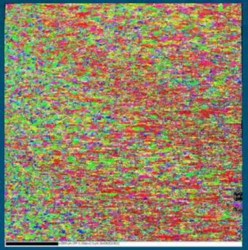
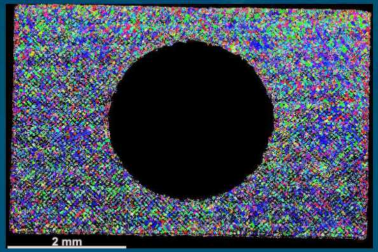
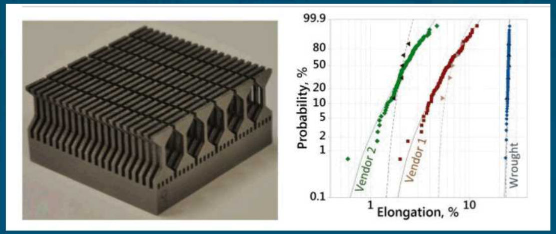
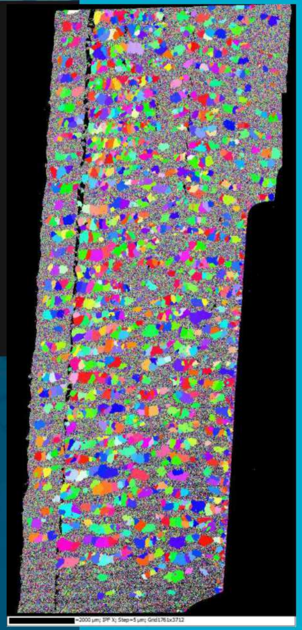
SAND2018-7685PE

