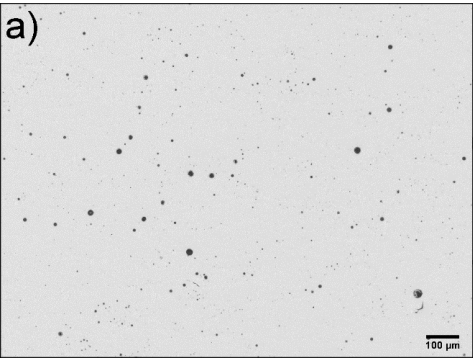
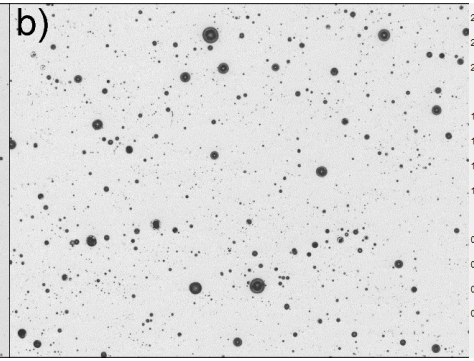
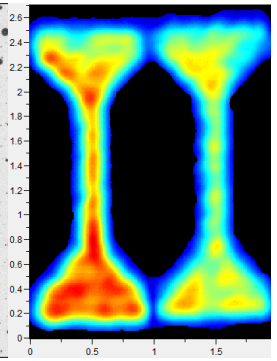
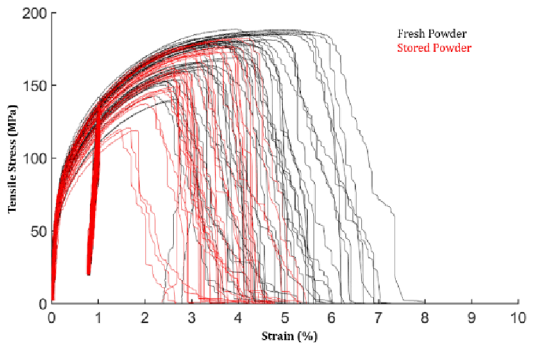
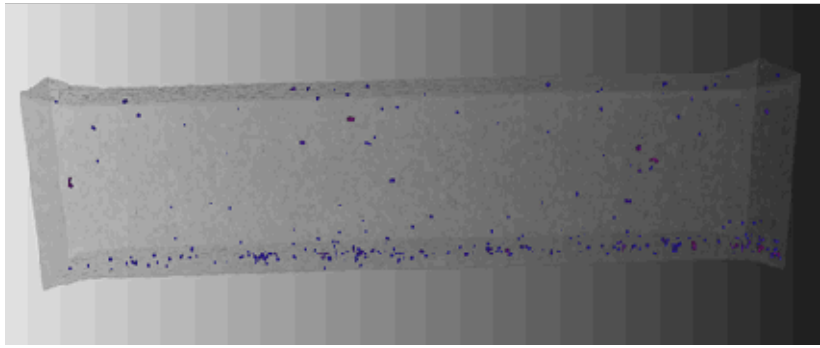
SAND2017-11005C







