Simulations of Wire Arc Additive Manufacturing with Inter-Pass Temperature

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Problem Statement

- Additive Manufacturing (AM) is a rapidly growing industry due to its ability to quickly produce cost-effective prototypes and customized parts.
- However, Wire Arc Additive Manufacturing (WAAM) still involves a trial-and-error stage, where physical testing, material waste, and operator time can significantly increase design cycles. For these reasons, simulation is a useful tool for designing new geometries in the additive manufacturing industry.
- Although simulation in additive manufacturing is not a new concept, if implemented in an industrial setting its application can reduce costs and improve design performance leading to faster adoption across industry.

Methods

The goal of this project was to create simulations that mimicked the actual printing process of the Lincoln Electric RND WAAM machine.

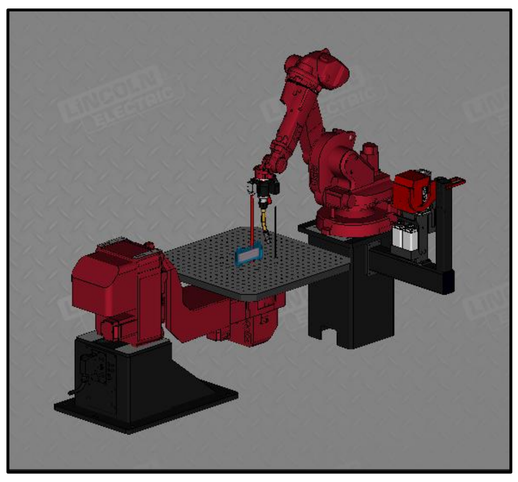

Figure 1 - Lincoln Electric's Sculprint RND Wire Arc Additive Manufacturing Machine

Thermal simulations of multi-layer welding were conducted using Simufact Welding 2025.4 with the Direct Energy Deposition (DED) method. Five geometries were selected to assess thermal response and to investigate the influence of inter-pass temperature in multi-layer WAAM builds.

Table 1 – Welding parameters used in the WAAM process

Variables	Input Values
Current	135 A
Voltage	24 V
Velocity	6.5 mm/s
Material	ER70-S
Inter-pass Temperature	320 °C

Table 2 – Bead height, width and number of layers for each geometry
There is a percent uncertainty relative to specific final geometries regarding keeping heat input the same.

Parameters	Thin Cylinder	Thin Rectangular Wall	Thick Cylinder	Thick Rectangular Wall	Flange
Bead height	1.06 mm	1.48 mm	1.20 mm	1.46 mm	1.18 mm
Bead width	11.67 mm	11.67 mm	5.35 mm	6.82 mm	7.14 mm
Number of layers	60	60	53	61	54

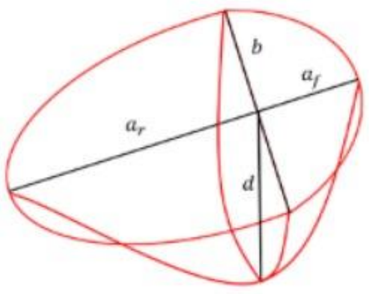

Figure 2 - Geometric Parameters of the Asymmetric Heat Source in Weld Pool Modeling
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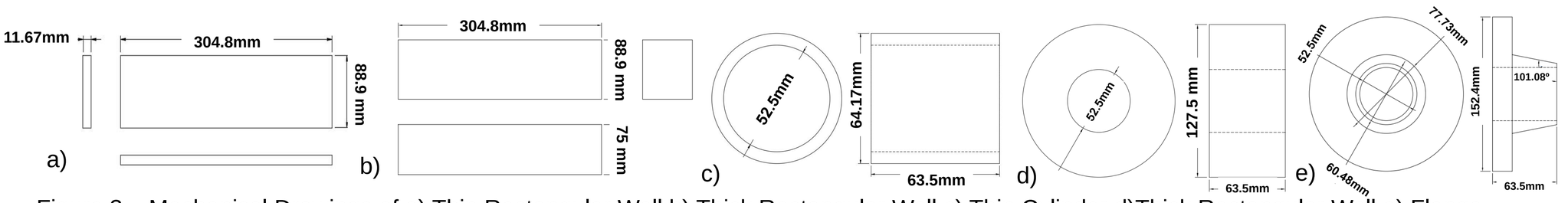

Figure 3 – Mechanical Drawings of a) Thin Rectangular Wall b) Thick Rectangular Wall c) Thin Cylinder d)Thick Rectangular Wall e) Flange

