Factors Affecting Qualification/Certification - Effect of Drifts in Key Process Variables within Tolerance on Mechanical Properties of Additively Manufactured Ti-6Al-4V Parts

Project sponsored by: Federal Aviation Administration (FAA)

Introduction

Project Title: Factors Affecting Qualification/Certification - Effect of Drifts in Key Process Variables within Tolerance on Mechanical Properties of Additively Manufactured Ti-6Al-4V Parts

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(See next slide for complete list of participants.)

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Project Team

Kevin

Challenge

For a fixed set of process parameters, factors such as powder specification, location, geometry, and time interval can also affect the fabricated parts' structure and properties

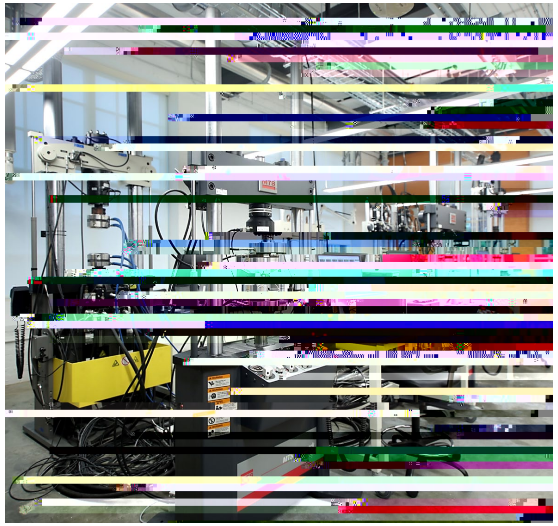
The effect of power re-use and location dependency will be investigated first so that their influence can be excluded from the KPVs drift study

Geometry and time interval will be kept constant

Fabrication and Testing Equipment

EOS M290 L-PBF Machine

X-ray Computed Tomography (XCT) Machine



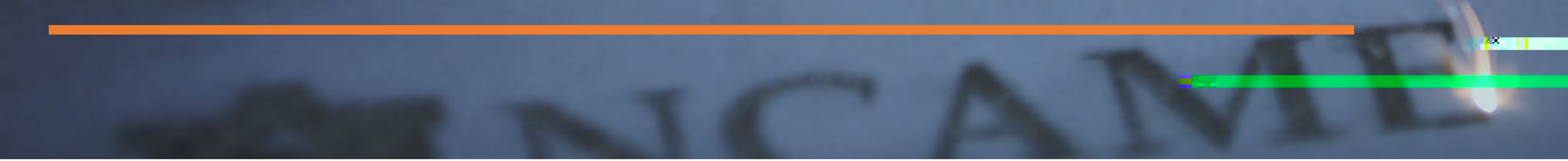
MTS Fatigue Testing Machines

Scanning Electron Microscope

AP&C Ti-6Al-4V Grade 5 powder (15-53 µm) was used as feedstock

During fabrication, time homogenization, and skywriting features were enabled in the infill region

