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316L Powder Influence on Part Performance: A Path to Creating Specifications

Michael Heiden, Bradley Jared

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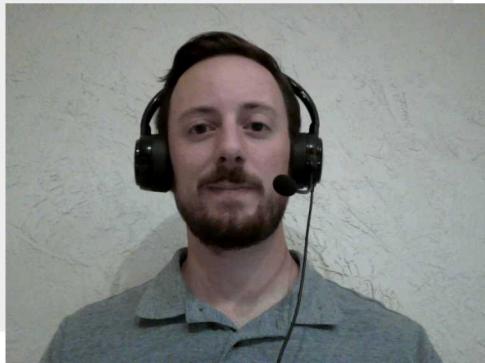

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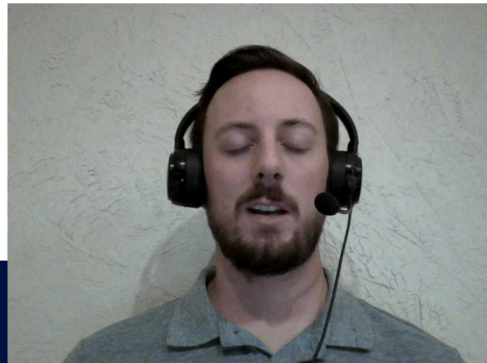
Bio

Michael Heiden

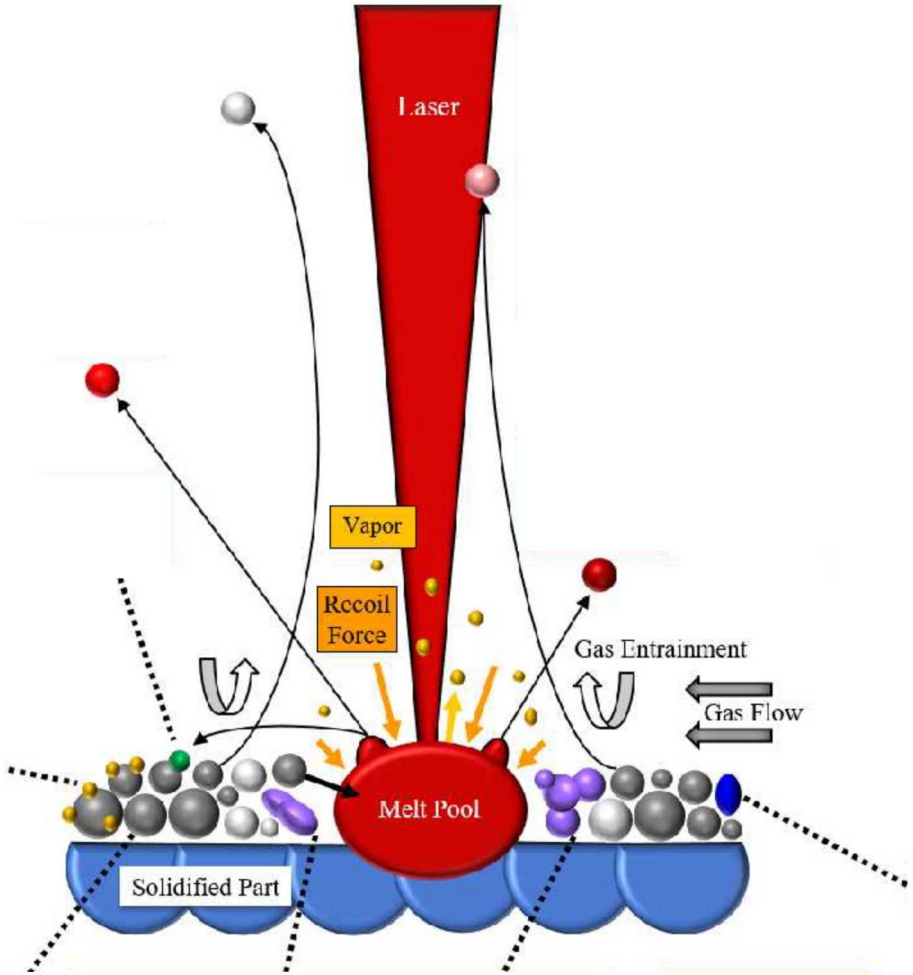
Dr. Michael Heiden is a Senior Member of Technical Staff, R&D, specializing in metal additive manufacturing Sandia National Laboratories. He obtained his Ph.D. in Materials Engineering from Purdue University (2017), where he received the NSF Graduate Research Fellowship for developing degradable fracture fixation biomedical implants. His current career focus involves advancing AM at Sandia. Research ranges from feedstock and machine optimization of laser powder bed fusion processes (LPBF), improving AM microstructural control and part performance, developing unique lattice designs, and progressing AM qualification via specification generation and distribution of AM knowledge.

Outline

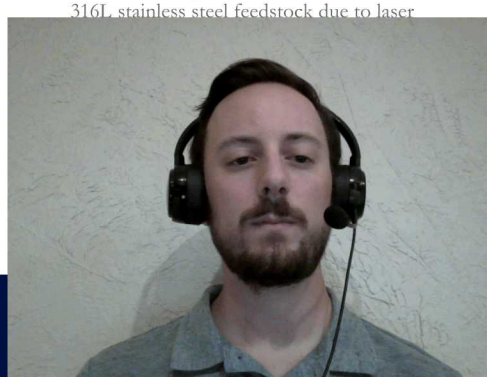
- Laser-powder interactions for 316L in LPBF
- Powder Reuse Effects on 316L Parts for Varying Lots
- Coupling Powder's Influence on Part Mechanical Properties



Laser-powder interactions for 316L in L-PBF



[1] Heiden, M. J., et al. (2019). "Evolution of 316L stainless steel feedstock due to laser



Coupling Powder & Mechanical Properties

Powder Sample

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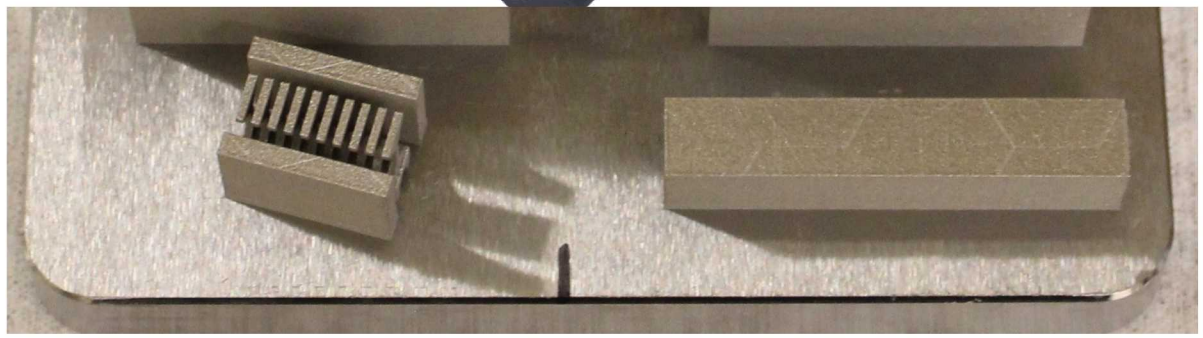
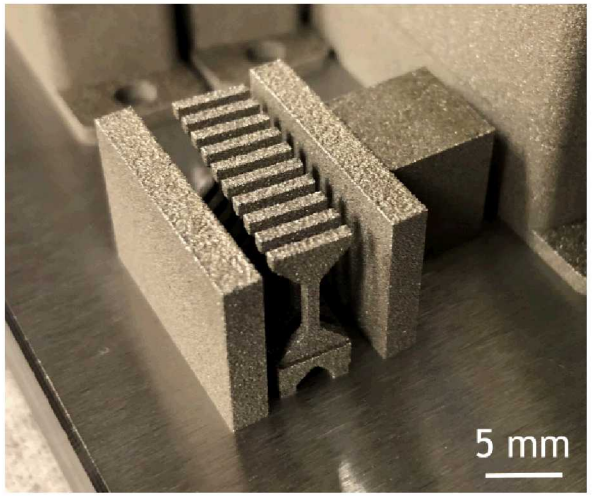


High Throughput Tensile Sample

Charpy Test Coupon



1. How much do part properties change with extensive powder reuse?

2. Do any powder characteristics indicate a “bad” quality part?

Types of 316L powder tested:

- Powder A
- Powder B

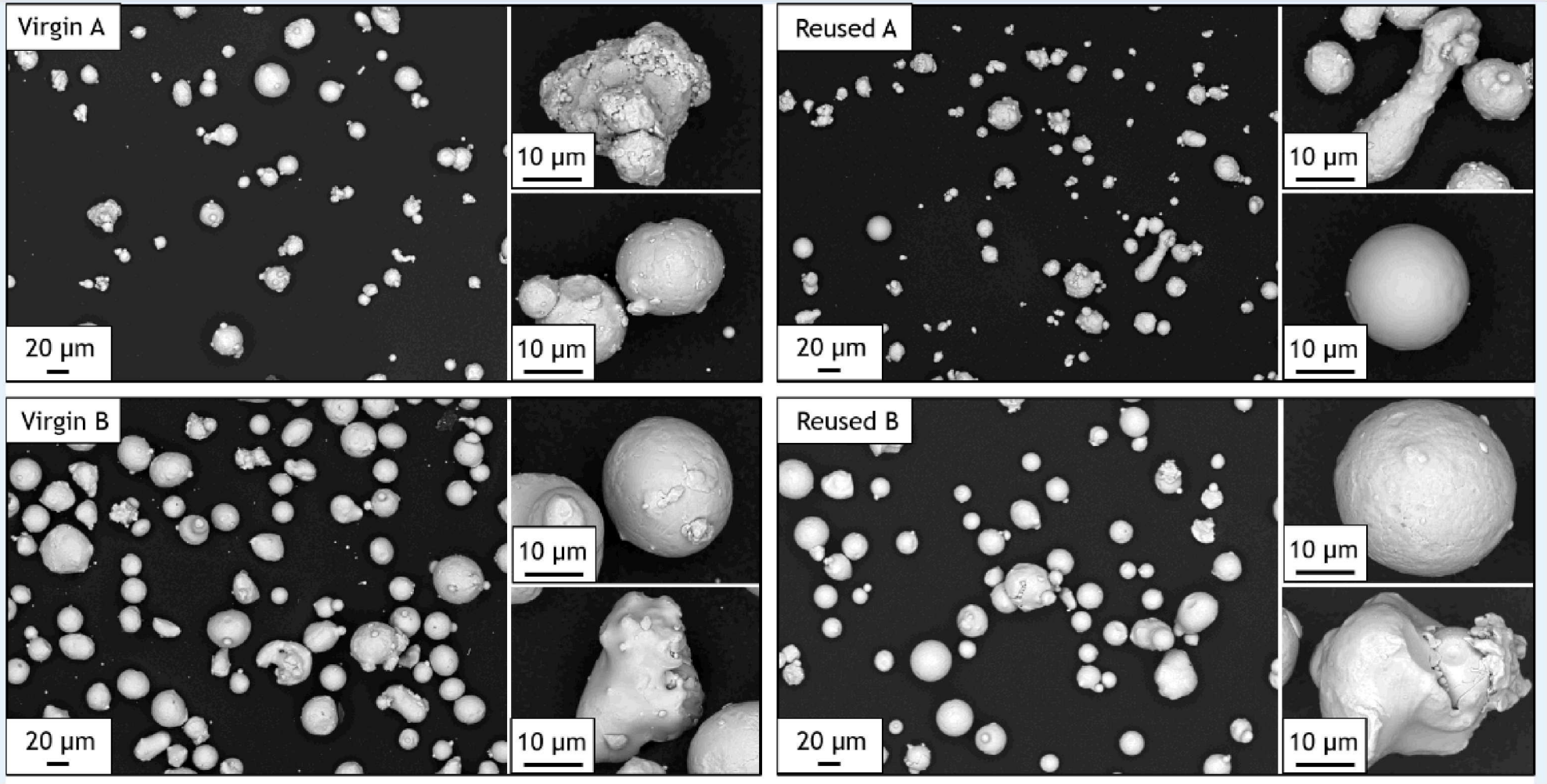
Properties tracked for each build:

- Powder Morphology
- Powder Bulk Chemistry
- Part Tensile Properties, Density, Hardness, Fracture Toughness

Machine parameters:

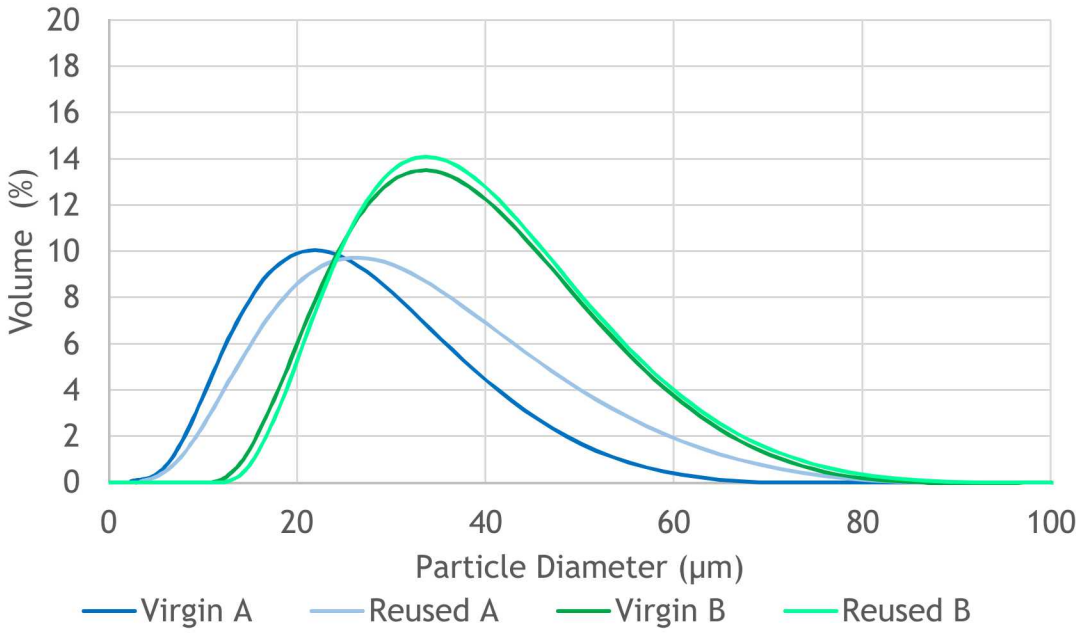
- Power: 110 W
- Mark Speed: 1400 mm/s
- Hatch Spacing: 50 µm
- Focus offset: 1.5 mm
- Style: Hexagon
- Lay

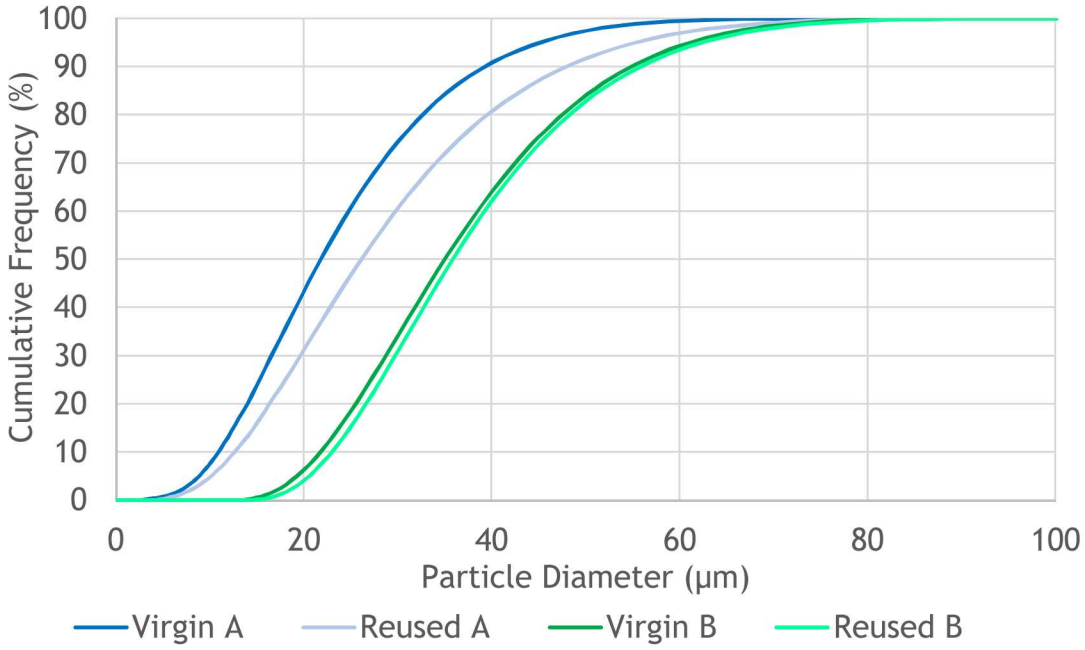
Starting Powders (SEM)



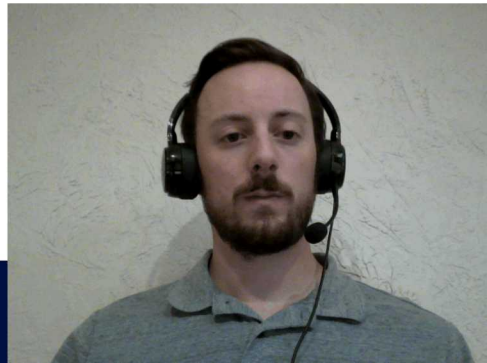
- No significant morphological differences
- Powder B had visibly larger particle sizes

