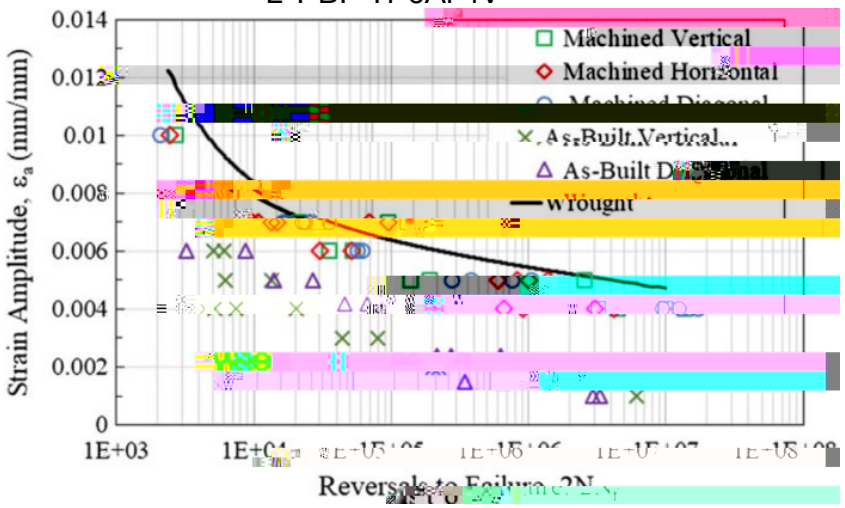
National Center for Additive Manufacturing Excellence