All specimens were stress-relieved at 704 °C for 1 hour followed by furnace cooling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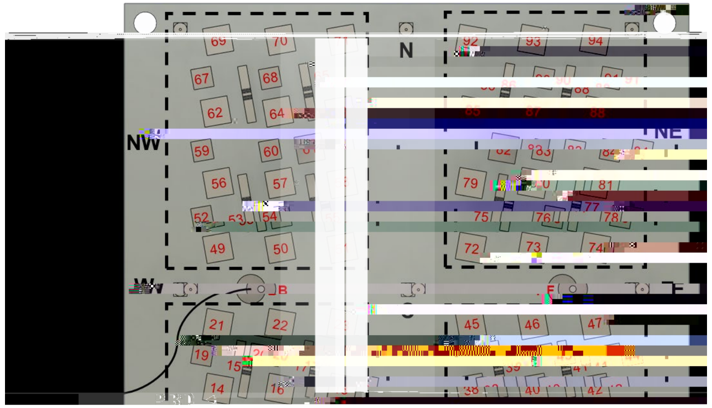
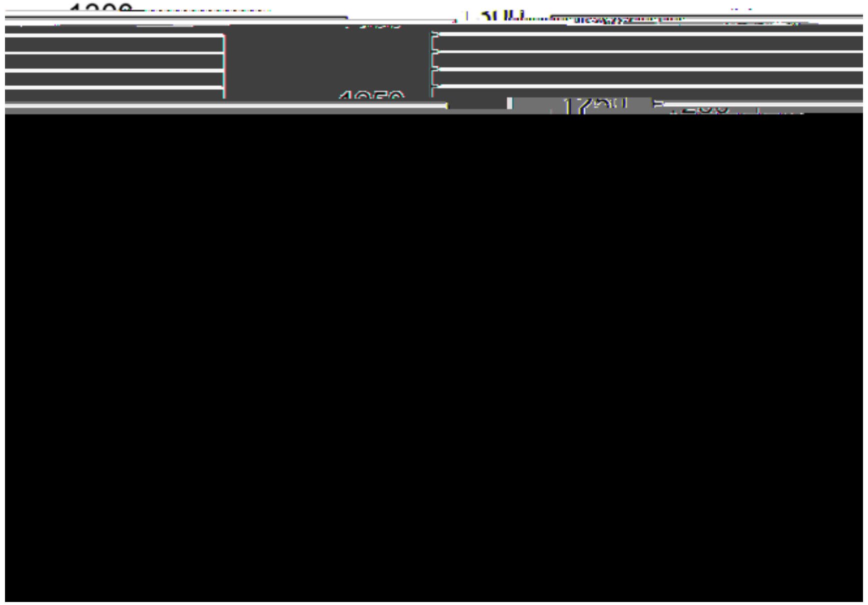
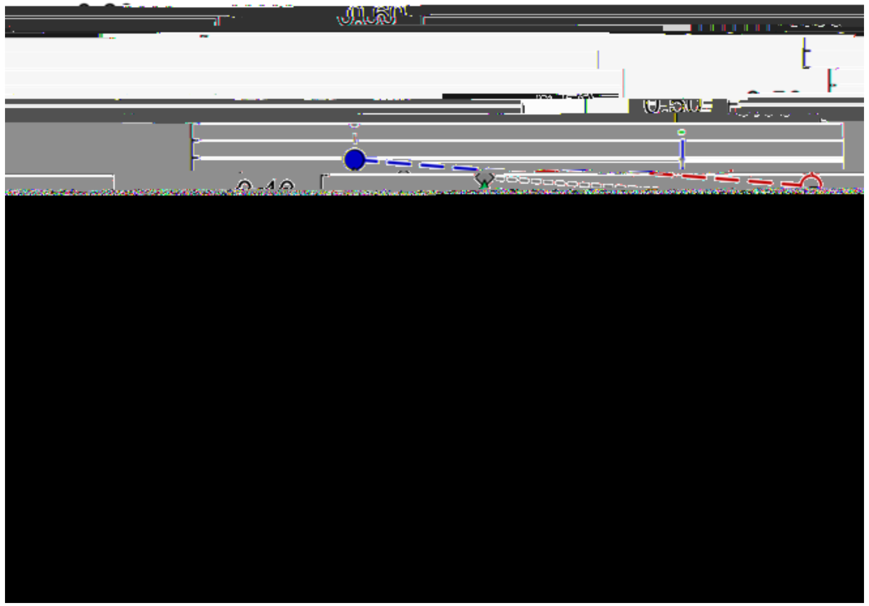
Effects of Powder Reuse on Tensile Properties