Suggestions for characterization of AM Metal Structures









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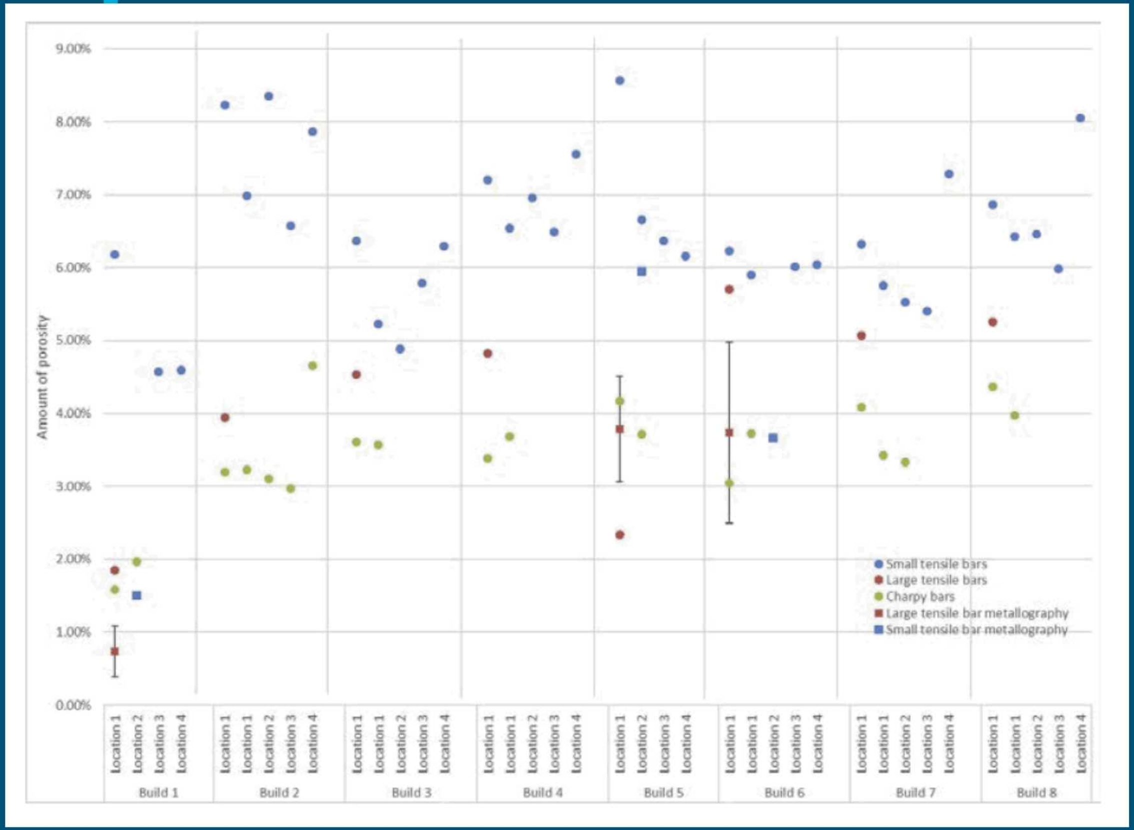
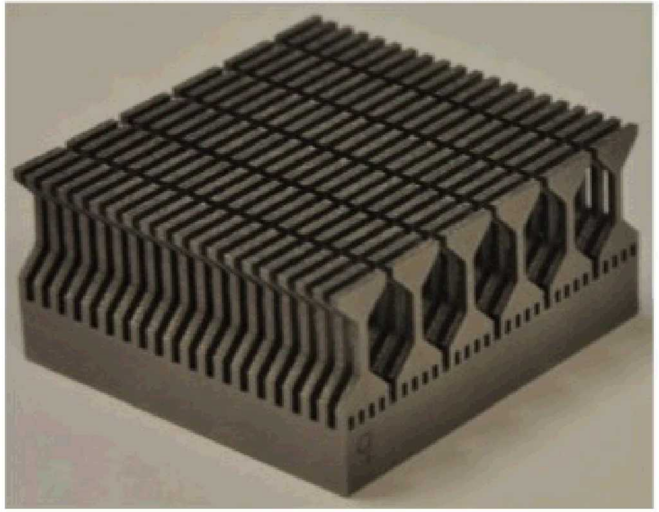
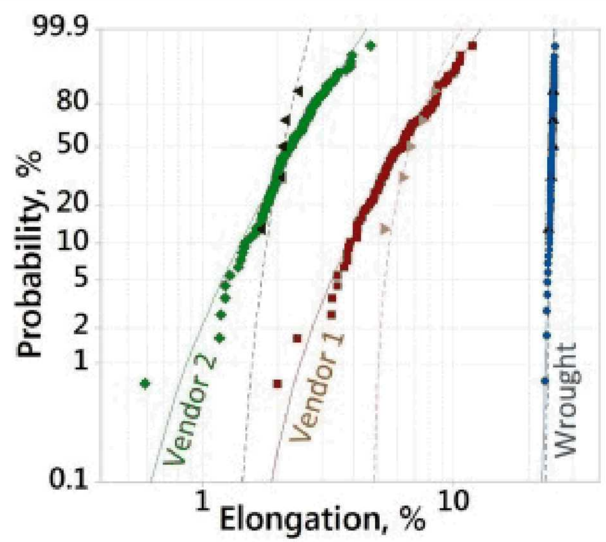
Variability in additively manufactured structures – important to understand and mitigate



Powder bed Al alloy porosity volume – large variability depending on sample size and shape and method (Archimedes vs. Metallography).