Particle Size Distribution

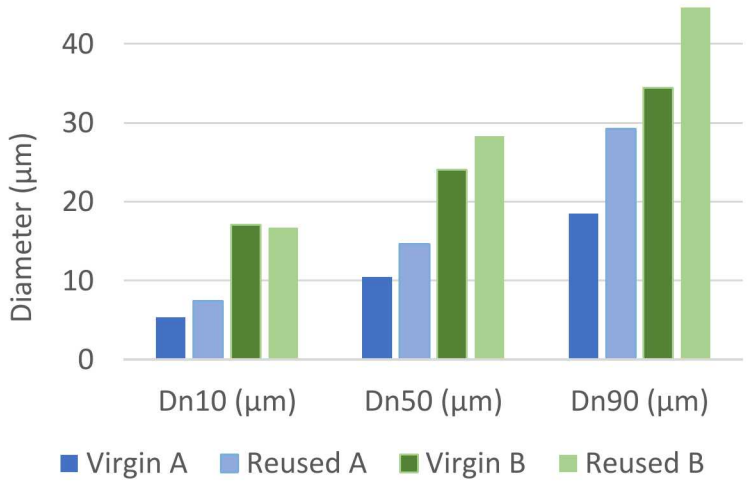


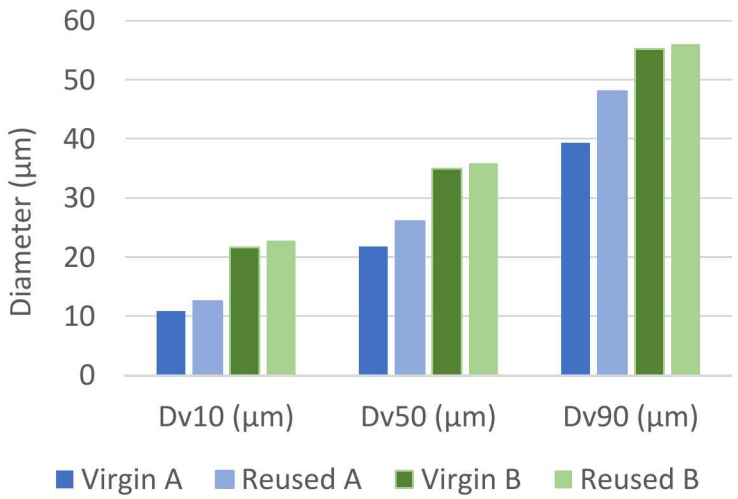


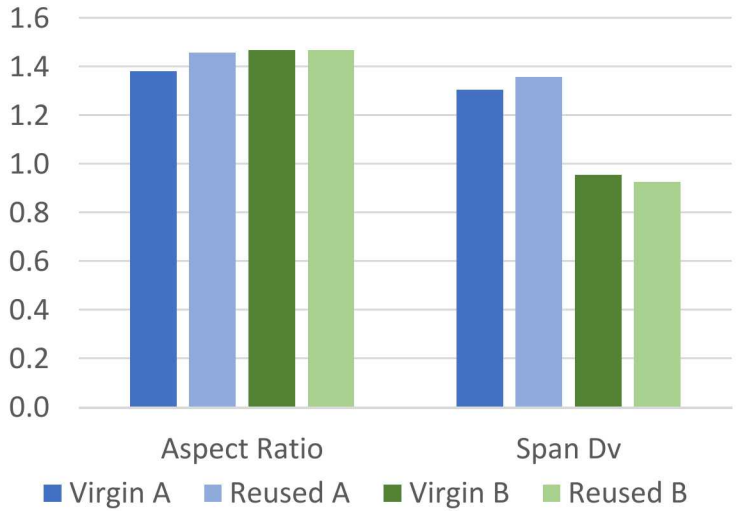
- Powder A and B have distinct distributions
- With reuse, powder can increase or not change much

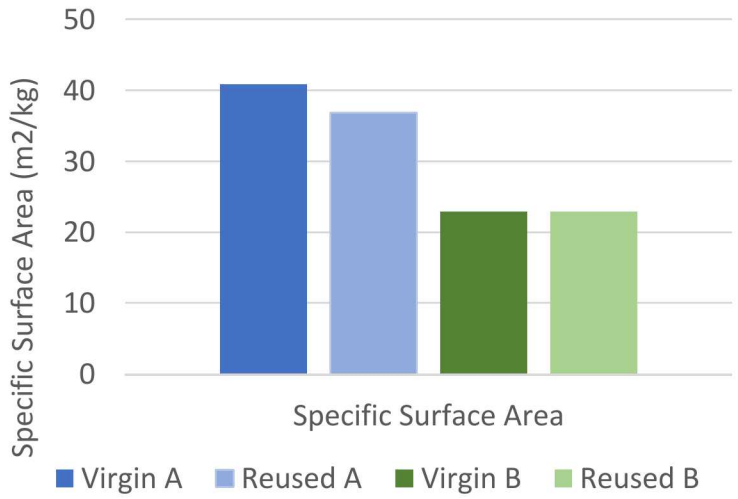


Particle Size, Aspect Ratio, Span, Specific Surface Area



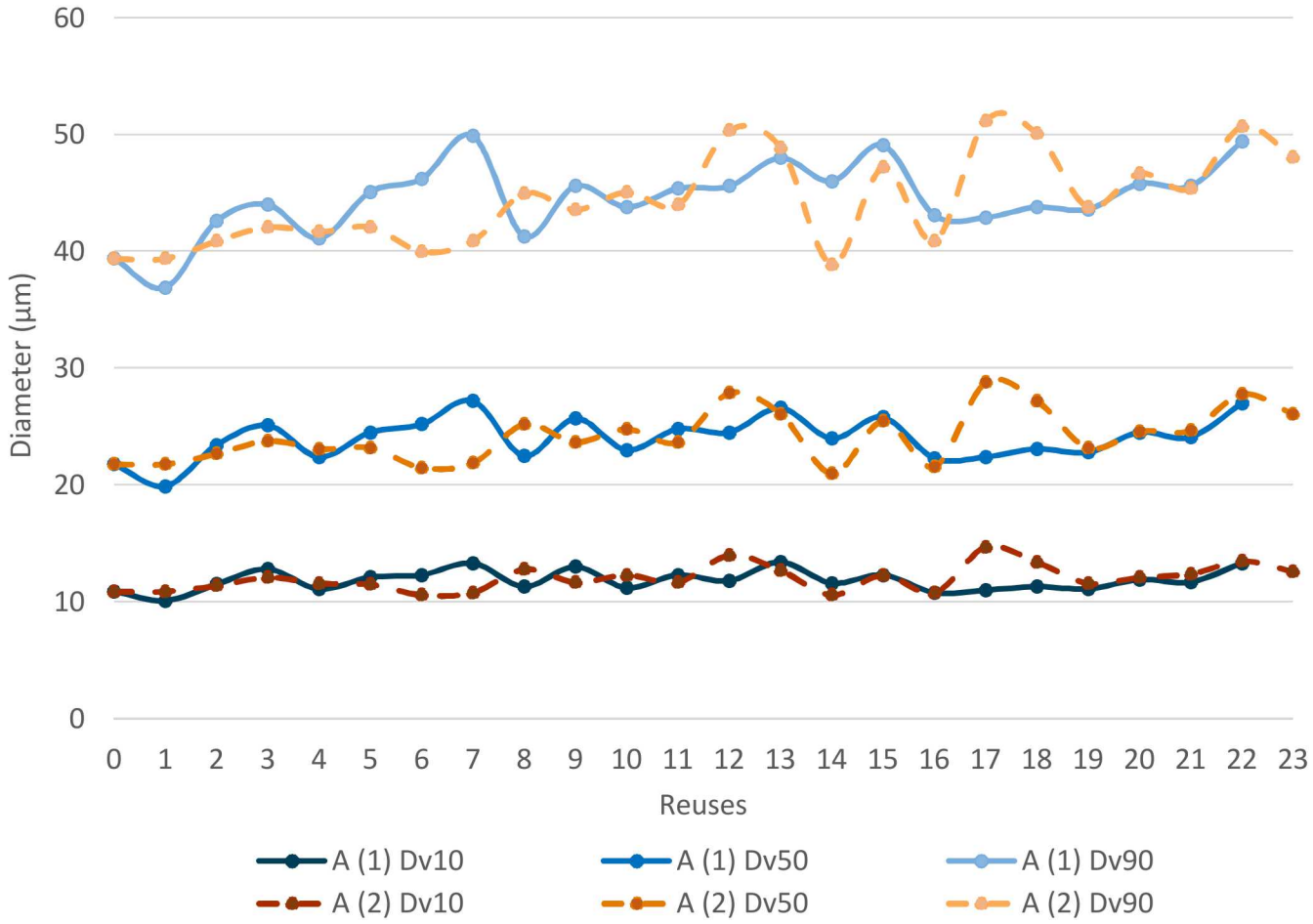






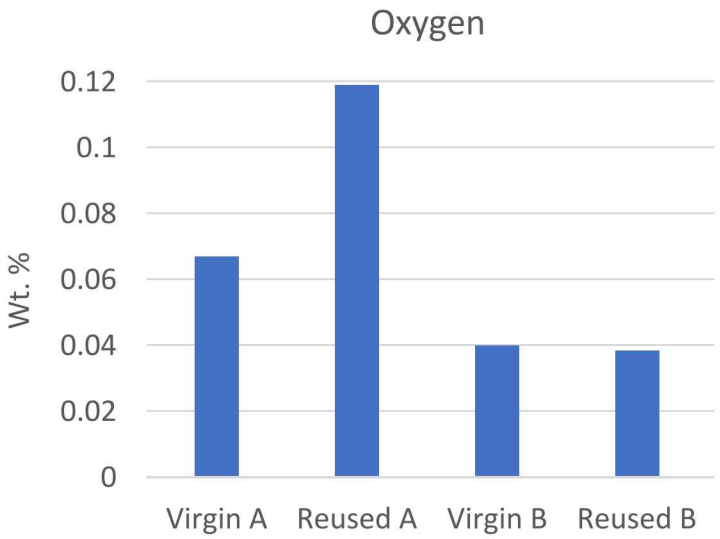
- Both powder sizes increase with reuse
- Aspect ratio increases or remains similar with reuse
- Specific surface area decreases or remains similar with reuse