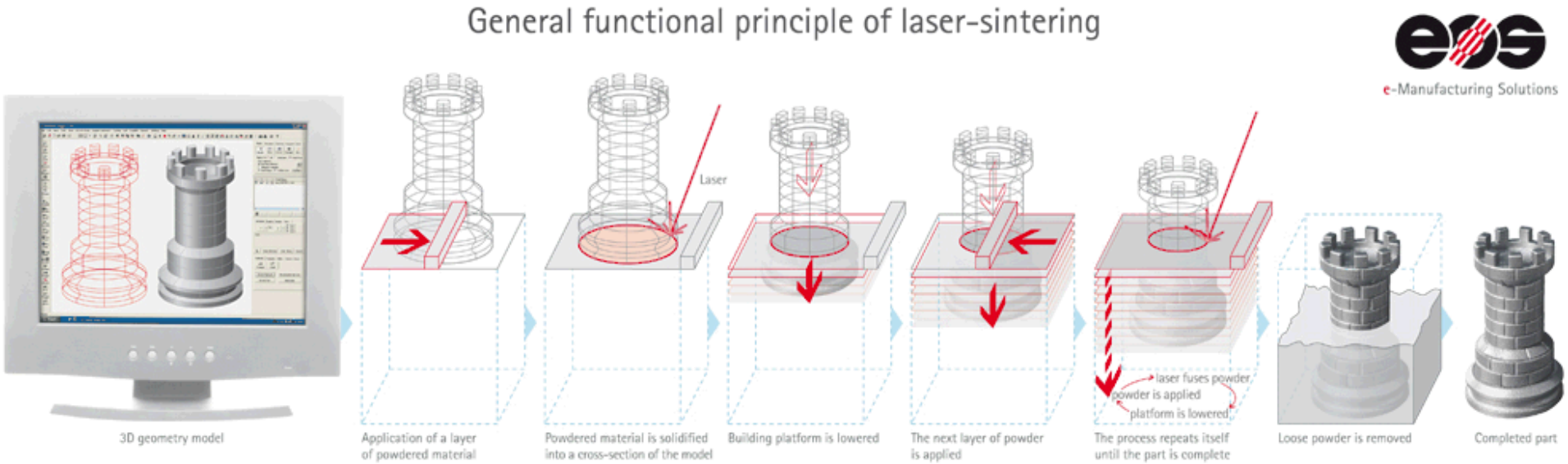




Statistical comparison of part and test article properties in AM aluminum

Lisa Deibler, Jay Carroll, Daniel Campbell, Heather Boldt, Clint Holtey

Laser melted powder bed



Upsides

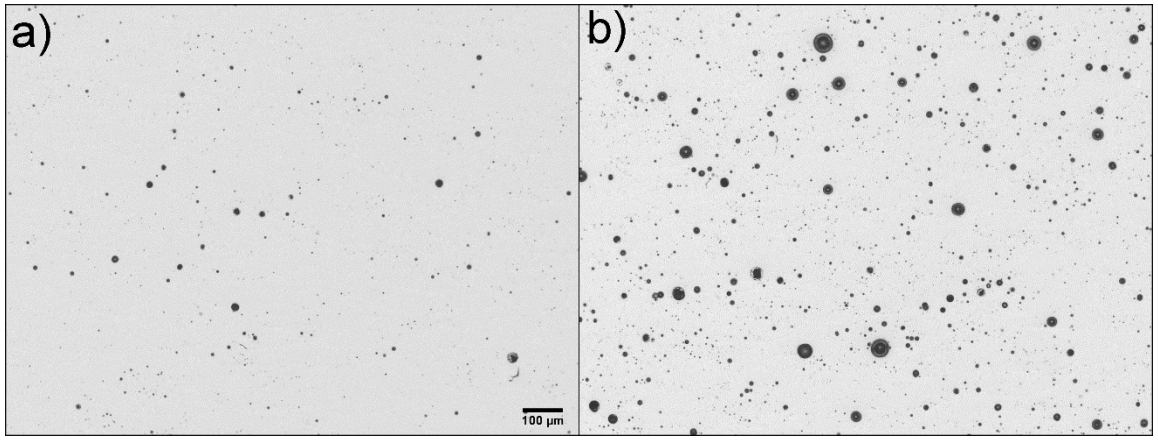
Rapid design to part
Un-machinable designs
Lower cost for complicated parts
Cool

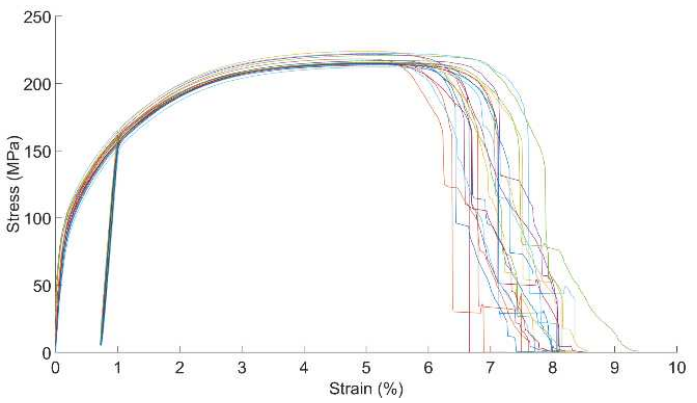
Downsides

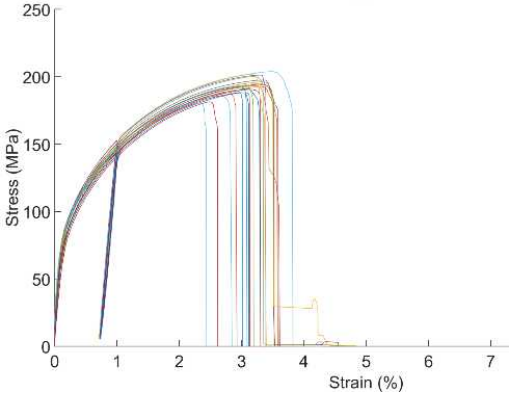
Surface finish
Rapidly solidified structure
Process/material control
Metallurgical structure control