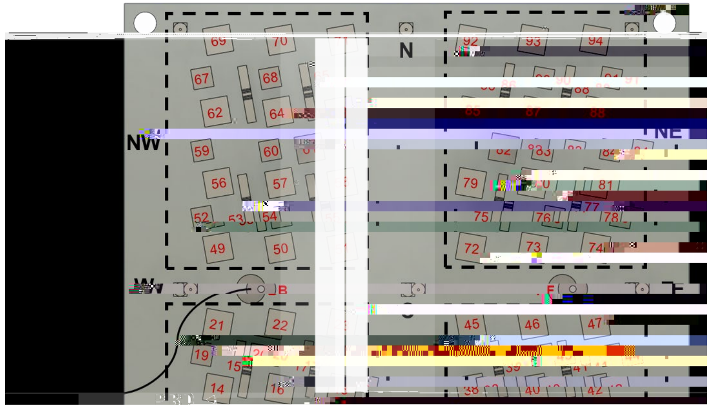


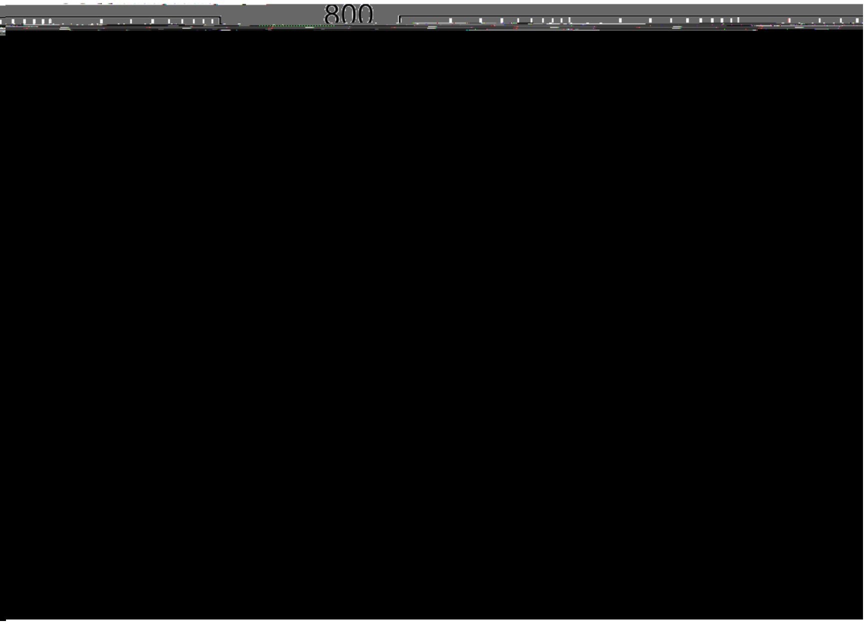


Slight increase in ultimate tensile strength and decrease in ductility with powder reuse was ascribed to the increase in oxygen/nitrogen content in the reused powder

Minor location dependency was also observed with south specimens exhibiting slightly higher strength and lower ductility

Effects of Powder Reuse on Fatigue Performance





Build Layout

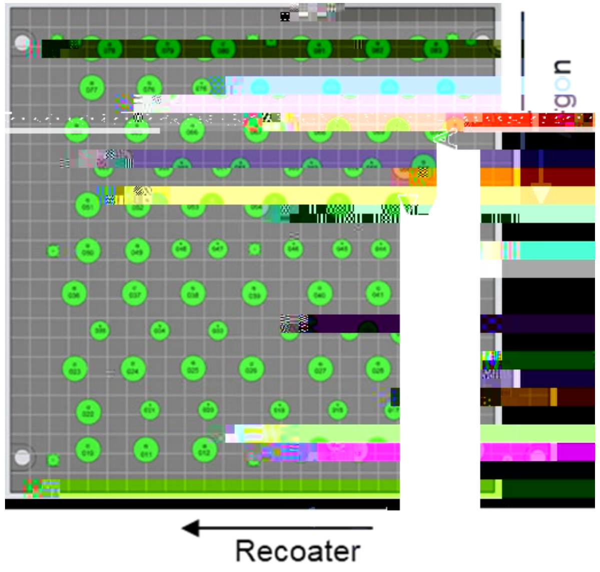
Fatigue Performance (North)

