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Homogeneity aspects in selective laser sintering (SLS)

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Abstract

A measure of powder layer heterogeneity has been proposed. It has been tested on the layers realized by different deposition techniques. Good correspondence of the actual measure to the subjective layer quality estimation has been shown. The influence of the laser scanning strategy on the quality of sintered structure has been examined. It is shown that both the sintering precision as well as the inner sintering quality is strongly affected by the hatch distance whereas this fact has been often neglected in the past.

Keywords: Selective laser sintering (SLS); Powder deposition; Accumulated fluence

1. Introduction

SLS is a solid freeform fabrication technique. It consists in building a three-dimensional object layer by layer out of a powder selectively heated by laser radiation. The liquid formed by the partially molten material binds the surrounding powder and solidifies when the temperature decreases, which leads to consolidation.

This work is dedicated to a study of homogeneity of the sintering process. Homogeneity of fabricated parts is one of the most important criteria imposed upon the SLS process [2]. Questions related to the powder layer deposition are discussed in Section 2. Section 3 describes a simplified sintering model based on the density of energy absorbed by the powder layer and Section 4 concludes the article.

2. Powder layer deposition

In selective laser sintering the deposition of the powder is an important sub-process. The quality of the powder layer is a very important issue for the process precision and stability [2]. The main quality demands for the layer are to be of constant thickness and homogeneous. However no universal deposition solution suitable for any kind of powder exists until now.

2.1. Deposition techniques

This paper reports on the results of the stainless steel OSPREY 90% −16 μm H13 powder deposition tests realized with four different techniques. Their principles are described in this subsection.

2.1.1. Classical deposition

Initially, a substrate should be covered with loose powder. The top surface of the powder layer is formed by wiping the powder heap with a blade on a certain height from the substrate. This height determines the layer thickness.

This technique has been successfully tested with wide range of powders with typical grain size 20–100 μm. It however fails in deposition of fine powders with typical grain size <5 μm due to powder grain agglomeration. It also gives challenging results for powders in the range of 5–20 μm, the quality of the deposited layer is far from being perfect (see Fig. 1(a)).

2.1.2. Pressure-gradient deposition

Some significant improvements of the classical deposition technique (see Section 2.1.1) have been proposed. They consists mainly in optimizing the angle and the shape of the scraping surface of the wiping blade. In the current tests the system equivalent to the one described in article [5] has been used.

This technique has been found to have a larger range of suitable powder grain size. The deposition tests also show a notable

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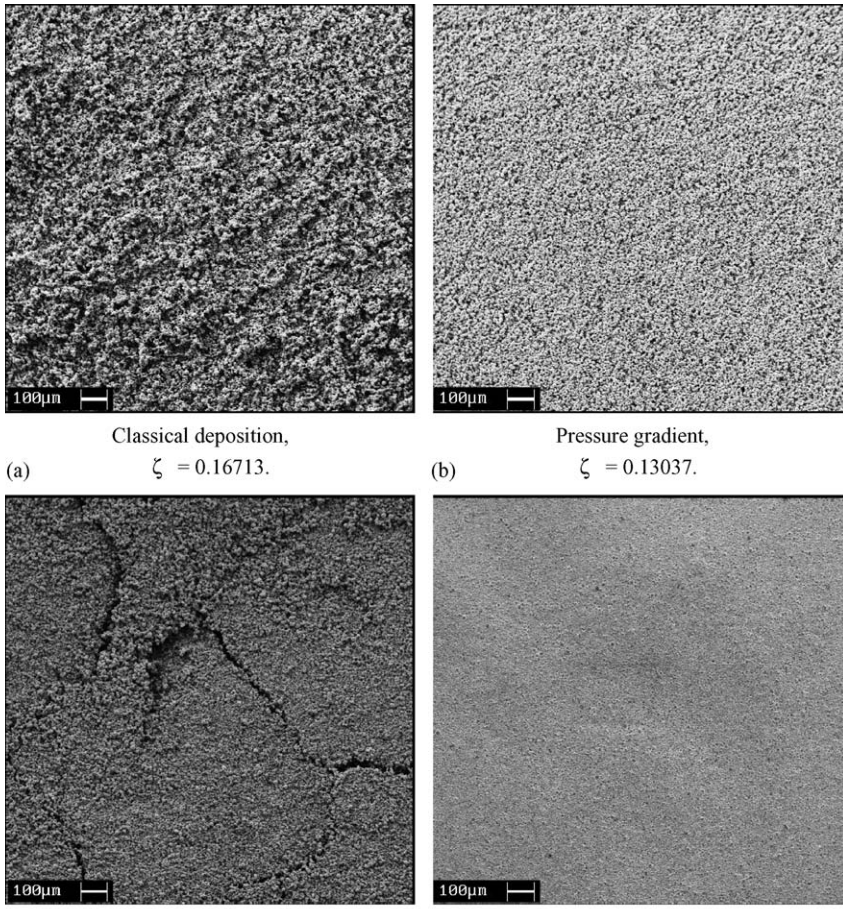

(a) Classical deposition, $\zeta = 0.16713$.

(b) Pressure gradient, $\zeta = 0.13037$.

(c) Ultrasound compaction, $\zeta = 0.1402$.

(d) Suspended deposition, $\zeta = 0.0945$.

Fig. 1. SEM images of powder layer deposited by different technologies and their heterogeneity coefficient ζ.

improvement of layer quality in comparison with the classical deposition (see Fig. 1(b)).

2.1.3. *Ultrasound powder compaction*

The plate vibrating with an ultrasonic frequency compresses loose powder. After the required layer thickness is achieved, the plate should be removed in a delicate manner to avoid destruction of the previously formed powder layer.

The powder layer deposited by ultrasound compaction locally (tens of grains) shows a slightly better quality than in the pressure-gradient case. The overall layer quality however cannot compete with the previously described technique because significant cracks appear on a larger scale (see Fig. 1(c)).

2.1.4. *Spread method*

A powder suspended in a highly volatile liquid (acetone was used here) is deposited on the surface to be covered by a powder layer. Under gravitational force the homogeneous suspension redistributes itself and forms a quasi-horizontal surface. After a while the liquid evaporates and the powder remains in a horizontally aligned layer.

The spread method definitely shows the best quality results in deposition (see Fig. 1(d)). It is however the most difficult technique to implement, it is almost incapable of being automated and the time necessary to form a powder layer is incomparably longer than in dry powder deposition. Moreover, the layer thickness becomes extremely difficult to control.

2.2. *Powder layer quality control*

In Fig. 1 and Section 2.1 the quality of four samples deposited with different techniques was compared. The quality of the layer is however estimated visually which is not always an evident and stable method. For computing purposes the luminosity of a pixel was associated to the height of the powder grain surface.

2.2.1. *Measuring procedure*

In this section a measure of the powder layer quality in term of its homogeneity is proposed. The coefficient of relative heterogeneity ζ (in the context of this article) can be estimated according to the following procedure.