Separating the stress concentrators and residual stresses while still relieving Hydrogen cracking allows for targeted results

Future Work



New Yaskawa robot arm installation is being planned, next is software setup. For future cooled experiments, a chiller is being looked into. Mechanical properties for the samples will be tested soon.

Results & Discussion

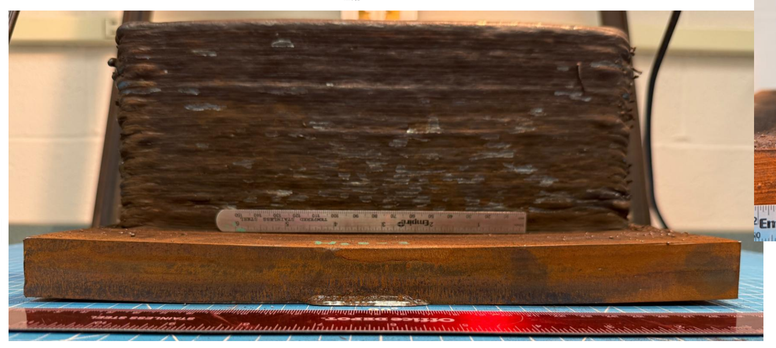
H2O-1

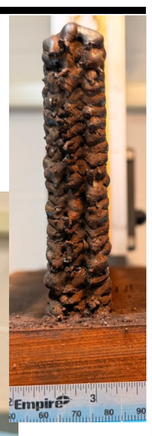
- IPT: None, continuous
- Water Gap: 15mm
- Productivity: High
- Result: Hydrogen cracking at ends

By replacing the IPT with water cooling, the weld does not become too hot to continue but the water level needs to be aggressively close to the deposition layer, resulting in insufficient time for Hydrogen to diffuse at high temperatures, causing Hydrogen cracking.

H2O-3

- IPT: 250
- Water Gap: 45mm
- Productivity: 1.17kg/h
- Result: small crack near end at ends

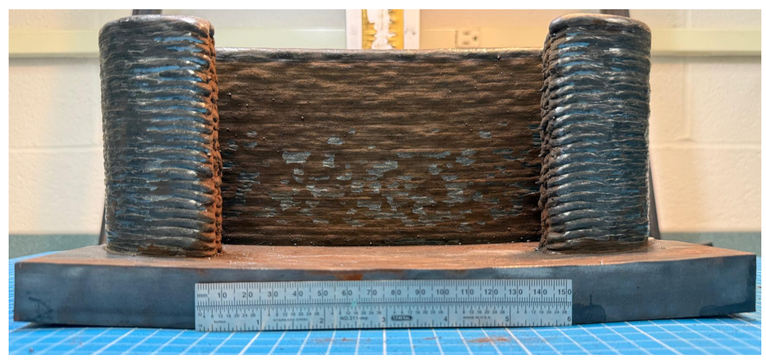


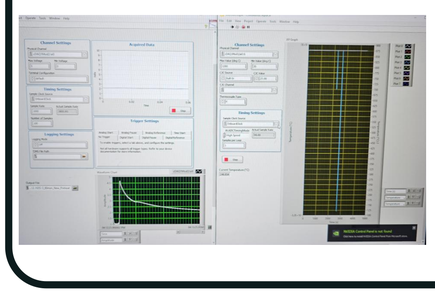


Increased gap to relieve Hydrogen cracking, higher IPT to give time for Hydrogen to diffuse, these cause lower productivity than previous build. Still small cracking near start and stop regions between layers, areas that have residual stresses and stress concentrators.

H2O-4

- IPT: 300
- Water Gap: ~30mm
- Productivity:2.6kg/h
- Geometry: C-Shape
- Result: Promising





Previous cracking occurred at the ends of build possibly due to stress concentrators and residual stresses, the C-Shape separates the causes of stress. There is no cracking even with aggressive cooling, ice, and less IPT and water to arc gap.

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