Overview of Texture Development in Metals Additive Manufacturing

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Abstract

Constructing a digital twin based on simulation for a process such as laser powder bed fusion requires a large set of models. Here we examine the physical components that control microstructure. Effectively all alloys currently used for metals 3D printing, i.e., additive manufacturing, are cubic, which means they freeze with < 001> biased towards the temperature gradient direction. Epitaxial growth from the base metal dominates as was demonstrated in a study of single track laser melting experiments in mono-crystalline CMSX-4. The combination of < 001> growth and epitaxy from the base metal sets up a classic growth competition. Remembering that prints comprise kilometers of welds threading the volume in different directions, the weak textures generally obtained are a consequence of the wide range of local growth directions. Simulation at the grain scale has been performed with the Potts model, phase field, cellular automata and others and all these demonstrate the strong sensitivity to the melt pool shape which is strongly sensitive to power density. The grains grow competitively along the local temperature gradient from the base metal which illustrates why one observes extended grains from the root of the pool and more nearly equiaxed grains from the sides. It is also the case that the columnar to equiaxed transition is sensitive to the freezing range, amongst other factors. Phase transformation in, e.g., low-alloy steels or titanium, further disperses orientation. Exploiting 3D printing to control anisotropy via texture therefore requires subtle methods to control the local growth direction(s), which will be illustrated by experiment & simulation. Returning to the perspective of a numerical digital twin, this is necessarily multiscale because it is impossible to simulate an entire part at the melt pool scale: this points to the necessity of reduced order models which we briefly discuss to summarize.

Keywords: texture, simulation, microstructure development, laser powder bed fusion, anisotropy

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