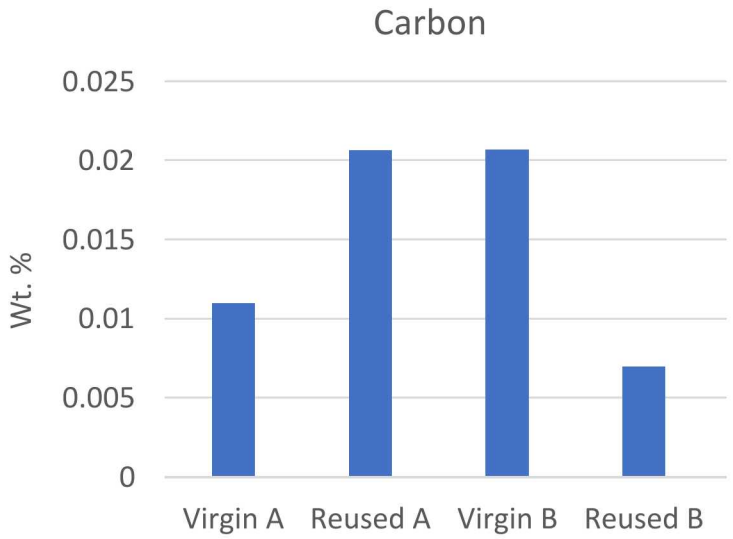
Particle Size with Reuse

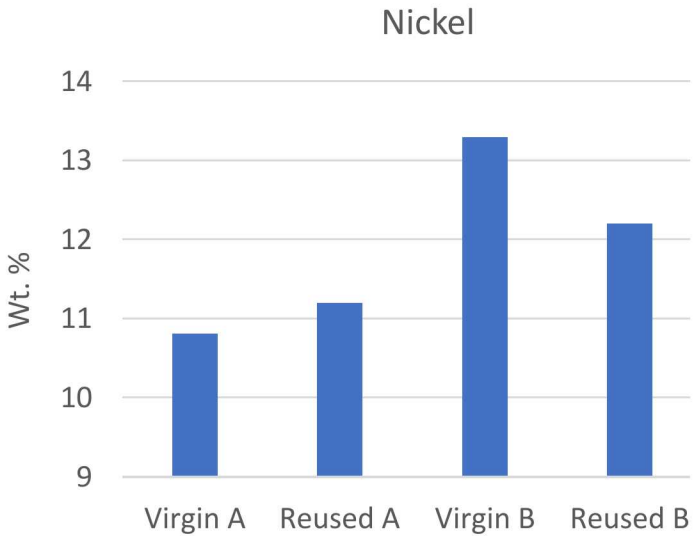


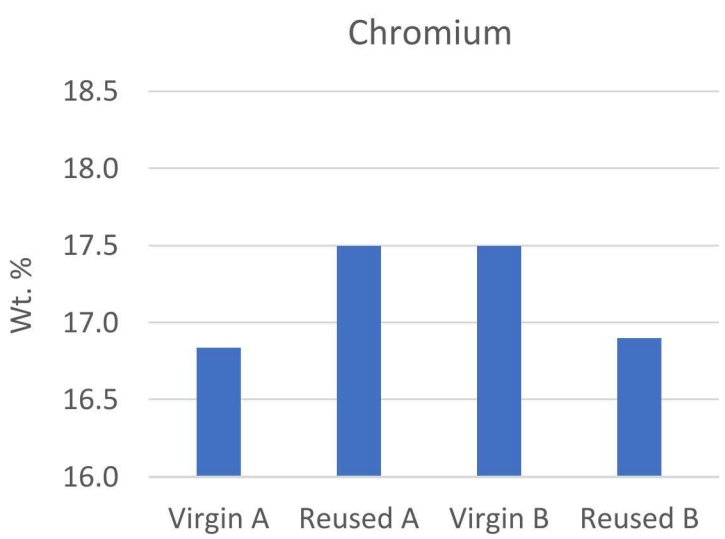
- Powder size measurements can vary substantially
- Different lots still follow the same increasing trend with reuse