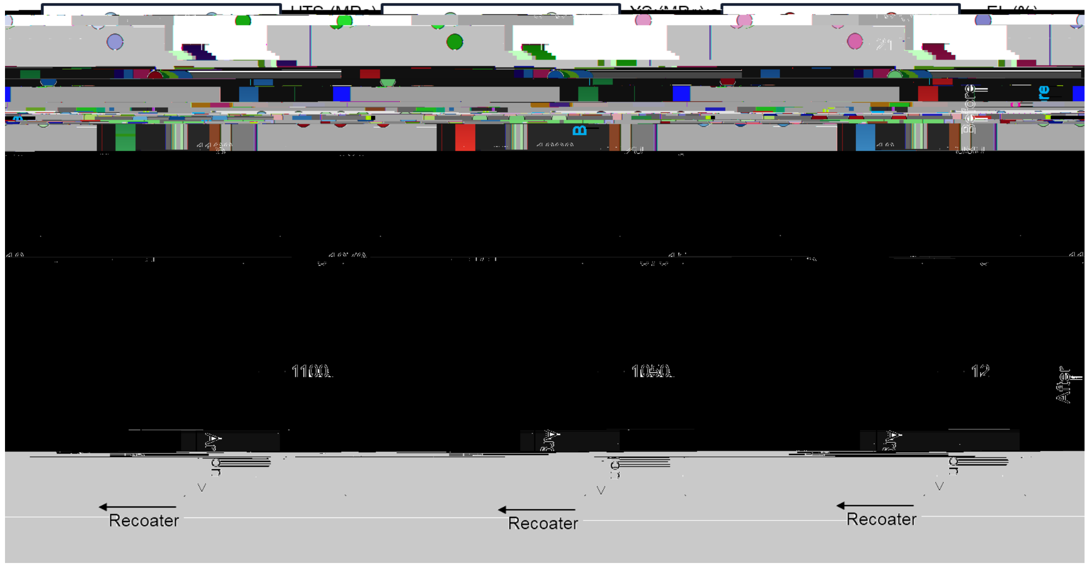
Fatigue Performance (South)

In North specimens, fewer defects in Print 4 led to slightly higher fatigue performance than other batches

Fatigue resistance of South specimens was lower than those from the North, and it was observed that the reuse of powder resulted in degradation, possibly due to the presence of spatter-induced defects

