Modelling of grain structure for additive manufacturing

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ABSTRACT

The control of the grain structure is of prime importance for mechanical properties as well as for the control of defects formed during mushy zone solidification of metallic alloys. Its modelling needs to be addressed at the scale of the product, i.e. the processing scale. This is particularly true for additive manufacturing for two reasons. First, epitaxial growth of the dendritic microstructure can proceed from one layer to the other and propagate the crystallographic orientation of the pre-existing grains. As a consequence, a given grain initially present at the start of the process (e.g., as part of the substrate) can still be found at the very last layer deposited by additive manufacturing. This was demonstrated for various metallurgical systems and could even be used for the production of single crystals by electron beam melting [1]. The second reason is due to the need for good prediction of heat and mass transfer in the melted region, which requires a solution of the energy and momentum conservation equations for the whole system under investigation.

The Cellular Automaton – Finite Element (CAFE) model aims at predicting the solidification grain structure for the entire product. Its basic algorithms are simple to reproduce and were shown to mimic well the growth competition between columnar dendritic grains growing in a temperature gradient [2, 3]. This situation is typically found in additive manufacturing involving melting and directional solidification. However, optimizations of the numerical implementations are required in order to access parallel computations and address large simulation domains.

The presentation will give an overview of the methods developed for simulating grain structure in additive processing [4]. This will be demonstrated for multiple pass welding with metal addition [5]. Discussions for extension to additive manufacturing by laser or electron beam melting will follow.

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