



Miniaturization of stent prototypes by μ SLM

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Bachelor's Thesis, Biomedical Engineering

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Introduction

Additive manufacturing, particularly micro-selective laser melting (μ SLM), presents a promising methodology for fabricating stents, enabling the creation of complex shapes and geometries unachievable with conventional manufacturing techniques. Achieving high precision and optimal structural properties necessitates the determination of ideal scanning and printing parameters. [1] Additionally, the precise control of the laser melting process is essential to prevent inhomogeneous heat distribution across the geometry. Localized overheating can result in adverse outcomes such as geometric deformities, increased porosity, warping, surface irregularities, and compromised fine structural integrity. [2] This thesis aimed to manufacture the stent designed by Carbonaro et al. (2023) [3] by μ SLM and explore the limitations of the Aconity mini 3D printer.

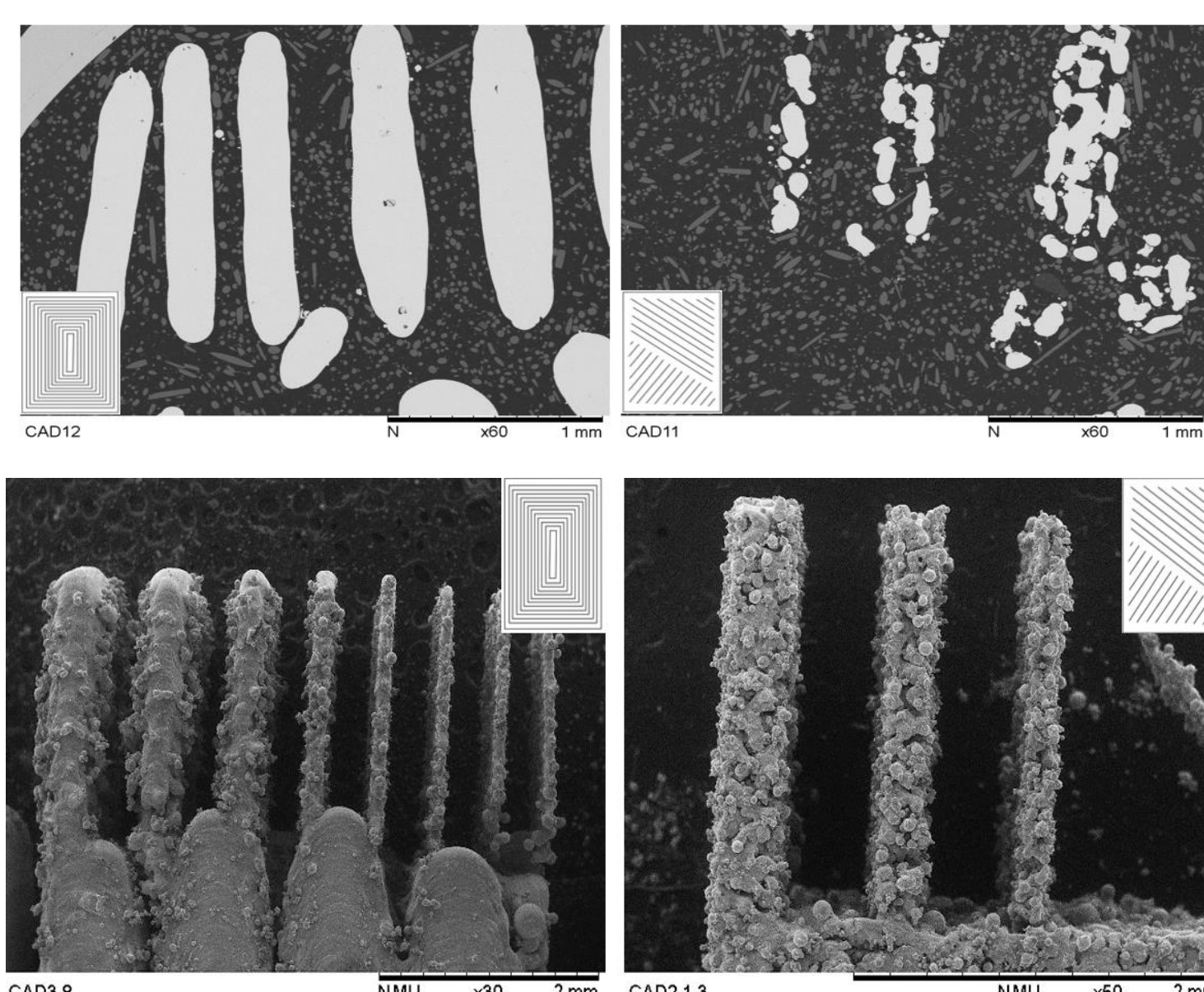
Materials & Methods

Models	Machine	Optimize scanning path and laser settings	Pyrometer & AconityCONTROL	Evaluation
	<ul style="list-style-type: none"> 400 W single-mode fiber laser 3D scan head Spot size: 40 μm Powder: Cobalt-chromium particle size: \varnothing 13.5 μm 	<ul style="list-style-type: none"> Scanning Strategy Hatch distance Offset Scanning direction Laser power Scanning speed Influence of laser power on strut incline 	<ul style="list-style-type: none"> Monitor thermal output Enhance surface quality Homogenize heat distribution Reduce porosity 	<ul style="list-style-type: none"> SEM: <ul style="list-style-type: none"> -Thickness -Width -Porosity Pyrometer images: <ul style="list-style-type: none"> -Heat distribution -Emission values

