Numerical Investigation on the Strength of 17-4 Ph Stainless Steel Structures Fabricated Using Wire Arc Additive Manufacturing

ADDITIVE DESIGN & MANUFACTURING SYSTEMS LABORATORY

Taylor Porter[1], Muhammad Irfan[1], Shalini Singh[1], Ahmed Qureshi[1]

[1]Department of Mechanical Engineering, University of Alberta, Edmonton, AB

INTRODUCTION

- 17-4 Ph (precipitation hardening) is a type of Stainless Steel (SS) known for having a strong resistance to corrosion.
- It has many benefits, however when exposed to chemicals, moisture, or heat for extended periods it is prone to corrosion.

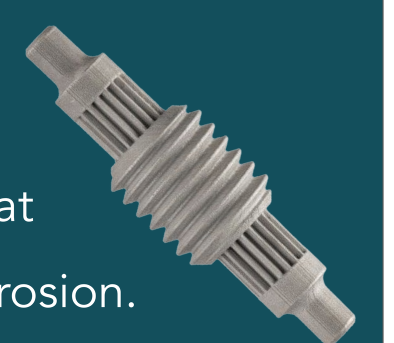


Fig.1 17-4Ph Roller screw

- 17-4Ph SS is widely used in many engineering industries for various applications such as engine parts, aircraft structural components, etc. (*Fig. 1*) & (*Fig. 2*)

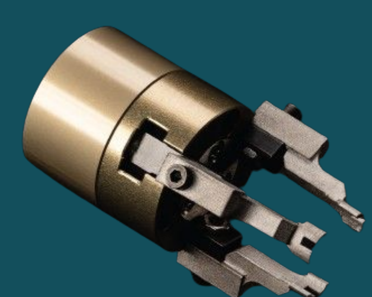


Fig. 2 End effector

- The objective of this study is to determine the mechanical properties of 17-4Ph SS when manufactured using Wire Arc Additive Manufacturing (WAAM).

BACKGROUND

- Additive manufacturing (AM), more commonly known as 3D printing, is the process of adding successive layers of a material atop itself until the desired object is formed.

Fig. 3 WAAM robotic arm. ADAMs Lab

- WAAM uses an arc welding process to melt the material as it is being deposited allowing it to be adapted for many industries.(*Fig. 3 & 4*)
- Compared to traditional manufacturing, AM is much more cost & environmentally friendly.

