Multi-scale feature prediction and signature identification for directed energy deposition

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Abstract:

Additive manufacturing (AM) techniques provide novel opportunities for the fabrication of advanced materials and multi-functional properties of complex geometries with reduced processing routes as compared to conventional manufacturing techniques. However, the ability to define and predict these responses within the processing-structure-property (PSP) relationships is not mature. In this study, we present a machine learning (ML) approach that can be used to identify both macro and micro-scale signatures of 316L stainless steel components manufactured using directed energy deposition (DED) to enable predictive processing strategies of AM signatures. At present, build height, dendrite arm spacing (DAS), and hardness were used to represent the PSP linkages. In total, 35 cubes were processed under a range of process conditions. A dimensionless number was utilized for the design of experiments, and a combination of high throughput (HT) processing and low throughput (LT) characterization methods were used. Sample build height was collected both in situ and post-synthesis in all samples, and the DAS and hardness were investigated in a select number of samples. The data from this analysis was then used in three ways: 1) develop an analytical model to explain the relationship between build height and process parameters, 2) develop a relationship between layer height and hardness, and 3) train ML models to predict build height, DAS, and hardness from process parameters. Results show that hardness, DAS, and build height can all serve as process signatures from which the processing conditions of DED can be determined. Furthermore, this investigation serves as an outline for ML-aided multi-objective design of experiments and can be expanded upon to include more signatures of interest.