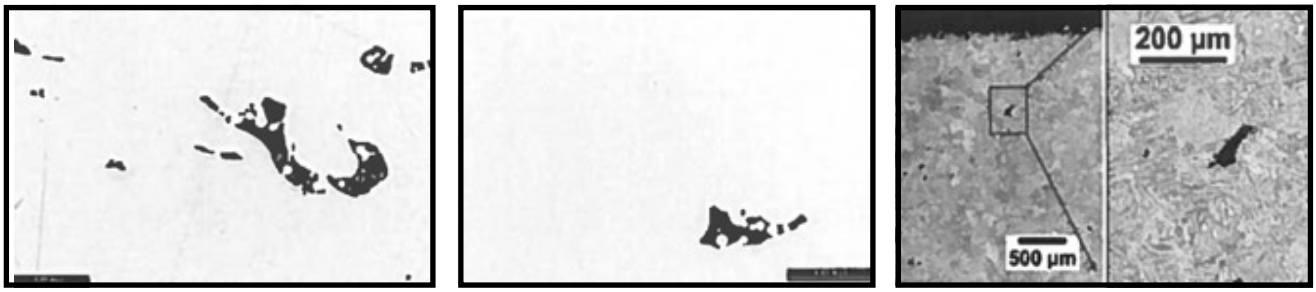
PROJECT SUMMARY 3013

MAMLS Understanding Stochastic Powder Bed Fusion Additive Manufacturing Flaw Formation and Impact on Fatigue



Examples of lack of fusion stochastic flaws observed in Ti-6Al-4V powder bed fusion additive manufacturing builds, post-build, and post-HIP.

PROBLEM

Stochastic flaws are observed in components produced by powder bed fusion additive manufacturing (PBFAM). The naturally occurring flaws are sometimes referred to as rogue or random flaws due to their seemingly random occurrence, even under optimized processing conditions. Stochastic flaws negatively impact fatigue properties, limit the ability to define design limits, hamper qualification efforts, and thus prevent widespread use of AM in many critical applications. To date, little is known regarding the probability of stochastic flaw formation, dependencies on primary and secondary process variables, and the impact of such flaws on fatigue properties.

OBJECTIVE

The objective of this project is to explore the relationships between PBFAM processes, the generation of stochastic flaws, and the subsequent impact such flaws have on fatigue properties. To achieve this objective, fatigue testing is to be performed on a high volume of AM samples which are then scrutinized via fractography, metallography, and examination of CT scans to quantify the impact of flaw characteristics on fatigue results. An additional goal is to systematically examine specific factors expected to contribute to the likelihood of formation of stochastic flaws through targeted experiments that couple comprehensive process monitoring with high-speed video.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to: MATERIAL

ASTM PROCESS CATEGORY: Powder Bed Fusion

EQUIPMENT: 3DS ProX 320, Renishaw AM250

MATERIAL: Ti-6Al-4V

TECHNICAL APPROACH

The technical approach is to develop statistically significant, pedigreed fatigue data for more than 150 Ti-6Al-4V components. Components are to be tested using an R-ratio of 0.1, subject to recommendations from industrial partners and the DoD sustainment community. Components are being evaluated to assess the influence of (i) virgin versus heavily reused powder and (ii) PBFAM system. Since the investigation targets stochastic flaws rather than intentionally embedded flaws, all processing is utilizing OEM-recommended process parameters. Natural build variations arising from changing location on the build plate and/or build density are being explored. Given that most fatigue-limited structures are used in critical applications, all samples are undergoing HIP prior to testing. Consistency in the post-process thermal treatment is also reducing variability in microstructure, thus allowing focus to remain on the effect of flaws.

Specific factors expected to contribute to formation of stochastic flaws, (e.g. powder thickness variations, contour-hatch and hatch-hatch overlap regions, scan direction relative to gas flow, etc.) are being systematically studied through targeted experiments that couple comprehensive process monitoring with high speed video and post-build CT scans in order to gain insight into the nature of stochastic flaw generation.

PROJECT START DATE

June 2018

EXPECTED END DATE

June 2020

EXPECTED DELIVERABLES

- Detailed plan for "fatigue" experiments defined
- Detailed plan for "understanding of flaw generation" experiment defined
- Interim report on first "understanding of flaw generation" experiment & analysis
- Final report (1. Fatigue results and analysis with raw data in electronic format, and 2. Results from flaw generation simulation & experiments with analysis)

FUNDING

$1.5M total project budget
($1M public funding/$500K private funding)

PROJECT PARTICIPANTS

Project Principal:
Pennsylvania State University

Other Project Participants:
3D Systems, Inc.
Moog, Inc.
Oerlikon, Inc.
UTRC

Public Participants:
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U.S. Department of Energy

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