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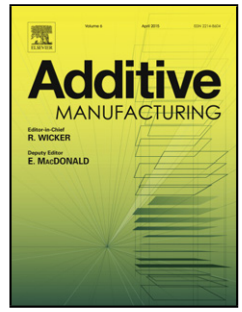

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Residual stress measurements on AISI 316L samples manufactured by selective laser melting

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Abstract

This paper aims to understand the formation and the effect of residual stress on selective laser melting (SLM) parts. SLM is a powder bed based additive manufacturing (AM) process and can be compared to a laser welding process. Due to the high temperature gradients and the densification ratio, which are characteristic of this process, residual stresses occur. The investigation of residual stress is performed using X-ray diffraction (XRD) for samples made of austenitic stainless steel AISI 316L (EN 1.4404). This research examines residual stress at different depths and at two outer surfaces. For the measurement of stresses at different depths, the samples' surface layers were removed by electropolishing. At sufficiently large distances from the top surface, the stresses in the area of the edge layer initially increase strongly and then decline again. The value and orientation of the resulting main stress components are dependent on the examined layer. At the top surface, the residual stresses are higher in scan direction than in perpendicular direction. In contrast, at the lateral surface the maximum main stress is perpendicular to the scan and parallel to the building direction. These two cases can be described very well by the two mechanisms in SLM, namely the temperature gradient mechanism (TGM) and the cool-down phase. It is also shown that at samples with a relative structural density of > 99 %, the residual stress values are independent of the applied energy density.

Keywords: selective laser melting (SLM), residual stress, X-ray diffraction (XRD), energy density, AISI 316L

1. Introduction

Additive manufacturing (AM) belongs to the 3D generating processes. The advantages of AM are geometrical freedom, material flexibility, reduction of process steps, mass customisation and shortened design to product time [1]. The process involves the tool-less production of samples, prototypes, tools or end-use parts from a digital model, e.g. customised medical parts, tooling inserts with near-surface cooling channels and functional components of high geometrical complexity [2].

The selective laser melting (SLM) process - as a part of AM - belongs to the the powder bed fusion technology. During the manufacturing process, a thin layer of powder is first applied to a substrate plate. A laser beam then melts the powder of the material and subsequently connects it to the underlying layer. With a scanning unit the laser beam is deflected and thereby generates the predetermined layer geometry.

The aim of SLM is to produce almost completely dense parts with mechanical properties comparable to bulk materials [3]. The major influencing factors for this process are building strategy and process parameters. The layered structure of the components provides considerable geometric freedom.

In the present study, the SLM samples were fabricated by using the island scanning strategy. The 3D-CAD model is divided into single layers with defined layer thicknesses, which allows the processing of the individual component layers independently of each other. To generate isotropic properties, the layers are subdivided into several square subfields and are filled by scanning the laser beam in tracks, creating a checkered pattern. This means the layer plane of the square subfields is shifted in the x- and y-direction (Figure 1 a)) and the superimposed fields are rotated by 90° (Figure 1 b)).

The basic procedural principles of SLM and selective laser sintering (SLS) are comparable. However, in the case of SLS, the connection of the powder particles re-

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