Effects of Filter Clogging on Tensile Properties

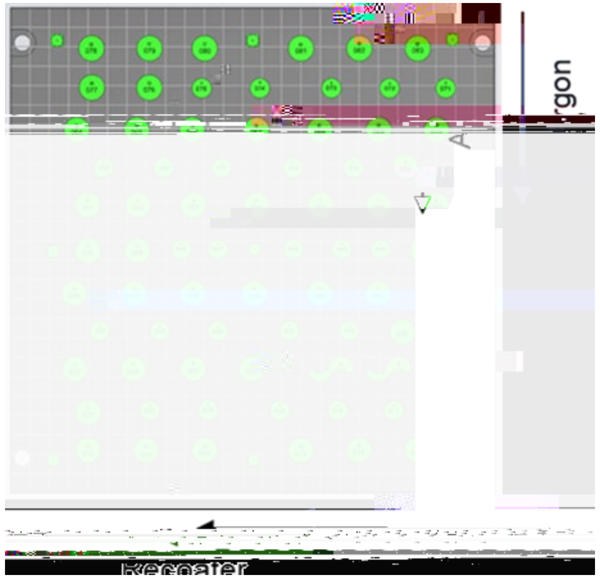


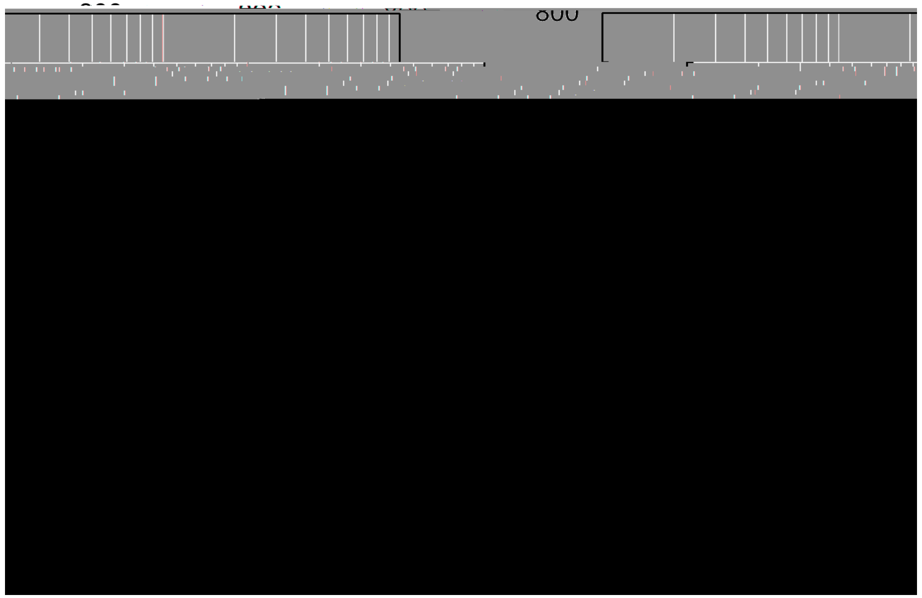


Note: 11 specimens per condition were tested from different locations of the build plate for this study

Overall, the center specimens exhibited superior tensile properties compared to those from the North and South, both before and after the filter change

Effects of Filter Clogging on Fatigue Performance





No significant difference in fatigue lives were found before and after the filter change

Objective & Approach

Objective: To understand the effect of KPVs drift within tolerance bands on defect characteristics and mechanical properties of L-PBF Ti-6Al-4V Gr. 5

Approach: Four steps are taken,

I. Quantify the powder re-use effects. Geometry and time interval will be kept constant

II. Identify the effect of filter clogging and location on the defect-structure, tensile and fatigue behaviors

III. Identify the combined effect of KPVs (laser power and hatch distance) drift and location on the defect-structure

IV. Evaluate the impact of KPVs drift on tensile, fatigue, and high strain rate fracture behaviors using specimens fabricated with worst KPVs/location combinations

V.

Design of Experiment for KPV Drift

	Hatch distance (h)		
Laser power (P)	h+	h0	h-
P+			
P0			
P-			

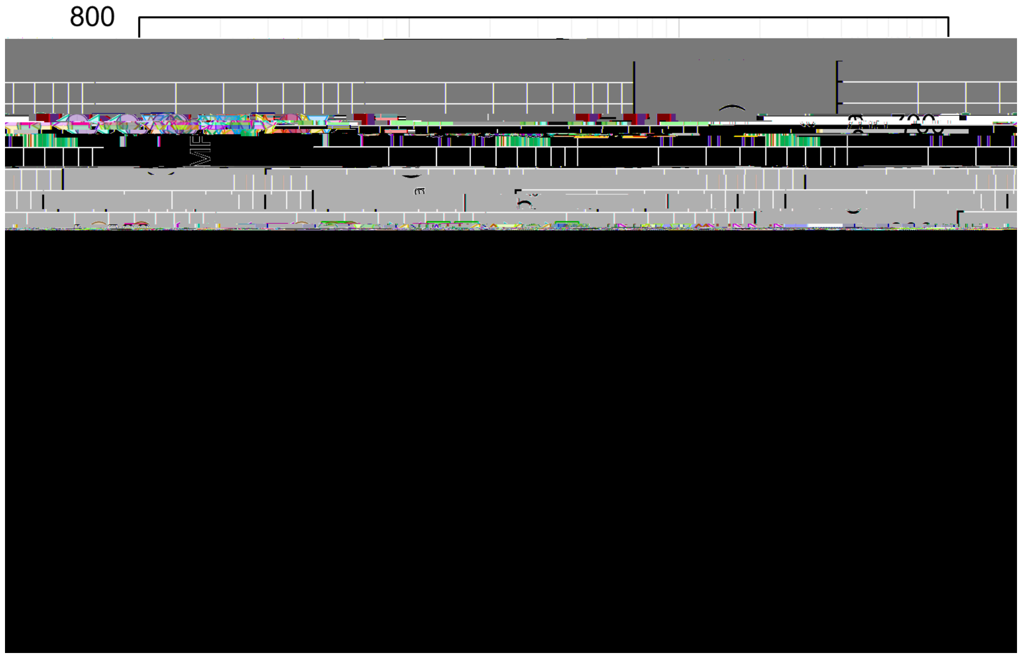
KPVs and their possible deviations in EOS M290 from the nominal values are laser power (± 4%), hatch distance (± 2.4%)

