Advanced Materials & Manufacturing (AAM)

Low Distortion Titanium Alloy in Laser Powder Bed Fusion Additive Manufacturing System

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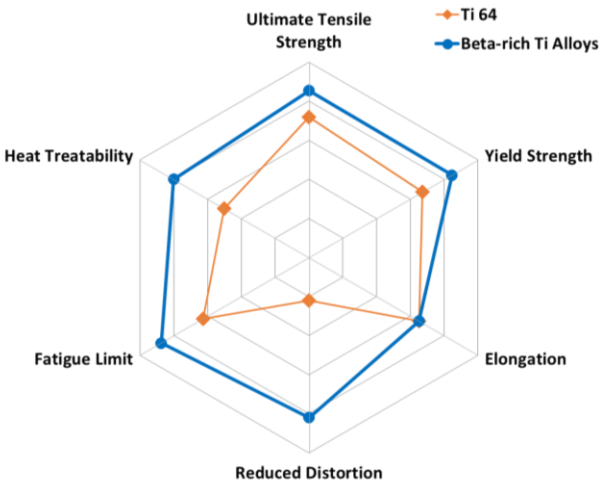
Printing Challenges in Laser Powder Bed Fusion Systems

- Titanium has challenges during printing in laser powder bed fusion (LPBF)
  - High residual stresses due to martensitic as-printed structure
  - Lack of heat treat options to fine tune mechanical properties
- High distortion in Titanium parts could lead to geometrical accuracy limitations and high scrap rates/cost during part development
- Beta-rich Ti alloys can be an advantage vs. Ti 64 in LPBF due to lower residual stresses, increased heat treat options, and higher mechanical properties



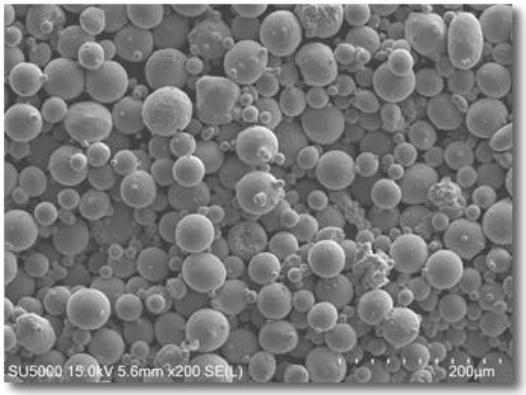
[1] Low Distortion Titanium in Laser Powder Bed Fusion Systems, Aerospace and Defense Technology, Dec. 2021

Improved Heat-Treatability

- ATI Titan 23™ is a proprietary high strength beta Ti alloy
  - U.S. Patent 11,001,909
- Ti-3.5Al-9V-5Sn-3Zr-2.5Mo
- This alloy offers superior performance in cast and wrought condition
  - Slow precipitation kinetics
  - Through section hardenability (11”)
  - Heat treatable
  - High strength capable

Commercialized Powder Production Method

- ATI produced powder via EIGA gas atomization using a full-scale production process
- Powder was screened to +15/-63µm powder size distribution for use in LPBF system
- Minimal Oxygen pickup of 0.05 wt.% compared to starting bar input feedstock (0.18 wt.% O in bar)
- Gas atomized powder is suited for AM use



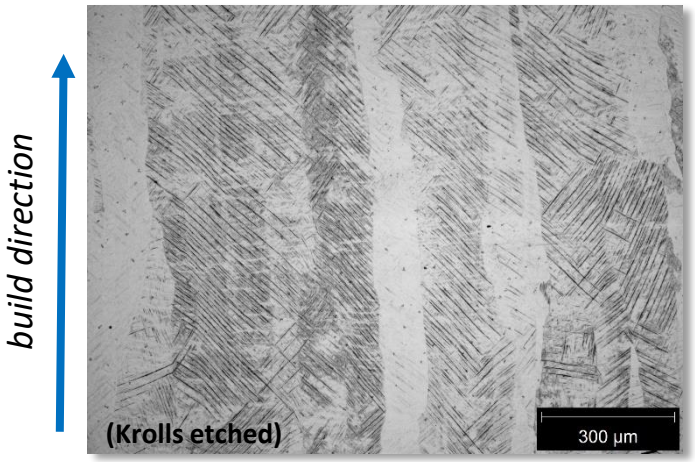
ATI Titan 23™ Powder 15-63um

V	Al	Mo	Sn	Zr	Fe	O	Ti
8.7	3.6	2.5	4.7	3.0	0.22	0.226	Bal.