ICP-MS + LECO Chemistry Changes

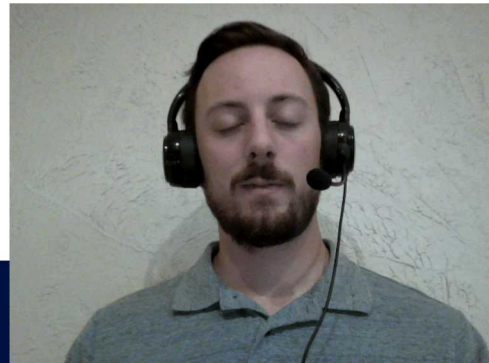




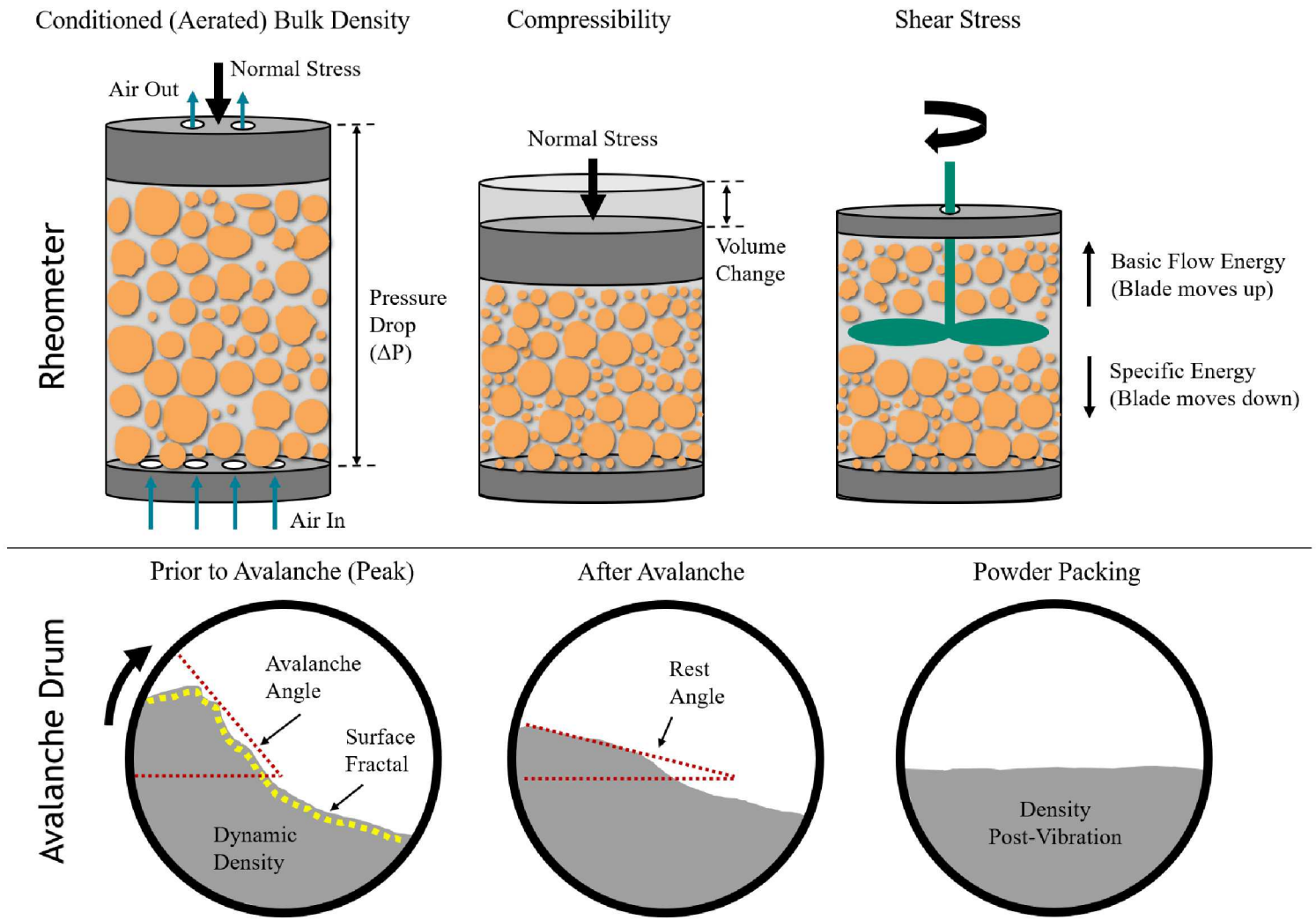




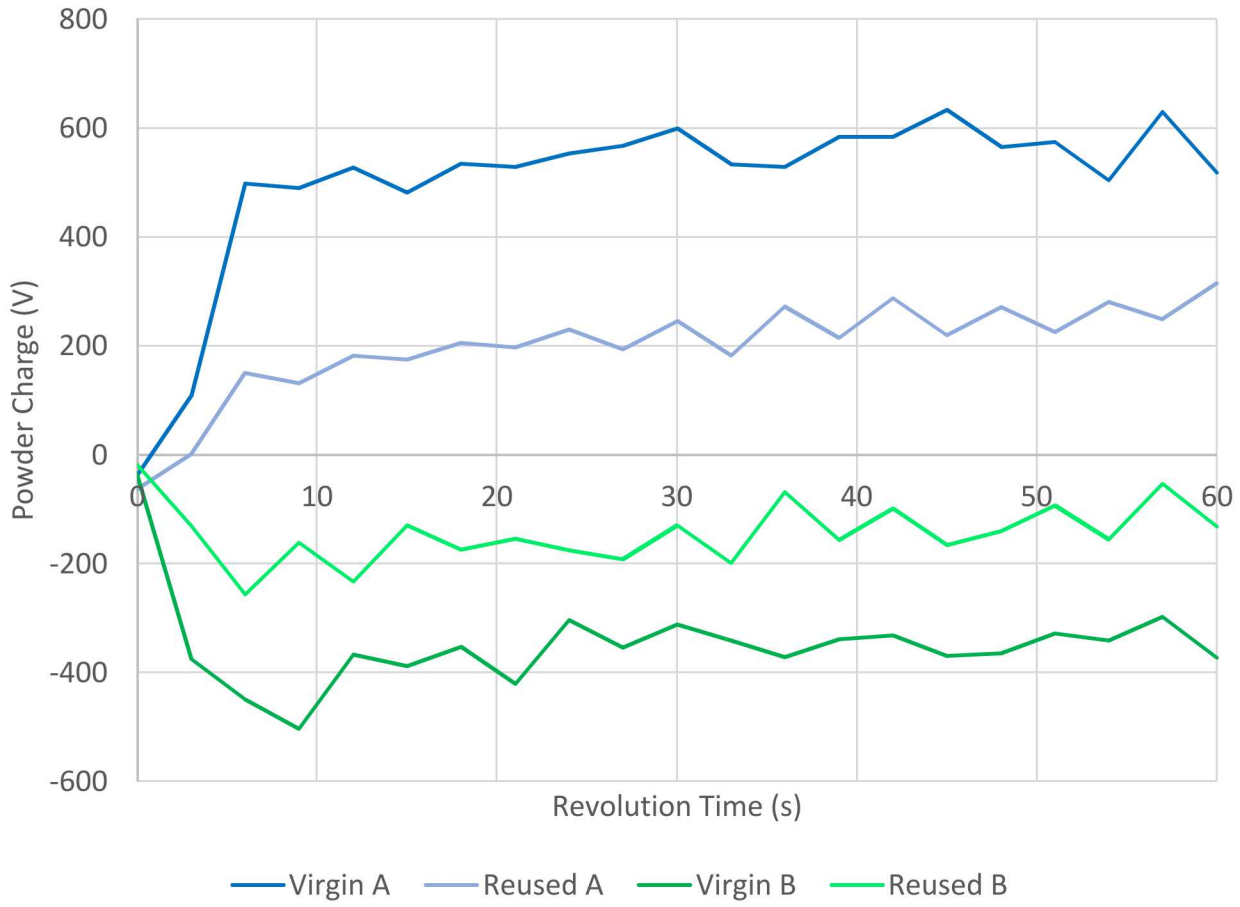
- Oxygen content can increase or remain similar with reuse
- Carbon can increase or decrease with reuse
- Nickel and Chromium can increase or decrease with reuse



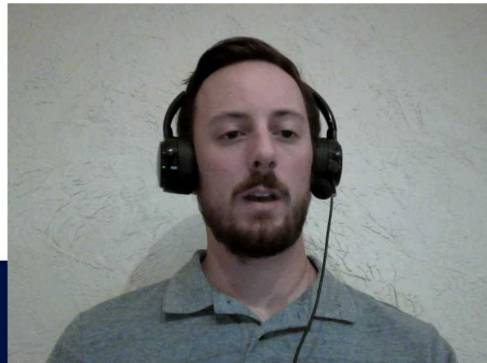
Flowability



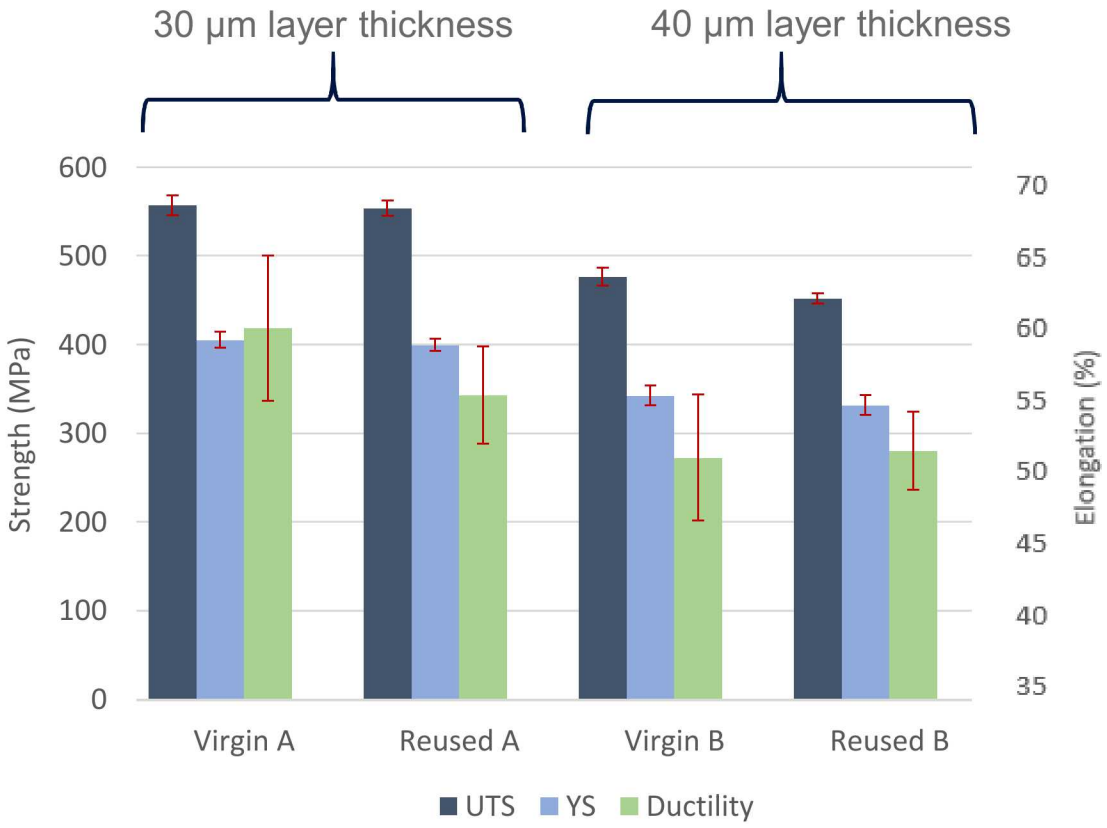
Triboelectric Charging

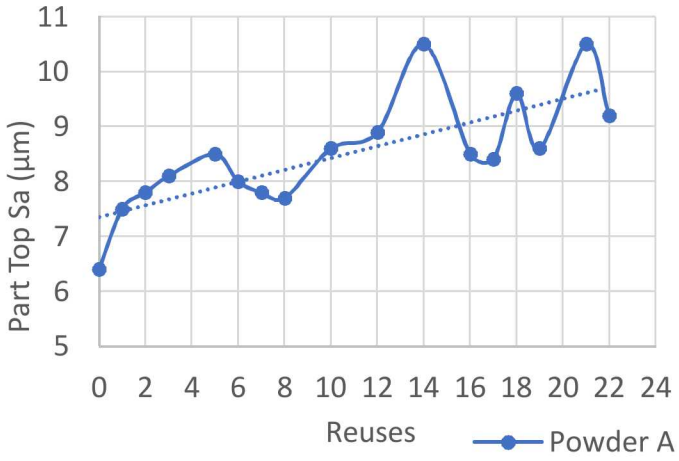


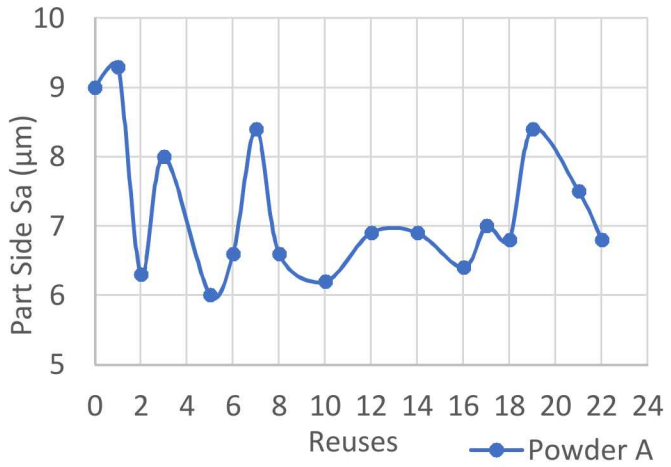
- 316L powders can have different charge signs, but generally decrease in charge (near zero) with reuse



