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Unraveling Metallic Additive Manufacturing with Simulation, Monitoring, and Machine Learning

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Abstract

Metallic Additive Manufacturing (AM) has begun to revolutionize many industries such as aerospace, automotive, and bio-medical engineering... However, extremely complex physical phenomenon behind the process are the biggest challenge in AM. Numerical simulation, system monitoring, and machine learning are the crucial keys to understand those phenomenon and to open the possibilities for AM to transform not only the manufacturing section but also how human fabricate things.

Research Focus

Elucidating Physics with Numerical Simulation

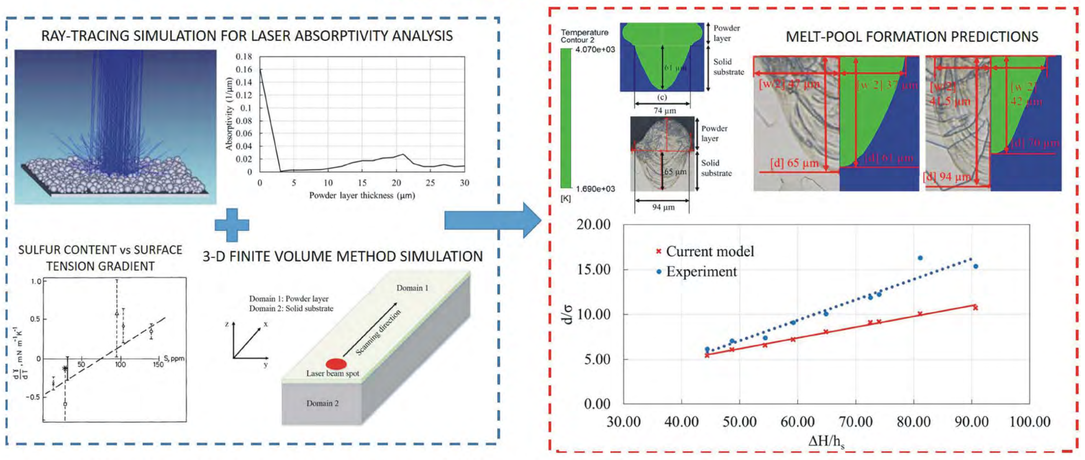

Fig. 1. Heat-and-mass transfer model for the melting and solidification in L-PBF process.

A highly comprehensive Computational Fluid Dynamics (CFD) model is constructed and run to predict the temperature field and the velocity field of the molten material during the process of L-PBF in order to predict the printability, calculate the cooling rates, and simulate the microstructure of printed parts.

