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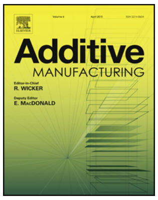

A study on the effect of energy input on spatter particles creation during selective laser melting process

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ABSTRACT

Selective laser melting (SLM) is a promising manufacturing technique for the production of complex metallic components. One of the crucial factors influencing the mechanical properties of the final product is spatter particles formation during the process. In this study, high- speed photography is utilized to record the formation mechanisms and the dynamic behavior of spatter particles. An image processing analysis framework is utilized to assess the distribution of spatter particles under various energy inputs. It is found that changing the laser scan velocity has more influences on spatter formation in comparison with the energy input. The relationship between the numbers of created spatter particles, induced unmelted regions and density variability are interpreted and discussed based on other observations, such as microscopic examination and density analysis of SLM parts. The obtained results could be used to enhance the current manufacturing process parameters optimization methods in SLM process.

1. Introduction

In recent years, additive manufacturing (AM) has gained a key role in manufacturing technology due to its potential in fabricating strong and complicated personalized parts with a high precision. Selective laser melting (SLM) is one of the most commonly used AM techniques, which has the capability of directly manufacturing near-fully dense metallic parts. SLM shows the potential to make metallic lattice structures with delicate and complex geometries, which are very challenging or even impossible to be fabricated by conventional manufacturing techniques. Although the SLM process offers a great opportunity to fabricate complex metallic parts, it is affected by defect formation during the fusion process. The induced defects such as porosities, cracks, and unmelted regions are detrimental to the physical and mechanical properties of fabricated parts.

Spatter particles as one of the major sources of defects creation during SLM process have been studied in few works. Simonelli et al. [1] studies the spatter particles morphology and their compositions. It was found that the laser spatter has a spherical geometry regardless of the materials that were being proceeded. In addition, it was concluded that the chemical composition of spatter particles contains oxygen. Mumtaz and Hopkinson [2] utilized a novel technique to control the heat delivered to melting pool and consequently decrease the amount of created spatter particle during SLM. Bin Anwar and Pham [3] and Ladewig et al. [4] investigated the effects of laser scan direction, part placement, and inert gas flow velocity on the spatter creation and consequently the tensile strength of Al-Si10-Mg during SLM process. Also, Liu et al. [5] and Wang et al. [6] examined the influence of defects made by spatter particles on the mechanical properties of 316L stainless steel and CoCr, respectively. Their results show the inclusions made by spatter particles have a significant effect on tensile properties of SLM parts. In another study, Khairallah et al. [7] and Ly et al. [8] used a three-dimensional powder-scale model to investigate the importance of recoil pressure and Marangoni convection in spatter particle formation in SLM technique. Repossini et al. [9] studied the suitability of the spatter-related information for the development of in-process monitoring tools.

The authors previously studied the role of recoil pressure in SLM process using multi-laser technology [10]. High-speed photography is utilized and the mechanism of spatter formation is recorded and analyzed by a developed computational image analysis frame-

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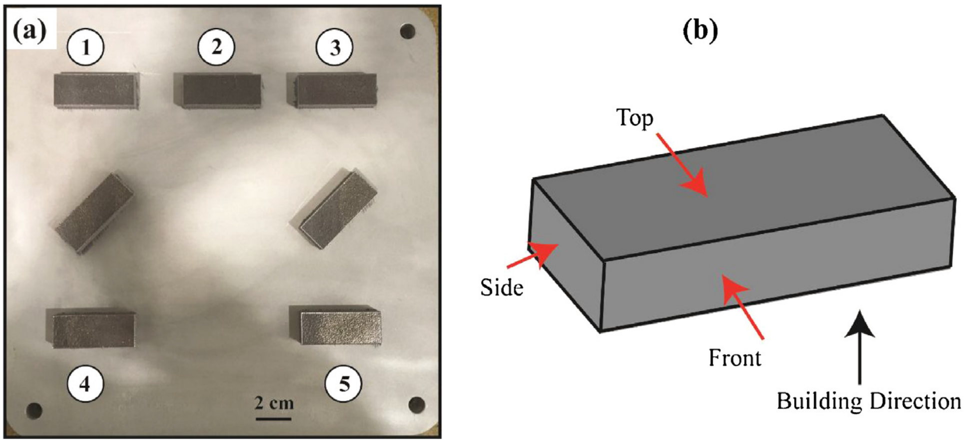