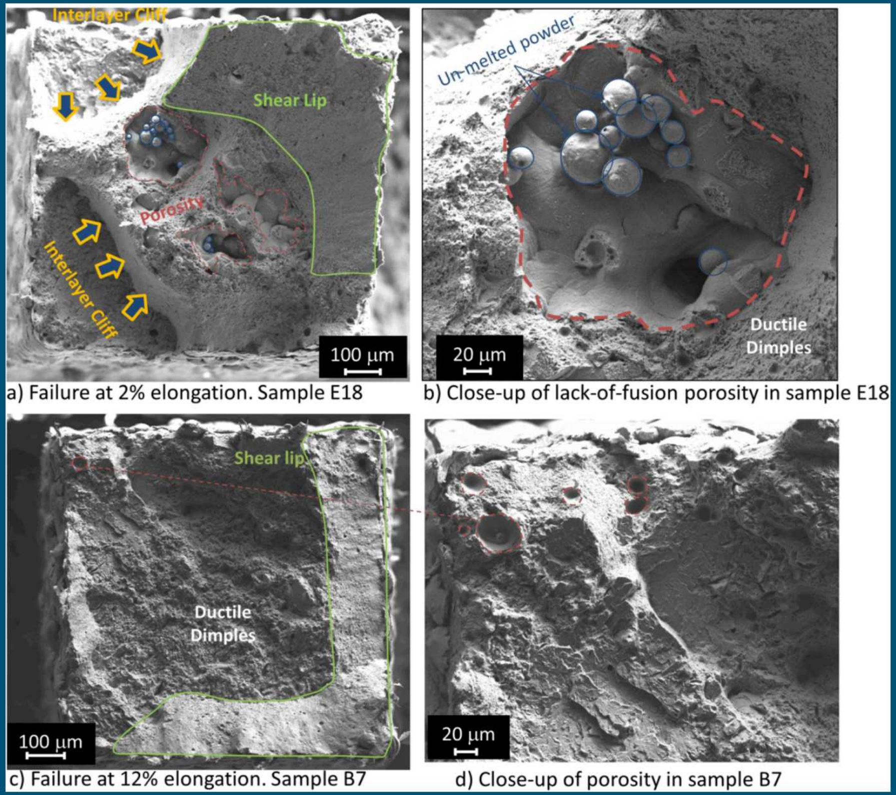
50 mm X 50 mm high-throughput tensile array of 17-4 PH produced by powder bed



Cumulative probability distributions for strain at failure for AM compared to wrought

Jared et al., Scripta Met, 2017, vol 135, p 141-147.

Microstructural variability – microstructure/property relationships cannot be ignored

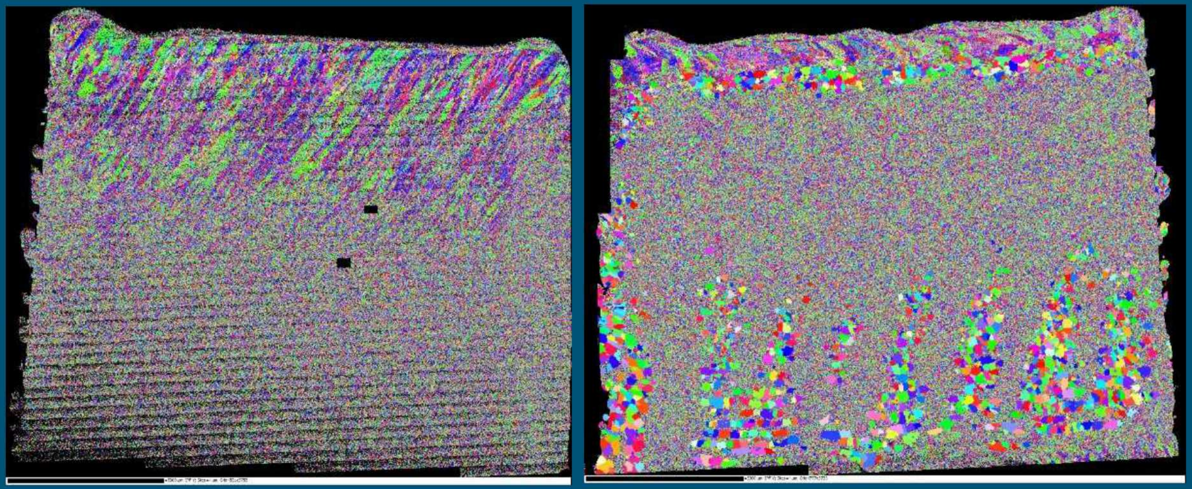


a) Failure at 2% elongation. Sample E18 b) Close-up of lack-of-fusion porosity in sample E18