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

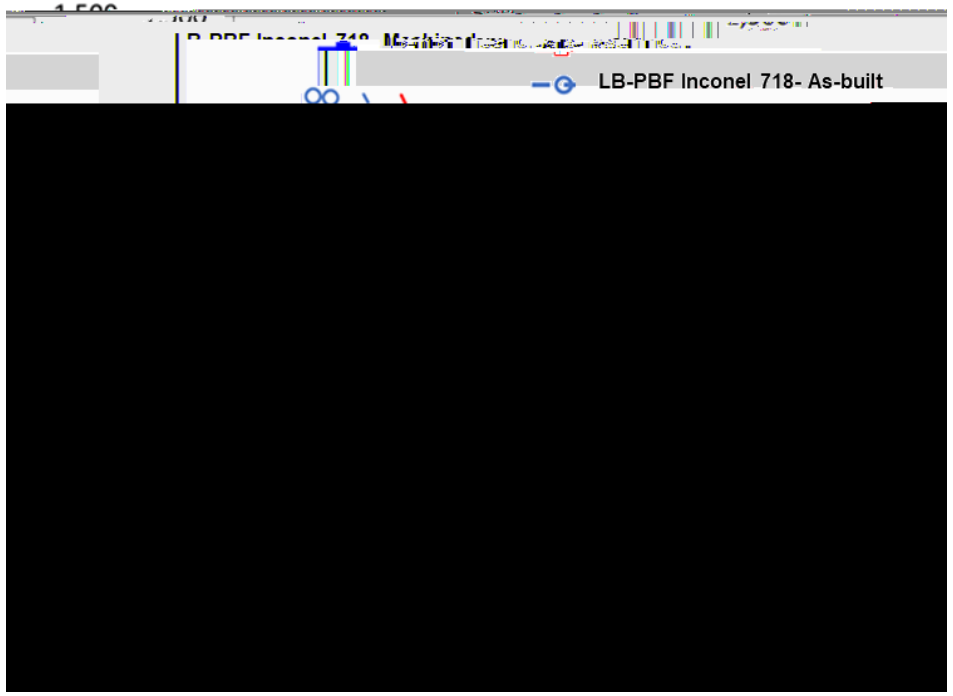
Background

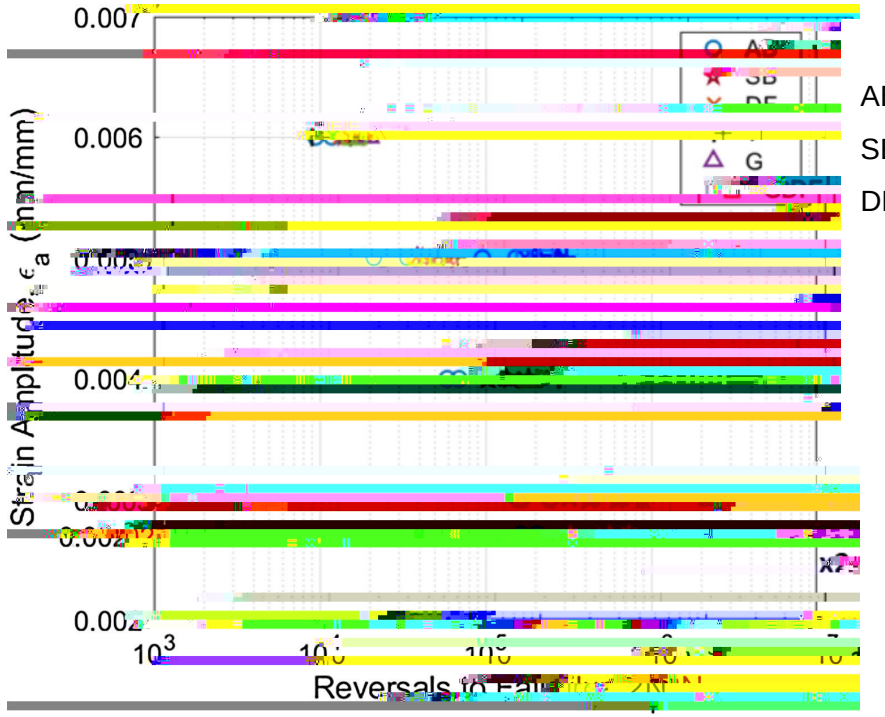
L-PBF Ti-6Al-4V



L-PBF Ti-6Al-4V

Background



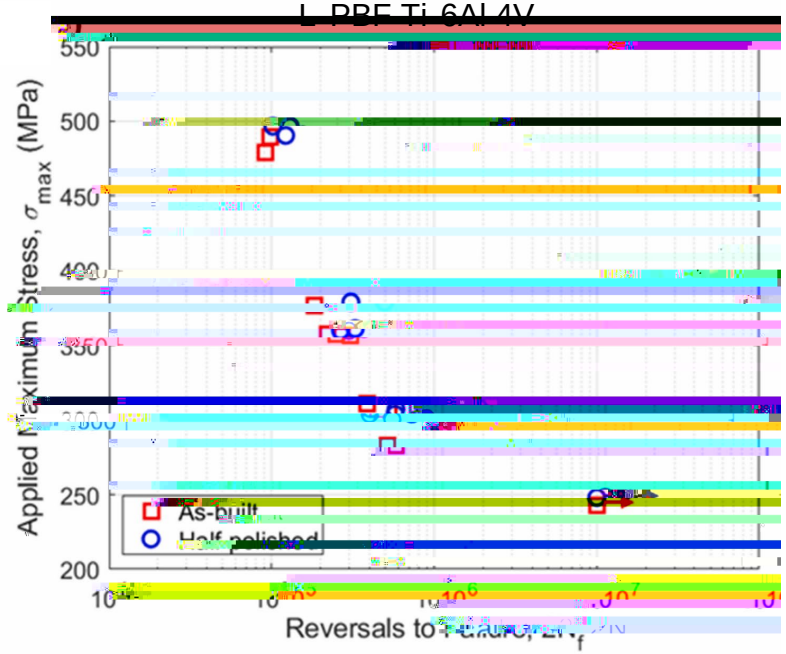


AB: As-built

SB: Sandblasting

DF: and

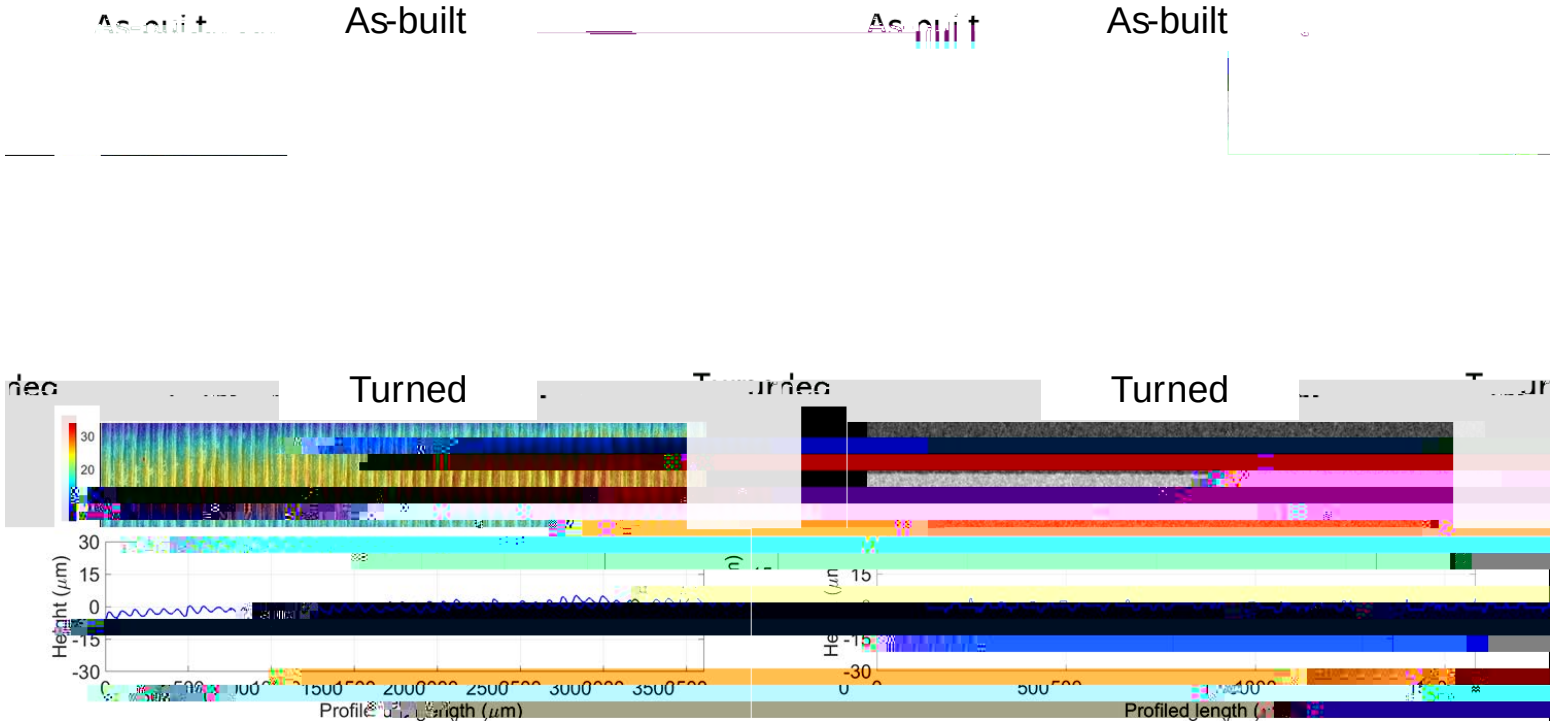
Challenge



Surface texture parameters	As-built		Half-polished	
	Line	Area	Line	Area
Arithmetical mean height (Raor Sa)	18.8 µm	19.8 µm	9.0 µm	11.6 µm
Root mean square deviation (Rqor Sq)	23.2 µm	24.5 µm	11.0 µm	14.0 µm
Maximum profile peak height (Rpor Sp)	62.8 µm	111.8 µm	15.5 µm	31.0 µm
Maximum profile valley depth (Rvor Sv)	58.7 µm	87.7 µm	35.2 µm	56.7 µm

- Although standard surface parameters for as-built and half-polished specimens differ by almost a factor of two, fatigue lives of half-polished specimens did not improve
- Standard surface parameters could not capture the effect of surface texture on the fatigue behavior of AM p

Challenge



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

Objective & Approach

- Objective: Factors Affecting Qualification/Certification – Surface Integrity of Additively Manufactured Ti-6Al-4V Parts
- Approach: Four steps are taken,
  - I. Explore the effect of key process variables and/or post-processing on surface and near-surface conditions
  - II. Evaluate the effectiveness of NDI techniques to assess their capability of detecting material and manufactu anomalies on the surfaces and near-surface
  - III. Determine the combined effect of surface and near-surface defects on tensile behavior and fatigue life
  - IV. Identify the key influencing defect features on tensile and fatigue properties and establish appropriate metric characterizing surface conditions