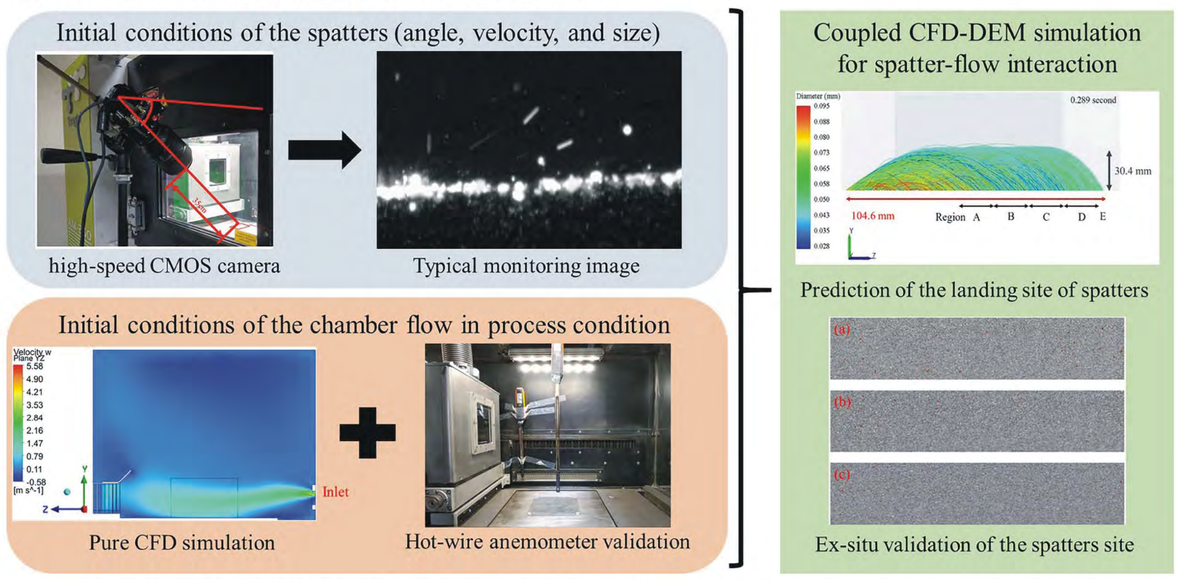

Fig. 2. Coupled CFD-DEM simulation to predict the trajectory of the generated spatters.

A multiphysics coupled Computational Fluid Dynamics (CFD) - Discrete Element Method (DEM) simulation is designed and run to study the interaction between the flow in the chamber and the spatter particles generated during the build process. The model is used to minimize the effect of spatters on the surface roughness and quality of the built parts.

Le, T. N., & Lo, Y. L. (2019). Effects of sulfur concentration and Marangoni convection on melt-pool formation in transition mode of selective laser melting process. ***Materials & Design***, 179, 107866.

Le, T. N., Lo, Y. L., & Tran, H. C. (2019). Multi-scale modeling of selective electron beam melting of Ti6Al4V titanium alloy. ***The International Journal of Advanced Manufacturing Technology***, 105(1-4), 545-563.

Le, T. N., Lo, Y. L., & Lin, Z. H. (2020). Numerical simulation and experimental validation of melting and solidification process in selective laser melting of IN718 alloy. ***Additive Manufacturing***, 36, 101519.

Chien, C. Y., **Le, T. N.,** Lin, Z. H., & Lo, Y. L. (2021). Numerical and Experimental Investigation into Gas Flow Field and Spattering Phenomena in Laser Powder Bed Fusion Processing of Inconel 718. ***Materials & Design*, 179, 107866.**

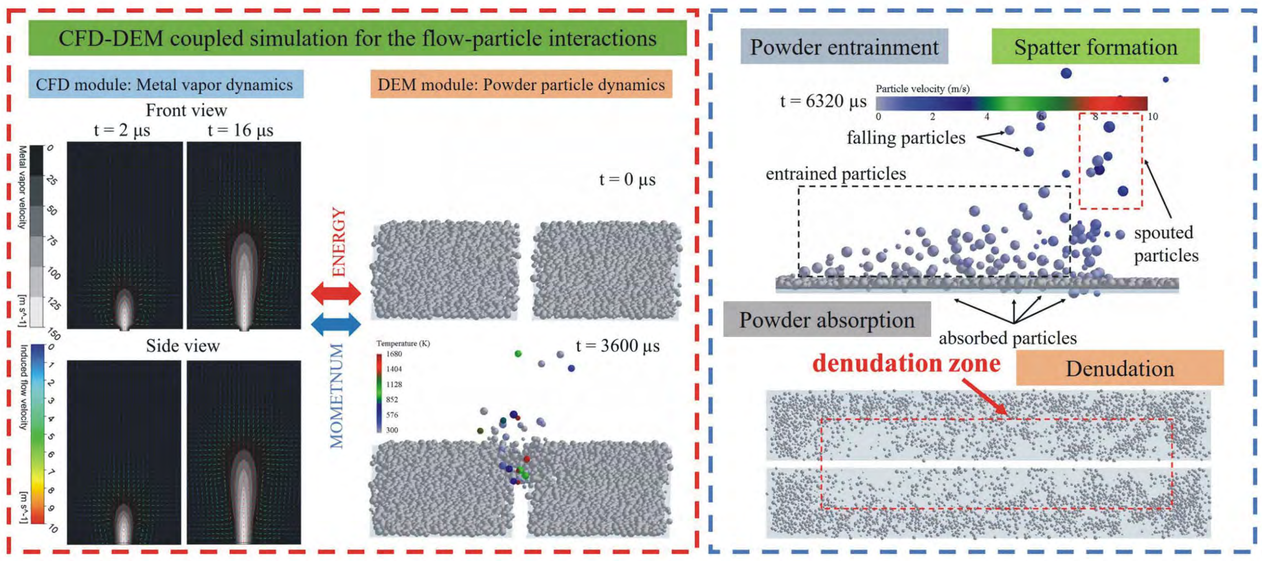

Fig. 3. Coupled CFD-DEM simulation for the flow-particles interactions in the L-PBF process.