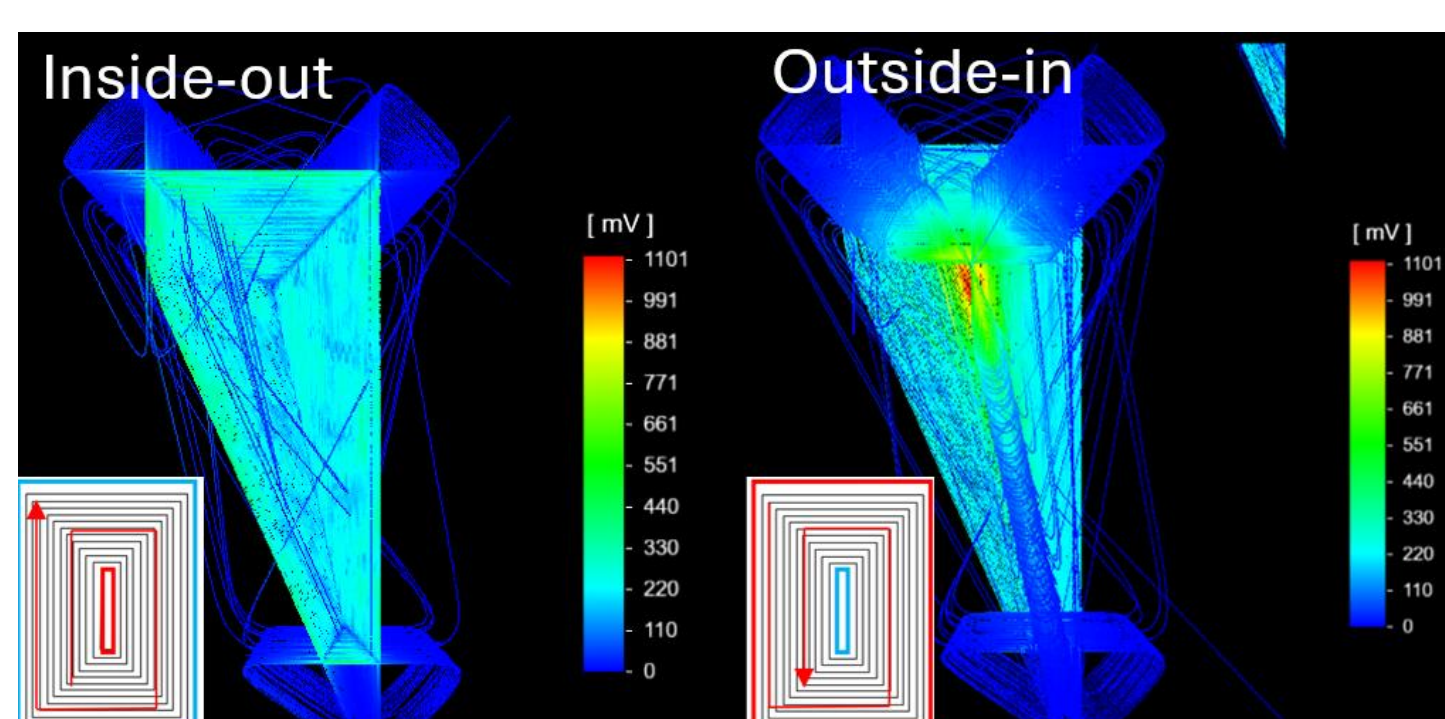
Results

Scanning path

- Concentric