Vacuum Sealing for Density Measurements of Additively Manufactured Parts

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Powder-based additive manufacturing processes tend to produce porosity in the final part [1]. This porosity in additively manufactured parts is a physical quantity that has been shown to correlate strongly with other mechanical properties, such as fatigue life, ultimate tensile strength, and yield strength [2]. Previous work has found that the Archimedes method of density measurement has a high accuracy for non-porous parts (± 0.08% for high densities) [1] and has been shown to provide rapid screening of a part with acceptable porosity levels [3], allowing for optimization of process parameters to reduce porosity and thereby increase the part's overall strength [1].

Current Archimedes density measurements for powder metallurgy samples require the use of oil impregnation to minimize errors related to surface porosity, a process that takes on average 30 minutes but could take up to 4 hours per part [4], proving to be inefficient when measuring en masse. Here, we aim to test a method for contending with porosity using vacuum sealing to determine its viability as a more efficient yet similarly accurate alternative to the standard oil impregnation Archimedes measurement technique.

Proposed Experimental Investigations

This research will use Niobium C-103 powder with known process parameters [5] to manufacture "thin wall" samples of 5 varying densities using the Optomec 860 MTS Directed Energy Deposition printer. These thin walls will be printed using a single laser pass on the Optomec — with a length of 19 mm and 25 layers tall — requiring approximately 72 cm^3 of powder assuming maximum layer thickness of 1mm and a 50% yield. The design of this experiment can be seen in *Figure 1*, specifically the relationship between levels, replicates, and repetitions for each sample.

Vacuum Sealing	**Oil Impregnation**
5 levels (varying densities, ρ)	5 levels (varying densities, ρ)
10 randomly selected replicates from 15 additively manufactured samples	10 randomly selected replicates from 15 additively manufactured samples
7 repetitions (trials)	

Total: 50 samples used, 75 manufactured

Figure 1: Design of experiment.

Research Outcomes

We foresee four possible outcomes of this research: (1) vacuum sealing results match the oil impregnation results, (2) a scaling factor is necessary between the two methods, (3) vacuum sealing produces less variability than oil impregnation, and (4) vacuum sealing shows more variability compared to oil impregnation. The first three outcomes represent a positive result for the vacuum sealing method, indicating its potential use as an alternative to oil impregnation and for further research to be conducted with regards to process automation.

References

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[2] Lifton, J.J. *et al.* (2022), "On the uncertainty of porosity measurements of additively manufactured metal parts," *Measurement*, Vol. 188.
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[4] ASTM-B962. *Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle* (2017).
[5] Daniel Palacios. "Statistical Methods for Process Parameter Development of Niobium Alloy C-103," Master's Thesis, Georgia Institute of Technology, Atlanta, GA, USA, 2023.