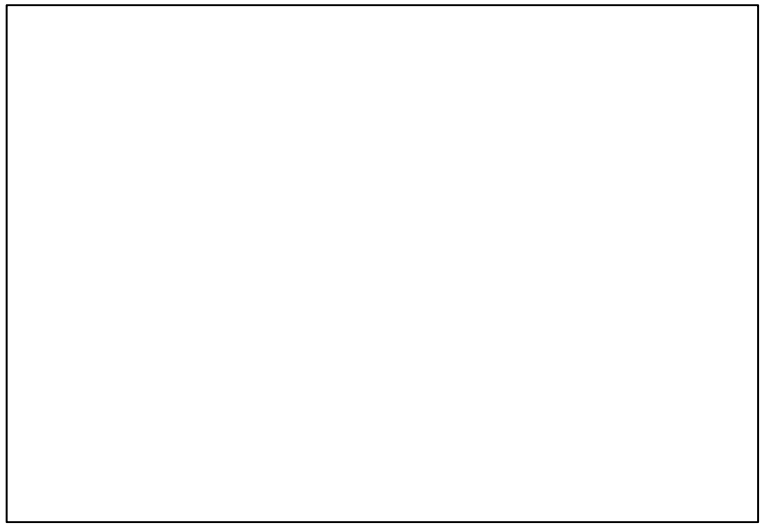
Task List

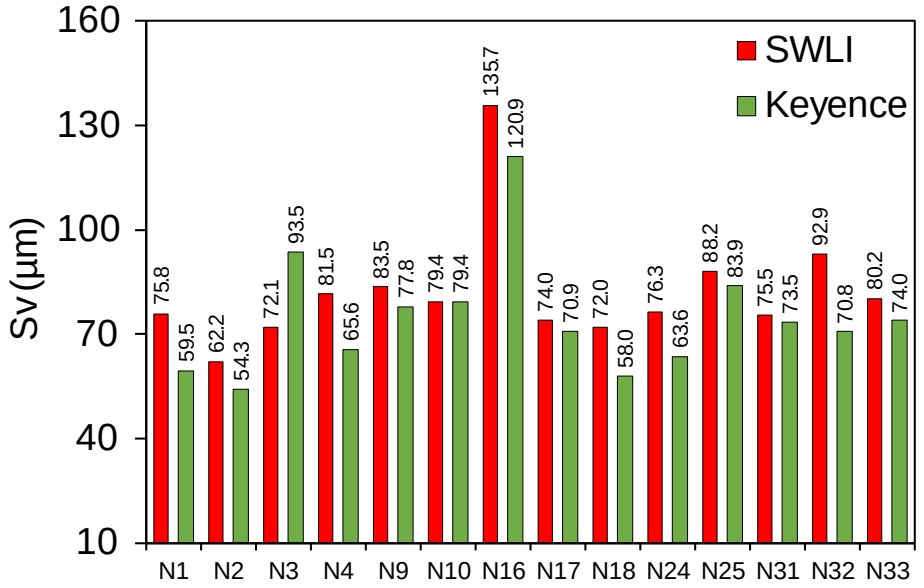
- TASK 1: Literature Review & Design of Experiment (DoE)
  - 1.1. Literature review
  - 1.2. DoE
- TASK 2: Fabrication & Surface Treatments of Specimens
  - 2.1. Fabrication of specimens with recommended infill parameters
  - 2.2. Fabrication of specimens with recommended contour parameters
  - 2.3. 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/near-surface critical anomalies
  - 5.2. Surface/near-surface defect features – tensile behavior correlation
  - 5.3. Surface/near-surface defect features – fatigue life correlation
  - 5.4. Representative surface metrics for the tensile and fatigue behavior of AM parts
- TASK 6: Final Report

Objective & Approach

- Objective: Factors Affecting Qualification/Certification Surface Integrity of Additively Manufactured Ti-6Al-4V Parts
- Approach: Four steps are taken,
  I. Explore the effect of key process variables and/or post

Results: Surface Texture of XCT Coupons





- Coupon without contour resulted in deepest surface valleys
- 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

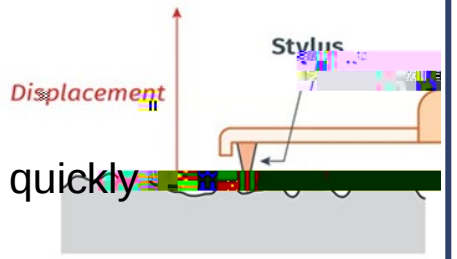
ƒ Reported Sa and Sv values were obtained using SWLI