c) Failure at 12% elongation. Sample B7 d) Close-up of porosity in sample B7

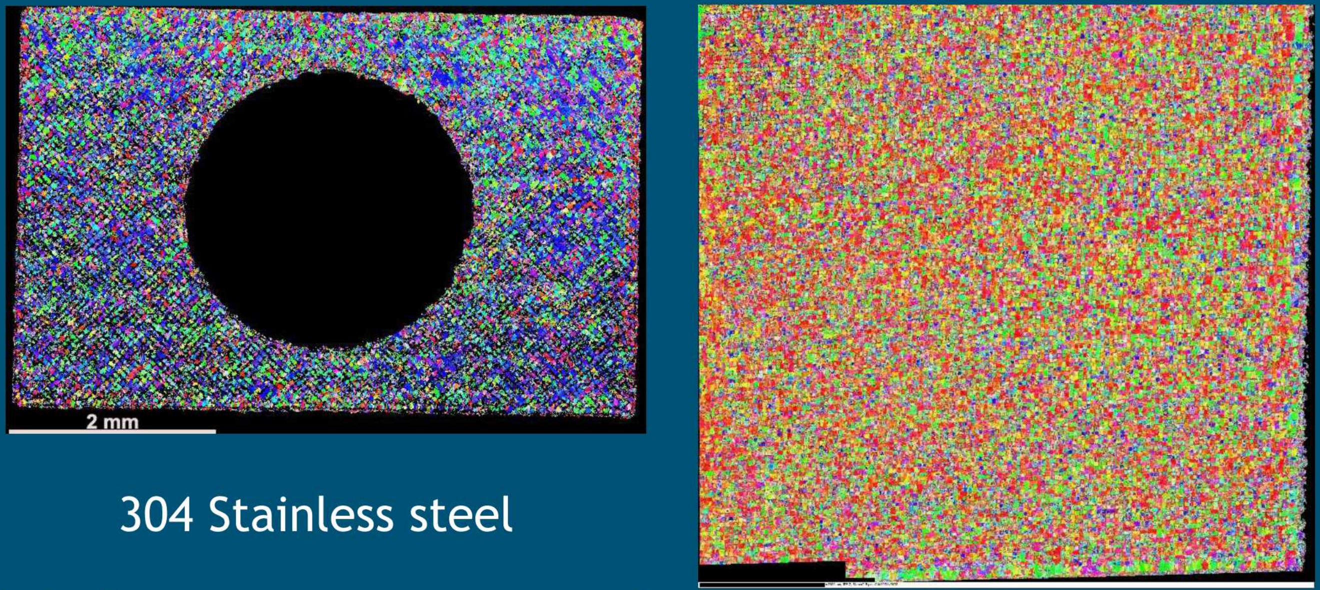
Porosity in AM powder bed builds

Salzbrenner et al., J. of Mater. Proc. Tech., 2017. vol241, p 1-12.