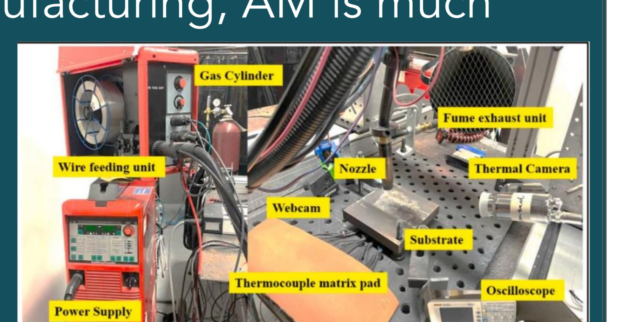
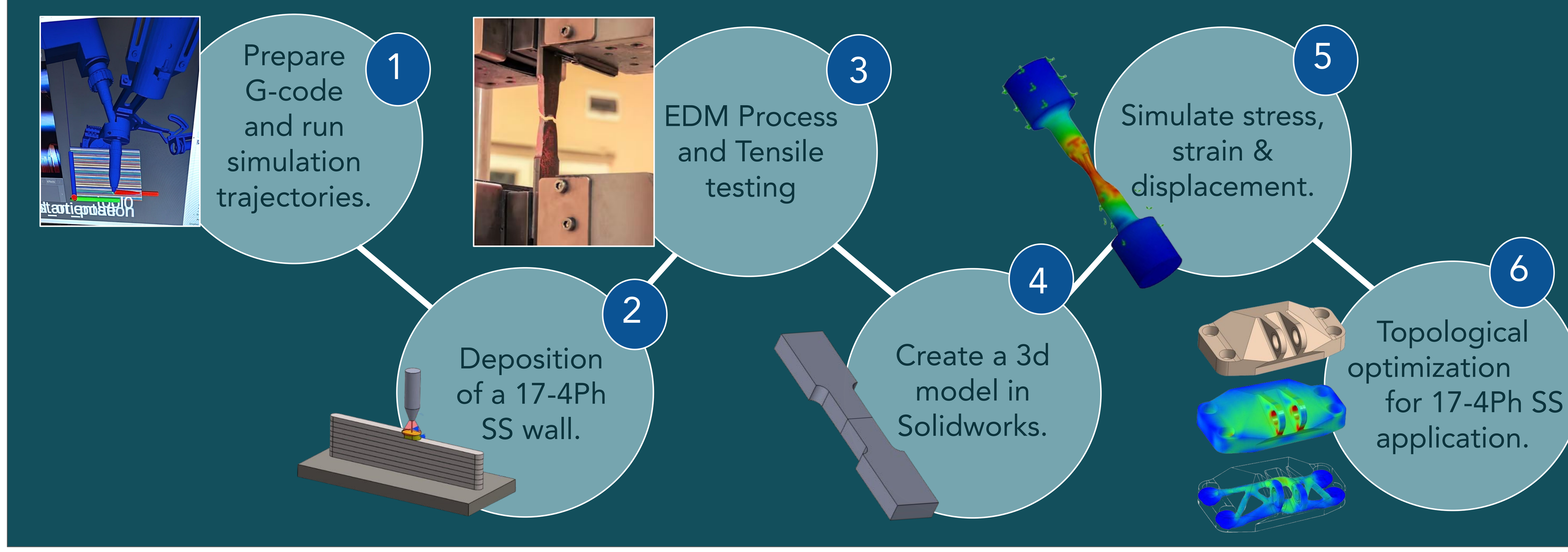


Fig. 4 Gantry system. ADAMs Lab

- Wire electrical discharge machining (EDM) removes material from a part using a conductive wire to generate a series of repeated electrical discharges.

PROCESS



METHODOLOGY

Experiment:

- The first step was to select the optimum parameters for the deposition of 128 layers of 17-4 Ph SS.
- Next step was to fabricate a 17-4 Ph SS wall using WAAM (*Fig. 4*).
- Later on, the ASTM E8 standard size sample was cut extruded from the wall using EDM Process (*Fig. 5*)
- Lastly, tensile testing was performed on the standard dog bone shaped sample for investigating the mechanical properties of the 17-4 Ph SS.

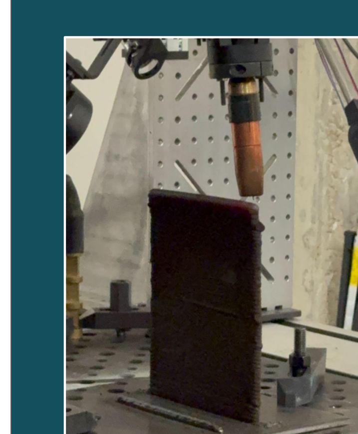


Fig. 5- 17-4 Ph SS Wall

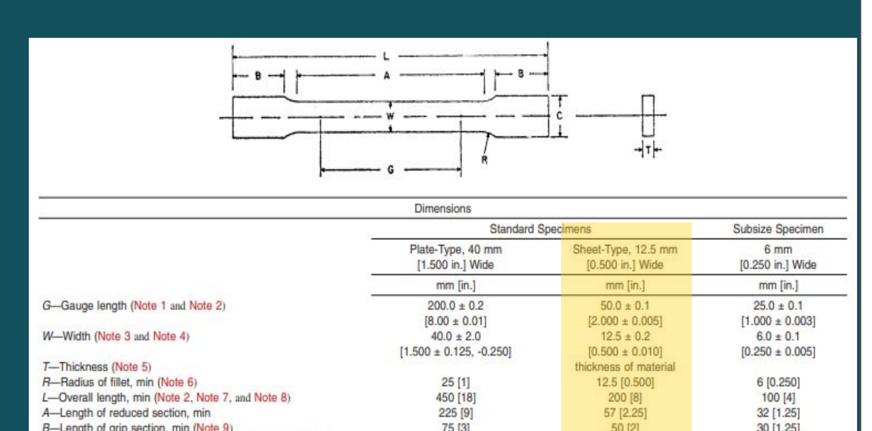


Fig. 6 - ASTM E8 dogbone standard

Simulation:

- A 3D model was created in Solidworks software by following the standard ASTM E8.
- LS-dyna software was used to perform a static simulation on the dogbone sample to validate it using the experimental result.

