ETI Annual Workshop, February 20 – 21, 2024

Prediction of optical signatures and their influence on part performance: a model system using 316L stainless steel

William Kunkel
Advisor: Dan J. Thoma
University of Wisconsin-Madison
wkunkel@wisc.edu

Abstract:

Additive manufacturing (AM) techniques offer novel opportunities for fabricating advanced materials and achieving multifunctional properties in complex geometries with reduced processing routes compared to conventional manufacturing techniques. However, the maturity of predicting these responses within the processing-structure-property (PSP) relationships is not mature. In this study, we investigate the PSP relationships for components made of 316L stainless steel using directed energy deposition (DED), which facilitates the development of predictive processing strategies for AM signatures. The study explores the link between deposition height (optical signature), hardness (physical signature), and capture efficiency. Additionally, analytical and machine learning (ML) models capable of predicting optical signatures and capture efficiency from processing conditions (electronic signatures) is examined. Bulk parts were processed under 44 unique conditions, resulting in variations in properties and microstructures. A combination of high-throughput processing and low-throughput characterization methods were employed to establish PSP relationships among optical signatures, physical signatures, and capture efficiency. Furthermore, the Buckingham Pi theorem was utilized to develop an analytical model capable of predicting optical signatures from electronic signatures is compared to the predictions made by ML methods such as gradient boosted trees, random forest regression, and gaussian process regression. Results indicate that hardness, build height, and capture efficiency can all function as process signatures, allowing for the determination of DED processing conditions. Moreover, electronic signatures can be paired with an analytical model or ML methods to predict both optical signatures and capture efficiency.