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Mechanical Properties and Trends in Additively Manufactured Aluminum

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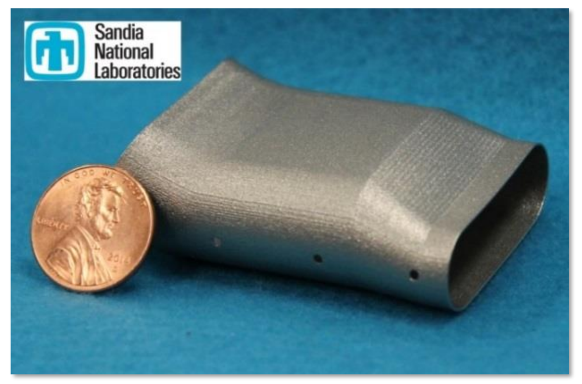
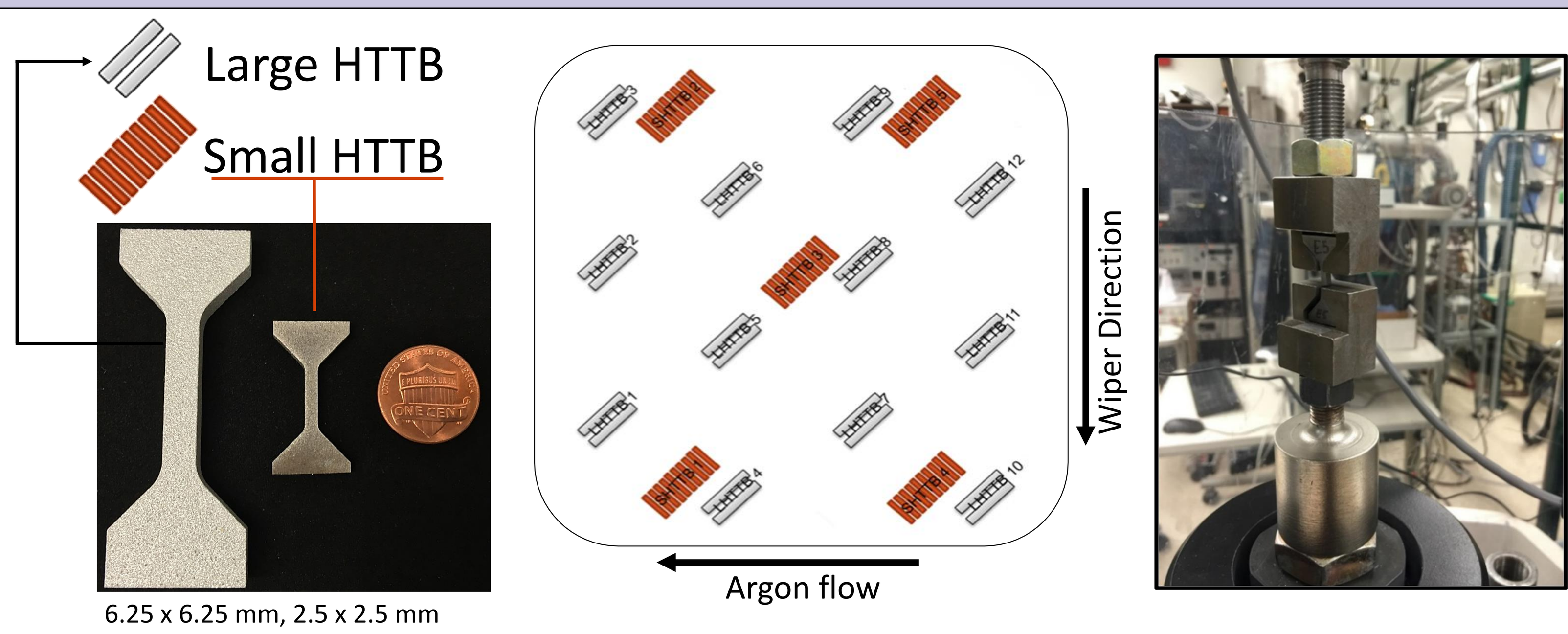
MOTIVATION