RESULTS

- Tensile testing result shows that the 17-4Ph SS has experienced a brittle fracture, which was validated using the failure simulation. *(Fig.6) & (Fig.8)*
- The graph shows that both experiment and simulation models fracture at 250 MPa and curve shows a similar trend (Fig.8)

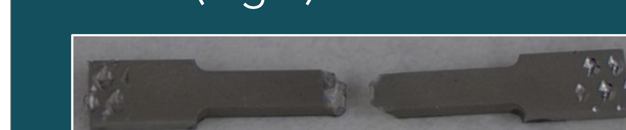


Fig. 7- Brittle fracture (Tensile testing result)

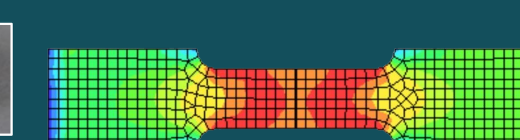


Fig. 8 - Simulation model

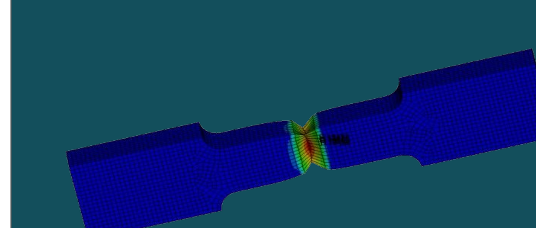


Fig. 9- Brittle fracture (Simulation result)

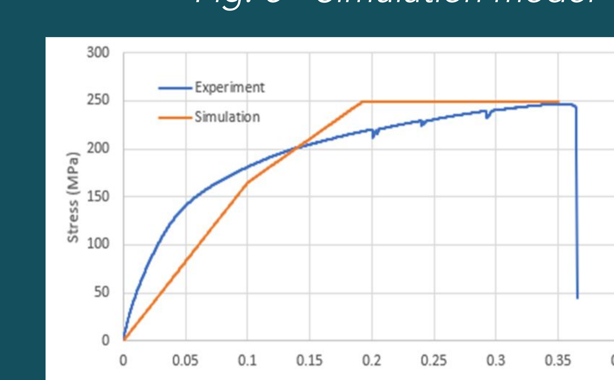


Fig. 10 - Stress vs Strain curve (Simulation and experimental)

APPLICATION

- 17-4Ph can also be used as a multi purpose precision maintenance tool.
- According to NASA (2016), this tool will allow astronauts to complete tasks with comfort and ease.
- Wrenches of varying sizes in the tool can be used for fastening and gripping screws.

