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Hui Chen, Qingsong Wei, Shifeng Wen, Zhongwei Li, Yusheng Shi

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Flow behavior of powder particles in layering process of selective laser melting: numerical modeling and experimental verification based on discrete element method

Hui Chen, Qingsong. Wei*, Shifeng Wen, Zhongwei Li, Yusheng Shi

State key Laboratory of Materials Processing and Die & Mould Technology, School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, PR China

Abstract: Powder-layering is an essential process of selective laser melting (SLM), but the underlying mechanisms of powder movement and packing at particle scale is unclear. Based on discrete element method (DEM), this study proposed a numerical model to investigate the flowing behavior of powder layered by a blade, where the contact force and cohesion force between individual particles were considered. DEM simulations gave visual morphologies of the flow profiles and velocity fields for powder-layering at particle scale, as well as the relationships between the quality of powder bed and the layering parameters. The model was validated by experiment results in terms of the macroscopic profiles of powder during layering, showing good prediction accuracy. Then, dynamic repose angle (DRA) and mass flow rate (MFR) were defined to make quantitative evaluation on the powder flow. Preliminary research shows that, the powder fluidity increases with the decreasing of particle friction coefficients, resulting in a denser and more uniform powder bed. The decreasing of particle radius R over the range of R > 21.8 μm can benefit the powder fluidity. However, when the particle radius decreases in the range of R < 21.8 μm, the weight of cohesion force rises and thus makes the powder fluidity worse. The increase of layering speed enhances the dilation of moving particles, and the decrease of layering height intensifies the local force-arches in particles. These will reduce the continuity and stability of the powder flow and is unfavorable for improving the density or uniformity of the layered powder bed.

Keywords: Powder layering; Particle flow; Selective laser melting; Additive manufacturing; Discrete element method.

1. Introduction

Selective Laser Melting (SLM), as a powder-based additive manufacturing process, has become an important technology for the production of a wide variety of components and structures in the last decade [1]. It is a powder-bed fusion process that employs high intensity laser as an energy source to melt and fuse selective regions of powder materials, layer by layer, basing on computer aided design (CAD) date. As depicted in Fig. 1a, the SLM consists of two major processing steps in each fabrication period [2,3]: powder-layering and powder-melting. Firstly, in the step of powder-layering, the delivery chamber rises by a certain level, and the building chamber declines with one layer thickness. Then the powder in delivery chamber is scraped into the building chamber by a layering apparatus to form a layer of powder bed. Secondly, in the step of powder-melting, a high energy density laser is used to melt selected areas of the powder bed, according to the CAD data. These two processing steps are repeated for successive layers of powder until the required part is completely built. The quality of the fabricated part is mainly influenced by three aspects [4]: the scan strategy of laser, the material formulation of powder, and the state of the powder bed. So far, an overwhelming majority of investigations are focused on the scan strategy of laser and the material formulation of powder in order to improve the quality of the fabricated part [5]. Actually, as shown in Fig. 1b, the state of the powder bed formed in powder-layering, such as packing density and

[*] Corresponding author at: School of Materials Science and Engineering, Huazhong University of Science and Technology, Luoyu Street 1037, Wuhan 430074, PR China.
E-mail address: wqs_xn@163.com (Q.S. Wei)