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Metal Particle Fusion Analysis for Additive Manufacturing Using the Stabilized Optimal Transportation Meshfree Method

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Abstract Selective Laser Melting (SLM) is an Additive Manufacturing (AM) process where a powder bed is locally melted. Layer by layer, complex three dimensional geometries including overhangs can be produced. Non-melted powder thereby acts as support structure. The process is held under an inert gas atmosphere to prevent oxidation. The principal machine parameters in SLM processes are the laser power, the scan rate and the laser spot radius. The powder bed is characterized by the material, the packing density and the particle size distribution. These factors define the structure of SLM finished parts. Up to date, the material and process development of SLM mainly relies on experimental studies that are time intensive and costly. Simulation tools offer the potential to gain a deeper understanding of the process - structure - property interaction. This can help to find optimal process parameters and to individualize AM manufactured parts.

A continuum framework for the finite deformation phase change problem is developed. For its numerical solution the stabilized Optimal Transportation Meshfree Method (OTM) is employed. The advantage of meshfree over conventional mesh based techniques is that the treatment of particle fusion is intrinsic to the formulation. This is important to resolve the complex moving boundaries between liquid melt flow and solid metal. In a numerical example consisting of two metal powder particles, the influence of laser heating and cooling conditions on melting and consolidation is analyzed. A detailed parameter study is presented. The insight gained from the simulations may help to narrow the parameter window for further investigations.

Keywords Additive Manufacturing · Selective Laser Melting · Phase Change Modeling · Implicit Meshfree Scheme · Optimal Transportation Meshfree Method

1 Introduction

The first processing step in Selective Laser Melting is to spread a thin layer of metal powder from a powder stock onto a build plate of bulk metal. Next, the powder bed is partially irradiated with a laser according to a tool-path derived from a CAD model. The laser causes the metal to melt, thereby the powdered material fuses together and forms a melt pool. Since the heat input is highly localized, the

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