Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 56 (2014) 64 – 71

Physics Procedia

8th International Conference on Photonic Technologies LANE 2014

Layerwise Monitoring of the Selective Laser Melting Process by Thermography

Harald Krauss[a,*], Thomas Zeugner[b], Michael F. Zaeh[a]

[a]*Institute for Machine Tools and Industrial Management, Technische Universitaet Muenchen, Application Center Augsburg*
[b]*Institute of Physics, University of Augsburg*

Abstract

Selective Laser Melting is utilized to build parts directly from CAD data. In this study layerwise monitoring of the temperature distribution is used to gather information about the process stability and the resulting part quality. The heat distribution varies with different kinds of parameters including scan vector length, laser power, layer thickness and inter-part distance in the job layout. By integration of an off-axis mounted uncooled thermal detector, the solidification as well as the layer deposition are monitored and evaluated. This enables the identification of hot spots in an early stage during the solidification process and helps to avoid process interrupts. Potential quality indicators are derived from spatially resolved measurement data and are correlated to the resulting part properties. A model of heat dissipation is presented based on the measurement of the material response for varying heat input. Current results show the feasibility of process surveillance by thermography for a limited section of the building platform in a commercial system.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: Selective Laser Melting; Process Monitoring; Thermography; Part Quality; Heat Dissipation

1. Introduction

Selective Laser Melting is a heat intense process giving rise for temperature monitoring in order to detect irregularities or errors. Thin layers of metallic powder particles are selectively melted by scanning adjacent vectors with a high energy laser beam. Using CAD data only, high quality metallic components are produced by stacking individual layers. Today, process monitoring is of great importance for demanding applications and it should be feasible with a reasonable cost-benefit ratio in order to help spreading the promising technology of additive layer manufacturing (ALM). In-Process monitoring approaches can be divided into off-axis systems measuring the whole build area at a time and on-axis systems focusing on the current beam position. In Craeghs et al. (2011), Zur Jacobsmühlen et al. (2013), Kleszczynski et al. (2012) and Grünberger et al. (2013) off-axis arrangements are presented, investigating the detection of coating errors that may arise when a new layer of metallic powder is applied. Furthermore the appearance

* Corresponding author. Tel.: +49-821-568-8334 ; fax: +49-821-568-8350 .
E-mail address: harald.krauss@iwb.tum.de

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2014.08.097

of the solidified surface is checked. On-axis setups use the same scanning and focusing unit as the processing laser in order to directly monitor the melt pool and its environment (Chivel (2013); Craeghs et al. (2010, 2012); Lott et al. (2011)). The usable wavelength band for monitoring of process emissions is severely restricted to a small band close to the laser wavelength because the same optics are employed. To enable real-time process control, on-axis setups apply sampling rates in the kHz range which are significantly higher compared to off-axis systems. This allows for continuous measurement of melt pool dynamics at scanning velocities of several meters per second.

Nomenclature

K	key indicator
j	layer index
c_p	specific heat capacity
a	thermal diffusivity
l	effective melt depth
η	absorptivity
v	scan velocity
d	hatch distance
Δ	imperfection level

2. Approach and Setup

A local change in heat flow during heat-up or cool down indicates inhomogeneous material properties and potential irregularities. Given a significant thermal contrast, these irregularities can in principle be identified and characterized. The approach in this paper uses the process heat that is induced by the laser to find inhomogeneities in the current layer. It aims at measuring the temporal evolution of the temperature distribution and comparing it to a simplified model in order to identify a process beyond its boundaries. The experiments were conducted on a commercial additive manufacturing system EOS M270 using a microbolometer thermal detector mounted off-axis at the process chamber door (Krauss et al. (2012)). The manufacturing system features a 200 W Ytterbium fiber laser, a high speed galvanometer scanning unit and an f/Θ-lens focusing the laser beam onto a fixed building platform. A TEM_{00} beam having a diameter of 70 µm and beam quality $M^2 < 1.1$ melts metallic powder particles with a mean grain size of 30 µm on the building platform. The thermal detector aims at a view angle of 55 degrees on this platform, reaches a pixel resolution of approx. 250 µm per pixel and operates at 50 Hz. Solidification is done using a stripe exposure strategy where adjacent hatch vectors of constant length and spacing are scanned and form a stripe of variable length depending on the part geometry. Even though the melt pool expands over a single hatch vector at maximum, the recurring energy input for adjacent scan tracks continuously reheats already solidified tracks (c.f. Figure 2). Process

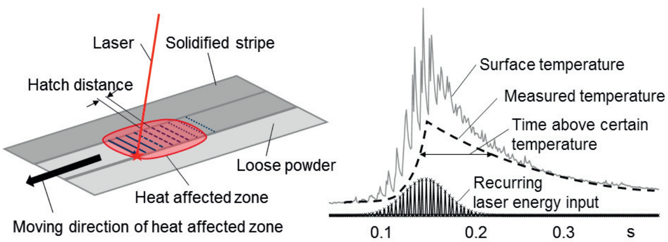

Fig. 1. (a) Stripe exposure; (b) Recurring energy input

irregularities may arise due to improper heat dissipation caused by, amongst others, varying layer thickness, foreign particles, process parameter fluctuation or drifts. However, the main contribution comes from the part geometry itself.