Additive manufacturing (AM) has great potential to revolutionize designs. However, for high-reliability applications, the scatter in material properties must be well characterized and understood. Properties of a selectively laser melted additively manufactured aluminum alloy AlSi10Mg were characterized. Multiple defect types from the AM process had impacts on the material properties. Using fractographic analysis, layer thickness of unfused powder on the outer build surfaces of each sample and porosity are found to increase with certain build parameters and locations. These flaws determine the mechanical behavior of each sample and point to important phenomena that need to be considered by designers.

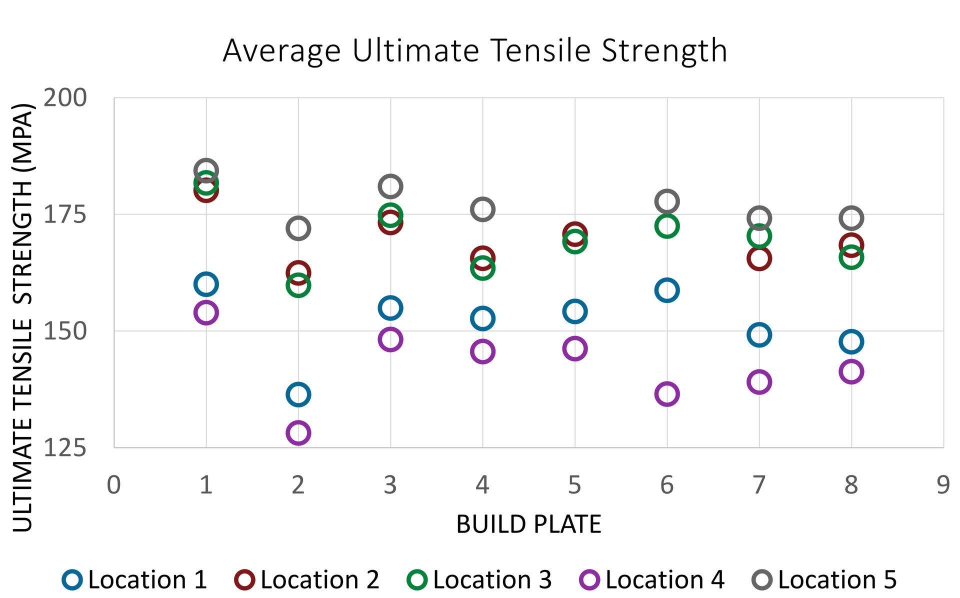


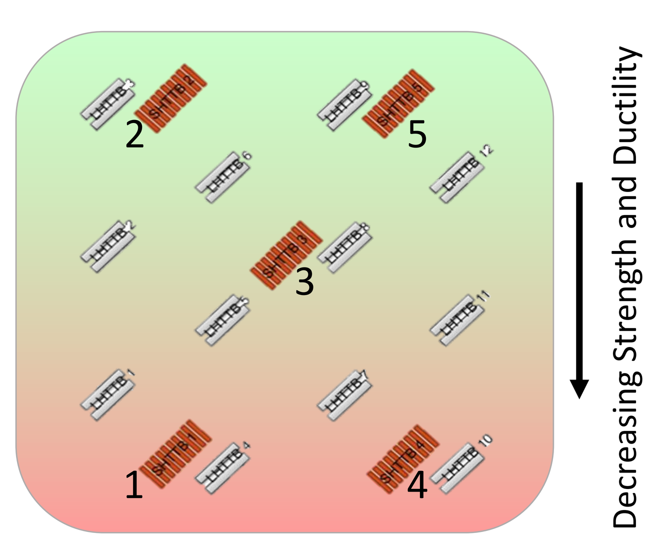
Laser Powder Bed Fusion and High Throughput Tensile Testing