scanning strategy leads to lowest porosity and complete structures

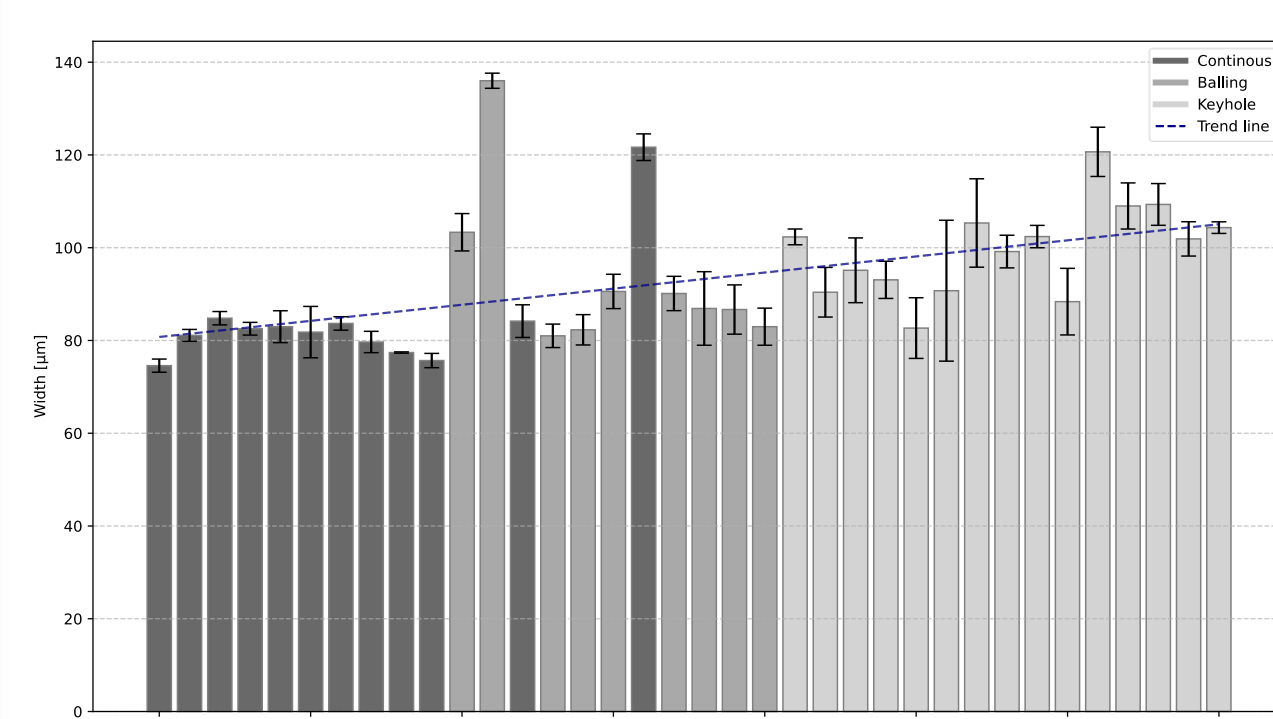
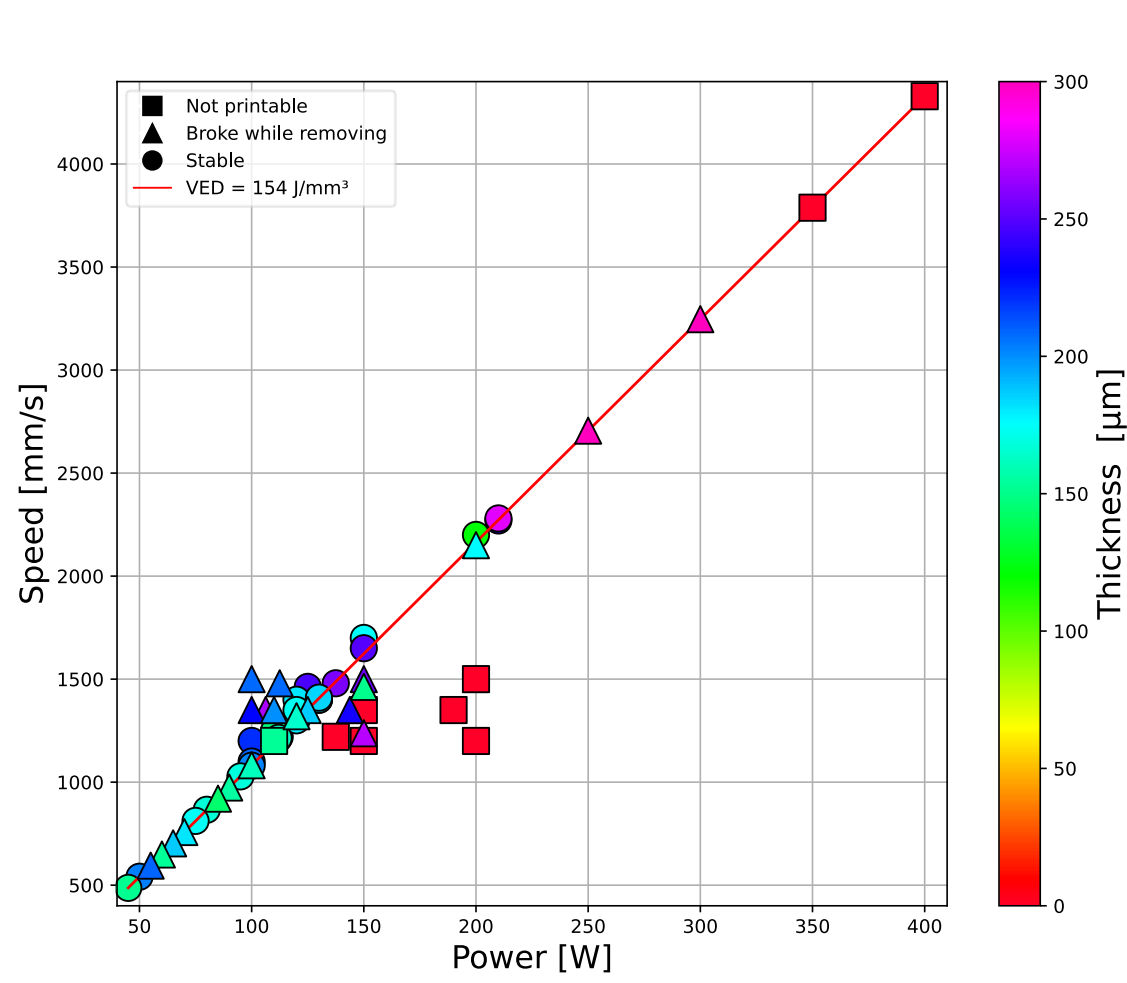


