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PROCEEDINGS

Multi-Modality In-Situ Monitoring Big Data Mining for Enhanced Insight into the Laser Powder Bed Fusion Process, Structure, and Properties

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ABSTRACT

Laser powder bed fusion (LPBF) is one predominant additive manufacturing (AM) technology for producing metallic parts with sophisticated designs that can find numerous applications in critical industries such as aerospace. To achieve precise, resilient, and intelligent LPBF, a comprehensive understanding of the dynamic processes and material responses within the actual conditions of LPBF-based AM is essential. However, obtaining such insights is challenging due to the intricate interactions among the laser, powder, part layers, and gas flow, among other factors. Multimodal in-situ monitoring is desired to visualize diverse process signatures, allowing for the direct and thorough revelation of key properties. In this work, we introduce the development and application of our unique LPBF-specific integrated multi-sensor monitoring system that can effectively and simultaneously quantify multiple physics phenomena at different spatiotemporal scales. Specifically, two-wavelength imaging pyrometry is reinvented for cost-effective and data-efficient melt pool temperature and morphology monitoring with high accuracy and sufficiently fast sampling rate (> 10,000 Hz) [1, 2]. New methods of camera-based laser scan monitoring and fringe projection profilometry are developed for melt pool registration, spatter monitoring, and layer surface topography measurement [3-6]. Machine learning methods are employed to analyze and fuse the in-situ multi-monitoring data for predicting in-process and post-print part properties [3, 7, 8]. This work introduces our current monitoring systems, big data analytics methods, and exemplary application cases to predict different part properties such as solidified melt pool depth, grain length, and porosity. Experiment results show that our LPBF process monitoring systems and part characterization methods are more accurate than typical methods due to the melt pool absolute temperature measurement capability. Our work will help advance LPBF process modeling, optimization, control, and qualification. It will also facilitate the materials research such as metallurgy modeling, microstructure characterization, as well as alloy design and in-situ fabrication.

KEYWORDS

Powder bed fusion; in-situ monitoring; melt pool; fringe projection profilometry; spatter

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References

1. Vallabh, C. K. P., Zhao, X. (2022). Melt pool temperature measurement and monitoring during laser powder bed fusion based additive manufacturing via single-camera two-wavelength imaging pyrometry (STWIP). *Journal of Manufacturing Processes, 79,* 486-500.
2. Zhao, X., Vallabh, C. K. P. (2024). *Systems and Methods of Adaptive Two-wavelength Single-camera Imaging Thermography (ATSIT) for Accurate and Smart in-situ Process Temperature Measurement during Metal Additive Manufacturing* (US 11,874,176B2). U. S. P. a. T. Office.
3. Zhang, H., Vallabh, C. K. P., Zhao, X. (2023). Influence of spattering on in-process layer surface roughness during laser powder bed fusion. *Journal of Manufacturing Processes*, *104,* 289-306.
4. Zhang, H., Prasad Vallabh, C. K., Zhao, X. (2023). Machine learning enhanced high dynamic range fringe projection profilometry for in-situ layer-wise surface topography measurement during LPBF additive manufacturing. *Precision Engineering*, *84*, 1-14.
5. Zhang, H., Vallabh, C. K. P., Zhao, X. (2022). Registration and fusion of large-scale melt pool temperature and morphology monitoring data demonstrated for surface topography prediction in LPBF. *Additive Manufacturing*, *58,* 103075.
6. Zhang, H., Vallabh, C. K. P., Xiong, Y., Zhao, X. (2022). A systematic study and framework of fringe projection profilometry with improved measurement performance for in-situ LPBF process monitoring. *Measurement*, *191,* 110796.
7. Vallabh, C. K. P., Sridar, S., Xiong, W., Zhao, X. (2022). Predicting melt pool depth and grain length using multiple signatures from in-situ single camera two-wavelength imaging pyrometry for laser powder bed fusion. *Journal of Materials Processing Technology*, *308,* 117724.
8. Vallabh, C. K. P., Zhao, X. (2021). Continuous comprehensive monitoring of melt pool morphology under realistic printing scenarios with laser powder bed fusion. *3D Printing and Additive Manufacturing*, *10(1),* 101-110.