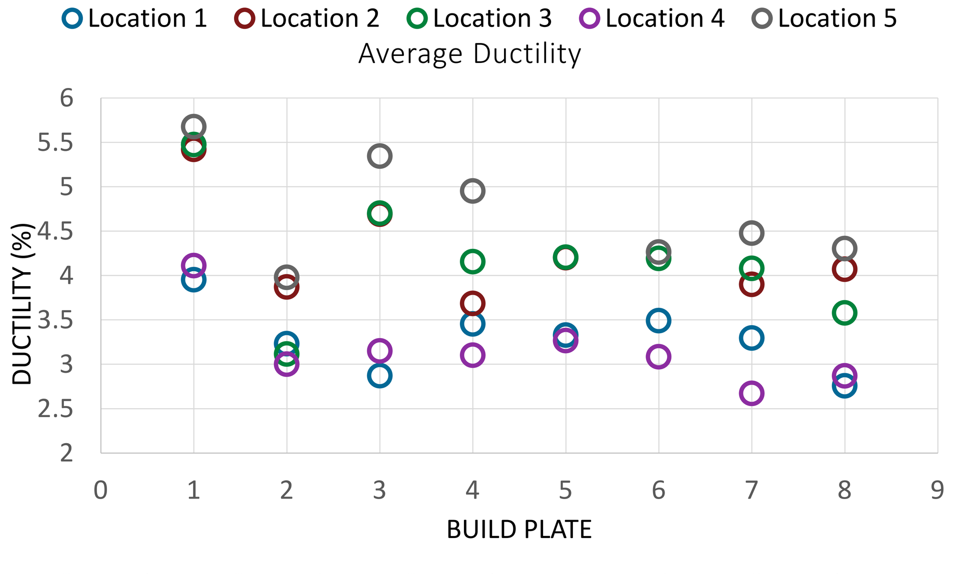


8 Builds defined condition of powder
Large HTTB have 12 print locations and Small HTTB have 5 print locations
~ 600 specimens printed: 400 Small & 200 Large
High Throughput Tensile Testing streamlines testing process by 10x

Trends Identified with Build Locations:
Small High Throughput Specimen

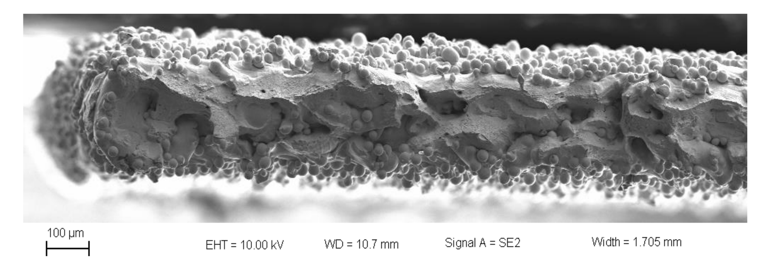






The small and large HTTB experienced location dependence, but this dependency was examined further in the smaller HTTB. Specimens built in location 5 were stronger, and more ductile. However, specimens built in location 4 were weaker, less ductile and had more variability.

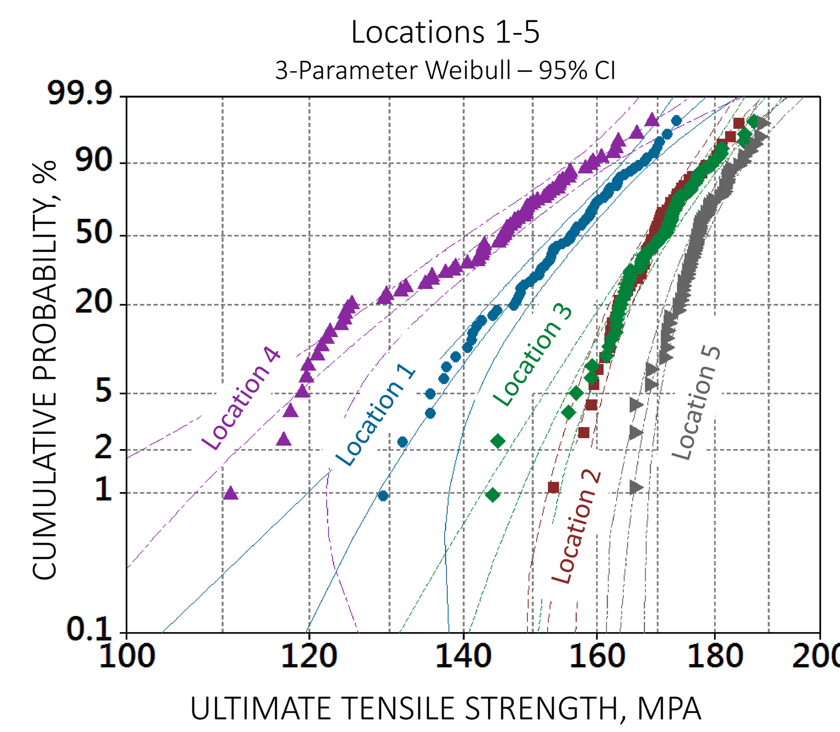
The Cross-Sectional Area and Specimen Location

