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Internal Connection Between the Microstructures and the Mechanical Properties in Additive Manufacturing

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ABSTRACT

Additive manufacturing (AM) reveals high anisotropy in mechanical properties due to the thermal accumulation induced microstructures. How to reveal the internal connection between the microstructures and the mechanical properties in additive manufacturing is a challenge. There are many methods to predict the mechanical properties based on the microstructural evolutions in additive manufacturing [1–3]. Here we summarized the main methods for the prediction of the mechanical properties in additive manufacturing, including crystal plasticity finite element method (CPFEM), dislocation dynamics (DD), and molecular dynamics (MD). We systematically examine these primary approaches for mechanical property predictions in AM, highlighting several unresolved issues: insufficient consideration of multi-scale microstructural features and inadequate representation of anisotropic behavior. Then, the dislocation dynamics model is integrated with the crystal plasticity model to show how the anisotropic microstructures affect the final mechanical properties in additive manufacturing. Preferential grain orientation along specific loading directions can enhance strength in those directions while reducing ductility in others. Additionally, the evolution of dislocation density and its interaction with grain boundaries significantly affects the materials hardening behavior [2]. By strategically adjusting process parameters like heat input, scanning strategy, and cooling rates, it is available to tailor the microstructure to either strengthen or weaken mechanical anisotropy. Promoting equiaxed grain growth through optimized thermal management can reduce anisotropy, while controlled epitaxial growth can enhance directional properties. These microstructural modifications provide a pathway for optimizing mechanical and structural performances in AM components.

KEYWORDS

Monte Carlo model; dislocation dynamics; mechanical property; crystal plasticity

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