Simulation of metallic powder bed additive manufacturing processes

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Metal additive manufacturing (AM) is a rapidly emerging manufacturing technology enabling the creation of parts with novel geometry and complex internal structures not possible using conventional subtractive technologies. However, despite a great deal of excitement about AM, the process is not as accurate and repeatable as promised and suffers from many challenges. Multiple rapid melting and cooling cycles of the metal AM process result in a highly transient temperature field and high-temperature gradients. The complex geometry of AM parts, which is one of the most important benefits of the technology, is a key factor leading to the formation of overheated areas. The AM-induced overheated areas are matters of keen concern with respect to their effect on accuracy and repeatability of the part geometry, residual stresses, distortion, and mechanical properties of the final part. To prevent overheated areas from forming during the AM process, it would be necessary to adapt process parameters and/or to develop smart scanning strategies. The AM process itself is very complex and multiphysical, with many parameters, such as scanning strategies, heat source speed and power, all playing important roles in producing parts without defects described above.

Heat transfer is undoubtedly one of the most important phenomena in AM, and an attractive way to understand the thermal processes arising in AM is using simulations. The first step to design algorithms and methods for adapting scanning speed and power as well as for developing smart scanning strategies is the identification of overheated areas. Our study focuses on this challenge.

Another key challenge is to additively manufacture parts with better properties than those of cast parts. Microstructure is a vital factor defining material properties. During the metal AM, a specific microstructure is formed, being different from the microstructure of the cast or wrought alloys of the same composition [1]. The accumulated experimental evidence on AM indicates the formation of a pronounced texture [1]. Texture may significantly affect mechanical behavior of the produced components. Nevertheless, recent studies show that crystallographic orientation and morphology of grains can be controlled by process parameters and scanning strategies [2]. A thorough understanding of the fundamental relationships between process, microstructure, and mechanical properties is required to develop and optimize the metal AM technology. Our work concentrates on the first part, namely on grain structure formation during AM. Particular emphasis was placed on the numerical efficiency of the chosen methods and models.

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