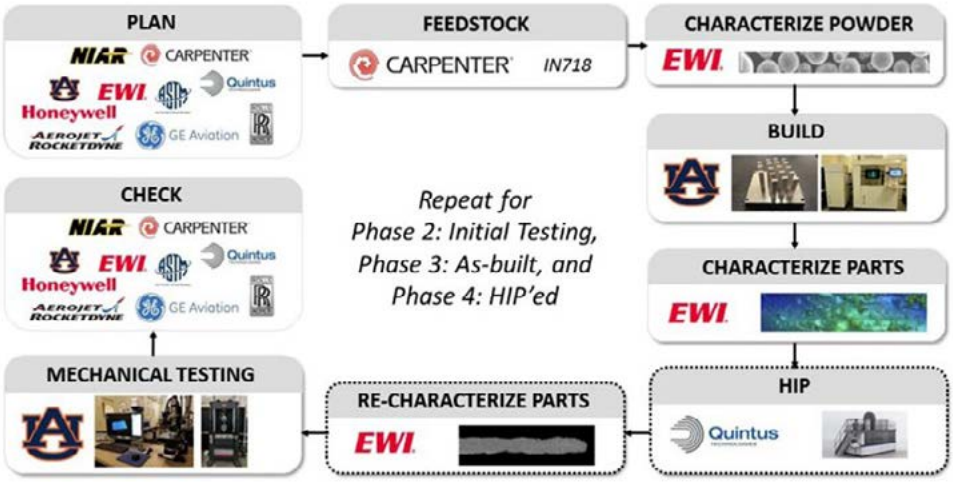
SUCCESS STORY 3025.002

Mechanical properties quantified for HIP and non-HIP in as-built thin wall IN718 parts

Data supports up to 15% time reduction of IN718 parts achieved through elimination of HIP



Utilizing a "Plan-Do-Act" methodology for developing an understanding of the mechanical debits associated with HIP vs. non-HIP LPBF IN718 parts.

PROBLEM

The cost/benefit of HIP and surface finishing is not well understood. The typical approach for IN718 components is to HIP, however, this process drives up part cost and lead times and eliminates the potential for the adoption or consideration of additive manufacturing (AM) processes for flight components due to the costs required for part qualification. There is a lack of best practices for post-processing of AM components, which is a key missing link in the process-structure-property-performance relationships. There has been much investment in understanding the AM process within the box of an AM system, but the "outside the box" parameters must also be understood to allow a holistic design-to-fly understanding of AM. A quantitative understanding of these processes would enable cost-benefit-based design and manufacturing decisions, reducing the cost of product development and simplifying qualification.

OBJECTIVE

The objective of this project activity was to determine and enable the use of quantitative mechanical performance debits for both as-built and HIP'd thin-walled components and components with narrow flow channels by generating a high-pedigree, coupon-level dataset using commercially available manufacturing and post-manufacturing process parameters; determining mechanical performance debits; validating those factors through limited functional testing; publishing draft standards that enable a reduction in qualification and certification cost and time; and correlating roughness measurement metrics to mechanical performance debits to enable quality assurance.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

PROCESS

ASTM PROCESS CATEGORY
Powder Bed Fusion

EQUIPMENT
EOS M290 (400W)

MATERIAL
Inconel 718

TECHNICAL APPROACH

The project was led by Auburn University and included EWI, NIAR, ASTM International, Carpenter, Quintus Technologies, and NASA. To maximize industrial relevance, the work was guided by AeroJet Rocketdyne, GE Aviation, Honeywell, Raytheon, and Rolls-Royce. Test specimens were fabricated with laser powder bed fusion (LPBF) using IN718, due to the availability of process parameter sets and industrial need and relevance. These parts were fabricated using an EOS M290-400W system, utilizing default EOS process parameters for IN718, in an argon build environment with 40-µm layers. Specimens were fabricated with a minimum support structure and HIP'd utilizing standard process parameters.

The project progressed through four "plan-do-check" cycles: initial testing to validate methods, including HIP, CT, optical metrology, and mechanical testing; as-built coupon testing; HIP coupon testing; and validation by burst testing thin wall components with narrow flow channels.

ACCOMPLISHMENTS

Microstructure and mechanical properties, including tensile and fatigue, of both thin wall features (TW) and narrow flow channels (NFC) manufactured with laser powder bed fusion (LPBF) were characterized in this project. With specimens of these geometries, this program determined the mechanical performance debits of using as-built surfaces relative to machined surfaces and using conventional heat treatment (HT) relative to the supplementation of hot isostatic pressing (HIP). Overall, the results suggested that the absence of either HIP or surface machining resulted in no measurable debits in low-to mid-cycle fatigue performance. Surprisingly, HIP was shown to decrease strength while slightly improving ductility under quasi-static loading. Surface machining improved ductility but did not influence strength. These results suggest that the production cost and lead time of IN718 TW and NFC AM parts can be reduced by eliminating post-processing steps that do not improve performance.

PROJECT END DATE

May 2021

DELIVERABLES

- Data management plan
- Test matrix and test artifact design
- Data management review
- Report summarizing validations measurements performed and test plan modifications
- Validation datasets
- High pedigree datasets
- Reports summarizing analysis results
- Data management review
- Draft standards
- Report comparing burst testing to expectations based on mechanical performance debits

FUNDING

$1,200,943 total project budget
($799,080 public funding/$401,863 private funding)

PROJECT PARTICIPANTS

Project Principal:
Auburn University

Other Project Participants:
Edison Welding Institute (EWI)
NIAR
ASTM International
Carpenter
Quintus Technologies
NASA
AeroJet Rocketdyne
GE Aviation
Honeywell
Raytheon
Rolls-Royce

Public Participants:
U.S. Department of Defense