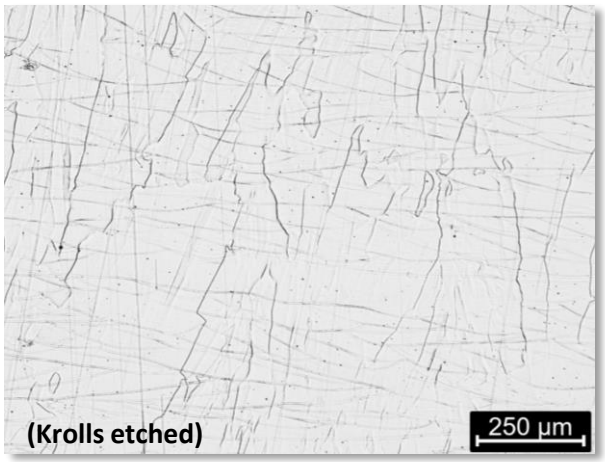
Powder Size Distribution (µm)		
D10	**D50**	**D90**
28.4	43.3	63.3

Simplified Printing Microstructures

- 50µm layer laser powder bed fusion process developed in SLM 125 using modified Ti 64 parameters
- Achieved 99.9%+ relative density in as-printed material
- As-printed structure appears to be free from martensite
- Material is printable and shows low residual stress