As built annealed

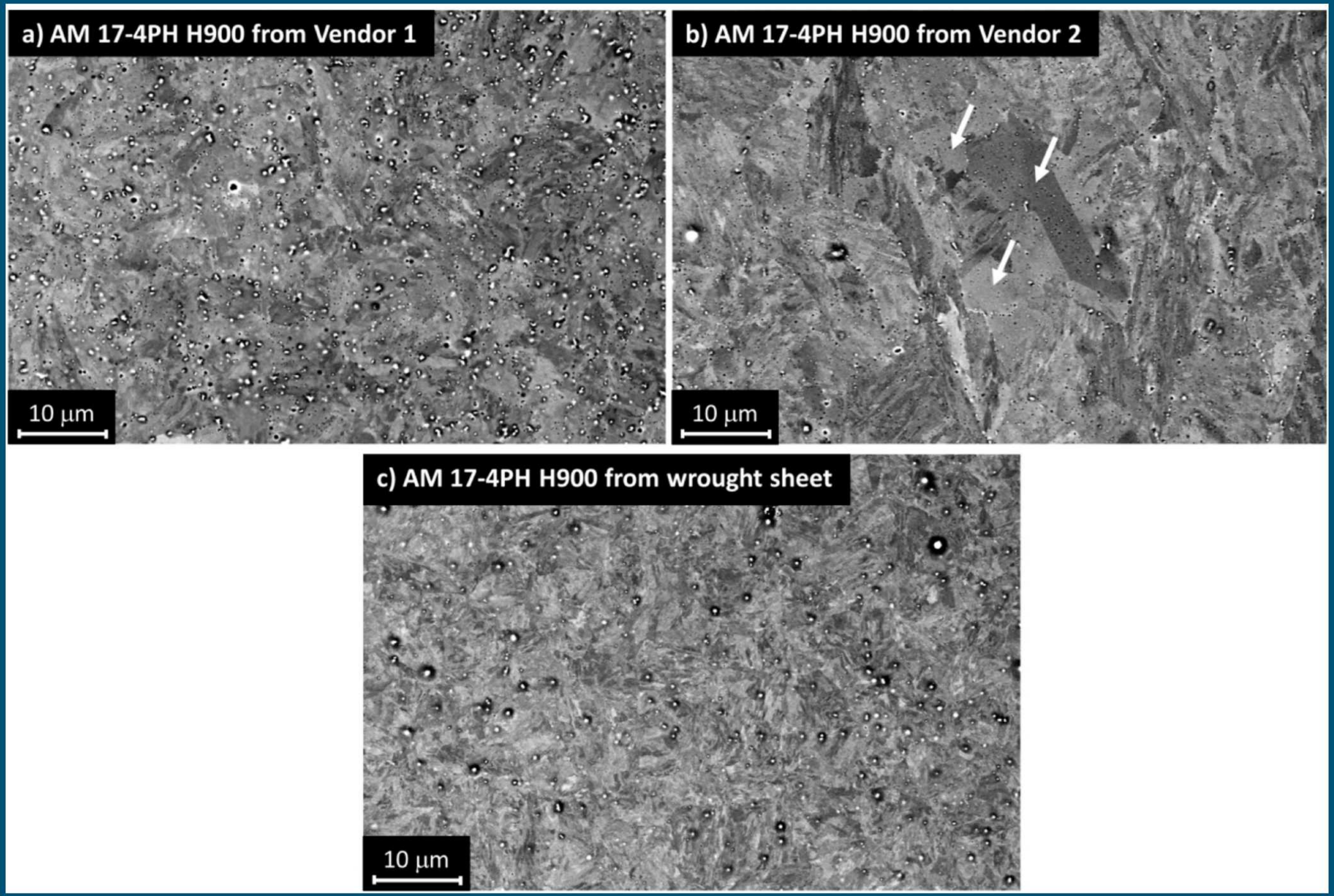
LENS 49 wt% Fe, 49% wt% Co, 2 wt% V alloy



304 Stainless steel

Attempts to reproduce conditions don't always yield similar structures or properties

Microstructural variability – microstructure/property relationships cannot be ignored