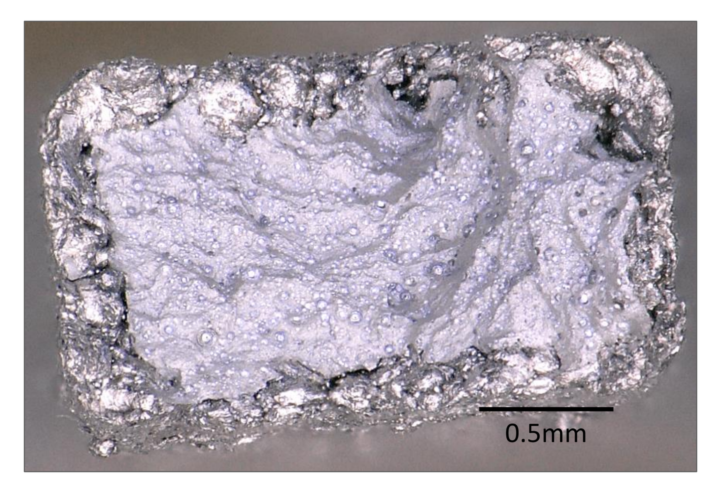


Area was measured using a micrometer, and in both, small and large HTTB the area can be difficult to define. However, effective cross sections can scale stresses significantly for the small specimens, and affects modulus, yield strength, ultimate tensile strength.

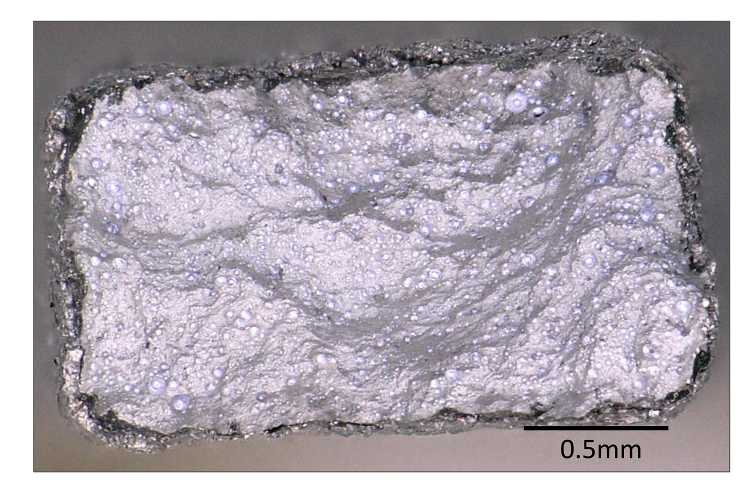
A layer of unfused powder on the outer build surfaces (crust)

1. Large area measurements when using the micrometer
2. Modulus, yield strength and ultimate tensile strength appear lower
3. Specimens with less crust tend to lie at the top of the build plate
4. Specimens with more crust tend to built at the bottom of the build plate.