A multiphysics coupled Computational Fluid Dynamics (CFD) - Discrete Element Method (DEM) simulation is constructed to investigate the momentum and energy transfers between the gas flow and the powder particles in the L-PBF process.

Le, T. N., & Lo, Y. L. (2021). Coupled CFD-DEM Model for Investigation of Powder Entrainment, Denudation and Spattering Effects in Laser Powder Bed Fusion Process, ***3D Printing and Additive Manufacturing***. **Accepted.**

Process Monitoring & Machine Learning for Defects Detection

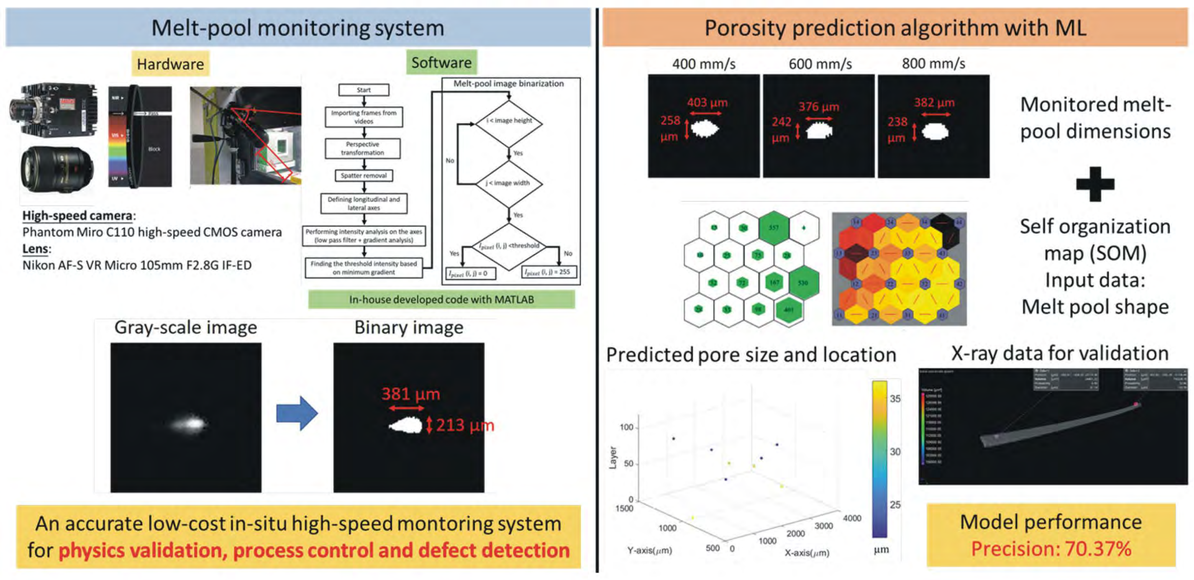

Fig. 4. The proposed framework to predict the porosity in the built part using in-situ monitoring data, X-ray imaging, and machine learning technique.

Melt-pool and spatter signatures contain valuable informations regarding the quality of the weld track such as **porosity.** High-speed and machine learning were deployed to utilize such inputs for anomaly tetection and correlation with defects.

Le, T. N., Lee, M. H., Lin, Z. H., & Lo, Y. L. (2021). Vision-based in-situ monitoring system for melt-pool detection in laser powder bed fusion process. ***Journal of Manufacturing Processes*, 68**, 1735-1745.

Lin, Z. H., **Le, T. N.,** Lo, Y. L., Tran, H. C., & Yang, H. C. (2021). Porosity prediction in Laser Powder Bed Fusion process using machine learning approach. **Under Review.**