Purdue Materials Engineering

"Uncertainty Quantification of Laser Powder Bed Fusion Computational Models"

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ABSTRACT

Laser powder bed fusion (L-PBF) is a relatively young metallurgical processing method which has many advantages over traditional casting and wrought based methods. Alloy systems suitable for the additive manufacturing process include Ti-6Al-4V, 316 stainless steel, Inconel 718 and 625 making it attractive for automotive, aerospace, and biomedical applications. Despite the potential, L-PBF is plagued by defects and inconsistent build qualities which make certification of critical components onerous. Additionally, experimental studies are difficult due to the cost of laser systems and feedstock material. Many researchers have turned to computational modeling as this allows for rigorous examination and isolation of the underlying physics to better understand where problems may arise, and where improvements can be made. However, models often fail to consider the role of systematic and statistical uncertainty while also relying heavily on assumptions and simplifications for computational efficiency. As such, there is no quantifiable metric for how reliable these models are. This work applies an uncertainty quantification (UQ) framework to computational models for L-PBF to understand the role of uncertainty and assumptions on model reliability as this provides insight into their limitations and areas of improvement.

First, the UQ framework is applied to a finite volume melt pool transport model to evaluate the role of uncertainty and model assumptions on melt pool shapes and solidification dynamics. This includes the role of simulating the powder bed thermophysical properties, surface tension driven Marangoni convection, and the thermodynamic relation dictating latent heat release. The transport model is then weakly coupled to a cellular automata (CA) grain evolution model to propagate and quantify the uncertainty in the as-built microstructure including crystallographic texture formation. Further propagation of melt pool and microstructure uncertainty to the resulting mechanical properties to close the process-microstructure-property relations are discussed. Lastly, recommendations for future model development and research are presented.

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