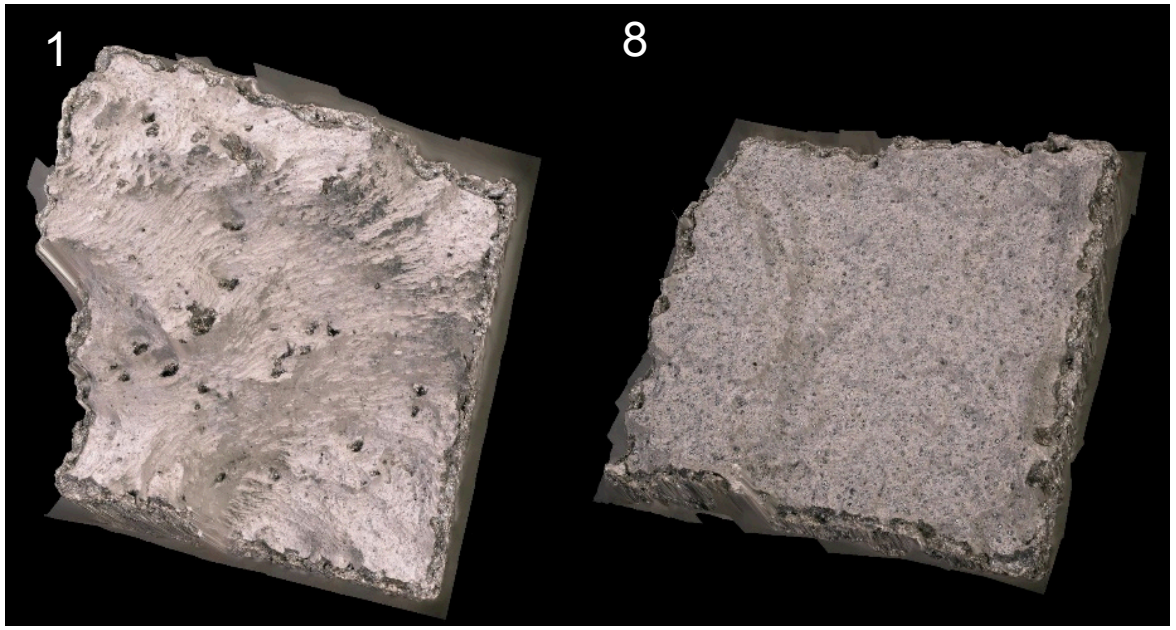
AM for high consequence parts

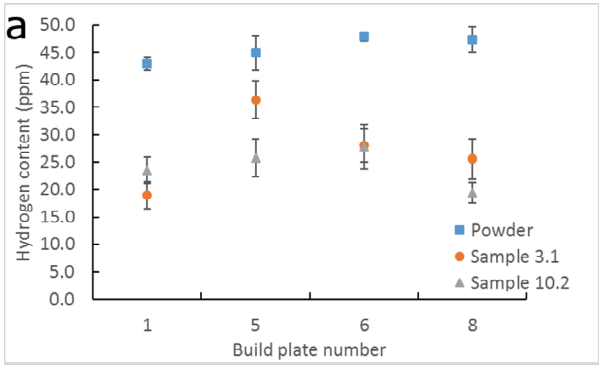
- How to ensure that AM parts are good? Characterization!

