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Investigation on the direct laser metallic powder deposition process via temperature measurement

Guijun Bi [a,*], Andres Gasser [b], Konrad Wissenbach [b], Alexander Drenker [b], Reinhart Poprawe [b]

[a] *Innovative Manufacturing Processes Group, School of Mechanical, Materials and Manufacturing Engineering, University of Nottingham, University Park NG7 2RD, UK*

[b] *Fraunhofer Institute for Laser Technology-ILT, Steinbach Str. 15, D 52074 Aachen, Germany*

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Abstract

The direct laser metallic powder deposition process was investigated with the aid of a radiant thermometer by building thin walls. The measured infrared (IR) temperature signal showed good correlation with the deposition process and the quality of the deposited samples. The influence of the powder particle size and the *z*-increment on the quality of the deposited samples and the IR-temperature signal was examined. It was found that the particle size of the powders shows no significant influence on the measured IR-temperature signal and the deposition process. However, both the deposition process and the measured temperature signal depended strongly on the *z*-increment. The variation of the melt pool temperature and cooling rate resulted in an inhomogeneous dimension accuracy, microstructure and hardness of the deposited sample. An abnormal deposition process can be recognized by the IR-temperature signal.

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Keywords: Metallic powder deposition; Laser; Temperature measurement; Radiant thermometer

1. Introduction

Direct metallic powder deposition with laser demonstrates great potential in the fabrication of three-dimensional components and repair of high-value machine tools and parts [1–6]. A three-dimensional deposition can be realized with the integration of a laser to the CNC-machine, owning to the good focusibility and flexibility of the laser beam. The generation of a component can be achieved by the CAD/CAM process chain. The costs and time can be significantly reduced to get a product ready for use in comparison with traditional manufacturing processes. This is of great importance for high-value parts with single or low mass production. There are many parameters which govern the process [7] and consequently, affect the quality of the product. The complexity of the process itself hinders its wide applications in the industry. Therefore, a thorough understanding of the deposition process is imperative. During the deposition process the change of the melt pool temperature influences its expansion. This results in a deviation of the real contour from the desired contour. In some extreme cases the deviation can add up to millimeter range [8]. A monitoring of the melt pool temperature can be useful for comprehending the deposition process. The influence of laser power, table feeding rate and powder feeding rate on the infrared (IR) temperature signal has been studied in [9] by the deposition of single tracks. In this study, the deposition process was investigated with the aid of a photodiode-based radiant thermometer by building thin walls. The measured signal was used to interpret the thermal behavior of the process. The influence of the powder particle size and the *z*-increment on the quality of the deposited parts was studied in detail.

2. Experimental procedure

The experiments were carried out with the setup shown in Fig. 1. The system includes a 4-axes CNC-machine, a cw Nd:YAG laser HL 3006D with a 3 kW maximum output power and a process head with integrated sensors for the temperature

* Corresponding author. Tel.: +44 115 9513738; fax: +44 115 9513800.
E-mail address: Guijun.bi@nottingham.ac.uk (G. Bi).

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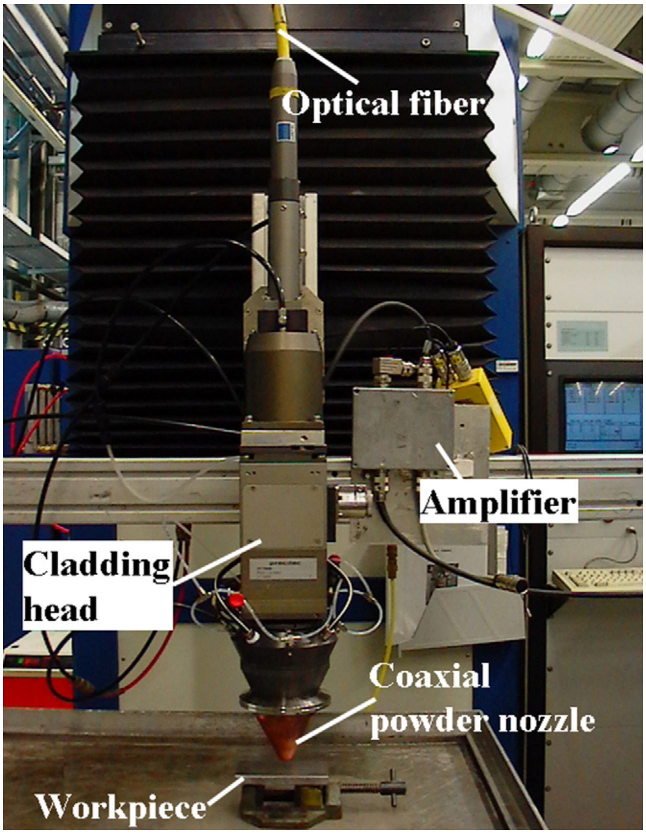