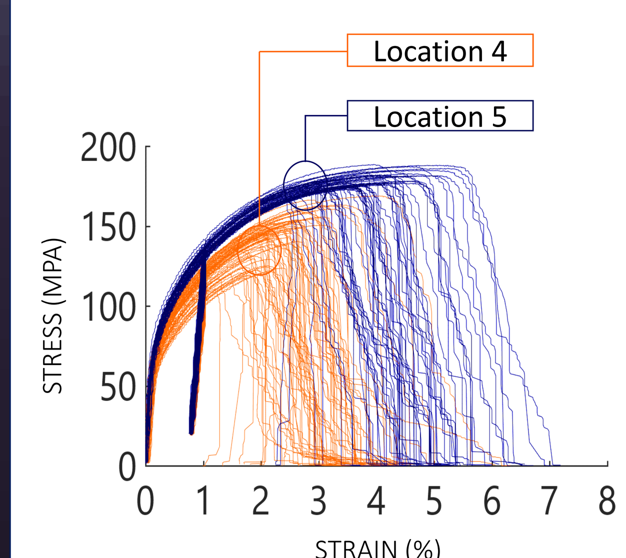


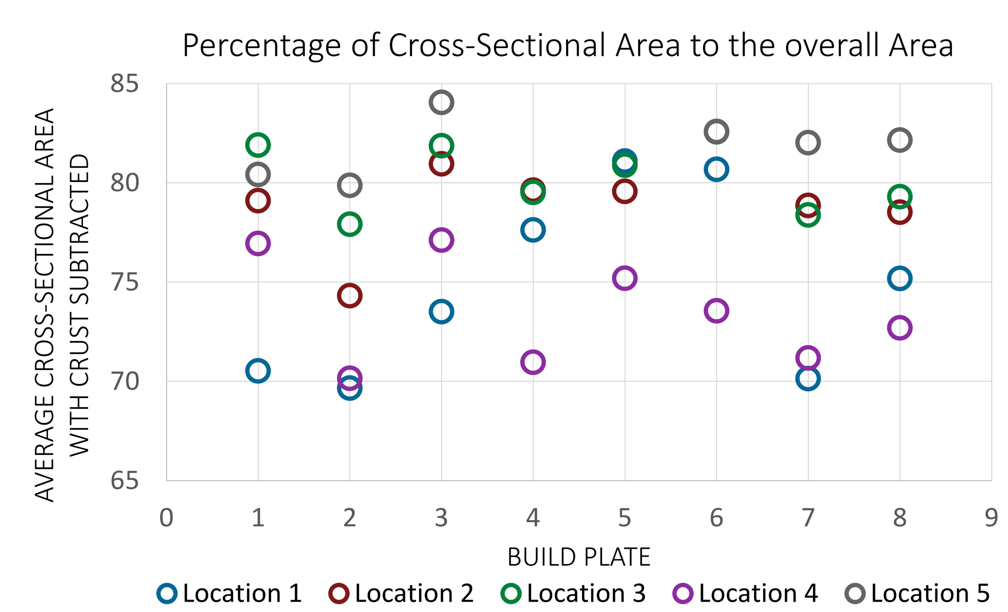


Build 3: Location 4

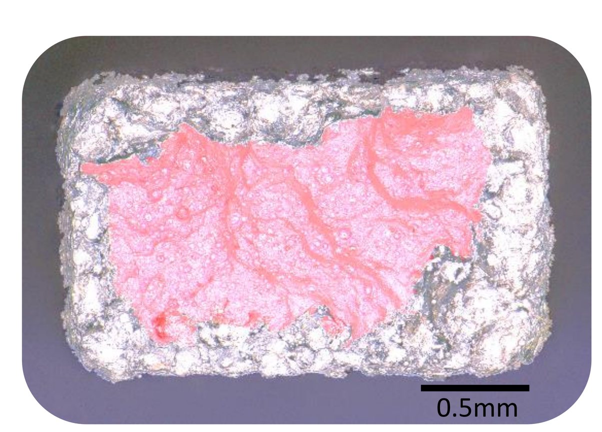


Build 3: Location 5

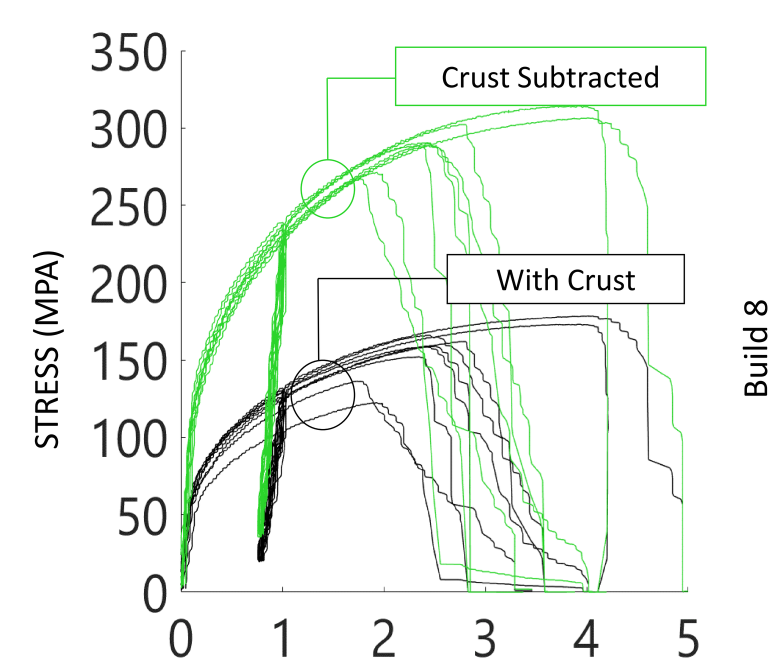




Eliminating the "Crust" Defect:
