Mitigating undulations via external electric fields in laser powder bed fusion

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Abstract

Periodic undulations in laser powder bed fusion often lead to defects and structural failure. External field-assisted laser-based additive manufacturing has gained popularity over the years due to its advantages in grain refinement and defect elimination. However, electric field-assisted powder bed fusion (PBF) process is limited due to several challenges. The powder bed complexity leads to heterogenous thermophysical properties causing defects and repeatability concerns in the process. In 2022, Zhang et al. [1] studied the Rayleigh instability in PBF. Their study showed that the contact angle influences the stability of the melt track. Moreover, it is known that contact angles highly depend on the surface tension (or free interfacial energy) of the participating phases. Additionally, past evidence has shown that electric fields can influence the surface tension and likewise the contact angle [2, 3]. Consequently, efforts are made to initiate and analyze the effects of electric field in the PBF process. Solidification is a transient process, and the Young-Lippmann equation which is often utilized for relating interfacial free energies with potential differences across interfaces does not account for the transient behavior during the process. Therefore, understanding the transient behavior and the underlying mechanism in electric field-assisted PBF is essential.

In this research, the effects of electric fields on undulations were observed in the dual laser-based PBF process. Stainless steel 316L powders and substrates at different process parameters were utilized to produce variations in the melt track undulations. Subsequently, different electric field signals with variations in waveforms and amplitudes are utilized during the process. Fig. 1 illustrates melt track undulations, which are affected by the introduction of an external electric field. Further investigations revealed that the electric field characteristics, such as variation in waveform, amplitude, and frequency, are highly directionally dependent. Finally, several materials characterization methods are utilized to support the aforementioned claims for plausible application through process enhancements such as defect mitigation and grain refinement.

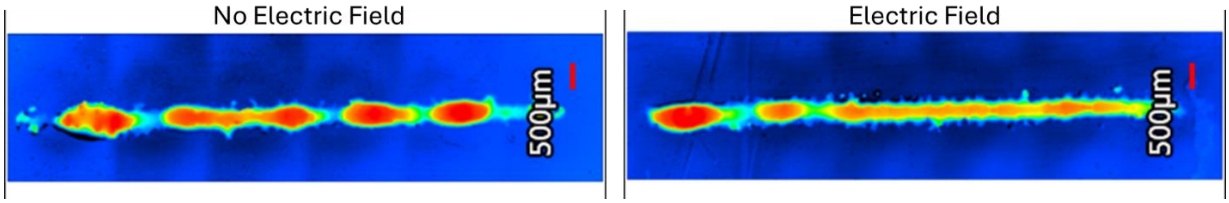

Fig. 1: Confocal images of the melt track with and without the application of an electric field.

References:

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