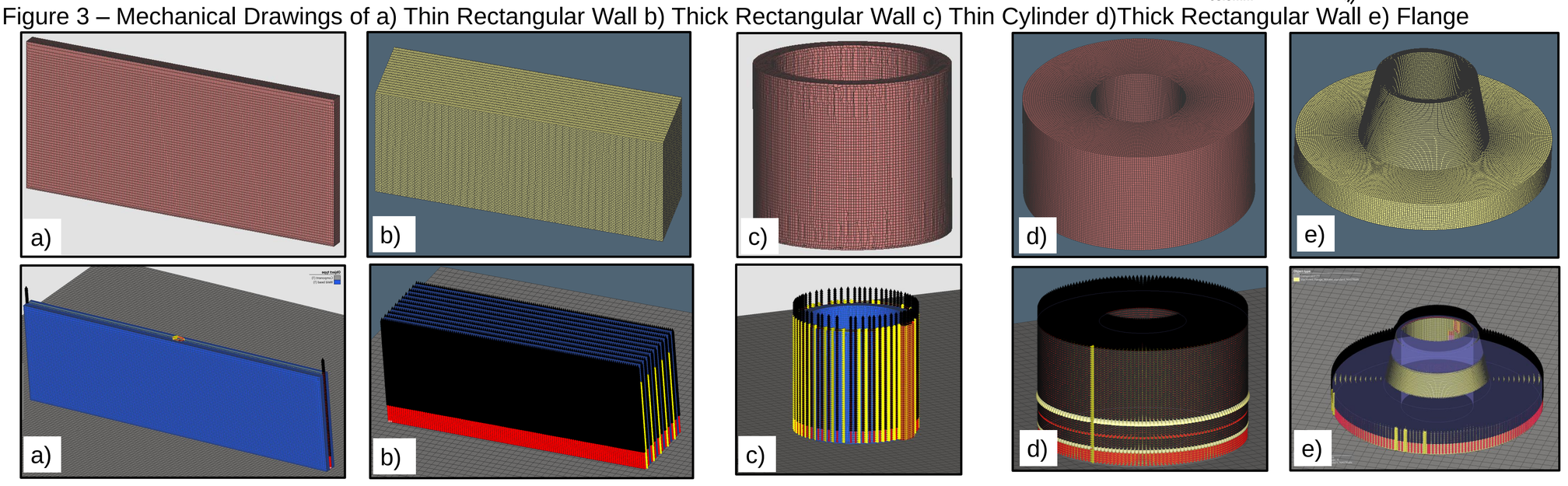

Figure 4 – Meshing Design of
a) Thin Rectangular Wall
b) Thick Rectangular Wall
c) Thin Cylinder
d) Thick Rectangular Wall
e) Flange

Figure 5 – Weld Path of
a) Thin Rectangular Wall
b) Thick Rectangular Wall
c) Thin Cylinder
d) Thick Rectangular Wall
e) Flange

Results

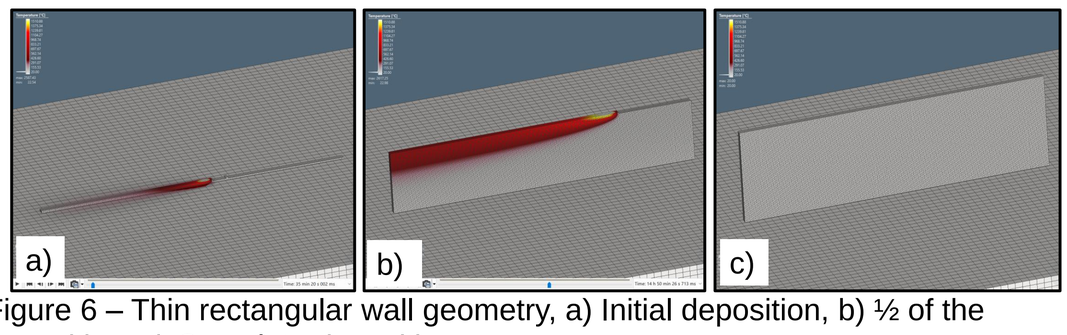

Figure 6 – Thin rectangular wall geometry, a) Initial deposition, b) ½ of the deposition, c) Complete deposition

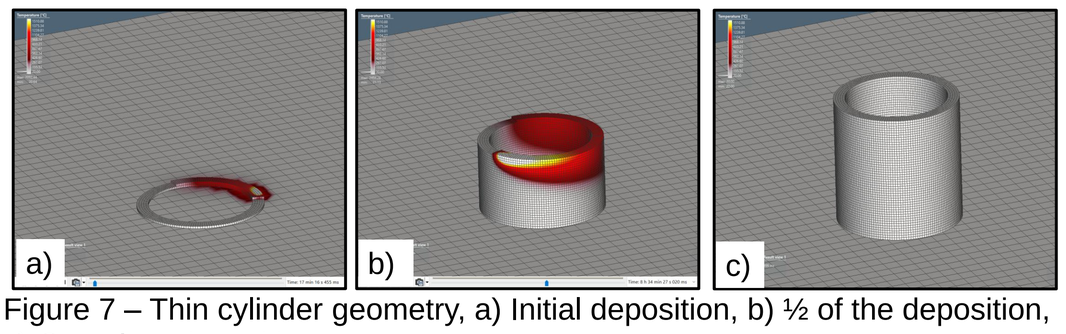

Figure 7 – Thin cylinder geometry, a) Initial deposition, b) ½ of the deposition, c) Complete deposition