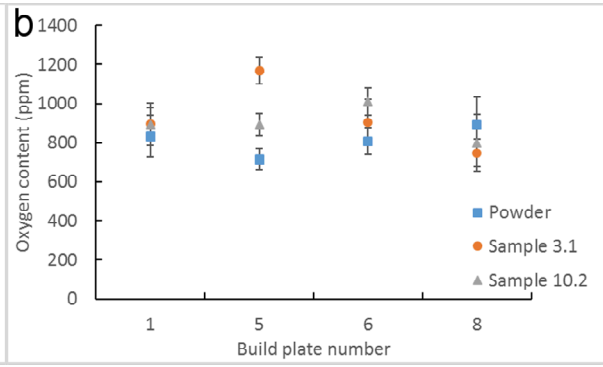






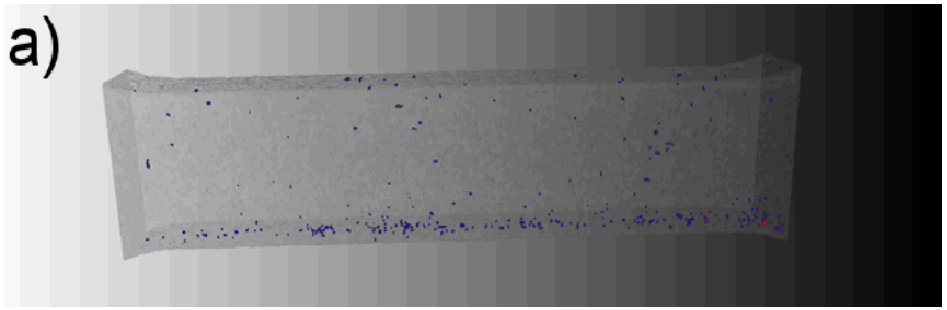


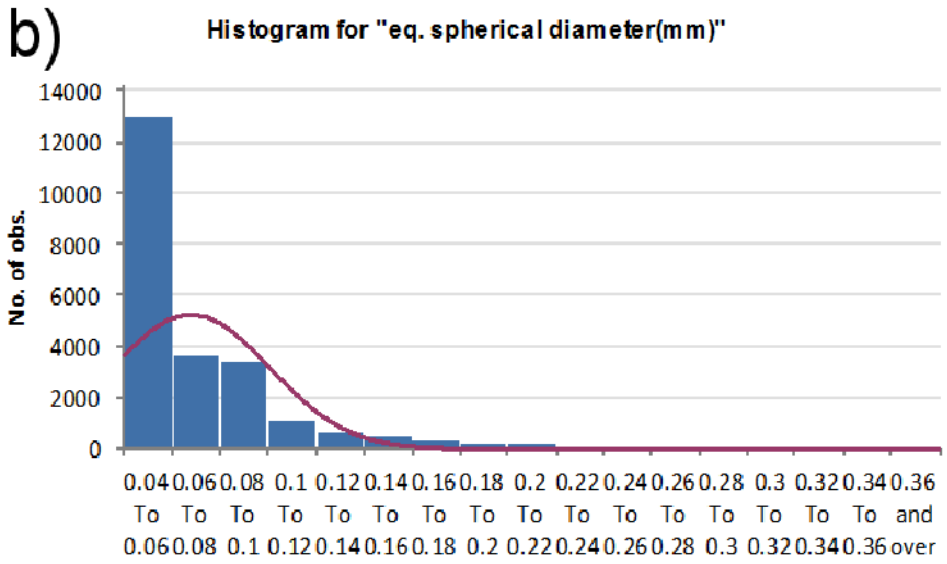


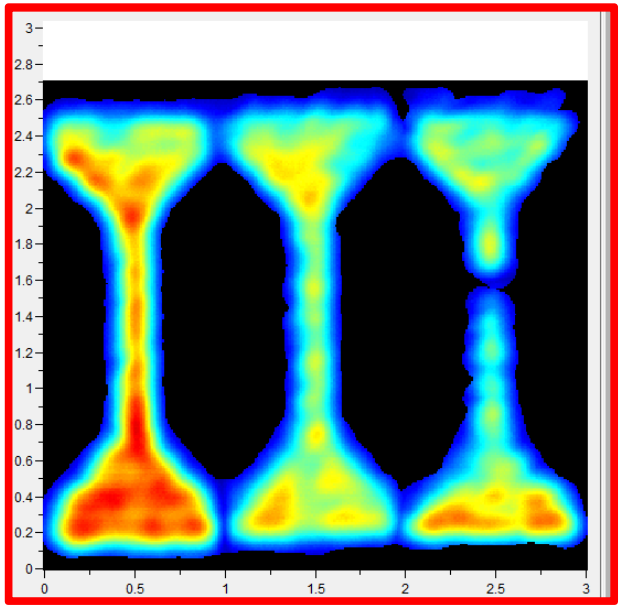


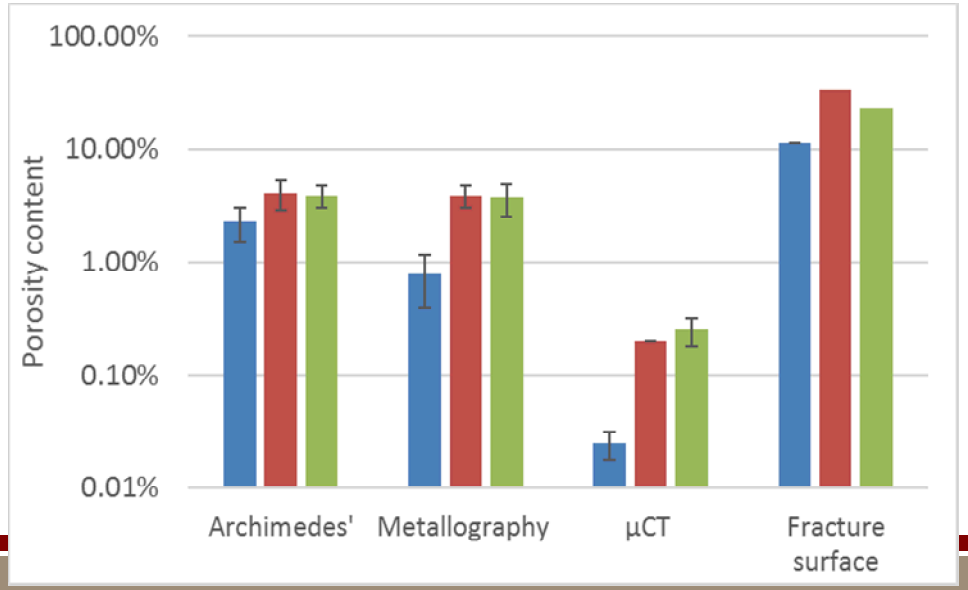
Non-destructive technology

- µCT
- Ultrasound
- Eddy Current
- Density



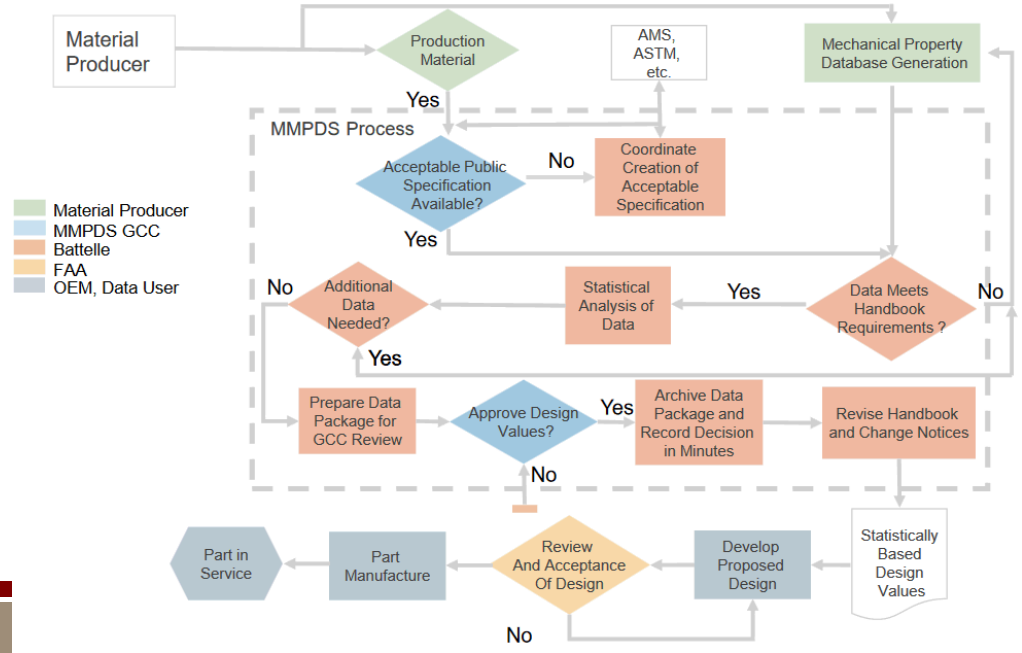






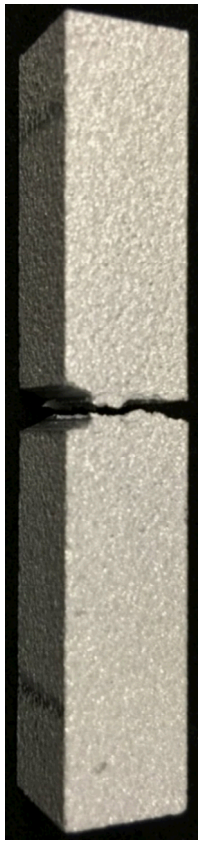
“Traditional” statistics based analysis

- Military Handbook 5/ Metallic Material Properties Development and Standardization Handbook (MMPDS)
- S-Basis – specification minimum
  - 3 heats, 30 tests
- B-Basis – 90% of population equals or exceeds with a confidence of 95%
  - 10 heats/10 lots, 100 tests minimum
- A-Basis – 99% of the population equals or exceeds with a confidence of 95%
  - 3 heats/10 lots, 100 tests minimum