10 builds were fabricated to be tested, 7 for fatigue/tensile, and 3 for high strain rate specimens

- 105 fatigue (7 x 15), 42 tensile (7 x 6), and 42 high strain rate (7 x 6) specimens were fabricated

Specimens were fabricated in their respective best and worst locations based on the XCT coupons results

Effects of KPV on Fatigue Behavior



In general, no specific trend in fatigue lives were noticed within KPV tolerance

Effects of KPV on Fatigue Behavior

700 MPa 600 MPa 500 MPa

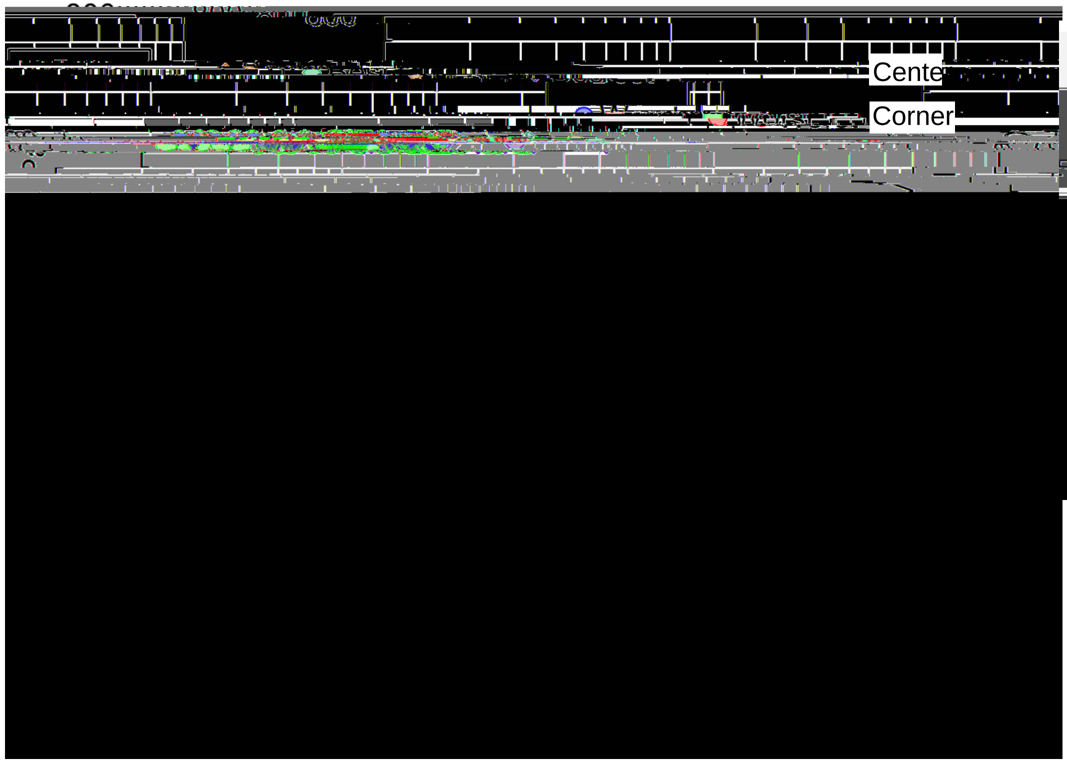
Although scatter was significant within KPV tolerance, there was no specific trend in fatigue lives

