SMART INDUSTRY

MultipLICITY

Multiple Lasers and Integrated Cameras for Increasing Trustworthy Yields in Additive Manufacturing

SETTING THE SCENE

- In which application domain has this research project been conducted?
- Which specific need/trend has been at the basis of this imec.icon project?
- Where do today's solutions fall short in meeting that need? (what are their limitations)

Laser-based additive manufacturing (LBAM) is used to 3D print a variety of products by melting powders, layer-by-layer, with a laser. LBAM is regularly used when high quality is required, including for automotive parts and medical implants. Unfortunately, the high quality these products require is hard to achieve. Various defects can occur during LBAM printing, including porosity and warping, that cause a part to fail quality control tests. Today, roughly 10% of LBAM printed parts are rejected and must be scrapped, limiting productivity and wasting both material and energy.

We believe that in-process monitoring and control systems can improve LBAM print quality by fine tuning the printing in real time. Existing research has shown that defects can be detected from monitoring data, but these approaches are either (a) too slow for real-time control, (b) too specific to a particular defect type or material, (c) limited to single-laser 3D printers, or (d) not informative enough to indicate a proper control action.

FRAMING THE RESEARCH OBJECTIVE

- What has been the project's objective? (in response to the limitations outlined in the previous section)

MultipLICITY aims to introduce in-process monitoring and control for LBAM in a way that is generic enough for multiple print materials and multi-laser printers. The monitoring relies on thermal-optical multi-sensor fusion to detect more defect types across various machines and materials. Real-time control algorithms then leverage the monitoring data to improve print quality, thereby improving the productivity and cost-efficiency of LBAM 3D printing.

THREE MAIN OUTCOMES

- What have been the [three] main outcomes of the project?
  - Which unique technology has been developed (tools, algorithms, platforms, ...)?
  - Which key learnings / insights have been acquired?
- How much better is our approach (compared to commercial solutions)? (quantify if possible)

MultipLICITY realized the following achievements:

- The design and creation of a high-speed short-wave infrared (SWIR) camera with 4 dynamically changeable regions of interest (ROI). This camera, combined with advanced thermographic calibration, allows for thermal imaging at up to 20,000 frames per second. This innovation, combined with the 4 ROIs, allows us to track the temperatures created by up to 4 different print lasers with an accuracy within 3°C.
- The design and creation of an adaptive 4D x-CT image reconstruction algorithm that allows for data-efficient imaging during destructive stress tests. The algorithm collects raw x-ray data, but instead of continuously reconstructing 3D x-CT images, a change detection algorithm is used to identify when the state of the stressed part has altered. Once an alteration has been detected, the image reconstruction algorithm can be turned on to capture the part's state change. By imaging the part in this way, the data required for image reconstruction is kept low while still capturing the key events in the stress test.

- The design and creation of high-speed porosity and warping detection algorithms for both metals and polymers. In both cases, advanced AI models were uncovered that fuse expert knowledge, printer signals, and images from high-speed optical and thermal cameras. The fused data is then inputted into a second AI model to predict localized warping and porosity defects. For metal LBAM printing, defects were detected within 42 microseconds through the application of advanced GPU optimization techniques. For polymer LBAM printing, defects were similarly detected within 100 microseconds, marking the first high-speed polymer defect detector that can enable real-time control. Both the metal and polymer AI defect detectors were also expanded to multi-laser printers, showing its scalability.

The achievements above were combined with advances in high-speed optical imaging, multi-laser melt pool simulation software, and real-time control algorithms into an integrated in-process monitoring and control system for laser-based 3D printing. We demonstrated the integrated system in both metal and polymer 3D printers to show that fully automated monitoring and control can be applied fairly generically across the LBAM sector.

NEXT STEPS

- What is going to happen with the main outcomes outlined above?
    - Are there any commercialization plans?
    - Are there plans for follow-up research?

The AM market access of Materialise will be used to commercialize the Multiplicity results. This will require two more investments. First, the system needs to be made more robust (higher TRL level) for the defects identified within the project. Secondly, research needs to be done to expand towards more types of defects.

The Multiplicity platform, as it is, will be presented as a stable platform for further research and be marketed as such. On top of that, the insights gathered during and after the project using the Multiplicity system have already led to new strategies in LPBF and those will be implemented and commercialized in the year after the project.

MultipLICITY project partners:

The MultipLICITY project was co-funded by imec, with project support from Agentschap Innoveren & Ondernemen

FACTS

NAME	**MultipLICITY**
OBJECTIVE	Multi-camera monitoring and quality control for multi-material, multi-laser 3D printing
TECHNOLOGIES USED	High-speed cameras, 3D printing, artificial intelligence, real-time control, x-CT imaging, FEM simulation, thermography
TYPE	imec.icon project
DURATION	01/09/2022 – 28/02/2025
PROJECT LEAD	Sven Cornelissen, Materialise
RESEARCH LEAD	Brian Booth, imec – IPI – UGent
BUDGET	€ 4,219,911
PROJECT PARTNERS	AdditiveLab, Materialise, Xenics, Dekimo, Rejig
RESEARCH PARTNERS	MaPS – KU Leuven, Flanders Make
RESEARCH GROUPS	iimec – VisionLab – UAntwerpen, imec – IPI – UGent

WHAT IS AN

IMEC.ICON PROJECT?

The imec.icon research program equals demand-driven, cooperative research. The driving force behind imec.icon projects are multidisciplinary teams of imec researchers, industry partners and/or social-profit organizations. Together, they lay the foundation of digital solutions which find their way into the product portfolios of the participating partners.

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