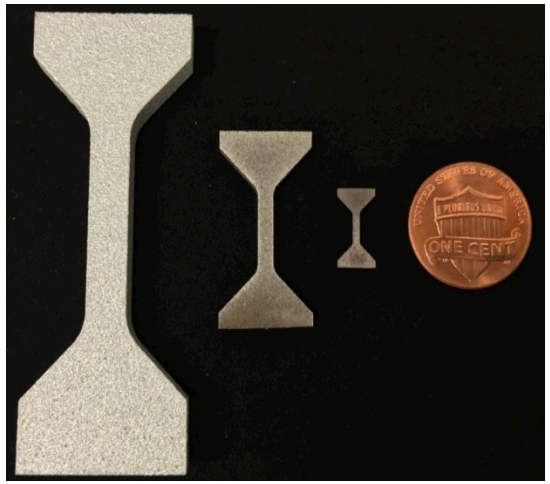


Test data types

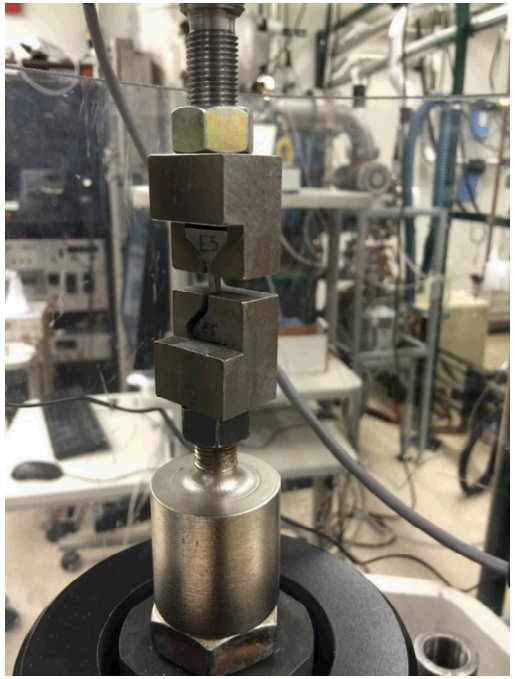
Charpy impact



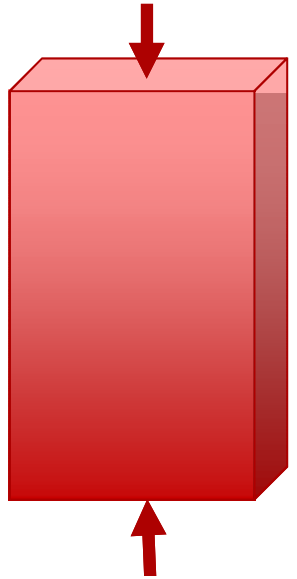
High throughput tensile – large and medium bars