ATI 64 as-printed

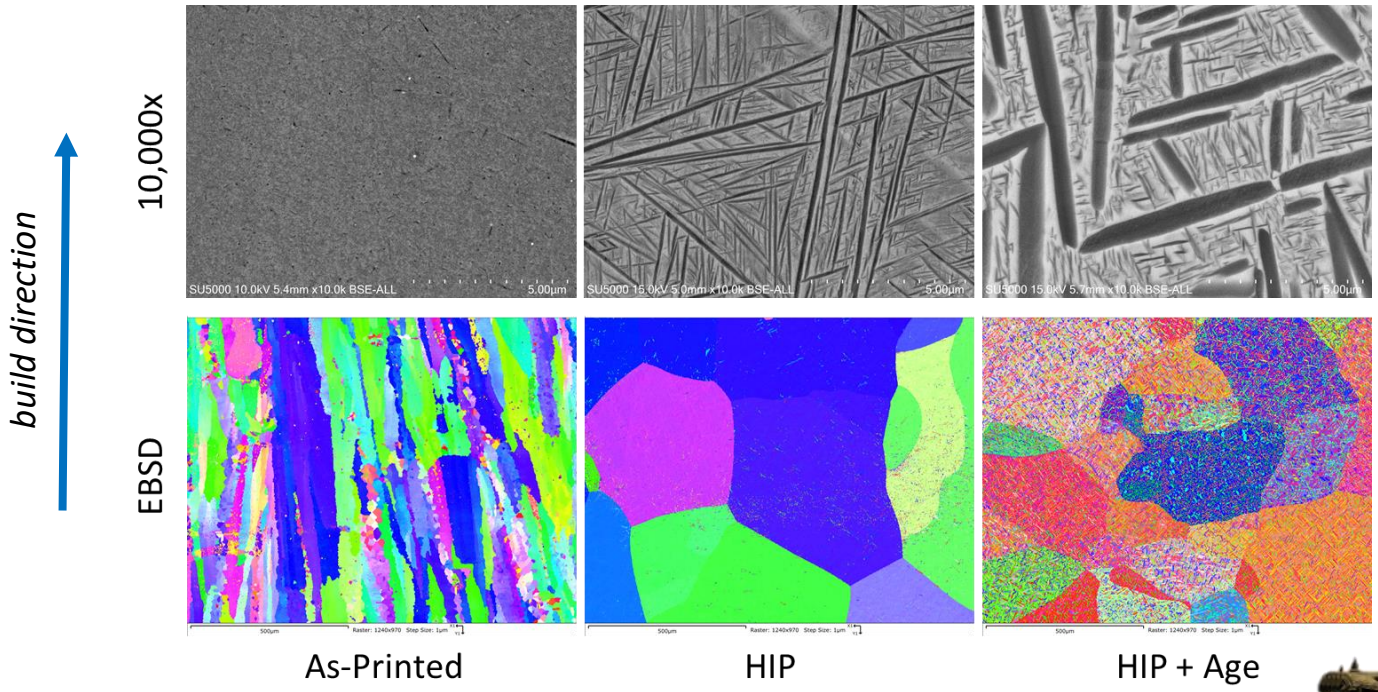


ATI Titan 23™ as-printed

Note: microstructures parallel to build direction

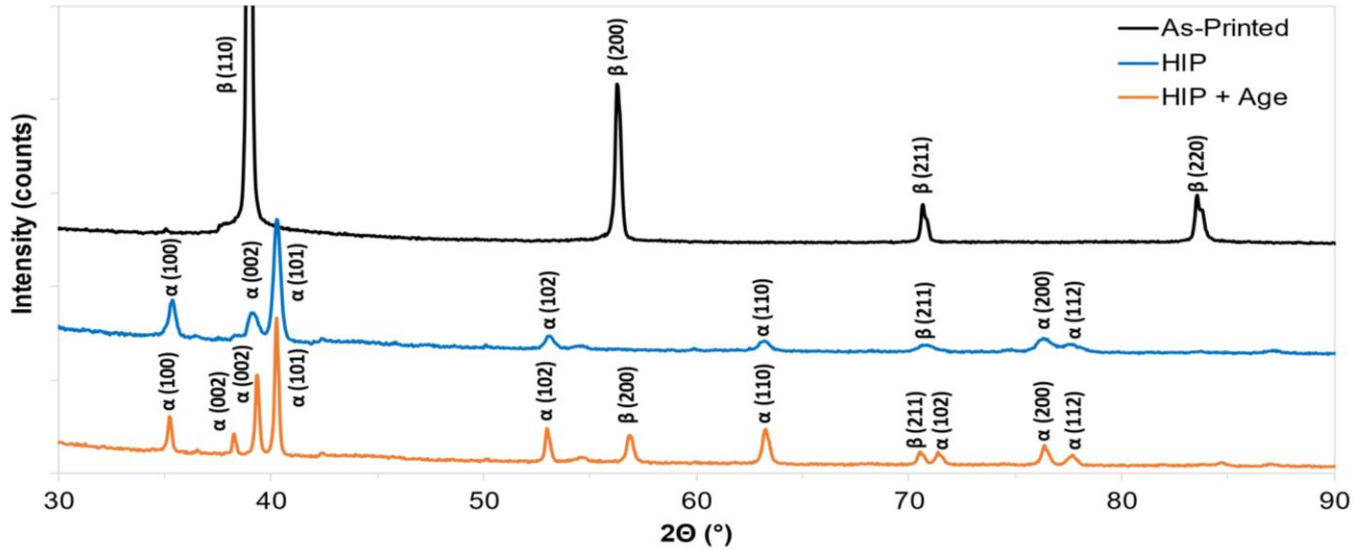
Homogeneous Post-HIP + HT Microstructure

- Small columnar beta grains are observed in the as-printed condition
- After sub-transus HIP, the material appears fully recrystallized
- Aging coarsens primary alpha and precipitates secondary alpha phase