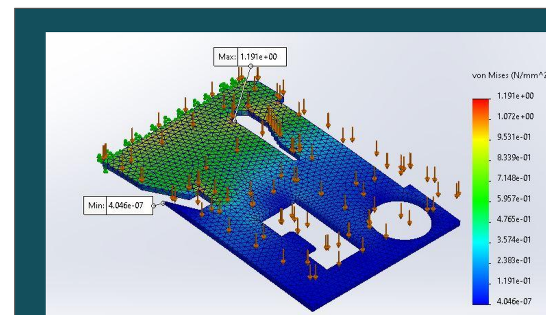


Fig .11- Minimal stress of 1.91MPa

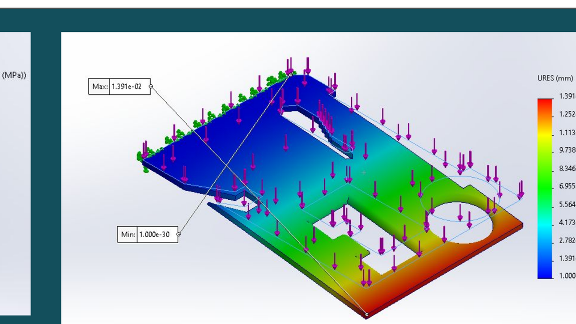


Fig.12 - Displacement of 0.013mm

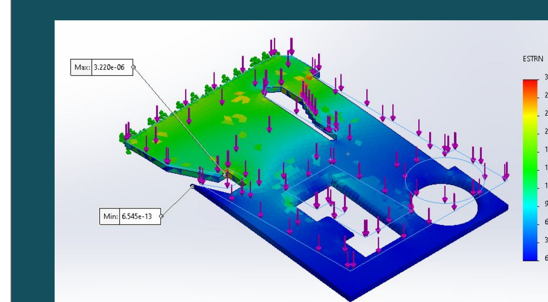


Fig .13- Minimal strain of 3.2 -E6

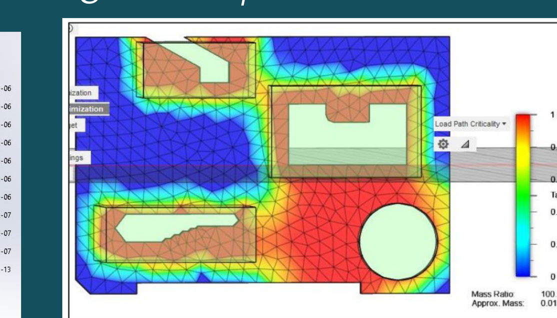


Fig .14- 0% Material Reduction

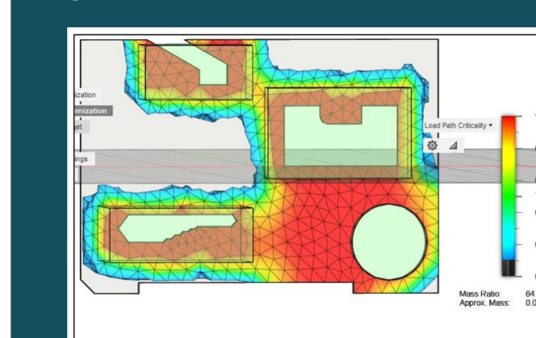


Fig .15- 30% Material Reduction

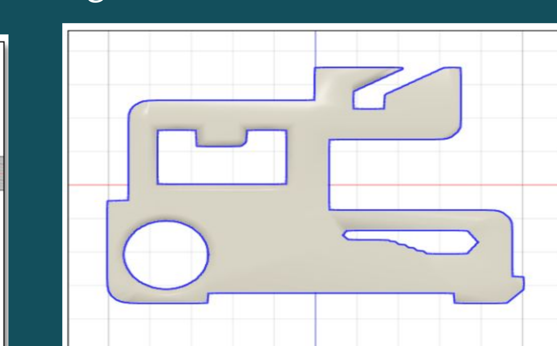


Fig .16- Final product

CONCLUSION

- The successful fabrication of 17-4Ph SS wall was achieved using the optimised parameters.
- Tensile testing shows a brittle fracture with the maximum stress of 250 MPa.
- Static simulation result using LS-Dyna validates the experimental results by displaying the same maximum stress of 250 MPa and a similar brittle fracture.
- Topological optimisation result shows that 30% of the mass can be reduced from the application without affecting the strength of the product.

ACKNOWLEDGMENTS

I would like to send my gratitudes to my PI, Dr. Qureshi as well as my supervisors Dr. Singh and Muhammad Irfan for giving me the opportunity to work alongside them in the lab this summer.
Thank you to Canada Summer Jobs for sponsoring me and allowing me to participate in this experience.
Finally I would like to thank the WISEST team and my fellow researchers for providing support and encouragement throughout my experience here. It wouldn't have been possible without all of you.

WISEST women in scholarship, engineering, science & technology

UNIVERSITY OF ALBERTA

Canada

REFERENCES

"Standard Test Methods for Tension Testing of Metallic Materials," ASTM E8, in *Annual Book of ASTM Standards*, vol. 15.06.

https://nasa3d.arc.nasa.gov/detail/mpm

https://www.desktopmetal.com/resources/174-stainless-steel