Investigation of Near-Net-Shape Fabrication out of Low-Carbon Steel Through Wire-Arc Additive Manufacturing (WAAM)

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Introduction

- Additive Manufacturing (AM), commonly known as 3D printing produces parts in a layer-by-layer manner.
- Wire Arc Additive Manufacturing (WAAM)[1] that utilizes Cold Metal Transfer (CMT) printing is a standout technology allowing for the manufacturing of large scale[2], near-net-shape and geometrically challenging metal parts.
- This study explores the optimization of parameters for fabrication of near-net-shape parts out of low-carbon steel, ER70S-6, through WAAM.
- ER70S-6 is a versatile alloy, that is highly available and is used in industries such as oil/gas for pipeline parts.
- Continued studies will optimize the use of WAAM, revolutionizing the manufacturing and repair industries[3].

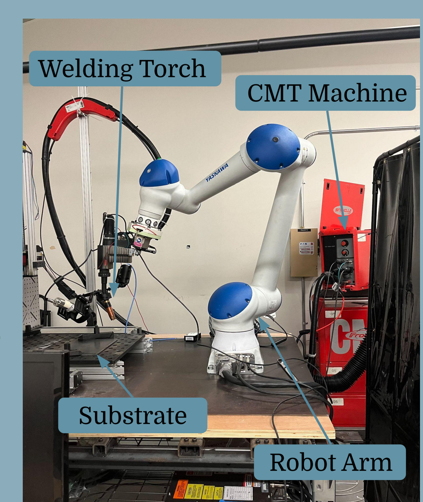
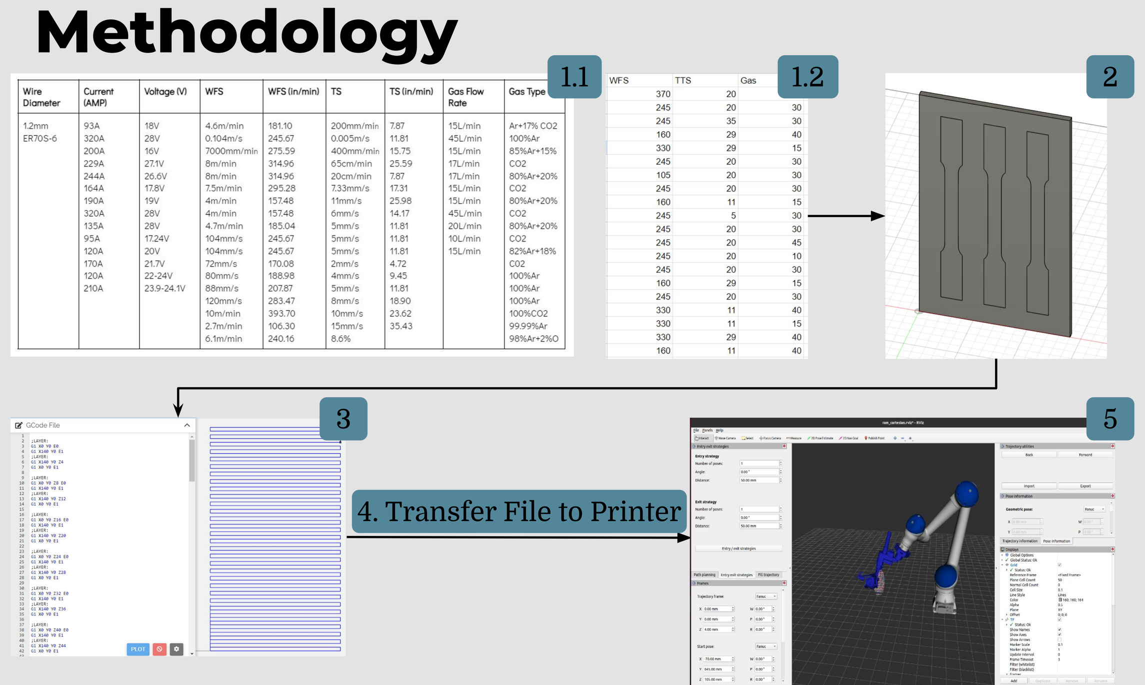


