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Electron Beam Melting Process Parameter Optimization Using Multi Objective Reinforcement Learning

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Abstract : Process parameter optimization in metal powder bed electron beam melting (MPBEBM) is crucial to ensure the technology's repeatability, control, and industry-continued adoption. Despite continued efforts to address the challenges via the traditional design of experiments and process mapping techniques, there needs to be more successful in an on-the-fly optimization framework that can be adapted to MPBEBM systems. Additionally, data-intensive physics-based modeling and simulation methods are difficult to support by a metal AM alloy or system due to cost restrictions. To mitigate the challenge of resource-intensive experiments and models, this paper introduces a Multi-Objective Reinforcement Learning (MORL) methodology defined as an optimization problem for MPBEBM. An off-policy MORL framework based on policy gradient is proposed to discover optimal sets of beam power (P) – beam velocity (v) combinations to maintain a steady-state melt pool depth and phase transformation. For this, an experimentally validated Eagar-Tsai melt pool model is used to simulate the MPBEBM environment, where the beam acts as the agent across the P – v space to maximize returns for the uncertain powder bed environment producing a melt pool and phase transformation closer to the optimum. The culmination of the training process yields a set of process parameters {power, speed, hatch spacing, layer depth, and preheat} where the state (P,v) with the highest returns corresponds to a refined process parameter mapping. The resultant objects and mapping of returns to the P-v space show convergence with experimental observations. The framework, therefore, provides a model-free multi-objective approach to discovery without the need for trial-and-error experiments.

Keywords : additive manufacturing, metal powder bed fusion, reinforcement learning, process parameter optimization
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