Effects of Location on Tensile Properties

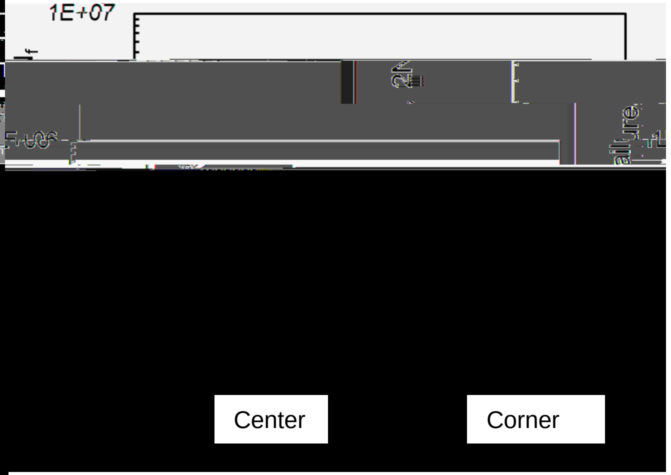
Center Corner

No significant change in tensile properties was noticed across different locations

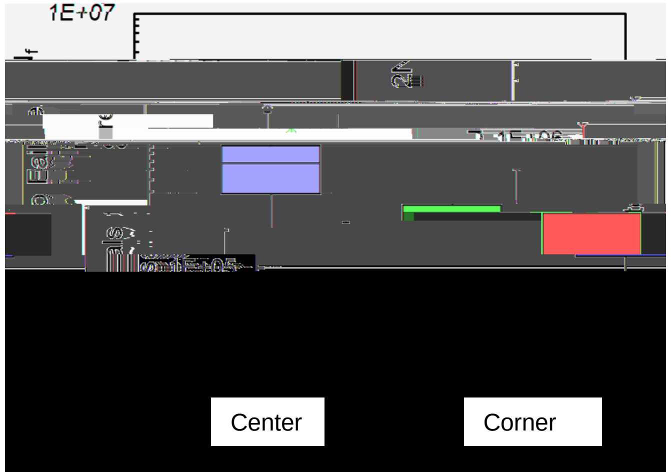
Effects of Location on Fatigue Behavior



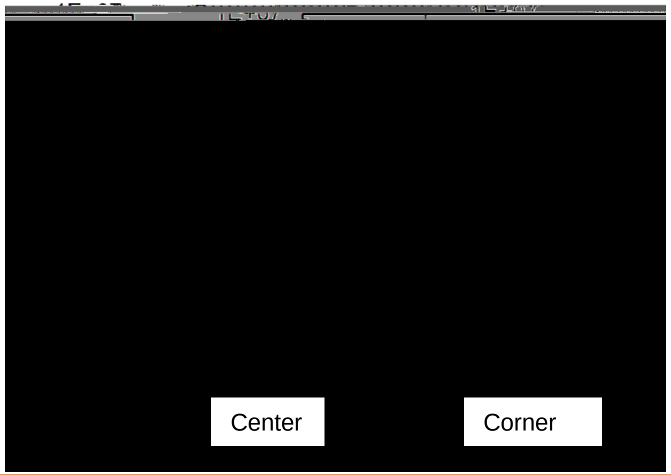
700 MPa



600 MPa



500 MPa



Effect of specimen location was more prominent at 500 MPa

Summary

Powder reuse exhibited a slight increase in strength and decrease in ductility

Powder reuse led to decrease in fatigue resistance

Filter clogging did not affect tensile and fatigue behaviors

Specimens fabricated within KPV tolerance did not show any specific trend in tensile and fatigue behaviors

The effect of specimen location on fatigue behavior was more noticeable at lower stress amplitudes

Thank you for your attention !

National Center for Additive Manufacturing Excellence (NCAME)