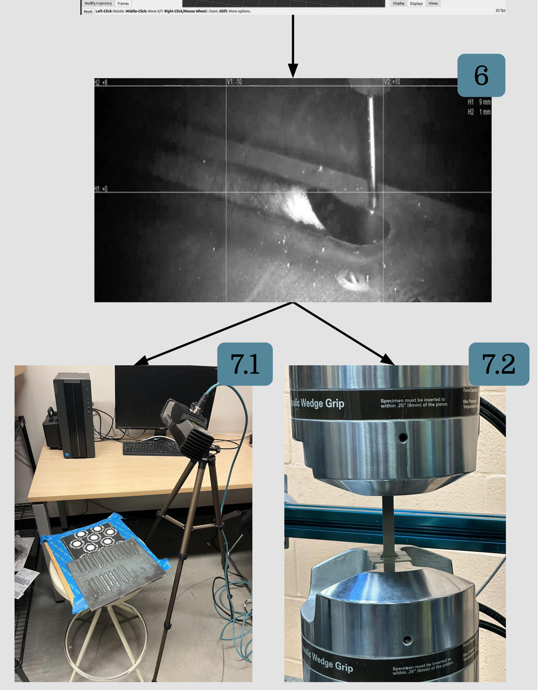
Fig. 1 WAAM and CMT machines

Fig. 2 Application of WAAM

Methodology



1. Design of Experiment (DOE) Preparation
2. Design CAD model
3. Slice and Convert STL File into GCode File
4. Transfer File to WAAM
5. Simulate Deposition Process
6. Deposition of Wall
7. Mechanical Properties Testing and Geometric Dimensioning



Processes

- With every application, a unique set of WAAM parameters are generated and optimized.
- Numerous parameters are considered in the optimization of the deposition, but 3 have a comparatively greater impact: Wire Feed Speed (WFS), Torch Travel Speed (TTS), and Gas Flow Rate (GFR).
- Initially 40 beads were printed with the parameters generated using a Central Composite Design (CCD) software, Minitabs.
- A few beads based of visual geometry were selected for measuring.
- Using Phoxi Control and a combination of the softwares Meshlab, MeshMixers and Autodesk Fusion were used to attain the bead measurements.

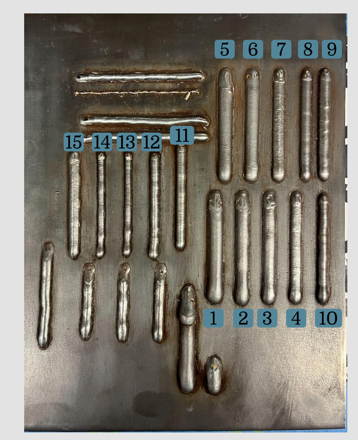


Fig. 3 Optimized Bead Prints

Low-Carbon Steel ER70S-6						
Bead #	WFS (ipm)	TTS (ipm)	GFR (cfh)	Length (mm)	Width (mm)	Height (mm)
5	200	7.00	25	64.82	7.86	3.83

Table 1 - Optimized Parameters for ER70S-6 Bead

- Based on the measurements it was determined that Bead #5 will be used for further for testing. It presented the most consistent results and it can be inferred that it is appropriate to use for examining the near-net shape and the minimum standard yield strength (YS) and ultimate tensile strength (UTS) values for reference (400 MPa and 483 MPa).
- A Computer-Aided Design (CAD) model of the wall and ASTM-E8 (tensile strength samples) were designed in Autodesk Fusion, simulating the prints and cuts needed to be made.
- A Laser 3D scan was taken of the printed wall to verify that it is a near-net shape, which means the initial part is manufactured closely to the desired final form
- The wall's dimensions need to as close as possible to the designed dimension of 140mmx8.00mmx240mm (x,y,z), for it to classify as a near-net shape.

