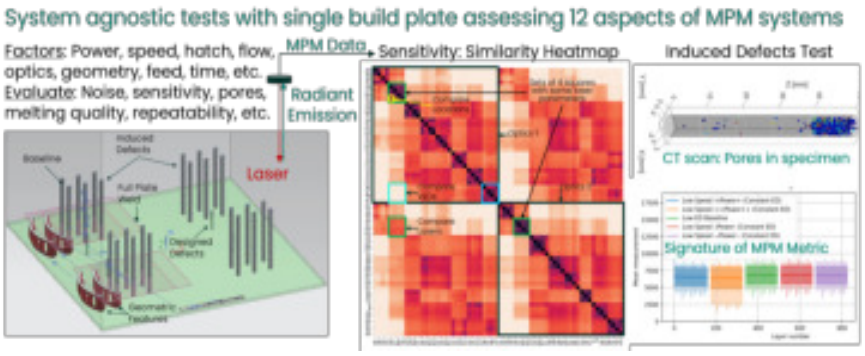
SUCCESS STORY

This project developed systematic analysis and visualization of MPM characterization tests with anomalies induced through novel geometry and parameter variations.

6-10x faster evaluation of 12 basic and advanced aspects of melt pool monitoring systems is made possible with this methodology.



Single build plate layout for system agnostic tests, along with heatmap comparing 64 regions of parameter variations and induced defects test results.

PROBLEM

In-situ process monitoring (ISPM) systems, such as melt pool monitoring (MPM), can enhance quality assurance and help overcome barriers to widespread adoption of additive manufacturing (AM). Reliable detection of quality issues, however, is a major challenge for these systems. The problem is exacerbated by the lack of systematic approaches to comprehensive and objective performance evaluation of commercial systems which use a variety of sensor types and processing techniques. As a result, users spend significant time and effort using trial and error to gain an understanding of the functional limitations of these systems

OBJECTIVE

The objective of this project was to develop test artifacts and protocols for characterization of MPM system performance for laser powder bed fusion (LPBF). The developed approach was anticipated to enable a best practice or standard method for:

- AM machine vendors to present results from their process monitoring systems from a recognized, standard artifact build.
- Process monitoring system designers to quantitatively assess the sensitivity, resolution, and indication range of their instruments.
- AM users to assess repeatability and reproducibility of their AM and process monitoring systems.

TECHNICAL APPROACH

A holistic approach that probes the MPM system response under a comprehensive set of strategically designed anomalous conditions was developed. The approach involved four types of tests:

- The full plate weld (FPW) test prints a few layers on the entire build plate with strategically varying conditions (e.g. power and speed) within and across layers. This provides a simple and robust evaluation of essential aspects such as position dependency, noise, and sensitivity.
- The designed defects test introduces small features that appear as defects in computed tomography (CT) scans of the printed specimen. This test verifies the ability of MPM systems to detect extreme cases of defects.
- The geometric features test is an advanced test that evaluates the system on a challenging ability to detect a category of defects known as shrink lines.
- The induced defects test is another advanced test that builds specimens with variations in process parameters to induce defects such as keyholing, balling, and lack of fusion. It also probes the MPM system's ability to detect those defects.

The tests were categorized into two levels of complexity. Level I tests involved printing artifacts, while Level II tests required extra steps such as CT scanning. For each test the MPM measurements were compared against appropriate benchmarks to evaluate the system performance.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

VALUE CHAIN

ASTM PROCESS CATEGORY:
Powder Bed Fusion

MATERIAL:
ALLOY 718, TI-6AL-4V

ACCOMPLISHMENTS

This project successfully developed and demonstrated four types of tests spanning two levels of complexity, all consolidated on a single build plate, to enable evaluation of 12 basic and advanced aspects of MPM systems against suitable references or "ground truths." The concise yet comprehensive tests reduced the evaluation time by a factor of 6 to 10.

The tests incorporated geometric features as well as non-geometric parameter variations representative of the intended use of the system under realistic process conditions. The FPW and designed defects tests probed key aspects of the system that are necessary for typical production settings today where benchmark builds are used to define normal behavior. The novel shrink line test and induced defects test challenged the state-of-the-art in defect detection and, considering the longer-term industry outlook, could be crucial for low volume production, first part qualification, and parameter development. Level I tests were conducted on two different commercial MPM systems, each using a different material, demonstrating the system agnostic capability of the approach for ease of adoption.

The detailed project report and data package described the purpose of each test, provided procedures to conduct the tests, and demonstrated analysis and interpretation of the test results. Simple yet elegant analysis techniques were provided to interpret the test data, enabling qualitative and quantitative evaluation of system performance.

PROJECT END DATE

August 31, 2021

DELIVERABLES

- Test protocols for evaluation of in-situ process monitoring system performance
- Analysis of melt pool monitoring data from two systems for multiple geometries and scenarios
- Technical data package with design, measurement, and analysis information
- Final technical report

All downloadable deliverables are available to members of America Makes via the Digital Storefront.

FUNDING

$94,100 total project budget
($65,000 public funding/$29,100 private funding)

PROJECT PARTICIPANTS

Project Principal:
Baker Hughes

Public Participants:

U.S Department of Defense

National Institute of Standards and Technology

5001.001.002.006 Development of Test Artifacts for the Characterization of AM In-Situ Process Monitoring Systems

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