

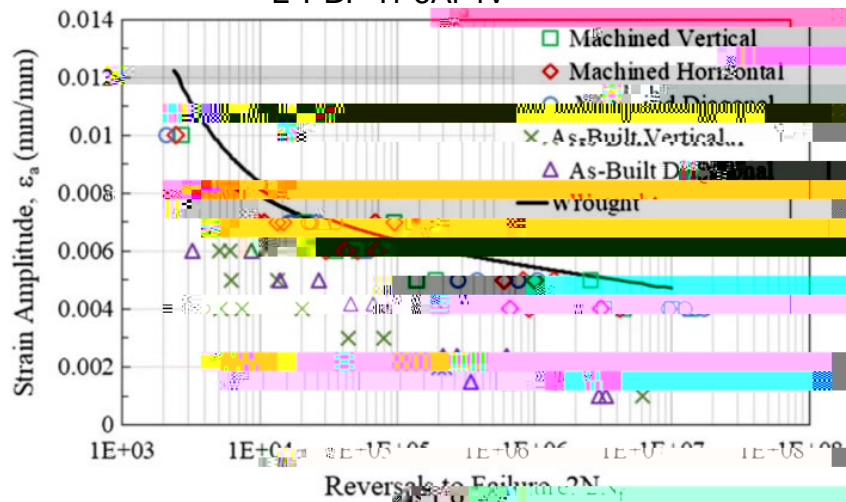


National Center for Additive Manufacturing Excellence

Factors Affecting Qualification/Certification - Surface Integrity of Additively Manufactured Ti-6Al-4V Parts

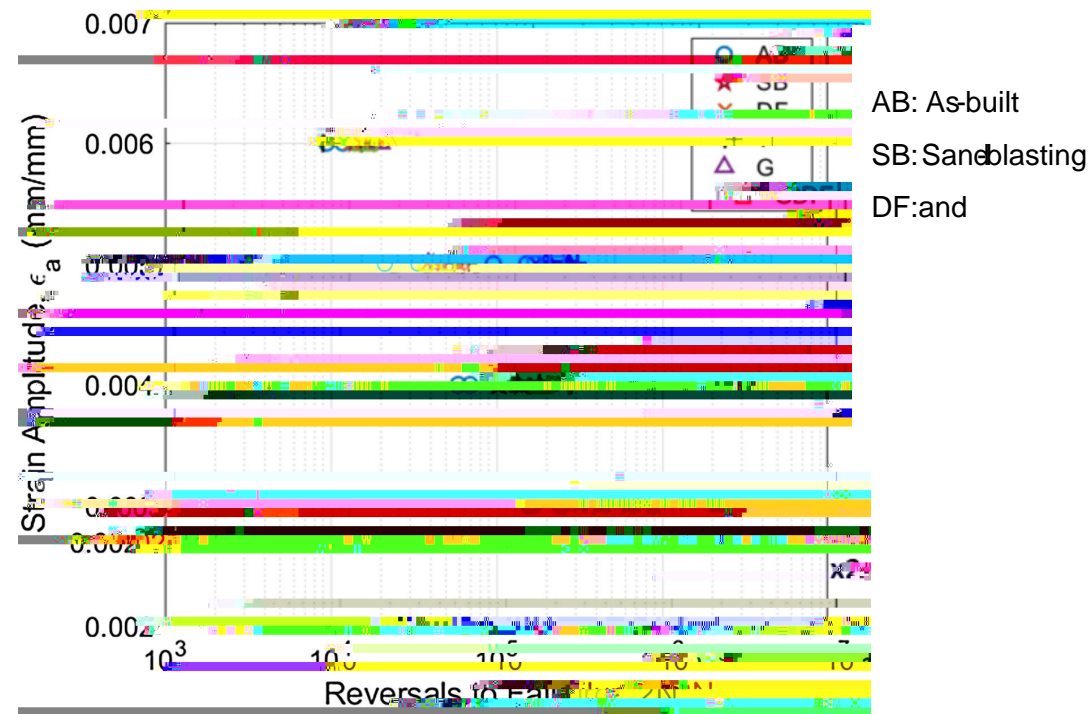
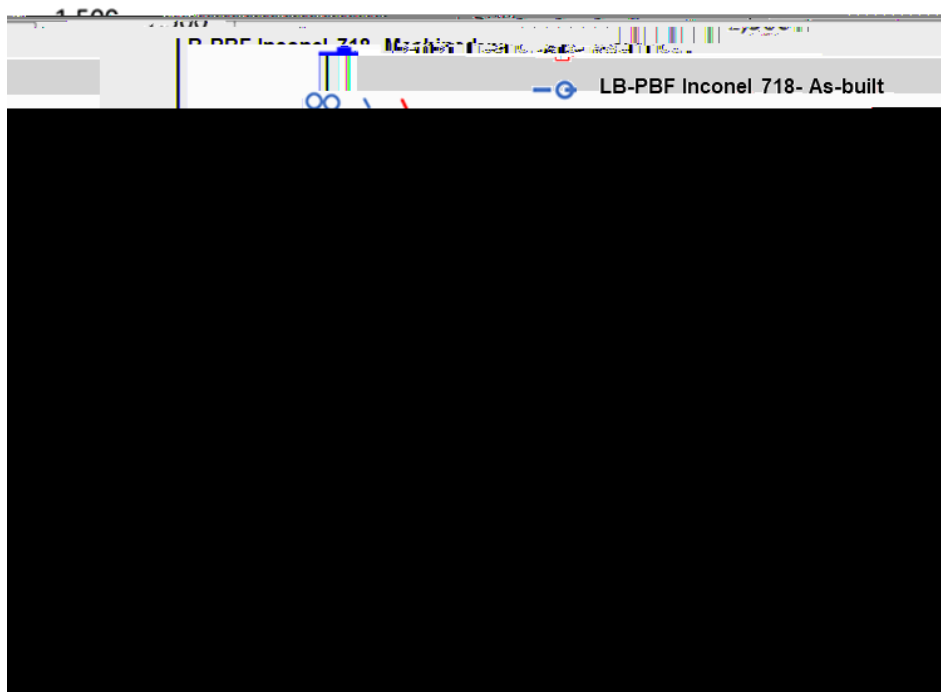
Background