Using Image Processing

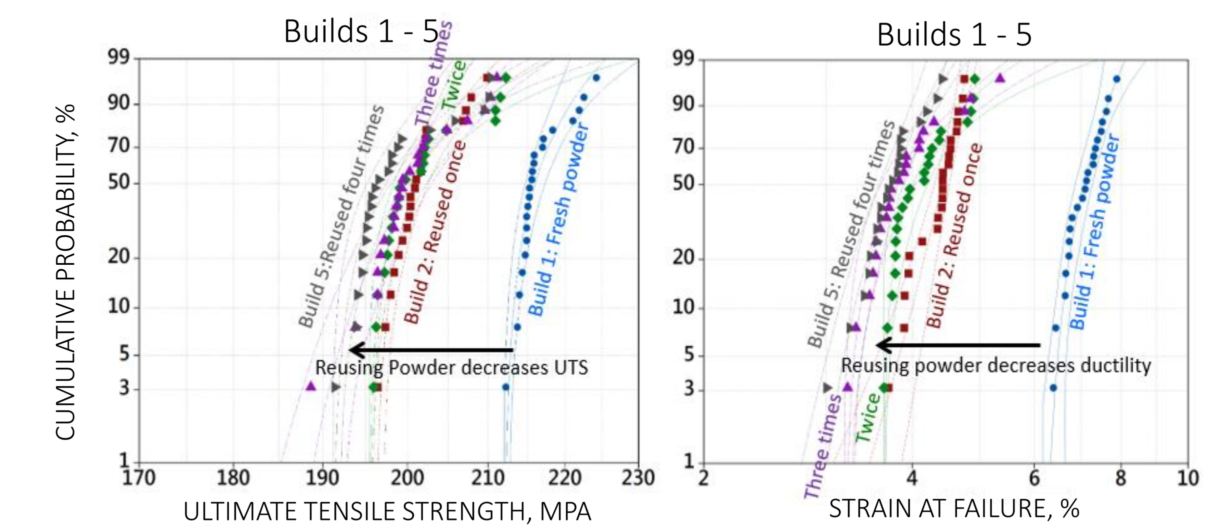


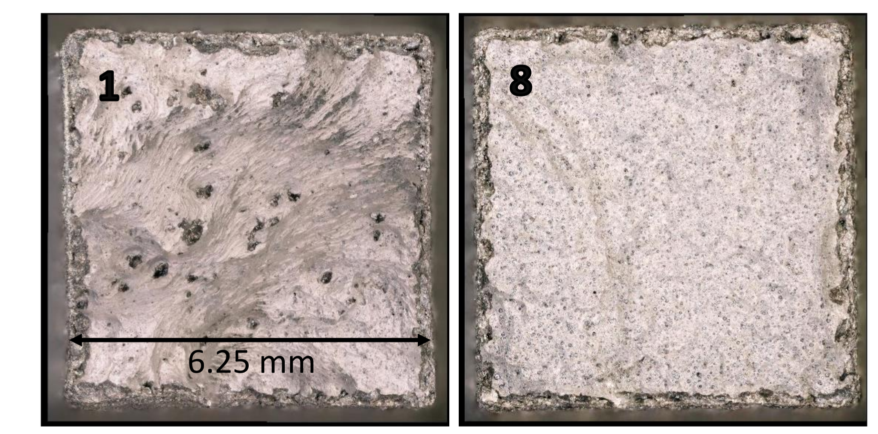
Adjusting for the crust area
Ultimate Tensile Strength Doubles
Yield Strength Increases
Unloading Modulus Increases