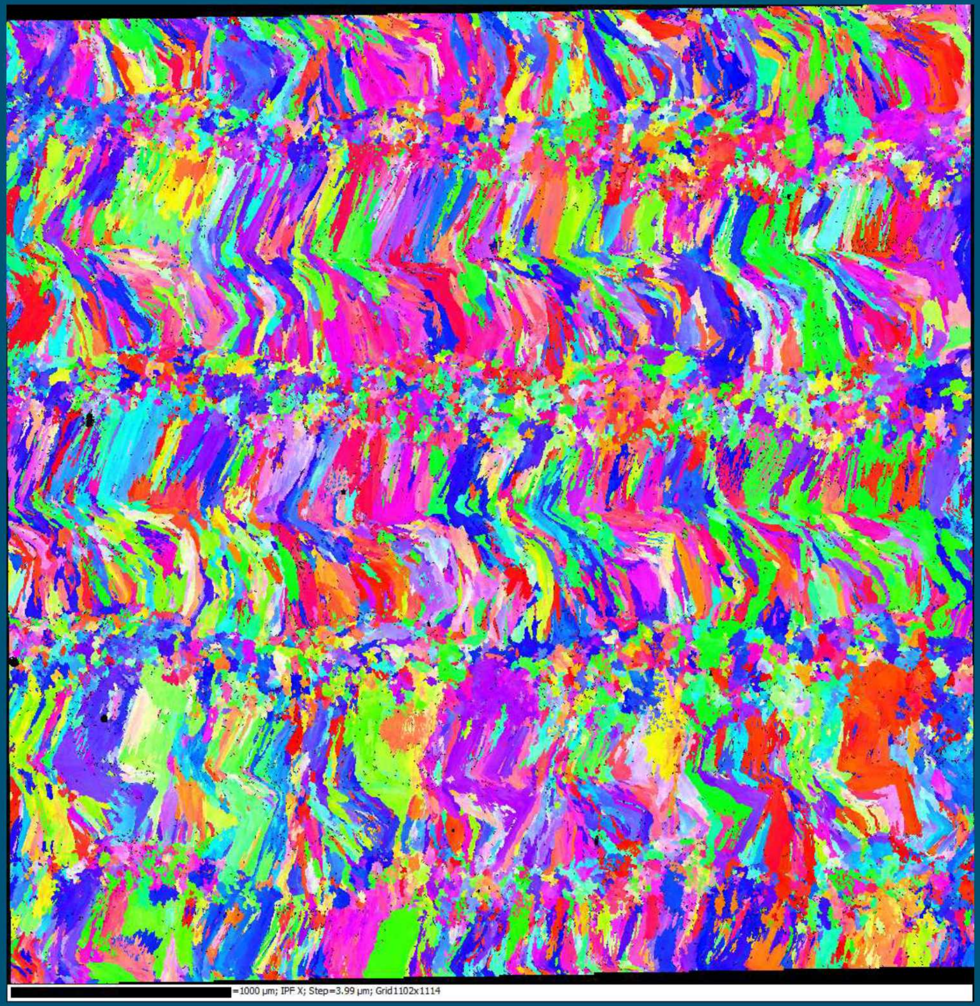


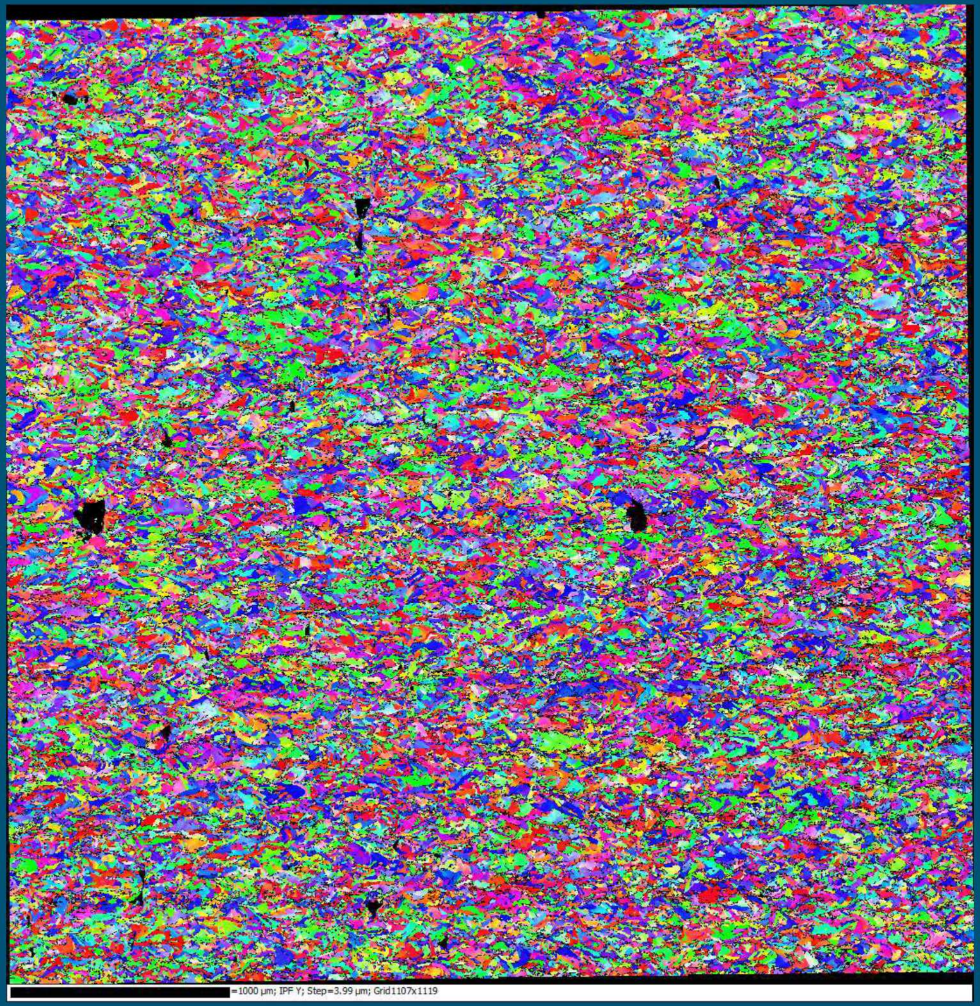
More retained austenite in vendor 2

Supposedly similar processes and materials do not yield the same microstructures

Salzbrenner et al., J. of Mater. Proc. Tech., 2017. vol241, p 1-12.

Microstructural variability – microstructure/property relationships cannot be ignored