L-PBF Ti-6Al-4V

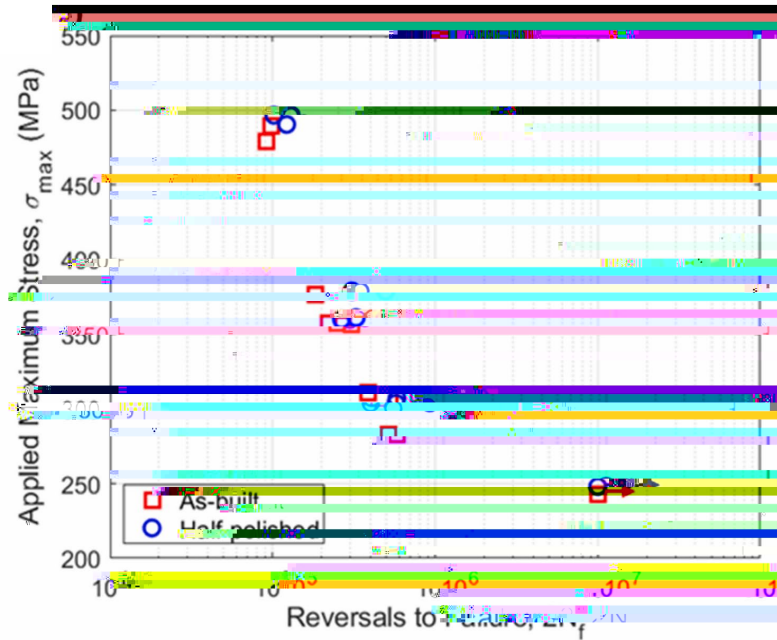


L-PBF Ti-6Al-4V

Background

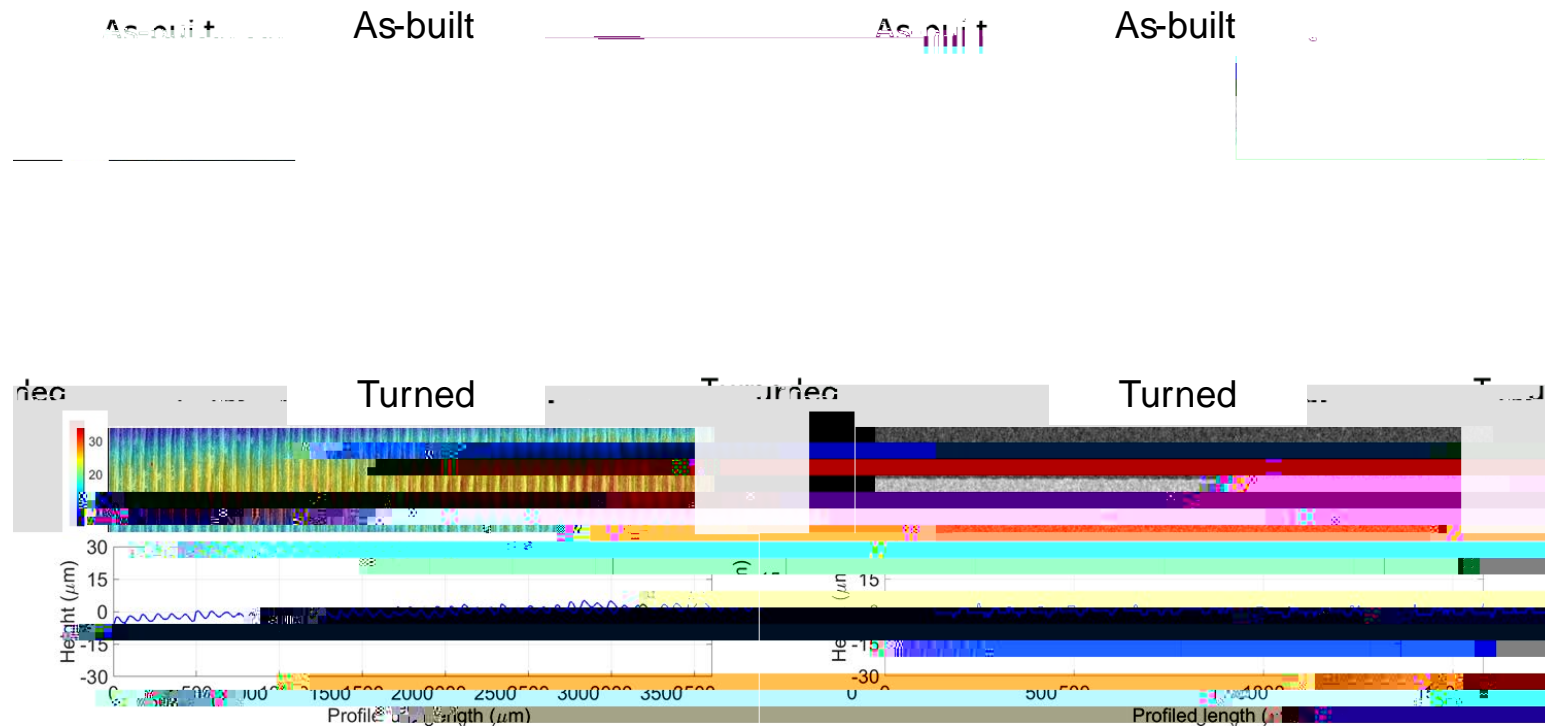


Challenge



Surface texture parameters	As-built		Half-polished	
	Line	Area	Line	Area
Arithmetical mean height (Ra)				

Challenge



- f* The applicability of different non-destructive inspection (NDI) techniques to measure the surface texture of parts has not been thoroughly studied
- f* While x-ray computed tomography (XCT) can capture surface texture and subsurface volumetric defects to use and the resolution may not be adequate
- f* Depending on the measurement technique employed, the calculated values of standard surface parameters

Objective & Approach

f Objective: Factors Affecting Qualification/Certification of Surface Integrity of Additively Manufactured Ti-4V Parts

f Approach: Four steps are taken,

- I. Explore the effect of key process variables and/or post-processing on surface and subsurface conditions
- II. Evaluate the effectiveness of NDI techniques to assess their capability of detecting material and manufacturing anomalies on the surfaces and subsurface
- III. Determine the combined effect of surface and subsurface defects on tensile behavior and fatigue life
- IV. Identify the key influencing defect features on tensile and fatigue properties and establish appropriate metrics characterizing surface conditions

