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The Phase Field Method for the Simulation of Grain Structures in Additive Manufacturing

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ABSTRACT

Microstructures is the key factor determining the properties of the additively manufactured components [1]. It can be highly affected by the temperatures generated during the additive manufacturing process. Phase field method, as established based on Ginzburg-Landau theory is an efficient tool to simulate the microstructural evolutions in additive manufacturing [2]. It can be used to simulate solidification, diffusion, phase transformation and grain growth [3]. Here we compared the new progress on the phase field method in the field of additive manufacturing. Due to the differences between the temperature field and the grain field, how to project the results from finite element model to phase field model is a challenge. Then, a three-dimensional multiscale model incorporating macroscopic finite element modeling (FEM) and microscopic phase-field modeling (PFM) was developed. Lagrangian interpolation function is used for the projections between FEM and PFM. The results indicate that the morphology of the melt pool is directly influenced by process parameters, which subsequently determine the temperature gradient (G) and solidification rate (R). The columnar-to-equiaxed transition (CET) is governed by the ratio G/R. An increase in the G/R ratio reduces undercooling and heterogeneous nucleation, thereby suppressing CET. Furthermore, $G \times R$ plays a critical role in controlling grain size. Finer grains are achieved as $G \times R$ increases.

KEYWORDS

Wire arc additive manufacturing; phase field method; microstructural evolution; multiscale model

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