Trends Identified with Powder Reuse:
Large High Throughput Specimen

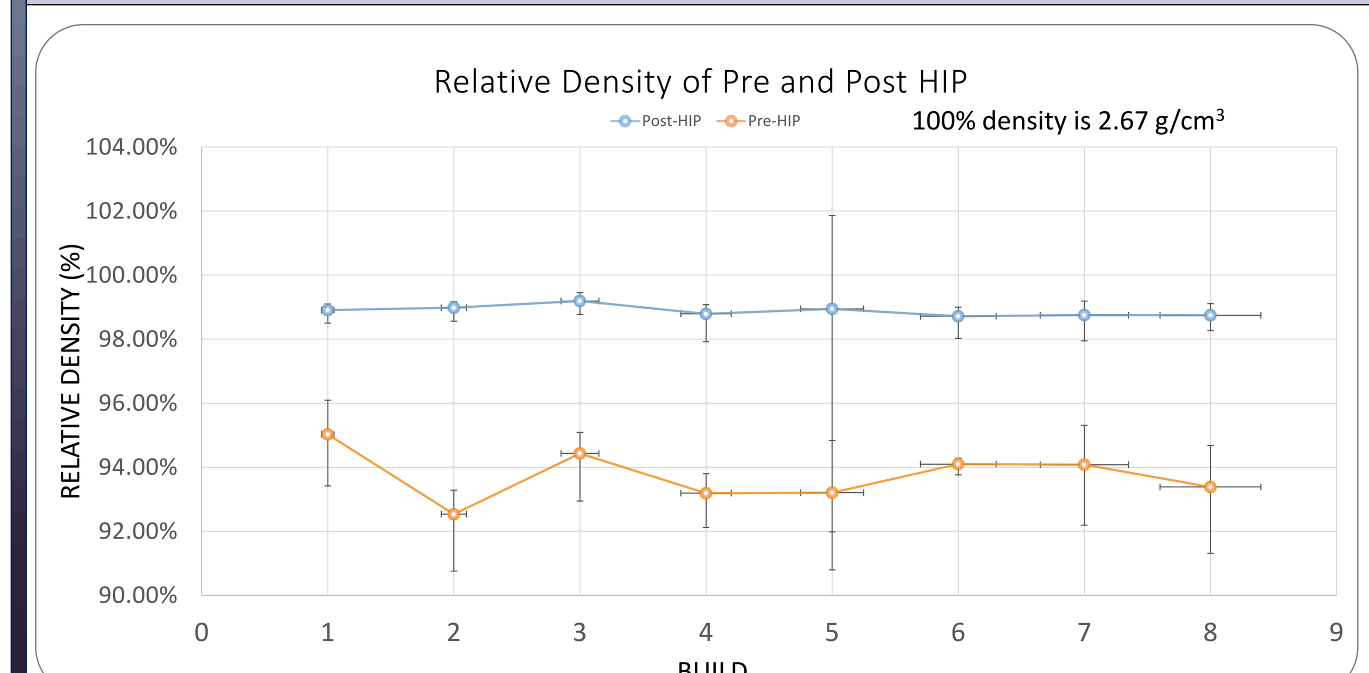
BUILD	Powder Condition
1	Fresh
2	Reused Once
3	Reused Twice
4	Reused 3 Times
5	Reused 4 Times
6	Fresh
7	Reused Once
8	Reused Twice

