Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 56 (2014) 48 – 57

Physics Procedia

8th International Conference on Photonic Technologies LANE 2014

Experimental approbation of selective laser melting of powders by the use of non-Gaussian power density distributions

Anna Okunkova[a,*], Marina Volosova[a], Pavel Peretyagin[a], Yuri Vladimirov[a], Ivan Zhirnov[a], A.V. Gusarov[a,b]

[a]*Moscow State University of Technology "STANKIN", Vadkovsky pereulok 3a, 127055 Moscow, Russian Federation*
[b]*École Nationale d'Ingénieurs de Saint-Étienne, 58 rue Jean Parot,42023 Saint-Etienne, France*

Abstract

Experimental results on laser beam modulation at selective laser melting (SLM) are presented. The modulation is a possible way to improve the efficiency of the SLM process. The optical diagnostics shows the energy loss up to 30%. This could be a consequence of high thermal gradients in the melt pool resulted by the Gaussian power density distribution. The Gaussian distribution can be changed to the flat-top one or to the inverse-Gaussian (donut) one. An experimental stand with a 200W laser source was developed. Twenty single tracks for each of the three modes were obtained for a Co-Cr alloy. The samples were studied by scanning electronic microscopy (SEM) on irregularity. Optical diagnostics by high velocity camera (HVC) shows that the use of the non-Gaussian laser beam distributions can significantly reduce the width of the free-of-powder consolidation zone, which is considered as the main reason for irregularity of single tracks. A better metallurgical bonding of the single tracks with the substrate was obtained by the use of the flat-top laser beam. Both of these facts show a significant influence of the laser beam energy distribution on the energy loss at SLM, especially for high power laser sources. The observed escape of granules shows a possible influence of the dynamic factor. The use of the non-Gaussian distributions can enhance 3D parts, for example, improve the geometrical tolerance and decrease the residual porosity.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: Additive manufacturing; selective laser melting; laser beam modulation; non-Gaussian power density distribution

* Corresponding author. Tel.: +7-909-913-1207 ; fax: +7-499-973-39-17 .
E-mail address:a.okunkova@stankin.ru, 9131207@gmail.com

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2014.08.095

1. Introduction

The technology of selective laser melting (SLM) is one of the methods to build up 3D objects based on layer-by-layer principles. It's an alternative to the traditional methods of processing and manufacturing. SLM is actively used for different applications. For example, application of SLM for implants from bioglass and bioceramics is discussed by Esteban-Tejeda et al. (2012). Shishkovsky et al. (2013) argues that SLM is useful in the aerospace industry for fabrication parts from oxide ceramics and intermetallic alloys.

In the last few years, the possibility to improve the productivity by the increase of power of the laser source was studied. Up to now, it does not give clear results. The experiments and the optical diagnostics show the non-desirable effects as overheating of the melt pool, the powder granule escape, and the Marangoni flow (see Yadroitsev et al. (2010)).

One of the reasons of the non-desirable effects could be high temperature gradients in the melt pool. It makes the track less homogenized and significantly enlarges the width of the free-of-powder consolidation zone (Yadroitsev et al. (2013)). The droplets, which escape from the melt pool, can damage the optical system of the SLM machine and pollute the ambience. This effect influences the microstructure of the material and can considerably reduce the mechanical properties (Doubenskaya et al. (2012, 2013)). The escape of droplets is supposed to depend on the gradient of power density distribution in the laser spot on the powder layer, which creates high-speed melt flows in the processing zone (Gusarov et al. (2007), Smurov et al. (2012)). The flows influence the granules near the board of the melt pool and heat them up. These effects were described by mathematical models (Gusarov et al. (2013)).

Today the SLM machine builders have no solution on the industry level. The above non-desirable effects can be only reduced by smoothing the temperature gradients in the melt pool. There are two main ways to achieve it: the preheating of the powder layer and the modulation of the laser beam. The powders can be preheated by preheating the working platform. But it is difficult to realize because of the problem of the heating coil placement.

Meanwhile, there are much more opportunities for laser beam modulation. These opportunities have been studied by different scientists in the period of 2000-2012 (Hendrics et al. (2012), Dickey et al. (2006), Voelkel and Weible (2008), Voelkel et al. (2005)) as a principal possibility to change a laser beam mode from the Gaussian one to the flat-top and the donut ones. However, there are no appropriate experimental studies for the SLM process.

The approach could correct the gradient of temperatures in the melt pool (to make it more smooth and uniform) with the purpose to create optimal conditions of the heat and mass transfer which can reduce or completely exclude the non-desirable effects as the droplets escape. The proposed shaping of the laser beam could reduce the porosity and the cracking of the parts and improve their quality and geometrical tolerance.

Nomenclature

A	laser beam cross section area, mm^2
D	laser beam diameter, mm
f'	focus distance F-theta lens, mm
R	distance between different distributions, mm
λ	laser wave length, µm
P	laser power, W
V	laser scanning speed, mm/sec
W	single track width, µm
L	width of powder consolidation area, µm
E_S	specific energy, J/mm^2
E_d	specific energy density distribution, J/mm^3

2. Problem statement

Dickey et al. (2006) showed that obtaining a uniform temperature field in the heating zone is possible with the flat-top or even the inverse-Gaussian laser beam mode. Klocke et al. (2003) defined around twelve main parameters