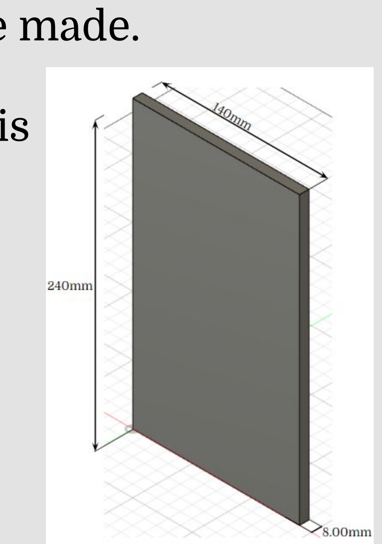


Fig. 4 Wall CAD model

Processes

- The CAD modeling follows The standard measurements to ensure result consistency and industrial uniformity.
- 3 ASTM-E8 samples were cut out of the wall sample using a EDM (electrical discharge machine) machine, following a pre-designed CAD model.
- The samples were pulled apart using the 810 Material Test System, which simultaneously computed a stress-strain curve graph.

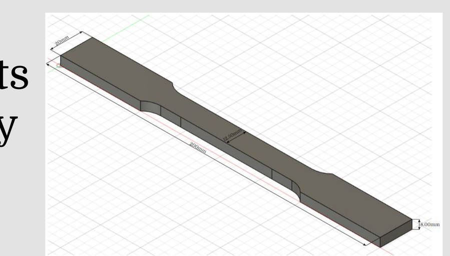


Fig. 5 ASTM-E8 Sample

Fig. 6&7 Post-Machining ASTM-E8 Sample & 810 MTS Machine

Results

- Through the optimization processes it was discovered that the WFS and TTS act together to produce the beads geometry, in response to the heat input levels (voltage and current).
- Increasing the heat input and WFS will usually result it a wider bead but this can be countered by increasing the TTS to make it skinner.
- During the bead optimization processes, it was noted that multiple samples with the same parameters needed to be printed, since the increase in temperature of the build plate will alter the beads geometry.
- ER70S-6 goes through a variety of heat processes all impacting the microstructural grain structure, changing the amount of force the metal can withstand.
- Ideally we expect the tensile strength values to be higher than the stand YS and UTS (400 MPa and 483 MPa).

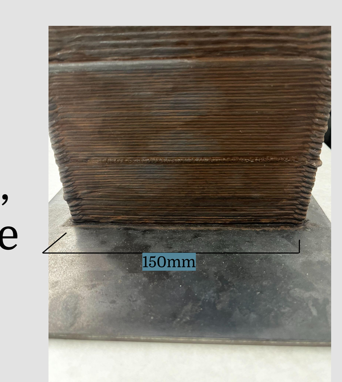


Fig. 8 Sample Wall Print

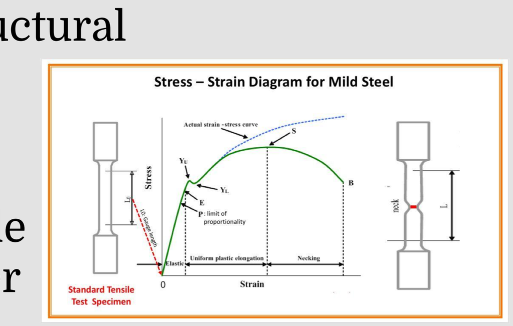


Fig. 9 Stress-Strain Curve Graph [4]

Future Work

- Further research aims to complete testing ensuring the wall fabricated have a good mechanical properties.
- Optimization of will continue till optimal geometry and mechanical properties are achieved.

Conclusion

- We predict that Bead #5 optimized parameters will provided a print with a near-net shape.
- Parameter optimization is unique to application purposes and attaining a near-net shape is only the first step. Additional research and testing is need to understand the quality of the printed object.
- Future tensile testing would provide an insight on the strength of the wall since the variation in parameters changes the microstructure of the metal, affecting its strength.
- WAAM technology is only in its beginning stages. In the future, it will revolutionize the manufacturing industry, eliminating tons of wasted materials and decreasing the time and money spent on production.

References

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