Supposedly similar processes and materials do not yield the same microstructures

Physical Characterization:

Mechanical properties

Yield stress

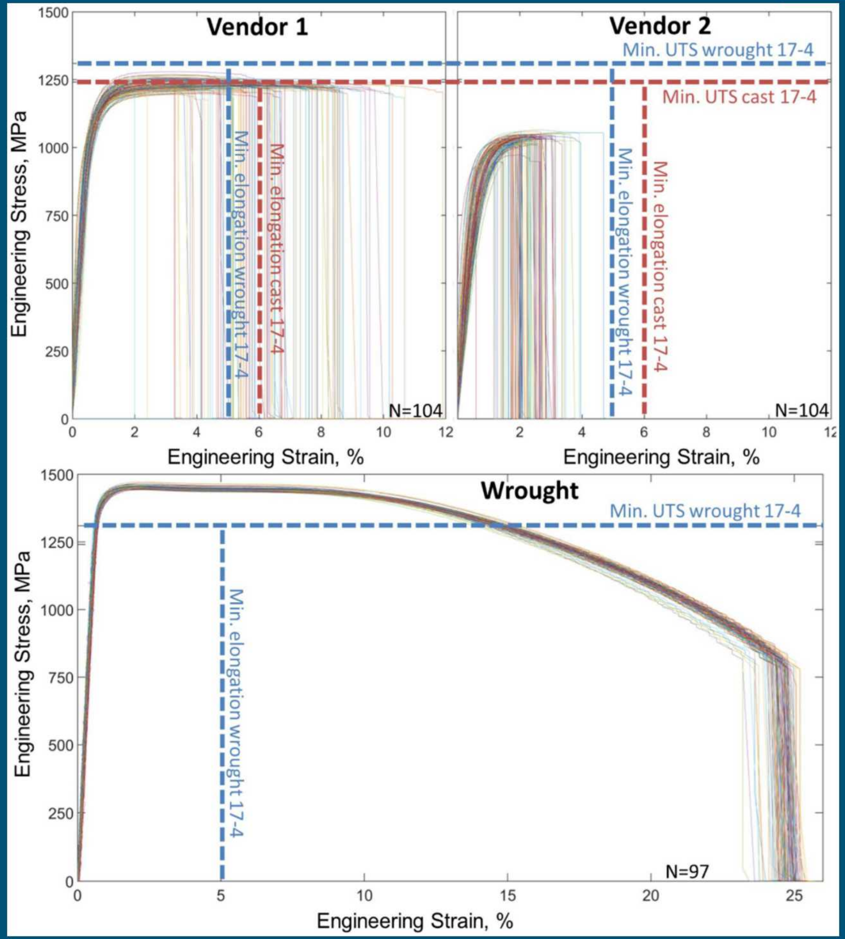
Strain

Ultimate tensile stress

Ductility

Porosity Measurement

Are Gamma Ti AM parts stronger/weaker more or less ductile than wrought parts?