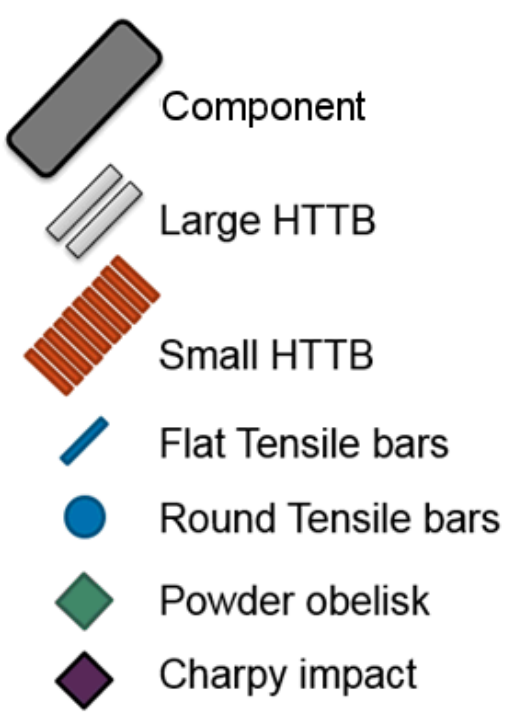
6.25 x 6.25 mm, 2.5 x 1.5 mm, 1 x 1 mm

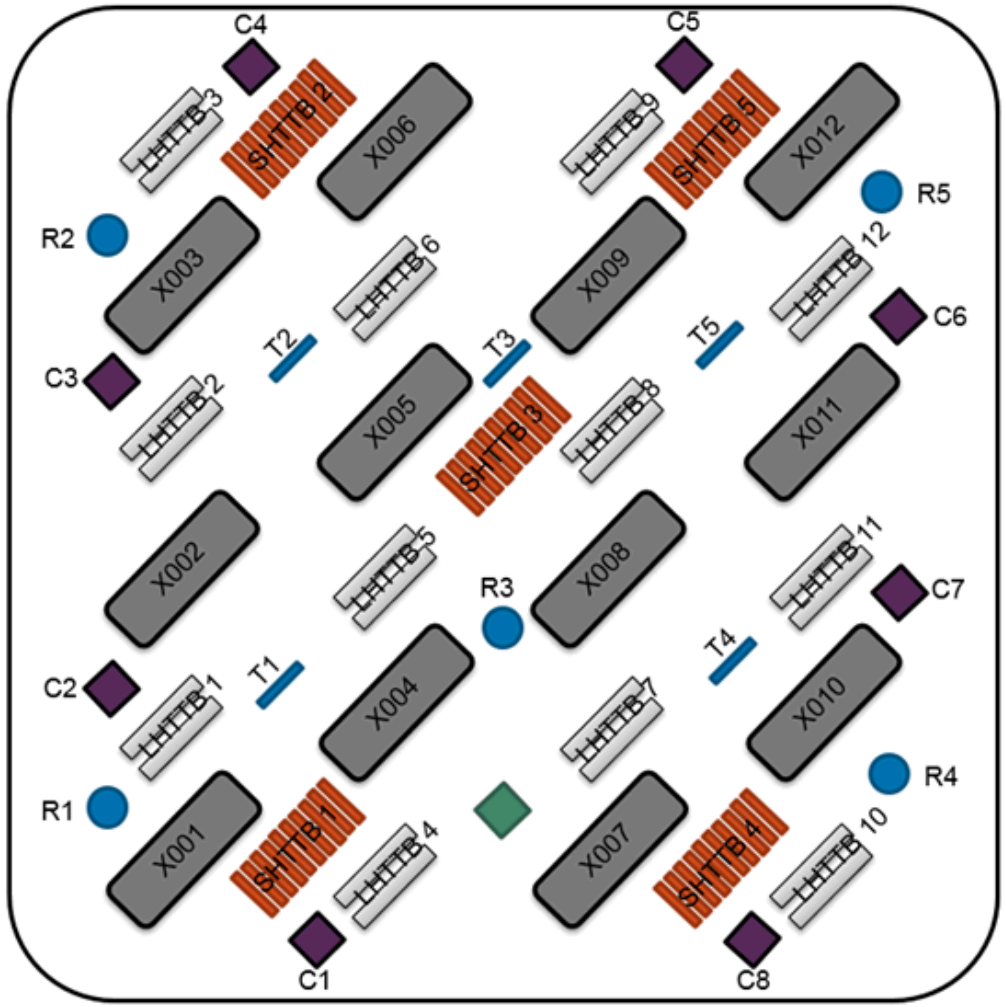


Component tests



Build layout

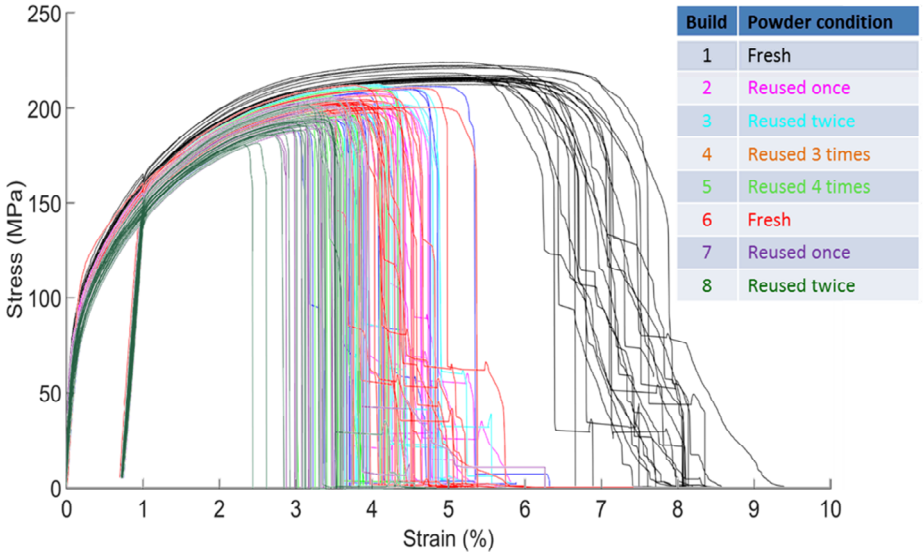




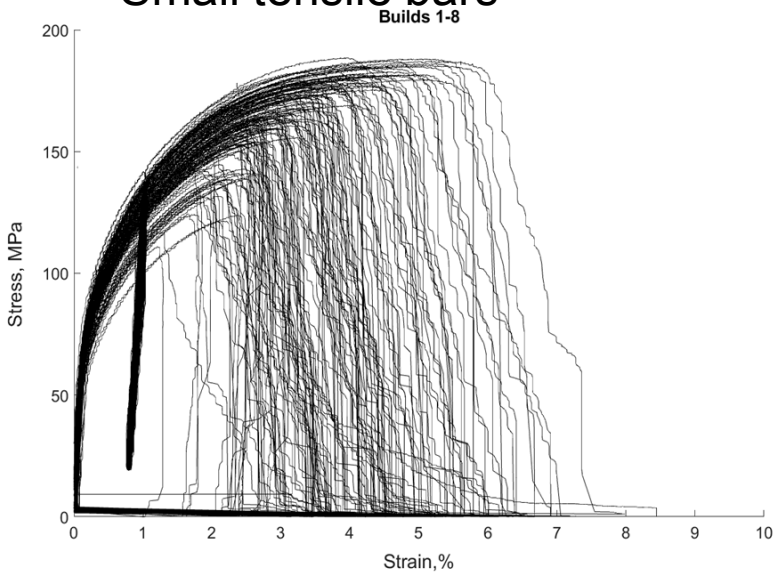
BUILD	POWDER CONDITION
1	Fresh
2	Reused once
3	Reused twice
4	Reused 3 times
5	Reused 4 times
6	Fresh
7	Reused once
8	Reused twice