Fig. 1. (a) Image of samples fabricated in this study on the SLM 2800HL building platform. Each sample has different manufacturing process parameters as listed in Table 1. (b) Schematic representation of one of the samples shown in (a) with the red arrows to demonstrate where parts are sectioned for microscopic analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Process parameters and the resulting energy input used in this study.

Sample	Effective Laser Power W	Layer Thickness µm	Scan Velocity mm/s	Hatch Space µm	Energy Input J/mm^3
1	350	30	1650	120	58.9
2	375	30	1650	120	63.3
3	250	30	1650	120	42.1
4	350	30	1200	120	81.1
5	350	30	2100	120	46.2

work. In the present research study, the developed computational image analysis framework is utilized to capture the dynamic process of spatter particle formation during SLM process of Al-Si10-Mg under various energy inputs. The number and the size of spatter particles under various energy inputs are assessed for the first time, and experimentally validated by the keyhole threshold criteria for the SLM process. The photography results are also compared with the microscopic examination and density analysis of SLM parts. The results shed light into the unknown relationship between the spatter formation mechanism and the induced unmelted regions in SLM parts.

2. Materials and methods

An SLM 280HL (SLM Solutions Inc., Lübeck Germany) machine equipped with two 400 W CW Ytterbium fiber lasers is used in this study. The laser beams have beams diameters of approximately 80 µm at the focal point of laser radiation. The building platform of the machine has dimensions of 280 mm × 280 mm × 350 mm. The build chamber is flooded with argon gas to decrease the oxygen level to less than 0.1% before starting the experiments. The argon gas is maintained throughout the process to keep the oxygen low during the fabrication. The pre-alloyed Al-Si10-Mg powder which has been gas atomized is used as printing powder. The average particle size is ranging between 30 µm and 50 µm. Rectangular

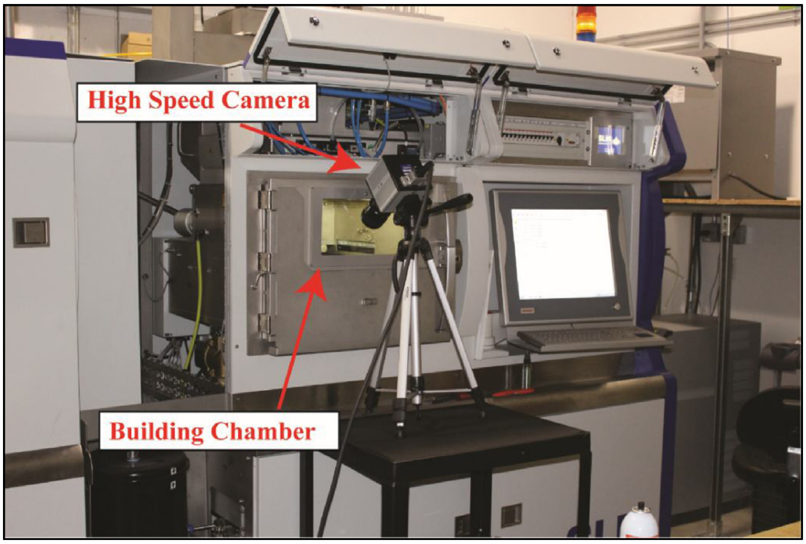

Fig. 2. A Fastcam 1024 PCI high-speed camera is placed in front of a 2800 SLMHL machine to capture the manufacturing process. The building chamber is bright enough to support high-quality high-speed video photography.