- Inside-out scanning direction leads to more homogenous heat distribution

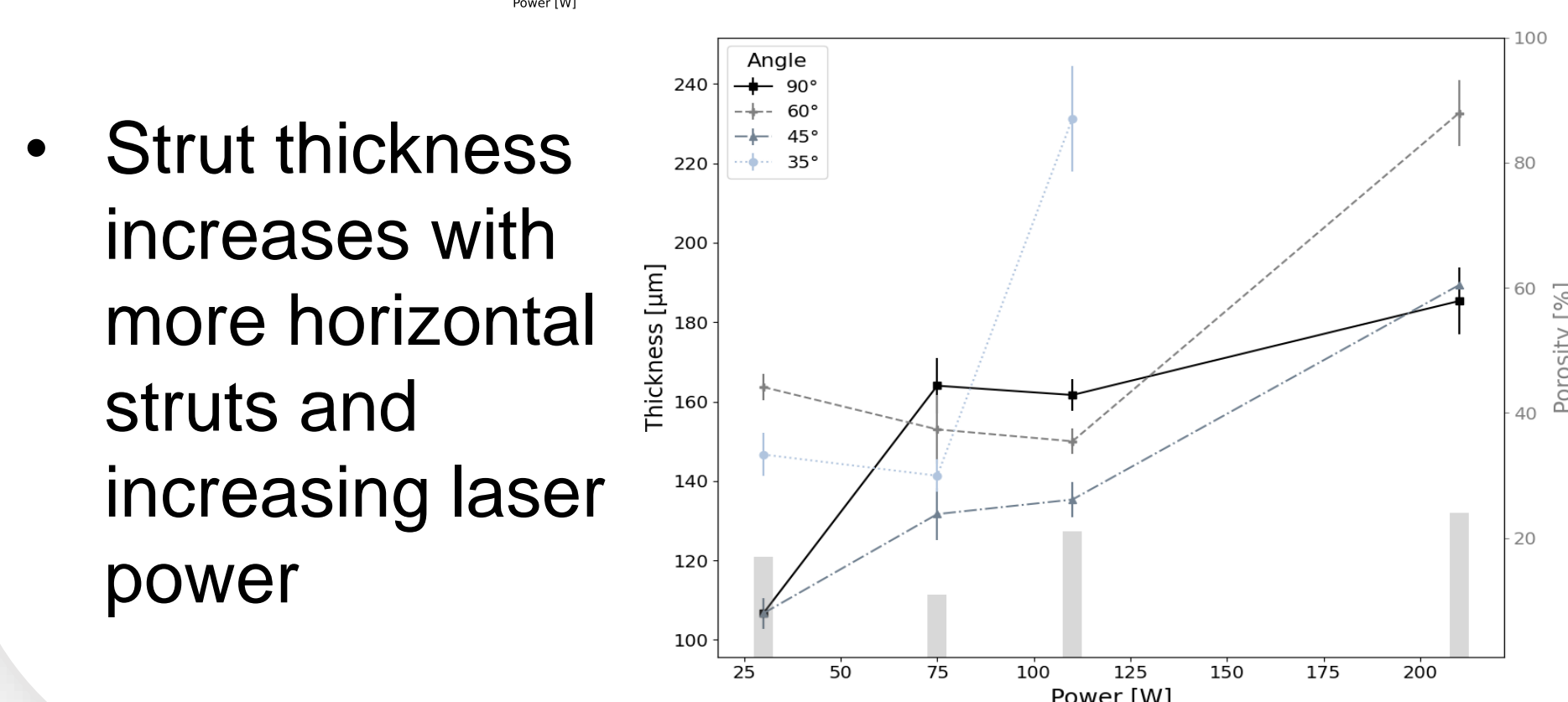


Laser optimization

- Strut thickness reduced by 40.8 % with optimized laser settings
- VED: 154 J/mm³ optimal to print stable geometries
- Low laser power is better to print thin geometries