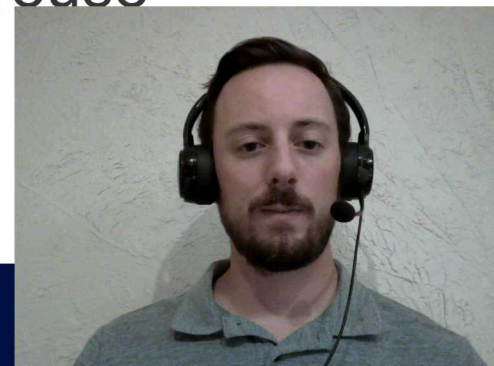
High Throughput Tensile Properties



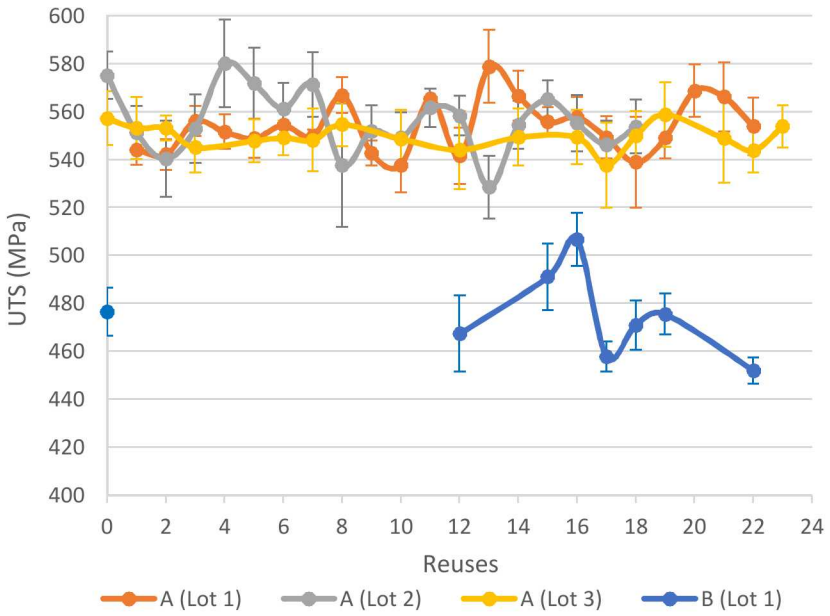


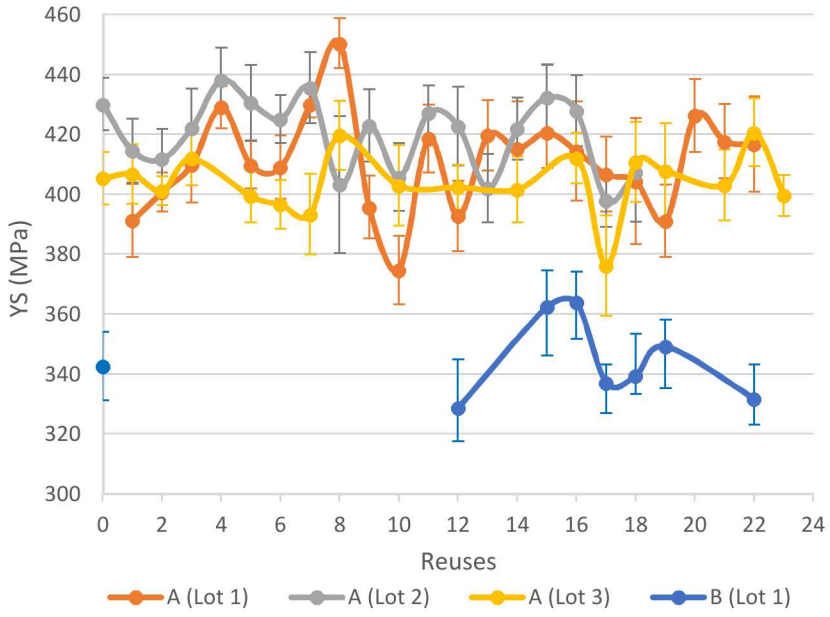


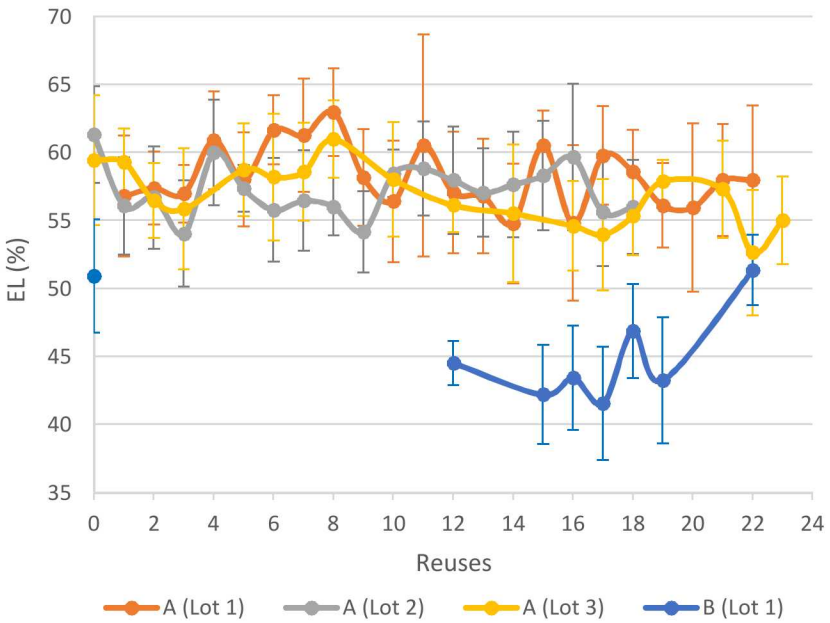
- Very little change to properties with reuse
- Possible reduction in ductility with reuse
- Top roughness increases with reuse