Objective & Approach

- Objective: Factors Affecting Qualification/Certification of Surface Integrity of Additively Manufactured Ti-6Al-4V Parts
- Approach: Four steps are taken,
  - I. Explore the effect of key process variables and/or post-processing on surface and near-surface conditions
  - II. Evaluate the effectiveness of NDI techniques to assess their capability of detecting material and manufactu anomalies on the surfaces and near-surface
  - III. Determine the combined effect of surface and near-surface defects on tensile behavior and fatigue life
  - IV. Identify the key influencing defect features on tensile and fatigue properties and establish appropriate metric characterizing surface conditions

Overview of NDI Techniques

Dektak



Advantages

-Measurements can be obtained quickly

Disadvantages

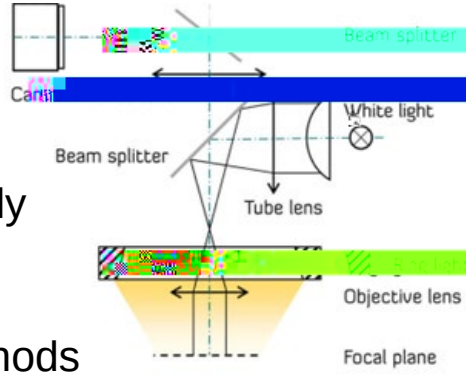
-Requires continuous contact with the surface

-Performs line scans not area

Cost:

Cost	~$10,000
Scan Time	2 Minutes

Keyence



Advantages

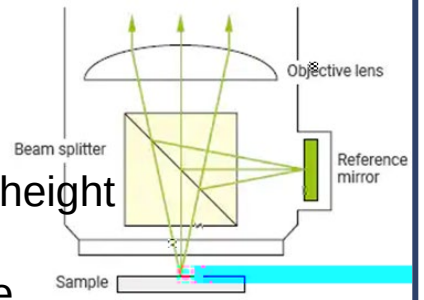
-Measurements can be obtained quickly

Disadvantages

-Glare can cause outliers in the data

-Resolution is not as fine as other methods

SWLI



Advantages

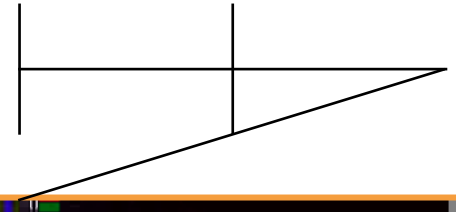
-Measurement can achieve subanometer precision in height

Disadvantages

-Cannot read spiky or nonreflective asperities

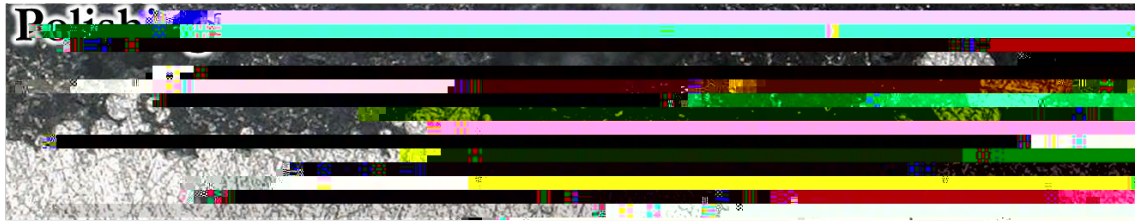
Cost	~$200,000
Scan Time	40 Minutes

XCT



Results: Surface Texture from the Matching Areas

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



Objective & Approach

- Objective: Factors Affecting Qualification/Certification of Surface Integrity of Additively Manufactured Ti-6Al-4V Parts
- Approach: Four steps are taken,
  - I. Explore the effect of key process variables and/or post-processing on surface and near-surface conditions
  - II. Evaluate the effectiveness of NDI techniques to assess their capability of detecting material and manufactu anomalies on the surfaces and near-surface
  - III. Determine the combined effect of surface and near-surface defects on tensile behavior and fatigue life
  - IV. Identify the key influencing defect features on tensile and fatigue properties and establish appropriate metric characterizing surface conditions

Summary

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

Thank you for your attention !

- National Center for Additive Manufacturing Excellence (NCAME)