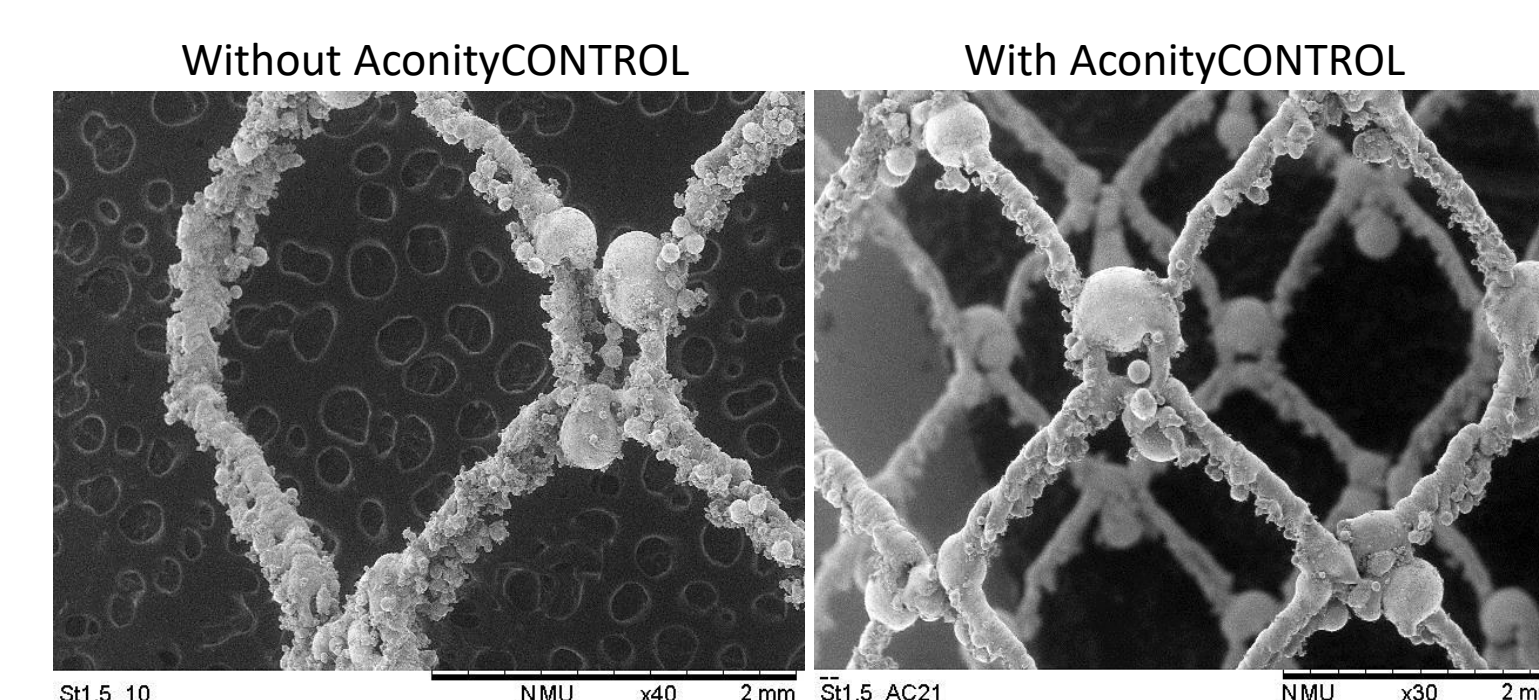
- Melt pool width increases 40 % when laser power increases



