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3D Multilayer Grain Structure Simulation for Beam-Based Additive Manufacturing

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The correlation of build parameters for beam-based additive manufacturing like scanning speed, beam power or hatching strategy on the resulting microstructure are still not fully understood. One of the key challenges lies in the difficulty to make in-situ observations during the build process. Technologies operating under vacuum conditions, like Selective Electron Beam Melting (SEBM), severe these challenges. Especially the high temperatures and long build times prevent the direct investigation of the resulting microstructure. Numerical modeling and simulation allows not only the direct observation of the influence of various build parameters. Constantly increasing computational power enables the calculation of a multitude of parameter combinations simultaneously and thus the virtual optimization of the build process without the need of time- and cost-intensive experiments.

The last few years have brought substantial progress in the development of numerical models, especially in 2D Simulations [1-2]. These sophisticated models are capable – among others – to predict the resulting microstructure caused by distinct build- and material parameters. Modeling the grain structure in 2D is limited, e.g., grains developing and growing outside of the calculation plane are not considered. Thus, it is not possible to take the common phenomenon of piercing grains that cut through the observation plane into account. Furthermore, the variation of the meltpool geometry due to various hatching strategies is disregarded with these models.

To consider those phenomena, it is necessary to model the build domain in 3D. The 3D grain growth model presented here bases on a cellular automata model [3]. This algorithm was originally developed for growing of dendrites into an undercooled melt, so various adaptions for additive manufacturing had to be made which will be demonstrated in this work. The beam is modeled as moving heat source using an analytical temperature solution [4] (cf. Figure 1a). This analytical solution is well suited for the use of our grain growth model as comparisons of the melt pool shape and dynamics with experimentally observed characteristics [5] show.

The very fine spatial and temporal resolution necessary for grain growth simulation cause an enormous challenge to the computational hardware as well as the applied algorithms. Therefore, our algorithm is massively parallelized and runs on an HPC-Cluster containing thousands of computation cores. With this computational power, it is possible to calculate a complete layer within minutes. This enables us to study the impact of various hatching strategies on the resulting microstructure of a complete additive manufactured part within reasonable time.

The presented numerical 3D grain growth model enables us to investigate the effects of various build parameters and hatching strategies on the resulting microstructure. It is not only capable of simulating the melting and re- solidification of a single layer (cf. Figure 1b). Multiple successive runs with individual beam guiding parameters enable the investigation of the effect of various hatching strategies on the 3D microstructure of an additive manufactured part (cf. Figure 1c).

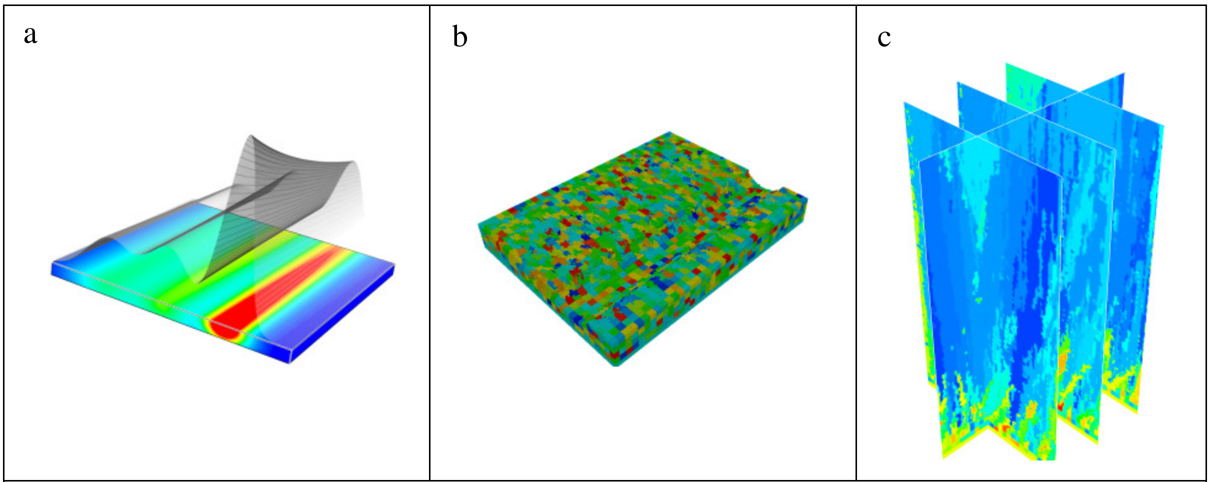

Figure 1: a) Schematic representation of the temperature field caused by three moving beams, b) Melting and re- solidification of a single layer, c) Simulated Microstructure of an additive manufactured part

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