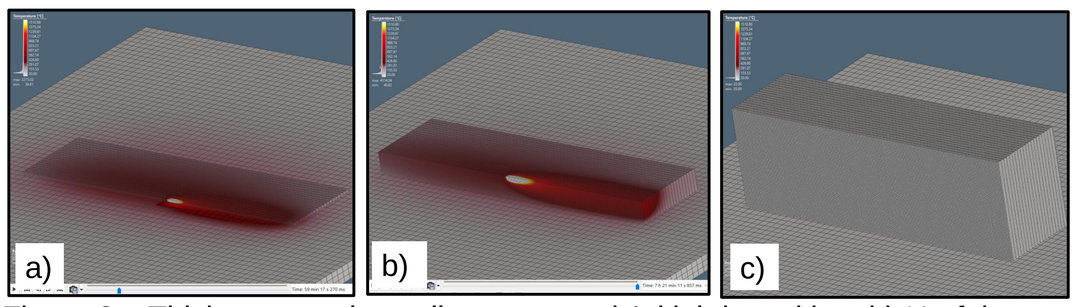

Figure 8 – Thick rectangular wall geometry, a) Initial deposition, b) ½ of the deposition, c) Complete deposition

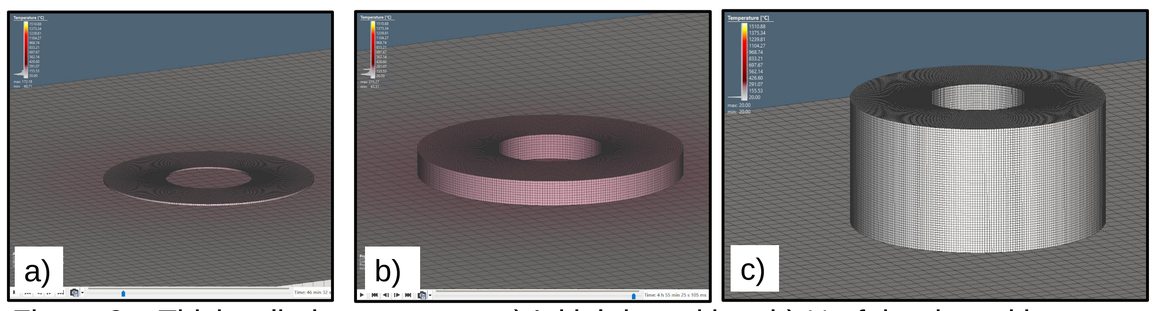

Figure 9 – Thick cylinder geometry, a) Initial deposition, b) ½ of the deposition, c) Complete deposition

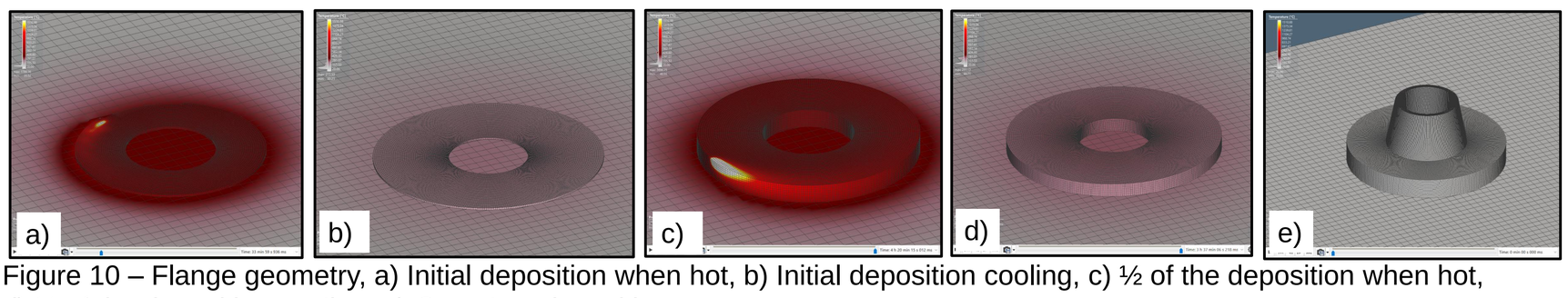

Figure 10 – Flange geometry, a) Initial deposition when hot, b) Initial deposition cooling, c) ½ of the deposition when hot, d) ½ of the deposition cooling, e) Complete deposition

Frames illustrate the progressive material deposition, from arc initiation to final build. Frames depict the cooling phase, showing the evolution of thermal gradients from initial heat input (yellow and red regions) to full thermal equilibrium (gray regions). The microstructure is modified as the heat dissipates and the component reaches ambient conditions.

Conclusion

- Five WAAM geometries were successfully simulated using Simufact, capturing heat distribution and layer-by-layer thermal evolution at an inter-pass temperature of 320 °C.
- The simulations demonstrated the effectiveness of thermal modeling in optimizing geometries prior to physical fabrication, reducing material waste and development time.

Simufact Welding

Acknowledgments

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