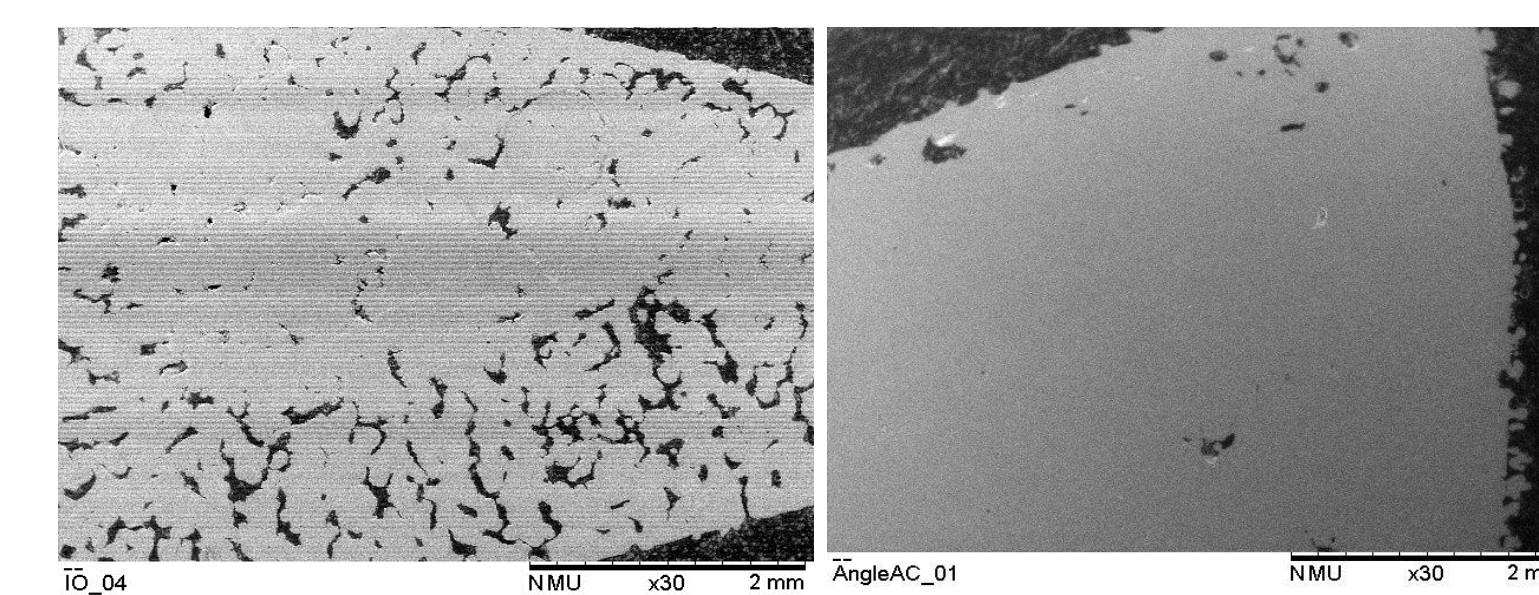
- Strut thickness increases with more horizontal struts and increasing laser power

