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Defect generation and propagation mechanism during additive manufacturing by selective beam melting

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Abstract

During powder bed based additive manufacturing processes a component is fabricated by locally melting of powder layers with a laser or an electron beam. The fast melting process of the stochastic powder bed induces vigorous melt pool movements which sometimes lead to faults acting as starting points for larger defects such as channels bridging many layers. Since the formation of these defects cannot be understood in the framework of a homogenized numerical approach we have developed a mesoscopic numerical model based on the Lattice Boltzmann Method for the local melting process which considers individual powder particles. The model takes into account full hydrodynamics including capillary and wetting effects. It is shown that these effects combined with the stochastic powder layer are the origin of fault formation. The numerical results are compared with experiments in order to demonstrate the predictive value of our model.

Keywords: Electron Beam Melting; Lattice-Boltzmann; Free Surface; Layer Connection Defects; Porosity; Additive Manufacturing

1. Introduction

Additive manufacturing has recently seen a risen interest, both in the consumer sector, as well as in industrial applications. However, only a few processes have been developed to a level at which they can compete with conventional manufacturing processes in series production. Two of these processes for metals are Selective Electron Beam Melting (SEBM) and Selective Laser Melting (SLM). As Karunakaran et al. (2012) point out, they are so far used for medical implants and considered for various small series production lines as well as high technology components.

SEBM and SLM both share the basic principle of consecutively building a three dimensional component from two dimensional cross sections in a powder bed. In both cases, a thin powder layer is applied and selectively heated beyond its melting temperature with the help of a beam. In this way, the 2D cross section of the part supposed to be built is molten within the powder bed. Subsequently, the process is repeated until the component is finished.

The complex local melting process is yet poorly understood. It is not only governed by the beam parameters such as shape, velocity and power, but also by the surface topology of the preceding layer and the configuration of the new powder layer. The spatial distribution of the powder particles is a stochastic result of granular flow, dependent on powder parameters, such as the mean particle diameter, and the deposition process.

There are various groups describing beam melting processes by simulation. The global temperature field has been intensively studied numerically. Models for this purpose are often based on finite element methods and

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