Task List

- TASK 1: Literature Review & Design of Experiment (DoE)
 - 1.1. Literature review
 - 1.2. DoE
- TASK 2: Fabrication & Surface Treatments of Specimens
 - 2.1. Fabrication of specimens with recommended infill parameters
 - 2.2. Fabrication of specimens with recommended contour parameters
 - 2.3. Surface treatments of specimens
- TASK 3: NDI
 - 3.1. Digital/optical microscope
 - 3.2. XCT
 - 3.3. Florescent penetrant inspection
- TASK 4: Mechanical Testing & Fractography
 - 4.1. Tensile & fatigue tests
 - 4.2. Fractography
- TASK 5: Data Analysis & Modelling
 - 5.1. Effectiveness of NDI techniques to detect surface/surface critical anomalies
 - 5.2. Surface/near surface defect features to tensile behavior correlation
 - 5.3. Surface/near surface defect features to fatigue life correlation
 - 5.4. Representative surface metrics for the tensile and fatigue behavior of AM parts
- TASK 6: Final Report

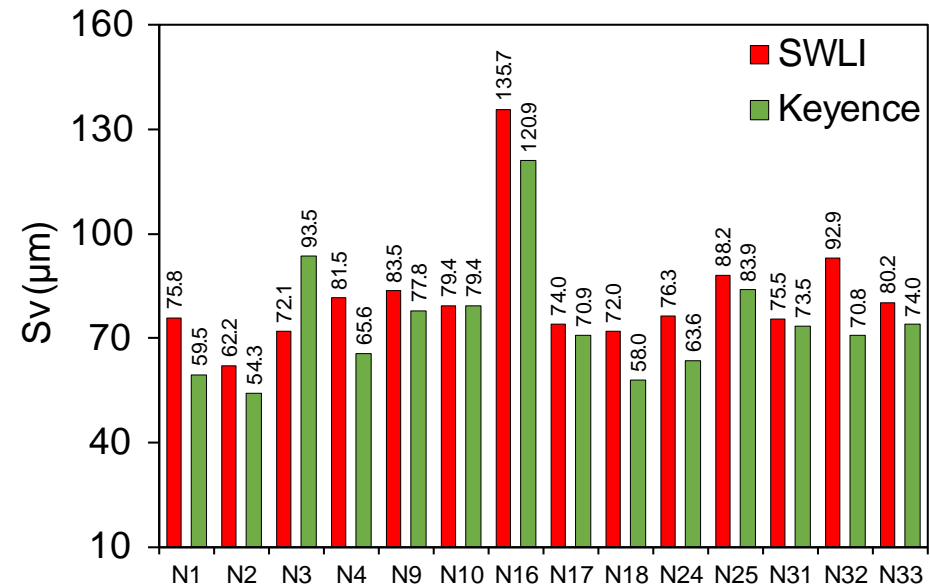
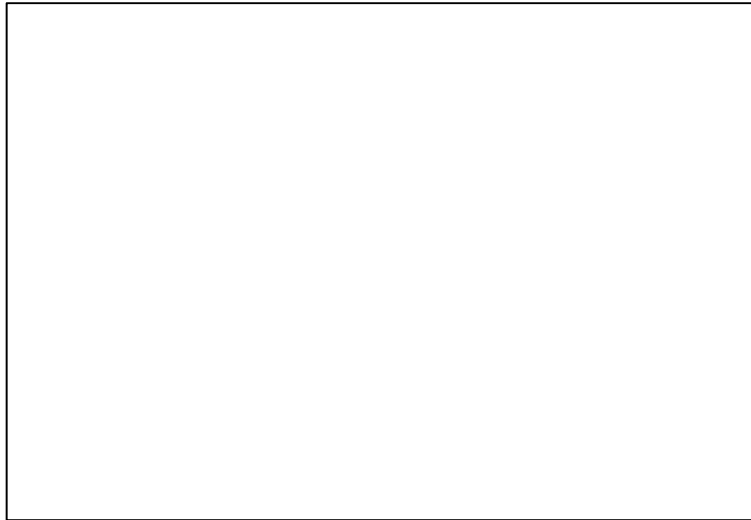
Objective & Approach