AconityCONTROL

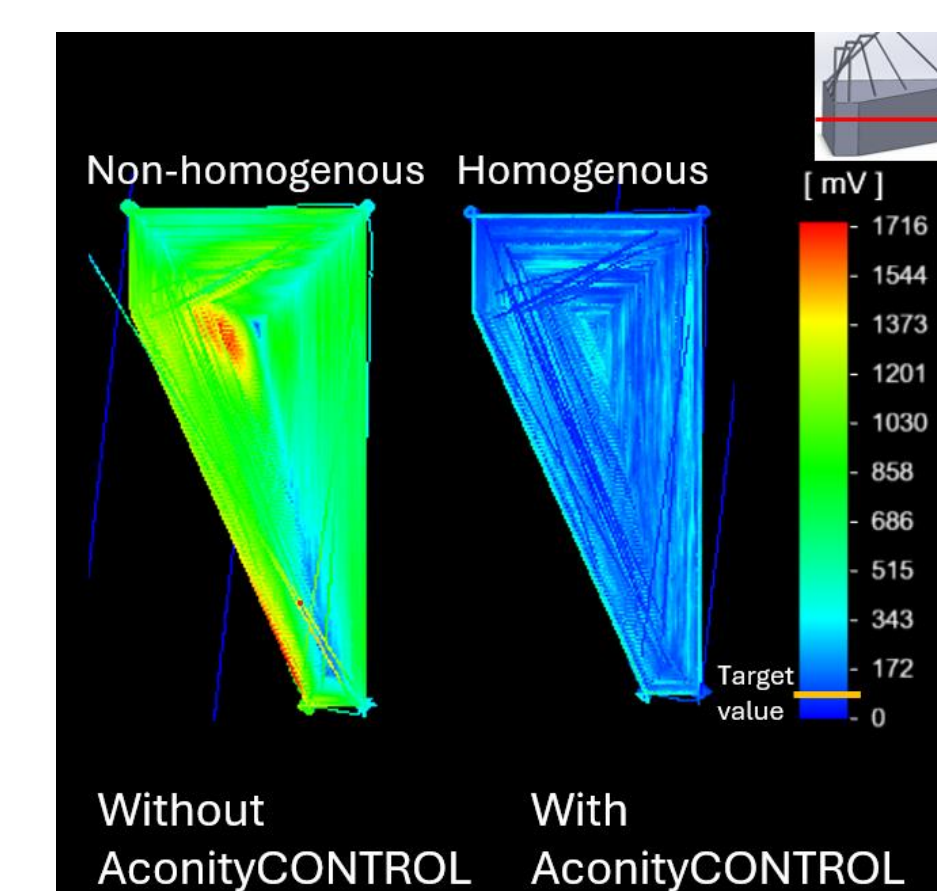
- Improvement of surface quality



- Porosity is reduced from 20 % to 1 %

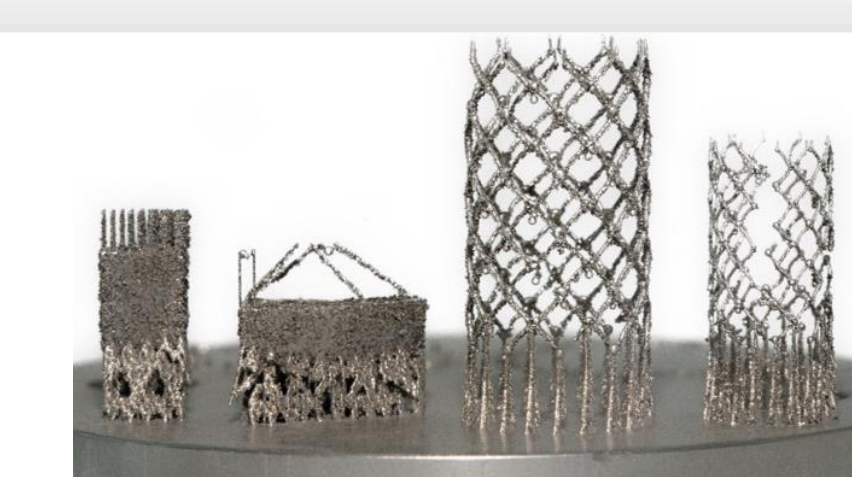


- Thermal emission is homogenized



Discussion & Conclusion

The thesis emphasizes the importance of optimizing scanning paths and laser settings to achieve small structures with the desired structural integrity. It also highlights the potential and limitations of μ SLM in medical device manufacturing, suggesting further optimization of PID control parameters and stent design to enhance heat dissipation and reduce porosity, defects and geometric variations.



References

[1] A. G. Demir and B. Previtali, "Additive manufacturing of cardiovascular CoCr stents by selective laser melting," en, *Materials & Design*, vol. 119, pp. 338–350, Apr. 2017, issn: 02641275. doi: 10.1016/j.matdes.2017.01.091.
 [2] E. Mirkoohi, D. E. Seivers, H. Garmestani, and S. Y. Liang, "Heat Source Modeling in Selective Laser Melting," en, *Materials*, vol. 12, no. 13, p. 2052, Jun. 2019, issn: 1996-1944. doi: 10.3390/ma12132052.
 [3] D. Carbonaro et al., "Design of innovative self-expandable femoral stents using inverse homoge nization topology optimization," en, *Computer Methods in Applied Mechanics and Engineering*, vol. 416, p. 116288, Nov. 2023, issn: 00457825. doi: 10.1016/j.cma.2023.116288.