Mechanical Properties

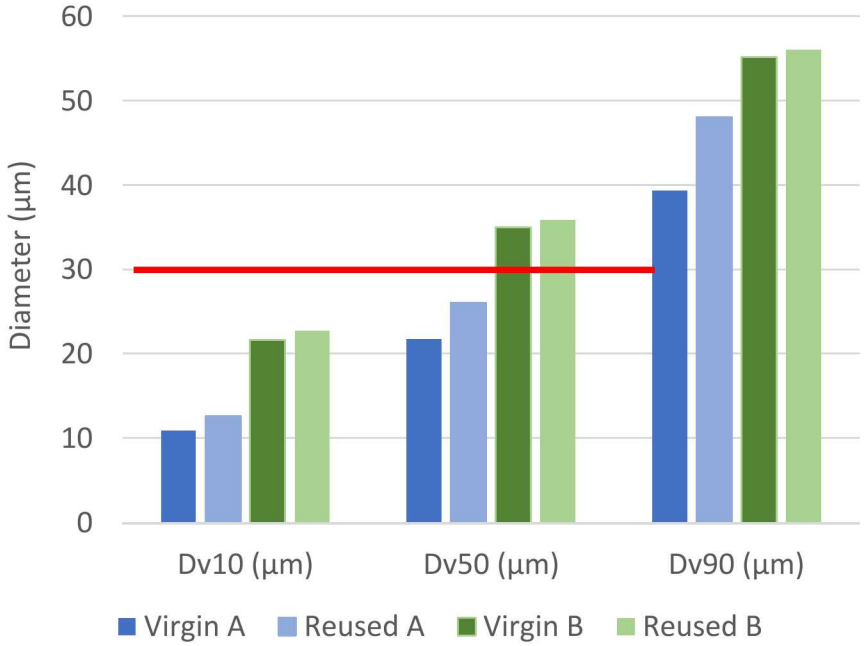


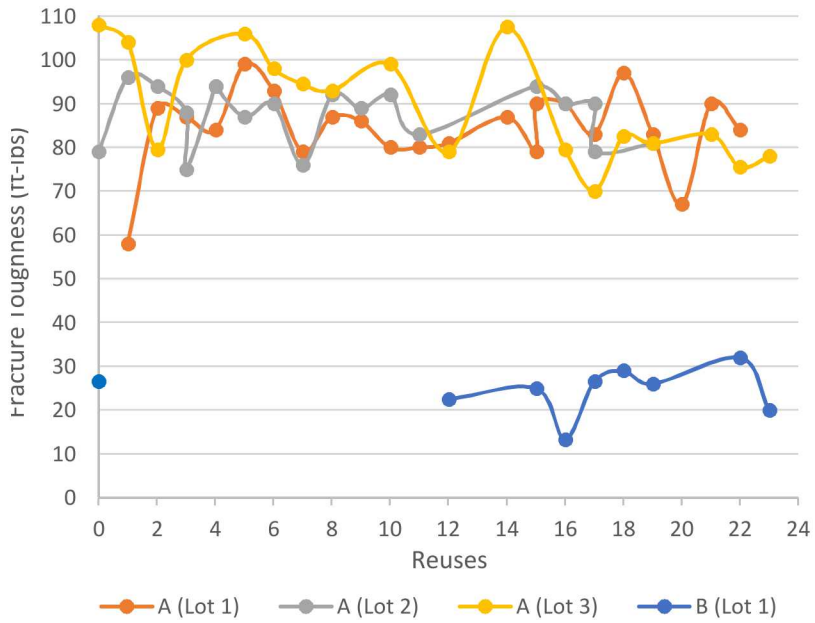


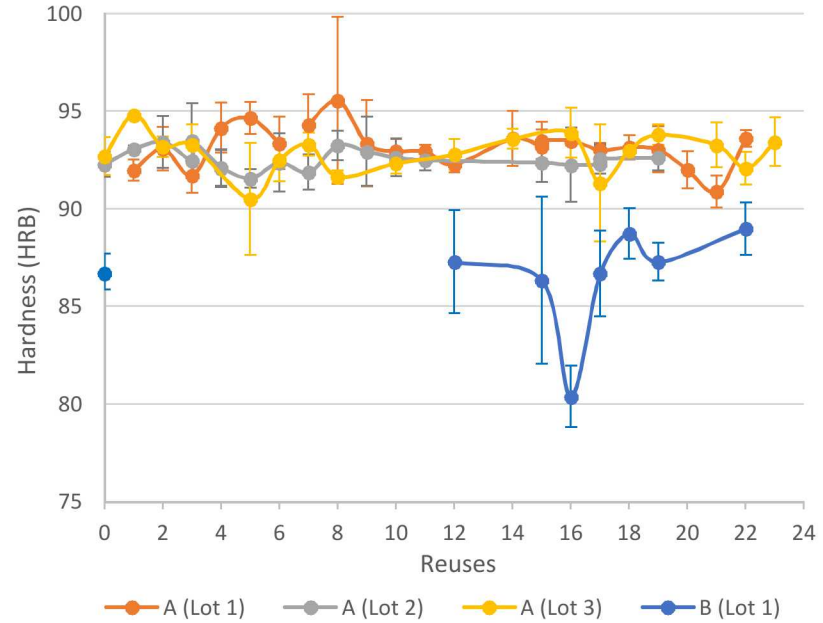


- Very little change to properties with reuse
- Possible reduction in ductility with reuse
- Top roughness increases with reuse

316L Mechanical Properties Relatively Insensitive to Powder Reuse







- Lots of powder characteristics change with reuse, but properties don't reflect that change for 316L stainless steel parts, as long as Dv50 remains below machine layer thickness
- When the process parameters don't vary, mechanical property variability is primarily due to slight process fluctuations and build location, rather than powder of 316L stainless steel

Acknowledgements

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Thank you.

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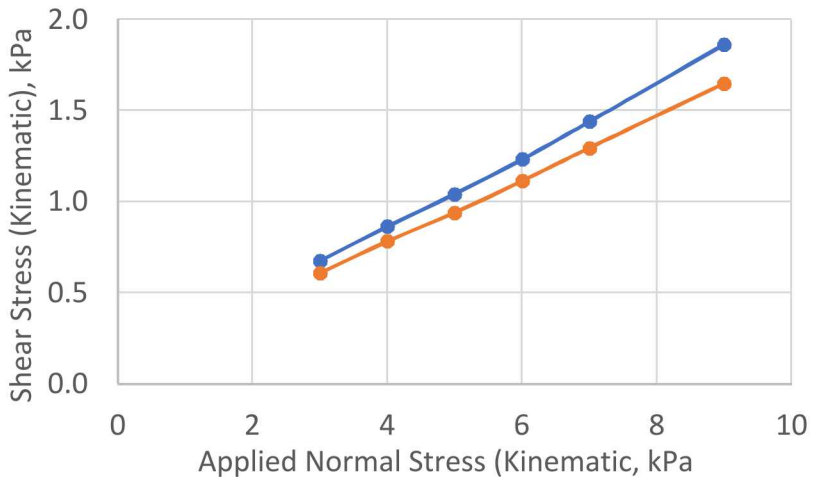
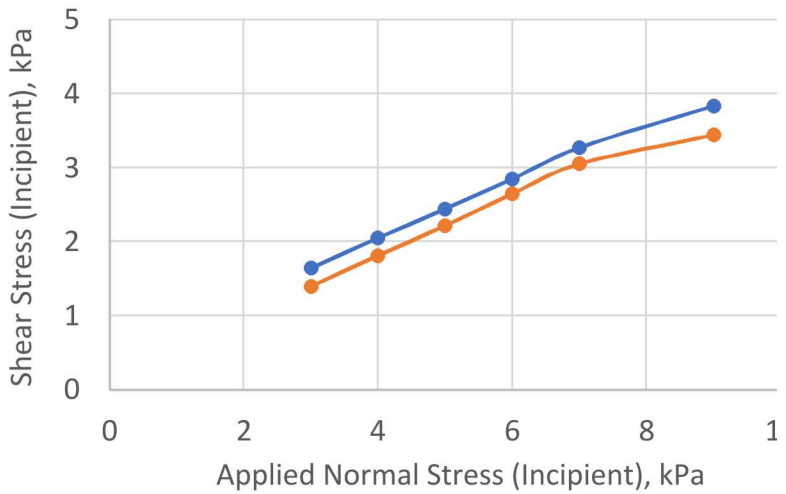
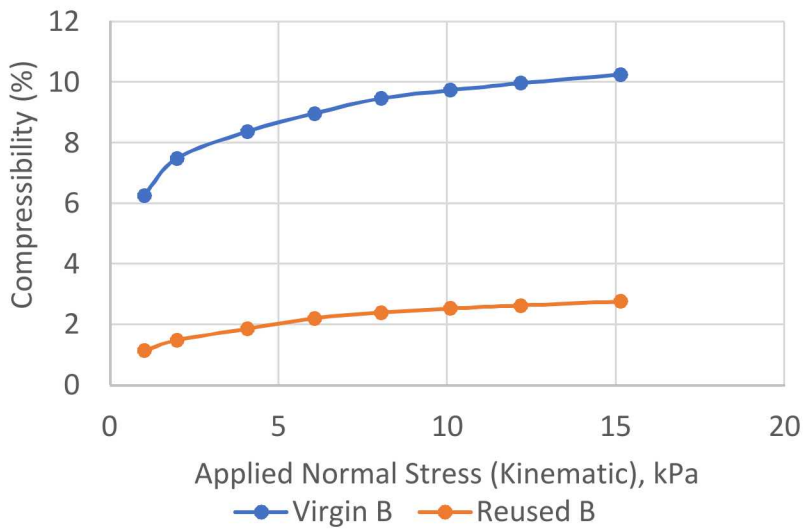
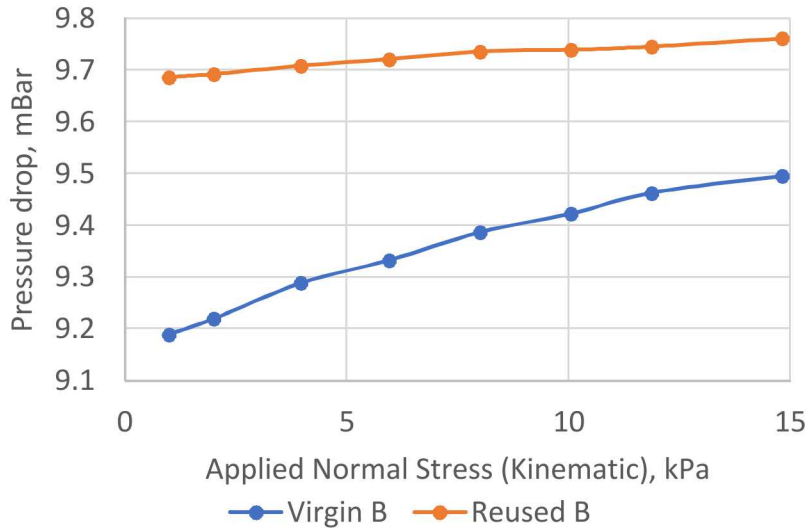
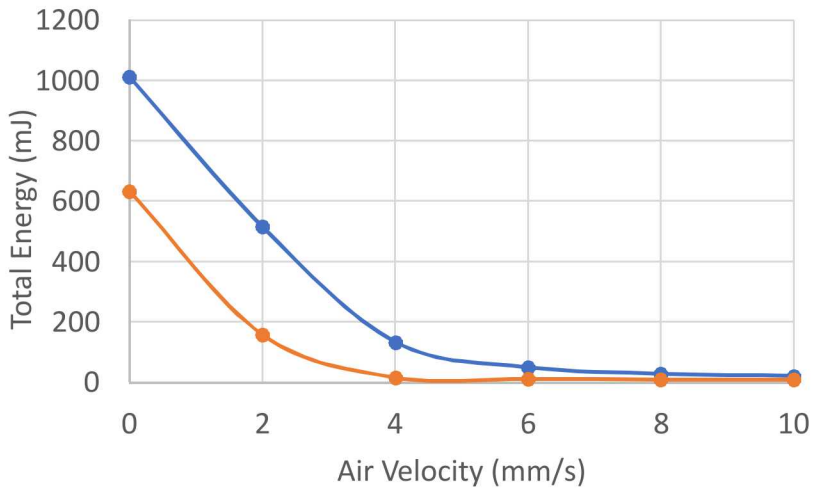
Flowability (FT4 Rheometer)