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f Approach: Four steps are taken,

- I. Explore the effect of key process variables and/or post

Results: Surface Texture of XCT Coupons



f Coupon without contour resulted in deepest surface valleys

f Infill process parameters (i.e., KH and LoF) did not significantly affect Sa and Sv values

Results: Selection of Process Parameters

Geometry	Orientation	Contour	Infill	Sa (μm)	Sv (μm)	Surface Treatment
Solid	Vertical	No contour	Default	19	135	No
Solid	Vertical	Order of contours	Default	20	74	No
Solid	Vertical	Order of contours	Default	20	70	No
Solid	Vertical	Order of contours	Default	19	76	No
Solid	Vertical	1 contour	Default	20	88	No
Solid	Vertical	1 contour	Default	17	75	No
Solid	Vertical	Different offsets	Default	21	92	No
Solid	Vertical	Different offsets	Default	17	70	No
Solid	Vertical	Default	KH	19	79	No
Solid	Vertical	Default	KH	21	83	No
Solid	Vertical	Default	LoF	21	75	No
Solid	Vertical	Default	LoF	18	62	No
Solid	Vertical	Default	LoF	20	93	No
Solid	Vertical	Default	Default	21	81	No

Note: Green shading indicates selected process parameters for fabrication of tensile and fatigue specimens

f Reported Sa and Sv values were obtained using SWLI

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Overview of NDI Techniques

Dektak

Advantages

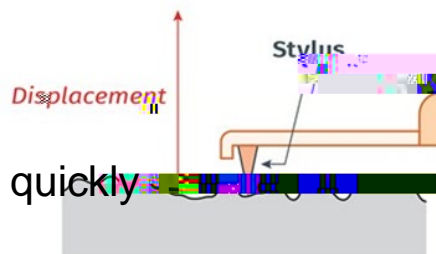
-Measurements can be obtained quickly

Disadvantages

- Requires continuous contact with the surface
- Performs line scans not area

Cost:

Cost	~\$10,000
Scan Time	2 Minutes



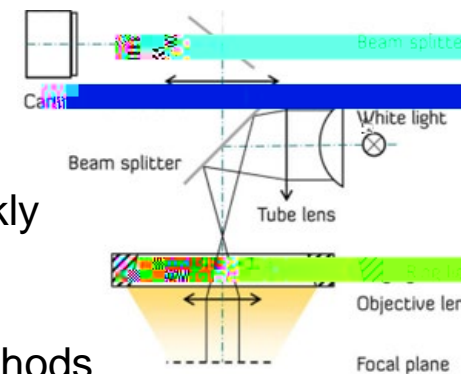
Keyence

Advantages

-Measurements can be obtained quickly

Disadvantages

- Glare can cause outliers in the data
- Resolution is not as fine as other methods



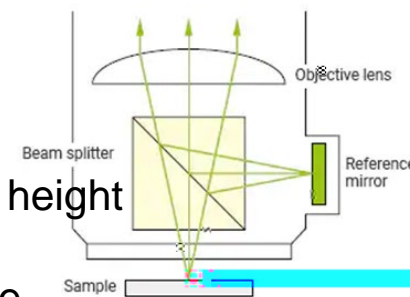
SWLI

Advantages

-Measurement can achieve subnanometer precision in height

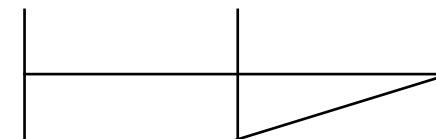
Disadvantages

- Cannot read spiky or nonreflective asperities



Cost	~\$200,000
Scan Time	40 Minutes

XCT



Results: Surface Texture from the Matching Areas

- f* XCT surface topography with overhang structures showed similar results to other techniques
- f* Dektak and Keyence showed lower roughness values



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Summary

- f* Variation in infill process parameters did not affect surface texture values
- f* Coupons without contour exhibited deepest surface valleys
- f* In general, Dektak and Keyence showed lower surface texture values compared to the SWLI and XCT
- f* The surface texture values obtained from the XCT were dependent on the specific method used for processing raw data
- f*

Thank you for your attention !

f National Center for Additive Manufacturing Excellence (NCAME)