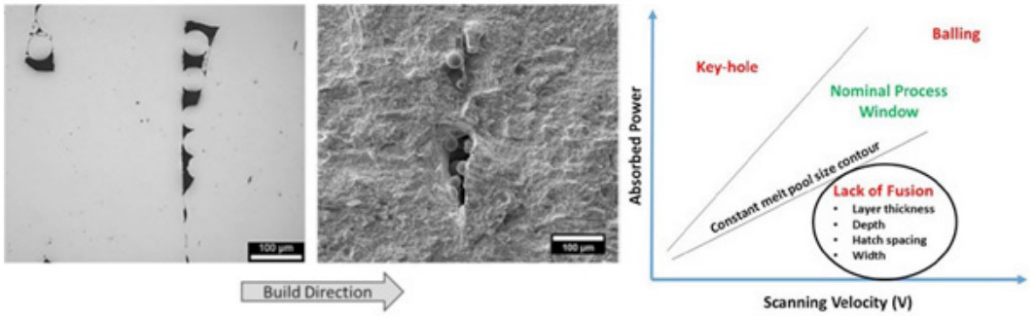
SUCCESS STORY 3012

*Establishment of airworthiness and inspection acceptance criteria for LPBF AlSi10Mg addresses U.S. Air Force sustainment applications.*

# Project quantifies effects of lack of fusion and feedstock contamination on mechanical and corrosion material properties for LPBF AlSi10Mg




*Lack of fusion defects shown (sectioned view and surface) that may have an effect on the physical properties of an additively manufactured part based on the absorbed power to scanning velocity ratio*

## PROBLEM

The U.S. Air Force is interested in the use of laser powder bed fusion (LPBF) to produce AlSi10Mg replacement parts, but material data which are readily available are inadequate to address airworthiness requirements. It is known that discontinuities (pores and lack of fusion) and material feedstock contamination may cause significant debits in AM product performance. Inspection technologies that can readily detect discontinuities and feedstock contamination relevant to sustainment applications require demonstration and validation. At present, the attributes of discontinuities and feedstock contamination which cause unacceptable effects on AM product performance are unknown and are necessary to establishing inspection acceptance criteria. Failure mechanisms of immediate concern include overload, dynamic loading, and corrosion. A quantitative understanding of the effects of feedstock contamination and discontinuities on LPBF AlSi10Mg tensile, fatigue, and corrosion properties will accelerate the development of airworthiness requirements and inspection acceptance criteria for a wide range of defense sustainment applications.

## OBJECTIVE

The objective of this program was to study the effects of a lack of fusion defects and powder contamination in the LPBF process. Several applications were identified involving casting-type alloys such as AlSi10Mg. The program built on the results of a previous effort under Phase 2 of the Maturation of Advanced Manufacturing for Low-Cost Sustainment (MAMLS) program by utilizing the baseline processing conditions, including post-processing.

**AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP**

This project aligns to: MATERIAL

**ASTM PROCESS CATEGORY:** Powder Bed Fusion

**EQUIPMENT:** 3DS ProX 320, UTC ATLAS

**MATERIAL:** AlSi10Mg

## TECHNICAL APPROACH

The approach consisted of two technical tasks to research the creation, detection, and effects of (task 1) lack of fusion (LoF) and (task 2) feedstock contamination. Processing parameters and manufacturing practices were developed to repeatably manufacture material containing LoF of various sizes and volumetric number densities. In addition, AlSi10Mg feedstock powder was intentionally dosed with contaminant (IN-718) in various graduations. The effects of discontinuities and feedstock contamination on material mechanical (tensile, fracture toughness, fatigue, fatigue crack growth) and corrosion (immersion, salt fog, intergranular, stress corrosion cracking) properties were tested and analyzed. Detectability of discontinuities and feedstock contamination was evaluated using several inspection lifing methods including computed tomography (CT), radiographic testing (RT), and process compensated resonance testing (PCRT). Laser power and velocity parameters were developed to create repeatable LoF defects of various sizes and defect densities to determine NDT detectability. The material mechanical and corrosion property data were integrated with an AM material lifing model for defense sustainment applications.

## ACCOMPLISHMENTS

Size, number density, and shape of lack of fusion were characterized for a range of AM and post-processing conditions. In addition, AM processing and manufacturing practices were developed to investigate the effects of incremental dosing of AlSi10Mg feedstock powder with a contaminant (IN-718). The effects of lack of fusion and feedstock contamination were quantified via mechanical and corrosion testing of LPBF AlSi10Mg test coupons. Materials with LoF < 140 µm exhibit a negligible influence on the material properties investigated. Materials with LoF >150 µm may not be suitable for fracture-critical applications. The HIP and aged conditions considered exhibited a significant effect on material mechanical properties.

For the powder contamination study, it was determined that < 0.025% contamination exhibits acceptable corrosion and mechanical performance. Mechanical properties were deemed acceptable when <0.1% contaminant. Stiffness was observed to be elevated for these conditions. Based solely on corrosion behavior, a contamination level of 0.025% is acceptable. Higher contamination levels of 0.05% and 0.1% would not be acceptable in an acidic environment but would be acceptable in warm neutral environments. Utilizing models, part orientation exhibited a more significant effect on component performance in comparison to feedstock contamination when <0.1%. Materials analyzed did exhibit anisotropy which may play a significant role in component acceptance and design.

## PROJECT END DATE

February 2021

## DELIVERABLES

- AM process parameters and material manufacturing practices for ProX320 and DART SLM test materials
- Tensile test data
- Fracture toughness data
- Fatigue and fatigue crack growth data
- Corrosion test data
- Fractography data
- Material lifing analysis results
- Radiographic, PCRT, and X-ray CT data
- Final project report
- Training module
- Data management plan

## FUNDING

**$1.53M total project budget**

($1M public funding/$534K private funding)

## PROJECT PARTICIPANTS

**Project Principal:**

Youngstown State University

**Other Project Participants:**

Pennsylvania State University
University of Dayton Research Institute
Case Western Reserve University
Oerlikon
3D Systems
Boeing Company
Lockheed Martin
Vibrant

**Public Participants:**

U.S. Department of Defense
National Science Foundation
U.S. Department of Energy