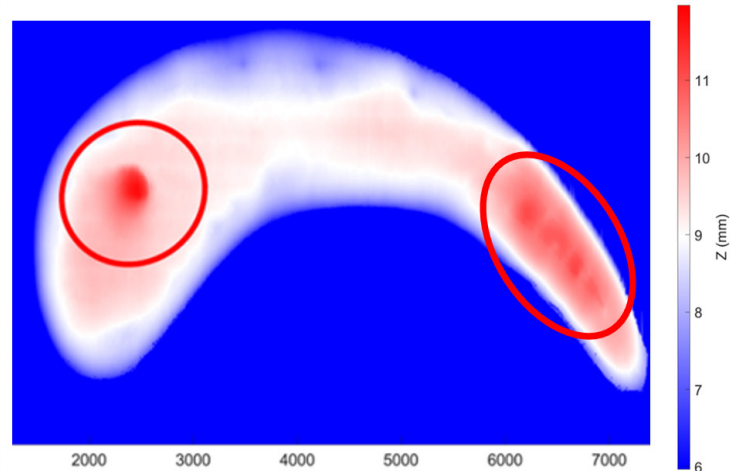
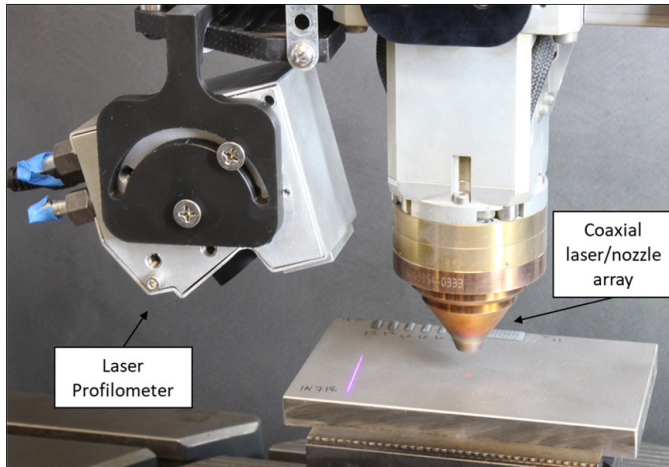


SUCCESS STORY

5001.002.002.001

Two in-situ laser systems utilized to identify defects and surface nonconformities

Anomalies identified in 30 seconds and nonconformities were removed to a resolution of 35 μm



Integrated laser profilometer and deposition nozzle (left). Sensor output showing overbuild on the deposition surface (right).

PROBLEM

Directed energy deposition (DED) process inconsistencies can lead to the generation of flaws, defects, and geometric abnormalities during component fabrication or repair. Post-processing to remove these defects can be time-consuming and expensive. Hybrid additive manufacturing (AM) systems combining additive and subtractive tools in the same build volume have the potential to correct these defects, but this has not been fully realized because in-situ defect detection remains challenging, dynamic tool path definition and adjustments are underutilized, and use cases and the required processing sciences are underdeveloped.

OBJECTIVE

The team sought to develop a system to identify and correct geometric non-conformities during the build process of a powder-fed DED printer with machining capabilities. This system would monitor powder flow as well as build geometry and then utilize an inter-layer dynamic tool path algorithm to machine away the non-conformities as the build progressed. The resulting methodology should be implementable for commercial AM systems printing commercially relevant geometries and materials.



AMERICA MAKES
TECHNOLOGY
DEVELOPMENT
ROADMAP

This project aligns to:



PROCESS

ASTM PROCESS
CATEGORY
Directed Energy
Deposition

EQUIPMENT
DMG MORI
Lasertec 65

MATERIAL
Inconel 718

TECHNICAL APPROACH

The Applied Research Laboratory (ARL) at Pennsylvania State University (PSU) and Applied Optimization (AO) integrated two sensors into a hybrid DMG Mori Lasertec 65 to monitor DED processes: (1) A laser line scanner to evaluate powder feedstock flow characteristics and (2) a laser line scanner to map surface topology of recently deposited material.

Parameter development was then conducted to determine optimal process conditions for the material and geometry to be deposited. Machining parameters were also determined to correlate with the deposition layer height.

As the deposition process proceeded and powder flow monitoring identified inconsistencies, the program was stopped until corrective actions were taken to achieve steady-state operating conditions. When powder flow was stable, the DED process progressed. Each newly deposited layer was scanned to evaluate the surface topology. When under-building or over-building conditions were observed the program was halted and corrective subtractive machining was performed to return the deposited region to a normal position with respect to the build direction. Once the deposited region was machined to a uniform height, the deposition head was recalled, and the DED process was able to proceed.

ACCOMPLISHMENTS

The project team executed semi-automated defect recognition and resolution using the HAMERR framework. The Anomaly Flagging System (AFS) was able to detect surface nonconformities below 5 μm . The algorithm compared topological data with predetermined layer heights, geometrical bounds, and threshold values to determine the required corrective machining prior to continuing deposition. The team has also identified the appropriate hardware and software, along with a compatible signal type, to fully automate the HAMERR process once the machine manufacturer provides access to the Programmable Logic Controller.

The implemented Powder Flow Monitoring (PFM) system was able to detect flow variations within ± 0.1 gpm. At this stage, output from this sensor still requires manual review and intervention (if necessary). Further analysis of sensor output data could lead to automated evaluation. While repair of the nozzle will necessarily remain manual, repair of any non-conformities caused by powder flow issues would be captured and repaired by the AFS algorithm.

Utilizing these systems, the HAMERR framework resulted in builds that were free of over- and under-build geometric abnormalities.

PROJECT END DATE

May 2022

EXPECTED DELIVERABLES

- Methods to employ HAMERR framework
- Sensor hardware and software integration into DMG MORI hybrid system
- Demonstration of build interruption on notional geometry with intentional defects
- Metallography and inspection data
- Sensor data
- Final report

FUNDING

\$100,000 total project budget

PROJECT PARTICIPANTS

Project Principal:

The Applied Research Laboratory at Pennsylvania State University

Other Project Participants:

Applied Optimization

Public Participants:

U.S. Department of Defense