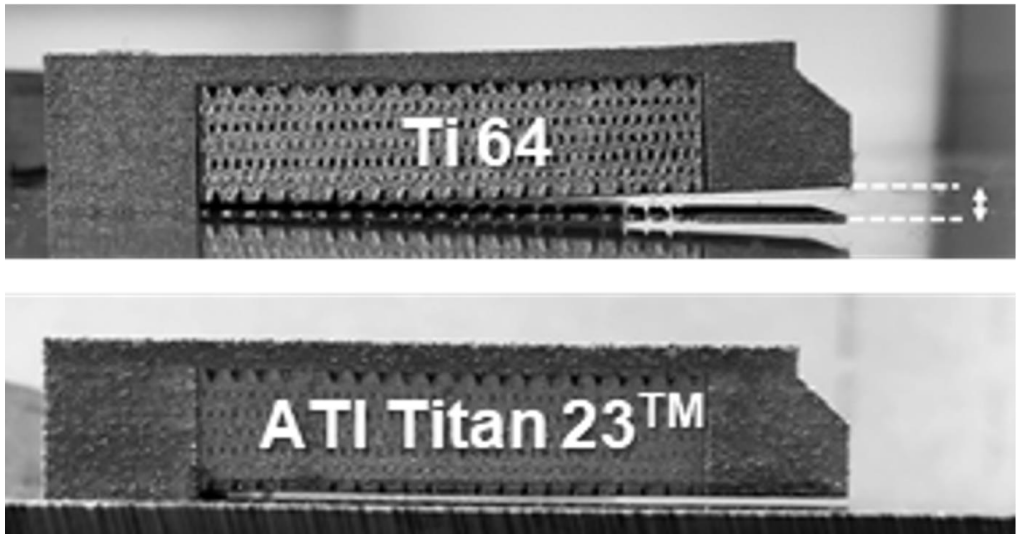
Superior Heat Treat-Ability in AM

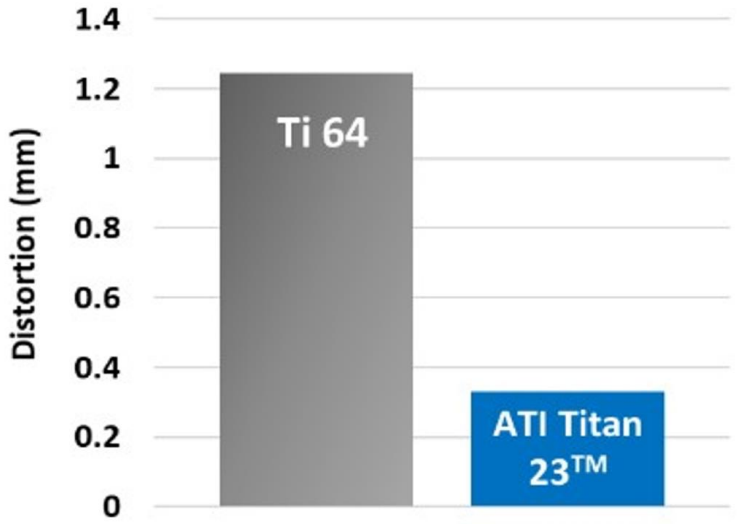
- XRD results confirmed printed material is all beta phase
- HIP process at temperatures under beta transus induced primary alpha precipitation
- Post-HIP aging treatment further increased alpha precipitation



Low Residual Stress and As-Built Distortion

- Lack of martensite in the as-printed condition leads to lower residual stresses and 75% less distortion compared to Ti 64 in the as-printed condition

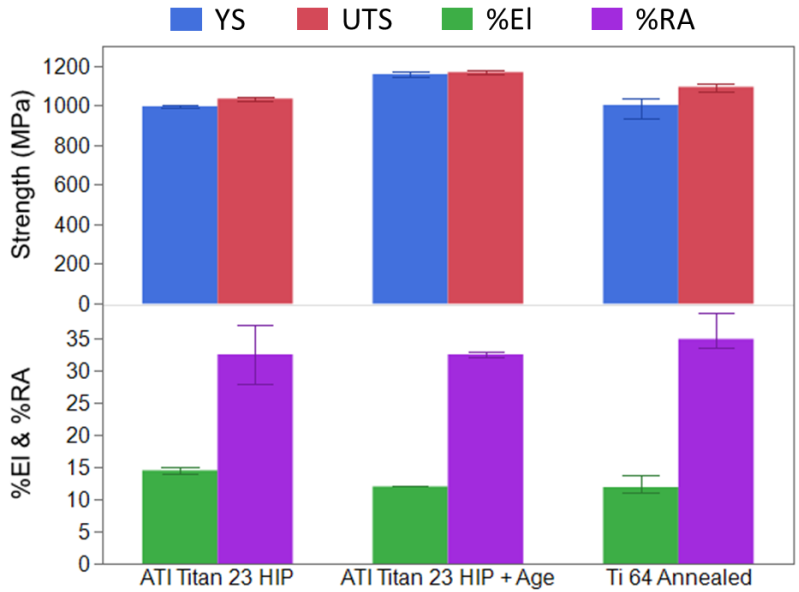




Improved Tensile Properties

- Primary alpha precipitation in the as-HIPed condition resulted in tensile properties similar to Ti 64
- Post-HIP aging induced secondary alpha precipitation and lead to 15% higher tensile properties than Ti 64

ATI Titan 23™ LPBF tensile bars build



*average of two tests

Summary

- Printability ATI Titan 23™ alloy was evaluated in a laser powder bed fusion system
- This alloy showed superior printability than Ti 64 due to the all-beta phase in the as-printed condition
  - Avoiding martensitic transformation during printing process
  - Reducing residual stresses and distortion by 75% compared to Ti 64
- The tensile properties of ATI Titan 23™ were equivalent to Ti 64 in the as-HIPed condition, and 15% higher in the HIP + age condition
- The superior printability and higher tensile properties of ATI Titan 23™ enables the application of large printed titanium structures like those found in large defense vehicles without the issue of process- induced distortions.