Raw test data

Large tensile bars



Small tensile bars

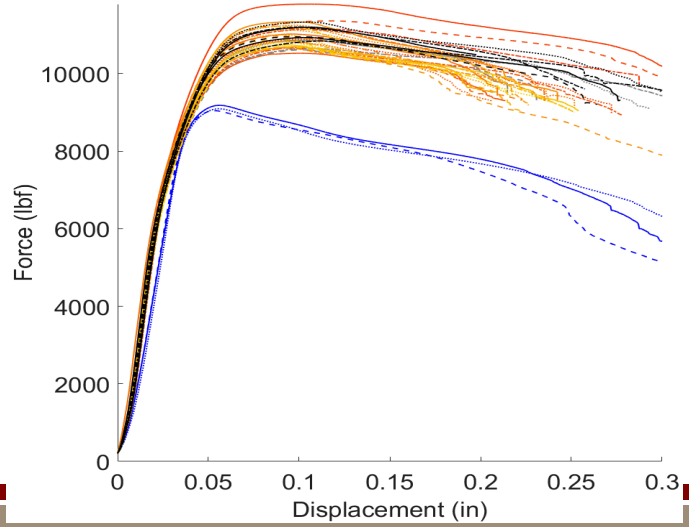


Data from tensile tests
Position
Yield strength
Unloading modulus
UTS
UTS % strain
Ductility
Area

Charpy impact

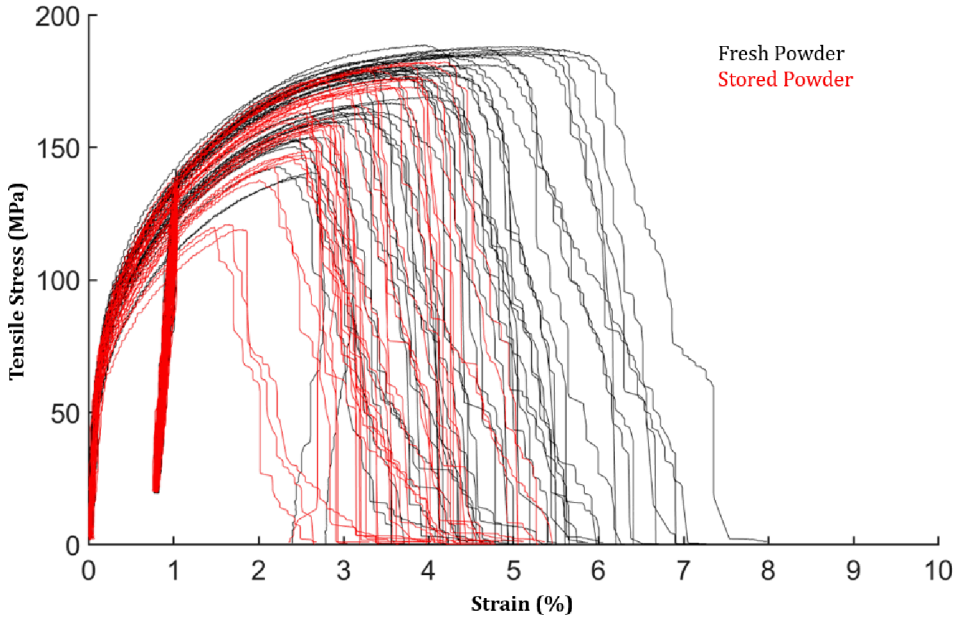
Data from Charpy
Position
Charpy toughness

Component quasistatic crush tests



Data from component crush
Position
Displacement at peak load
Peak load
First crack displacement
First crack load
Through crack displacement
Through crack load