Large sample set tested – wrought material consistent, AM not so much!

Salzbrenner et al., J. of Mater. Proc. Tech., 2017. vol241, p 1-12.

Microstructural Characterization

Metallographic preparation – Ti samples must be prepared correctly so that artifacts do not dominate our observations

Optical microscopy – Low magnification overviews of the microstructures allow overall materials qualities to be observed. Ie. Grain size

Scanning electron microscopy
Imaging - SEM imaging can provide detailed images of the microstructure. These details are not always observable using light, Grain size, second phases, small voids…

EDS - (or WDS in the Microprobe) – allows the elemental chemistry of the sample to be determined and visualized. Did you make what you wanted? Are there gross or fine segregation patterns that compromise the material…

EBSD – crystallography and texture – The crystallography or texture of materials can determine or greatly impact the mechanical properties of materials. EBSD links the critical details of texture to the microstructure over large or small length scales.

Transmission electron microscopy (TEM) Imaging – details <1 nm can be resolved
Elemental analysis – compositional analysis of fine scale features (>1 nm) can be studied.

Linking Physical and Microstructural characterization

Fractography – imaging of fracture surfaces in the SEM to determine fracture modes and causes. The great depth of field of SEM imaging allows he details of the fracture surface to be observed. Is the fracture ductile/brittle. Was the fracture mode micro-void coalescence? Did porosity in the AM part nucleate fracture? Did fracture originate on second phase particles/

In-situ testing –load frames in the SEM to visualize and monitor fracture process
Watching or observing the details of the fracture process in-situ can provide more details and understanding of where fracture occurs in AM materials.

Can use digital image correlation (DIC) in the SEM to visualize strain distributions during fracture to provide details on strain at fracture and important deformation and fracture details.

Combined straining and imaging and EBSD analysis is possible to allow the crystallographic changes that are associated with fracture to be understood.

Combined heating, compression or tensile testing while imaging the sample with the MicroComputed Tomography capability – allows imaging and provides understanding of the fracture process.

Required samples for scoping study of multibeam LENS gamma Ti

Type of test coupon	Why do we need it?	Characterization	Metrics/targets
Blocks at least 1 cm X 1 cm X 1 cm (produced by standard wirefeed single beam LENS and multibeam LENS) Scan pattern TBD	Establish single beam and multibeam microstructures in larger material sections	OM, XRD, SEM, EBSD, EPMA, TEM	Grain size, texture, pore size and distribution, deposited composition, phases present and distribution.
Fin structure 2 cm long and 1 mm wide. (Produced by standard wirefeed single beam LENS and multibeam LENS) scan pattern TBD	Establish single beam and multibeam microstructures in thinner, faster-cooled material sections	OM, XRD, SEM, EBSD, EPMA, TEM MicroCT	Grain size, texture, pore size and distribution, deposited composition, phases present and distribution.
Samples for tensile testing-	Determine room and elevated temperature properties - in-situ DIC in SEM or during tensile testing	Multiple tensile tests followed by detailed fractography in the SEM, possible application of microCT	Correlate room temperature properties with elevated temperature properties and microstructure.

Main Points:

Many different characterization techniques that can be applied to these samples – we need to carefully select the techniques to be used in this study.

Comparison between the AM produced structures is difficult unless most (known) sources of variability are removed (starting material, build geometry…..)

If these are not controlled – comparisons between single beam and multibeam laser systems are meaningless or worse totally misleading.