Fig. 1. Experimental setup for direct laser metallic powder deposition and temperature measurement.

measurement and monitoring the laser power signal. Additionally, an accurate powder feeder was employed for the experiments. The laser beam was guided to the workstation through an optical fiber and focused by an optic which has a 200 mm focal length. The process head ensured a coaxial powder feeding. A germanium photodiode with a functional wavelength of 1300–1600 nm was integrated coaxially to the laser beam, which ensures that the temperature measurement is not influenced by the change of the scanning direction of the laser beam. The powders used were stainless steel 316L with a diameter of 20–53 and 53–150 μm, respectively. The compositions of the powders are shown in Tables 1 and 2, respectively.

The building strategy for the thin wall is displayed in Fig. 2. The wall was generated continuously through the forward and backward movement of the workpiece in relation to the process head. The table had to firstly decelerate and then accelerate, due to the change of the moving direction of the worktable at both ends of the wall. Thus, the speed of the table at both ends was zero, whereas the laser was not switched off. This phenomenon exists for all three-dimensional depositions. Besides the laser power, powder feeding rate and table feeding rate, the z-increment is an important parameter and it can influence on the quality of the end product, such as dimension accuracy, surface roughness and surface oxidation [8]. The particle size of the powders is another important factor for the deposition process. Thus, the studies were carried out by building thin walls with different z-increments and the 316L powders of two particle sizes.

Table 1
Composition of the stainless steel 316L powder in size of 20–53 μm

Element	Wt.%
C	0.019
Cr	16.8
Fe	Base
Mn	1.0
Ni	12.5
Mo	2.4
Si	0.6

Table 2
Composition of the stainless steel 316L powder in size of 53–150 μm

Element	Wt.%
C	0.017
Cr	17.5
Fe	Base
Mn	1.3
Ni	13.0
Mo	2.7
Si	0.7

Through preliminary experiments, the basic parameters were determined as following: laser power, P_L: 300 W; beam size, D_L: 1 mm; table feeding rate, v_v: 500 mm/min; powder feeding rate, m_p: 2.4 g/min; length of the wall, L: 60 mm; number of the layers: 120.

3. Results and discussion

3.1. Effect of the particle size

Two thin walls were built with 316L powers in size of 20–53 and 53–150 μm, respectively. The optimum z-increment of 0.15 mm for the real growth of the deposited layer was obtained. The pictures of the two walls are shown in Fig. 3. They show a similar surface quality and dimension accuracy. The measured IR-temperature signals are shown in Figs. 4 and 5 with different time resolutions. From the complete curves measured for 120 layers it can be seen that the temperature increases rapidly at the beginning and then keeps increasing

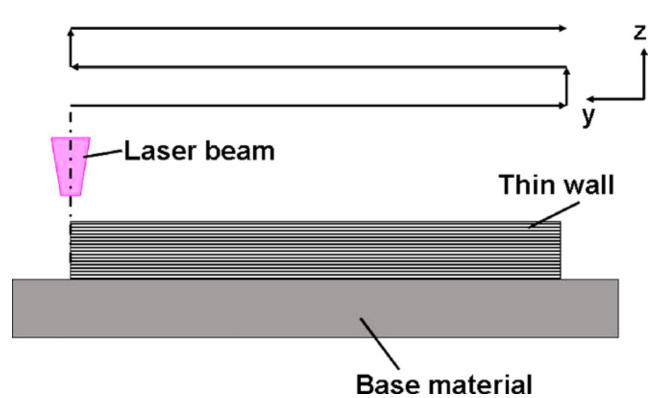

Fig. 2. Schema of the building strategy.