Statistical analysis – effects influencing peak tensile load



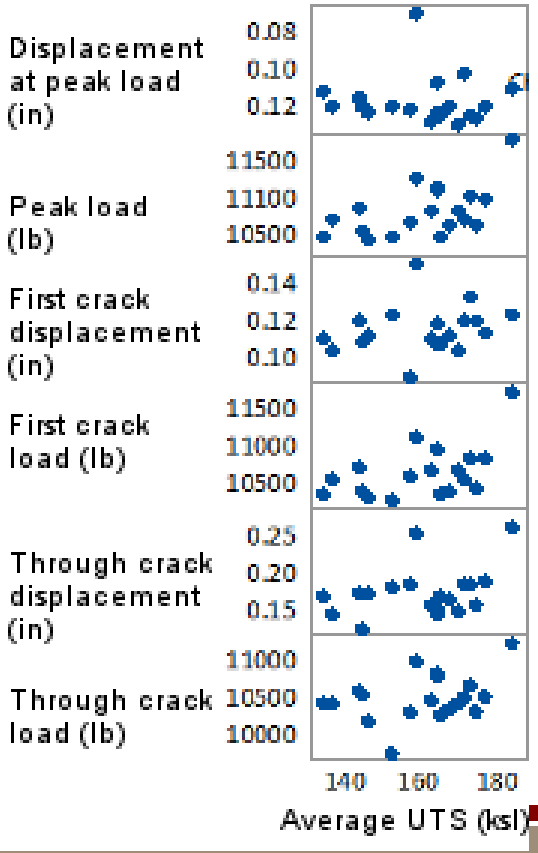
ANOVA analysis of peak tensile load

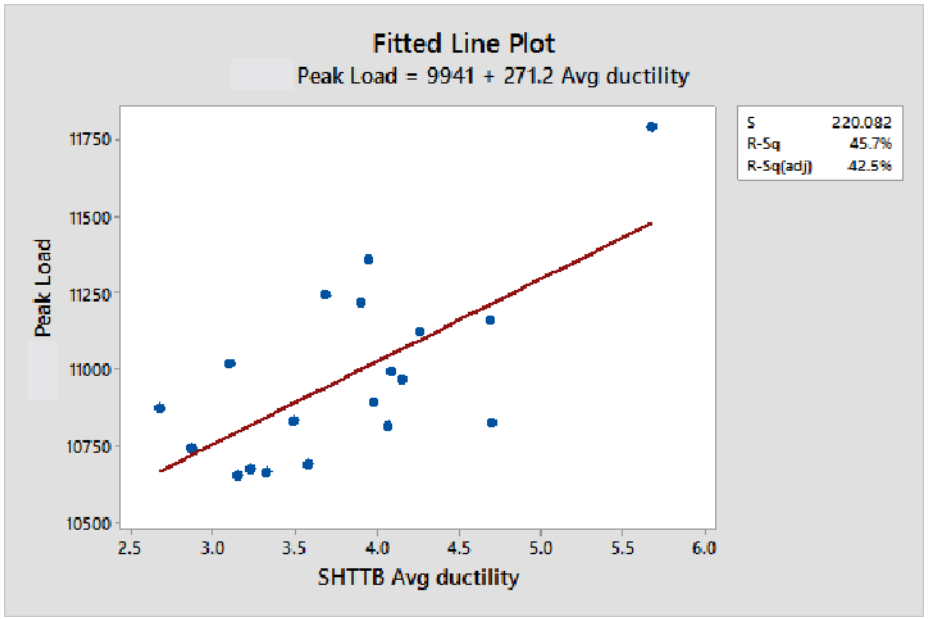
Source	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	P-Value
Including build plate 1					
Wiper direction position	1	464804	464804	14.35	0.002
Argon flow position	1	14658	14658	0.45	0.512
Build plate	7	**1053722**	150532	4.65	**0.007**
Error	17	453352	32382		
Total	23	2045610			
Excluding build plate 1					
Wiper direction position	1	359065	359065	12.49	0.004
Argon flow position	1	37933	37933	1.32	0.273
Build plate	6	**321629**	53605	1.86	**0.169**
Error	12	345018	28751		
Total	23	1043867			

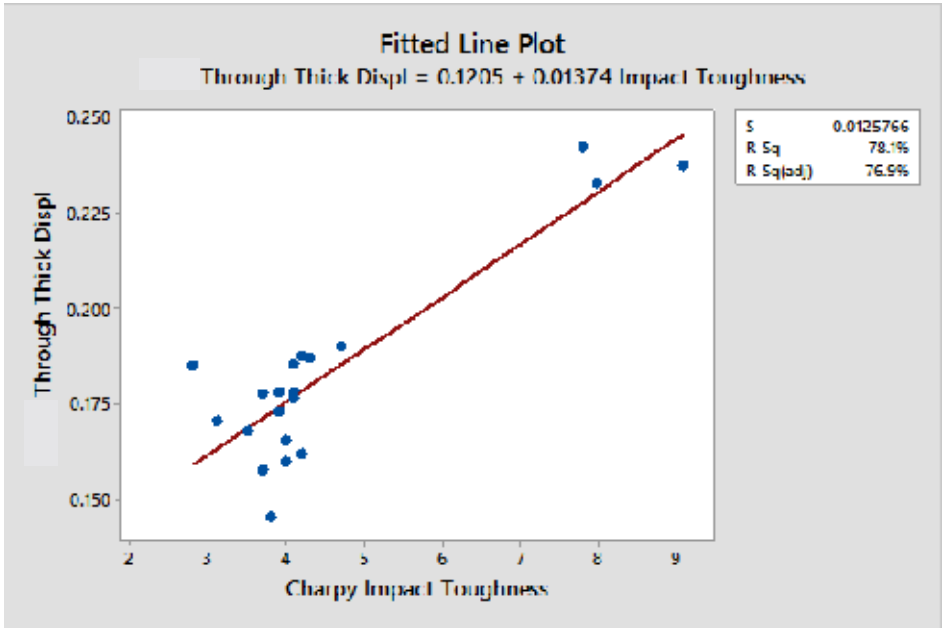
- Position with respect to Argon flow is not significant.
- Position with respect to wiper IS significant
- Build plate is significant if build plate 1 is included, but is NOT if build plate 1 is excluded.

Statistical analysis – Correlation of test articles with component performance

- There are not any obvious correlations between the data from the small tensile samples near the components and the components.
- Charpy impact toughness is slightly better correlated with the displacement at through thickness crack.







Conclusions

- Traditional methods of ensuring parts are good are not as useful for AM parts. The process is too variable.
- It is important to test a statistically significant number of samples.
- Wiper direction is strongly correlated with peak load in this data.
- Looking at nearest neighbor test samples may not be correlated to part properties.

Acknowledgements

- Andrea Exil
- Chris Finfrock
- Chad Taylor
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