Metal 3D Printed Component Certification

AMMTO
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Abstract

Dr. Niall O'Dowd has developed a real-time in-process monitoring system for industrial 3D printers. The system provides actionable part quality data by measuring several in-situ part features, reducing wasted energy and lost schedule time through earlier part scrap. As additive manufacturing continues to penetrate mainstream production markets, reducing material waste and energy consumption becomes critical. Phase3D's monitoring system provides an increasingly sustainable solution that helps reduce the material waste associated with additive manufacturing.

Alignment with Office Mission

By monitoring the 3D printing process, it is possible to reduce material and energy consumption by 9-15 percent, which translates into a potential reduction of 690 MtCO2e emissions by 2042. The technology is also cost-effective, unlike 3D printer-specific monitoring systems, which are cost-prohibitive and inconvenient for customers often interested in OEM-agnostic quality control systems. The technology has been shown to be feasible for commercial integration, and data from Argonne National Laboratory's Advanced Photon Source are being used to correlate final-part defects to in-situ feature data measured with the monitoring system.

Challenges and Impact

The US DoE and DoD have published works detailing the importance of developing AM technologies. The Energy Efficiency and Renewable Energy Office has reported that AM has the potential to vastly accelerate innovation, compress supply chains, minimize materials/energy usage, and reduce waste, but a key challenge of AM is process control[5], which Project Fringe addresses specifically. In the DoD's Additive Manufacturing Roadmap, AM is described as a major topic of interest, and the need for a coordinated plan to collectively mature AM in support of DoD requirements is clear[6]. The National Institute of Standards and Technology (NIST) published the Measurement Science Roadmap for Metal-Based Additive Manufacturing[7], reporting the requirement for standards development to facilitate quicker and more cost-effective certification of all materials, processes, and products.

Project Outline

Innovation: Real-time inspection for 3D printing
Project Lead: Dr. Niall O'Dowd
Project Partners: DOE AMMTO, Phase3D

Timeline: August 2021 – August 2023

Budget:
$450,000 in funds through a CRADA for R&D at Argonne National Laboratory and a fellowship stipend for Niall O'Dowd.

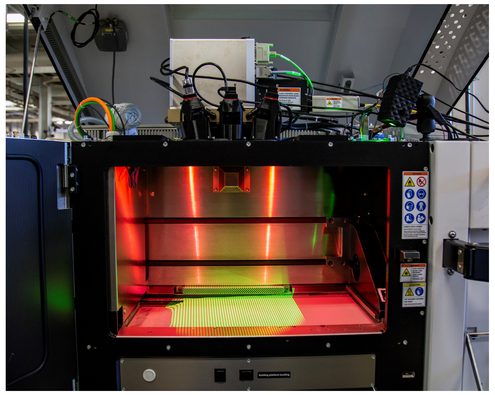
End Project Goals:

1. Build a minimum viable product which operates inside Renishaw AM400
2. Analyze previous APS data to establish a correlation between powder non-uniformities and final-part defect
3. Outside-of-Argonne development of mounting systems for monitoring system
4. Use APS beam time to test powder non-uniformity for specific alloys and laser parameter combinations

Background

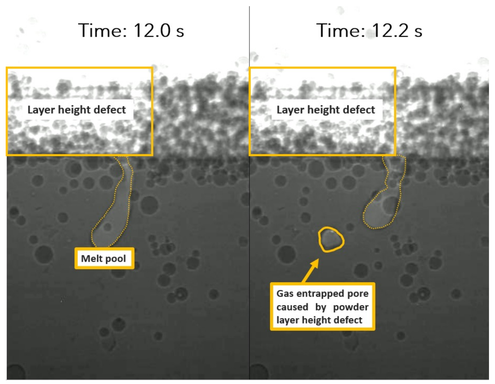
Additive manufacturing (AM) is an industry witnessing explosive growth within the manufacturing sector, reporting a market size of over $13 billion in 2022, and immense projected growth at a CAGR of over 30%, estimated to reach above $30 billion by 2025[1]. However, AM's growth in metal components, powered by the transition from prototyping to full-scale production is severely limited by poor part repeatability and reliability issues, which are the primary factors preventing further industry adoption[2], [3]. For example, the aerospace market share, accounting for 45% of the metal AM market, has estimated part rejection rates of up to 30%, resulting in immense lost project lead times, and lost revenues which are projected to increase over $4 billion by 2025[4].

Results

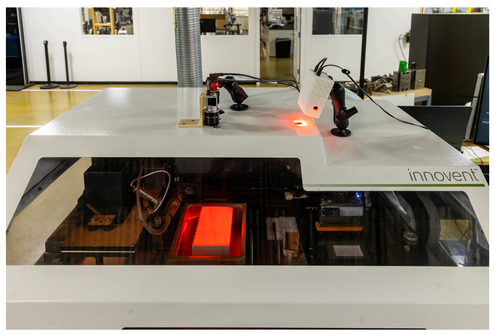


Corresponding to Key Achievement 1,
A real-time inspection system for industrial 3D printing was developed and tested in operation.

Anomalies as small as 15µm were measured and recorded during a variety of prints on Stainless Steel, Titanium, and ceramics



Corresponding to Key Achievement 2,
Synchrotron x-ray data from the Advanced Photon Source shows causal relationship between layer height defects and porosity in Ti64 powder bed fusion.



Corresponding to Key achievement 3,
an inspection system was developed for use on non-Argonne 3D printers

Conclusions

Part quality monitoring has been shown to significantly reduce the bottom line cost of AM, with the ability to save operation time and energy, by reducing final part rejection rates, through early build cancellation. Additionally, part quality monitoring can enable AM usage to *further* grow into applications where high confidence in part quality is needed (aerospace, medical, nuclear, etc.). However, AM printers do not have a standardized part quality assurance system, and 3 D printer suppliers are intrinsically unable to produce third-party verification of part quality.
Phase3D has successfully developed an anomaly inspection system for additive manufacturing components.

Key Achievements

1. Build a minimum viable product which can operate inside Renishaw AM400
2. Use APS beam time to test powder non-uniformity for specific alloys and laser parameter combinations
3. Outside-of-Argonne development of mounting systems for monitoring system

Future Work

Dr. Niall O'Dowd is continuing research on this topic through a spinout company, Phase3D, further analyzing the impact of the measured real-time anomalies on part quality as a whole.

The Nuclear Science and Engineering group at Argonne National Laboratory are continuing material and component characterization for nuclear components.

Technology Transfer

The technology and use cases defined during this program are being utilized through trade secrets and modeling the effects of real time anomalies on final 3D printed component quality.

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