A STRATEGY TO DETERMINE THE OPTIMAL PARAMETERS FOR PRODUCING HIGH DENSITY PART IN SELECTIVE LASER MELTING PROCESS

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Abstract

Finding the processing conditions which can produce high density components using Selective Laser Melting (SLM) technique based on trial-and-error is costly and time consuming. With a given SLM machine characteristics (e.g., laser power, scanning speed, laser spot size and laser type), powder material and powder size distribution, the present study proposes an approach to reduce the time and cost in searching optimal parameters for fabricating fully dense parts. The proposed method include several simulation models which are powder bed simulation, Monte Carlo ray tracing simulation, Finite Element Heat Transfer simulation and surrogate modeling. These simulation models are employed to find the viable processing parameters to produce high density component. The experimental results show that the proposed methods results in a maximum component density of 99.97%, an average component density of 99.89% and a maximum standard deviation of 0.03%.

Keywords: Additive manufacturing, Selective Laser Melting, Surrogate Model

1.Introduction

In SLM processing, before conducting experiment to fabricate high density part, the optimal parameters for single tracks are generally found though experimental study. For instance, by conducting single scan track experiment, King et al. [1] concluded that key-hole formation in the melt pool can lead to high porosity in the fabricated component. As a consequence, processing window should not contain parameters which result in key-hole melting regime. Furthermore, the authors in [2] conducted single track experiment in a wide range of laser power, scanning speed and powder layer thickness to study the effect of those parameters on the formation and stability of single scan track. This study concludes that the instability of single scan track lead to the reduction of the density of final parts.

However, experimental methods for searching the processing parameters are costly and time consuming. To address the mentioned issues, the present study used the powder bed simulation, ray tracing simulation, Finite Element (FE) heat transfer simulation and surrogate modeling to find the optimal powder layer thickness. Additionally, the simulation package also predicts the combination of laser power and scanning speed to ensure the stability of single scan track. Accordingly, the processing condition which has high potential to produce fully dense component can be predicted from simulation. For demonstrating the feasibility of the proposed approach, the found parameters were employed to fabricate 316L stainless steels cube with dimension of 10 mm × 10 mm × 5 mm.

2.Methodology

With a given SLM machine, powder material, and powder size distribution, the density of fabricated component depends on the laser power, scanning speed, and powder layer thickness. Table 1 summarizes the powder and SLM machine characteristics considered in the present study

Table 1: Powder and machine parameters

Powder material	Stainless Steel 316L (SS 316L)
Powder size distribution	d_{10} = 22.94 μm; d_{50} = 38.52 μm; d_{90} = 56.88 μm
Range of laser power (P)	50 – 400 W
Range of scanning speed (v)	100 – 2000 mm/s
Laser spot size	D4sigma = 120 μm
Laser type	Nd: YAG laser

Based on the given powder size distribution, the sequential addition model developed in our previous study [3] was employed to construct 316L powder beds with thickness ranging from 10 μm to 70 μm. Furthermore the Monte Carlo ray-tracing simulation developed in our previous work in [3, 4] was utilized to analyze the absorption characteristics for different cases of powder layer thickness. Then, FE heat transfer simulation and surrogate modeling was used to construct the processing map for the SLM process. Finally, following the step-by-step procedures proposed in our previous work in [5], the viable region of laser power and scanning speed corresponding to the optimal powder layer thickness was found by the simulation package. Fig. 1 shows the fabricated 3D cube in the optimal region and Table 2 shows the results of measured density of the eight 3D cubes.

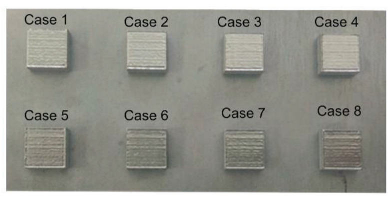

Fig. 1 3D cubes produced using optimal SLM parameter settings.

Table 2 Mean and standard deviation values for densities of eight SLM-produced cubes

Case	1	2	3	4	5	6	7	8
Density	99.90 %	99.70 %	99.97 %	99.96%	99.91%	99.80%	99.95%	99.96%
Standard deviation	0.01%	0.02%	0.01%	0.03%	0.01%	0.01%	0.04%	0.01%

The results presented in Table 2 confirm that the processing parameters selected using the proposed systematic procedure result in both a high SLM quality (i.e., a high density) and good reproducibility. In other words, the proposed method provides an extremely effective and low-cost solution for determining the optimal SLM processing parameters in comparison to traditional trial-and-error-based experimental methods.

3.Conclusion

This study has presented a systematic approach for determining the values of the laser power, scanning speed and powder layer thickness which maximize the density of SLM components. Additionally, for different SLM machine's brands, the configurations such as range of laser power and scanning speed, laser type, laser spot size would be various. By taking those parameters into account during the optimization process, the proposed methodology can help user find the optimal processing condition for producing part with high density efficiently. Additionally, the simulation model for calculating the packing density and analyzing the absorptivity of powder bed can be used to design the suitable powder parameters for new powder material.

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