Metric	Virgin B	Reused B
BFE (mJ)	991.76	1077.37
SI	0.97	1.00
FRI	1.04	1.13
SE (mJ/g)	3.50	2.86
CBD (g/mL)	4.55	4.72
BDtap (g/mL)	4.84	4.66

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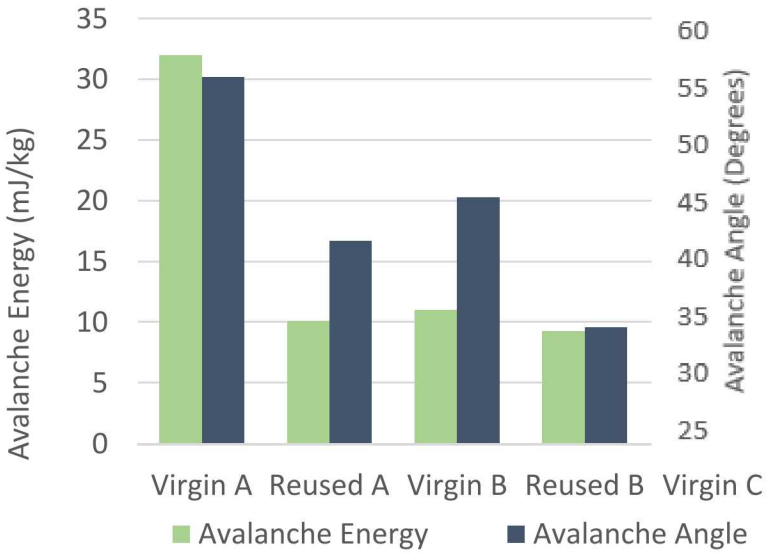
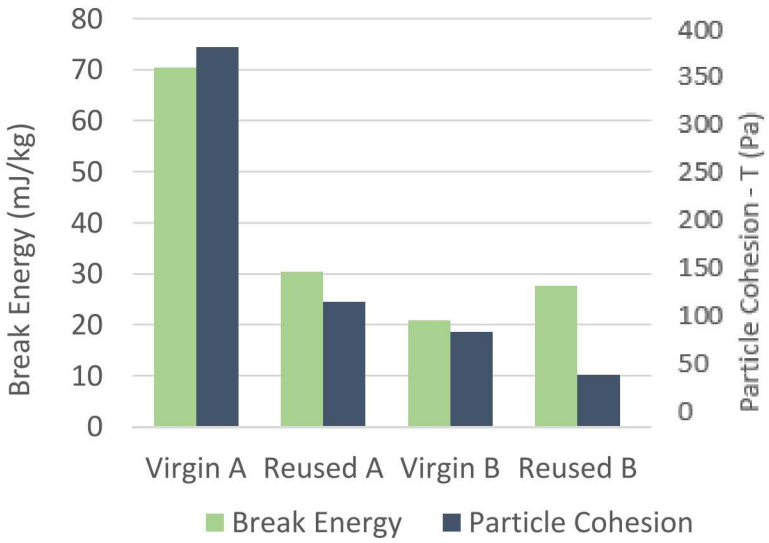
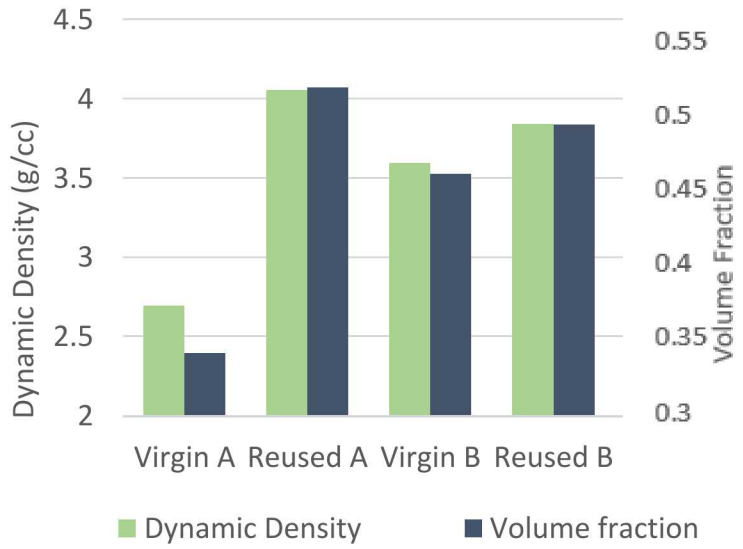
Flowability (Avalanche Drum)







- Avalanche Energy, Rest Energy, Break Energy, Particle Cohesion decrease with reuse
- Dynamic Density increases with reuse

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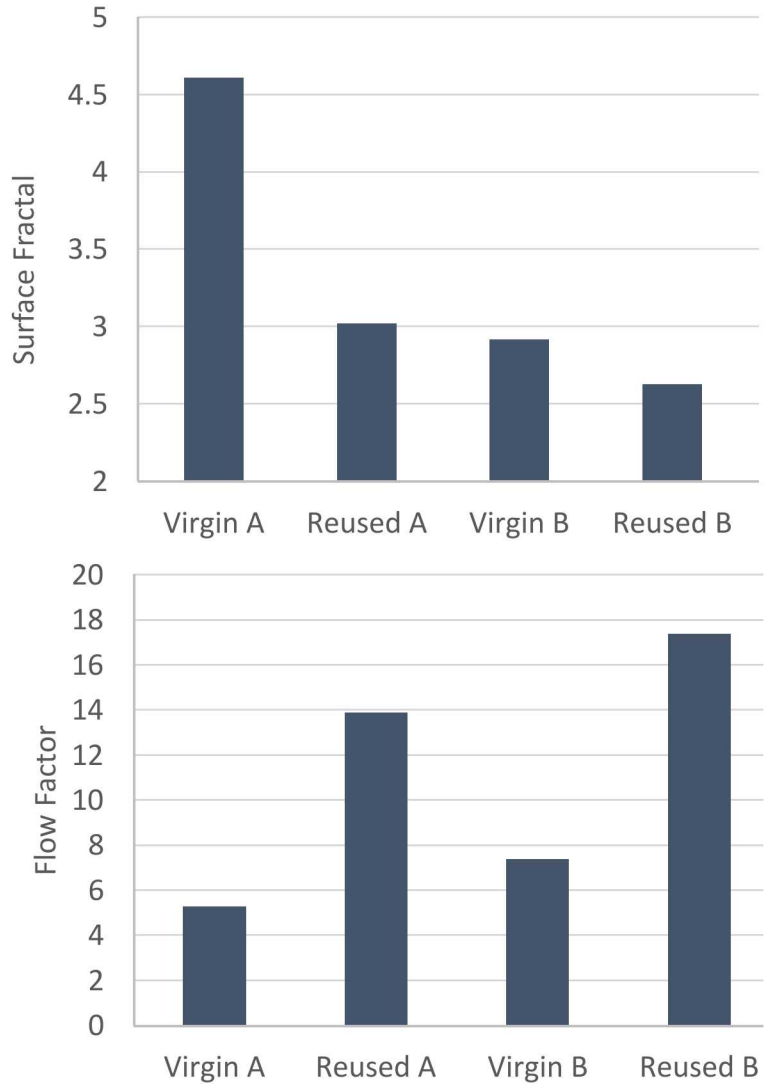
Flowability (Avalanche Drum



- Surface fractal decrease with reuse
- Flow factor increases with reuse

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