Fast Simulations of the Grain Structure Evolution in Additively Manufactured Materials

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ABSTRACT

This work presents an efficient approach for the three-dimensional (3D) cellular-automata-based simulation of the grain structure evolution during laser beam melting (LBM) process. The approach aims at reducing computational time without sufficient loss of quality of the results. The transient heat transfer is described by a local steady-state temperature field moving with the heat source instead of the global temperature field calculated in the whole computational domain. The local steady-state temperature field incorporates the melt and heat-affected zones (HAZ). The geometries, sizes of melt zone and HAZ, as well as the temperature distributions inside them, are defined by thermal simulation of a single laser pass. The simulation results obtained with the use of the moving local steady-state temperature field are in good qualitative and quantitative agreement with those calculated in a conventional way on the basis of the global temperature field using the cellular-automata finite-difference (CAFD) model reported in [1]. For the CAFD model developed previously [1], the computation time depends on the number of simulated layers in a quadratic way, while for the presented approach the dependence is linear. When using the developed approach, the computation time is reduced by 99.9% for model specimens of 1×1×0.63 mm in comparison to the conventional CAFD calculations.

The presented approach was used to analyze the influence of the laser power on the grain structure of Ti-6Al-4V alloy. The framework enabled the 3D model specimens containing 233 layers to be considered. Results of the thermal simulation of a single laser pass are in reasonable agreement with the experimental data [2]. By use of the statistical methods, characteristics of grain size and texture were estimated and compared for the LBM of Ti-6Al-4V specimens produced with different laser powers. It is concluded that the pronounced grain selection stops after a certain number of layers. The higher laser power results in an increase of grain size; however, no direct correlation between the average grain length and the laser power was found. Texture evolution with the build height was analyzed with the use of pole figures and texture indices. The texture strength is shown to increase with the laser power, with other conditions being equal.

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