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Development of laser beam modulation assets for the process productivity improvement of selective laser melting

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Abstract

A system of optical monitoring and diagnostics of selective laser melting process with alternative beam power density distributions is developed. The experimental work with input parameters variation showed the correlation between obtained power density distribution and geometrical parameters of single tracks. Technological gaps of stable track formation for different distributions have been detected, and high-speed process photography have been realized.

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Keywords: selective laser melting, laser power density distribtuion, additive manufacturing, optical monitoring, CoCrMo powder.

1. Introduction

Nowadays the methods of rapid prototyping and additive manufacturing are developing very intensively. One of the most perspective methods of solid growing is selective laser melting. SLM is important in such industries as machine and aviation building and individual medical applications [1-3]. Main principle of the method is layer-by-layer growing solids by remelting of powders with laser beam in accordance with 3D models [4, 5]. Still there are some unsolved problems in the method productivity. With enlarging of the laser source power, the problem of the productivity could not be resolved directly [6].

Optical diagnostics of the process while processing showed that there is the conscience of the thermal hit in the melting pool as powder granules' escape, interruption of the powder layer equability, Marangoni effect, active chemical interaction with camera environment, overheat and dynamic effects in the melting pool [7]. Problems above could be connected with the features of temperature gradients in the melting pool [8], resulted from the power density distribution (TEM00).

In this paper, the development of optical assets for laser beam modulation to improve the productivity of selective laser melting by the example of single track formation from CoCrMo powder was represented. Parameters of the system for experimental assets for alternative Gaussian laser power distribution were obtained. System approbation was made by using the methods of optical monitoring and diagnostics.

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Nomenclature

d	diameter of powder granules
V_P	velocity of powder feed
V_S	velocity of scanning
S_1	velocity of platform feed
S_2	velocity of powder dosage feed
P	laser beam power

2. Material and methods

2.1. Material

As a material for current research work the commercially available powder of cobalt-chrome alloy CoCrMo was used (table 1). This powder was produced by using the method of gas atomization. It has a spherical particle morphology, which is more preferable for SLM use. Powder presents a spherical morphology that was identified by the SEM investigation using Tescan Vega 3 LMH instrument (Czech Republic) (fig. 1).

Granulometric analysis was performed by Alpaga 500 nano instrument (Occhio SA, Belgium). Statistical distribution of particles was by equivalent diameter of d5= 14.5 µm, d50= 30.3 µm, d95= 45.9 µm with a mean equivalent diameter of about 30 µm. 67.1% of particles has a spherical morphology, meanwhile 2.4% has irregular one (fig.2).

Because of limited space for experimental work and large quantity of used optical equipment the melting processes were produced without any additional protective cover or protective atmosphere. The previous practice of work with CoCrMo powder for SLM showed that this material has the largest heat resistance in comparison with other popular materials as Ti6Al4V or maraging steel. Chemical composition is represented in the table. Powder layer thickness was measured by optical microscope Olympus BX51M (Japan). For the experiments, the powder was sieved, blended and dehumidified by heating at the temperature of 100 °C during 4 hours. The carbon steel St20 was used as a substrate.

Table 1. Chemical composition of CoCrMo powder

Element	Co	Cr	Mo	Si	Mn	Fe	C	Ni
Content, %	60-65	26-30	5-7	>1	>1	>0,75	>0,16	>0,1

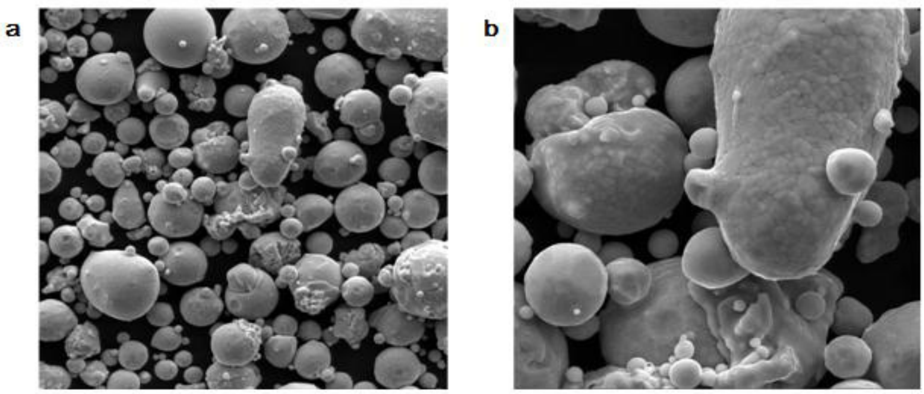

Fig.1. SEM images of CoCrMo powder x1200 (a) and x4000 (b)