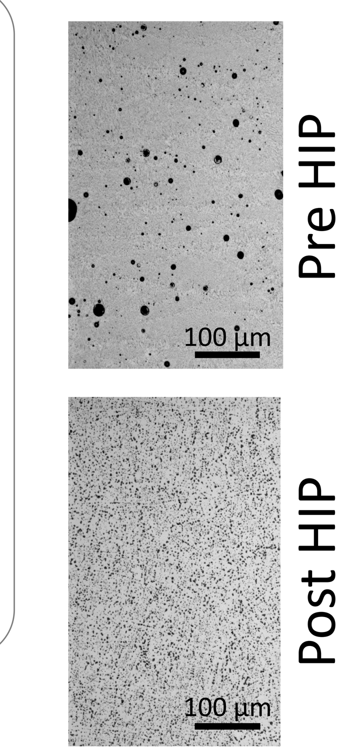


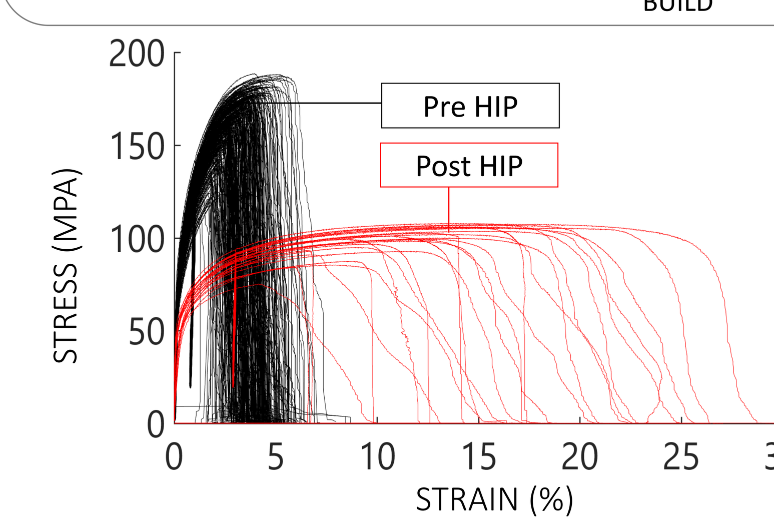


Reusing powder:
Reduces strength (~10%)
Lowers ductility (~40%)
Increases variability
Density decreases with Powder Reuse, due to increasing porosity

Eliminating the Porosity Defect:
Hot Isostatic Pressing







The Hot Isostatic Pressed samples seemed to gain ductility while loosing around 50% of their strength. Furthermore, there is a higher Strain to Failure distribution that calls into question the reliability of the HIP material.

SUMMARY:

Sources of Variability in the Structural Properties of Additively Manufactured AlSi10Mg:

- **Crust fraction and Location:** Crust thickness increases at build plate locations where specimens are weakest.
- **Porosity distribution and Powder Reuse:** Porosity increases with powder reuse, and results in weaker, less ductile samples.

Areas for Further Research:

Crust fraction and Location:

- Identify causes of crust discrepancies on the build plate.
- Explore the remaining crust on the larger samples.

Porosity distribution:

- Research effects the HIP temperature has on material properties

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