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Basic Research on Lattice Structures Focused on the strut shape and welding beads

Julia Kessler[a,*], Nicolae Bâlc[b], Andreas Gebhardt[a], Karim Abbas[a]

[a]Aachen University of applied sciences, Faculty of Mechanical Engineering and Mechatronics, Goethestr. 1, 52064 Aachen, Germany
[b]Technical University of Cluj-Napoca, Department of Manufacturing Engineering, B-dul Muncii, 103-105, 400641 Cluj-Napoca, Romania

Abstract

This survey is about the requirements of lattice structures which are made by Selective Laser Melting. The process is based on Additive Manufacturing. It allows the generation of almost every shape. Even complex lattice structures can be manufactured using this technology. Moreover it is possible to integrate high performance lightweight structures into applications. Lattice structures are distinguished into periodic structures and stochastic cellular structures, each type with its individual properties. In a great field of applications periodic lattices are integrated. Because of the great demand for high performance applications, the industry has a big interest in lattice structures. A survey on this topic is indispensable. The main aim is to extract the most influencing process parameters that effect the properties of the structures and to create a construction guideline using the extracted results. Due to the fact that periodic lattices consist of struts, the basic research is focused on those.

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1. Introduction

Additive manufacturing (AM) is an important and future oriented technology because of the manufacturing capability which allows a new spectra of products. The procedure differs from the conventional manufacturing processes. It is possible to produce highly complex components with inside-lying structures and functional areas. This is done within one process step. The related manufacturing process is based on different material and manufacturing concepts. The fundament of every procedure is based, in first instance, on a digital model constructed and transferred in a three-dimensional physical object. During the process the product is generated layer by layer.

* Corresponding author. Tel.: +49-241-6009-52803 .
E-mail address: kessler@fh-aachen.de

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Therefore in a previous step the digital model is sliced with a special software, that defines the to be generated layers and outlines. The difference of the manufacturing methods are the processing's of materials. Materials in different aggregate states are transformed temporarily or permanent into a different condition. Focus of this research is the Selective Laser Melting process. It pertain to the powder-based AM procedure. The original source of this procedure is a metal powder. During the process the powder is evenly distributed on a platform. Followed by this the powder will be temporally and selectively melted with a laser. Thereby the laser exposes the predefined outlines and surfaces. In the subsequent step of the procedure more layers of powder are placed and exposed with the defined information. Underlying outlines are welded now with the new exposed areas. The process is repeated until the entire object is generated. This results almost 100% dense components. After the process, depending on the to be achieved quality, in some cases further post processing is necessary. Due to the adhesion of powder particles, what is a result of the AM process itself, the surface roughness is not optimal. Because of the thermal conductivity and the heat that is introduced to the material within the process, deformations and defaults appear. This leads to the fact that complex geometries need additional support structures. The support structures are simultaneously generated during the manufacturing process and afterwards they need to be mechanically removed. The particular is to have the opportunity to manufacture prototypes, functional-components and completed products. These products can withstand, depending on the used material, high mechanical forces and loads as well as thermal loads. The products are usable in various fields of applications, they range from automotive industry to medical technology products. A special focus in these fields of applications, which are driven by investigation, are high performance lattice structures. The following scientific works show main topics in these fields. [1, 2, 3, 4, 5, 6]

Process based pores that appear in the struts reduce the mechanical properties and the actual aimed quality of structures. Concerning this, Chunlei Qin et al. investigated the relationship between the laser beam and the molten pool. The influences of the laser-power and the scanning speed were the focus of this investigation. The evaluation was performed with the help of microscopes and high-speed-imaging. The results showed that the laser-power has a decisive influence on the strut-diameter and that an interaction of the laser beam and the molten lead to a violent molten pool. This violent interaction causes the generation of pores and bad surface-roughness. [7]

A different focus was investigated by R. Waulth et al. they dealt with the built orientation and special thermal treatments like the Hot Isostatic Pressing (HIP) or the stress relief heat treatment. The evaluation through optical and mechanical analysis showed that HIP treated lattice structures are specialized for dynamic loaded components, however at the same time can be used for statically loaded components as well as stress relieved can be. Further the generation of horizontal struts should be avoided because of their disadvantageous properties. [8]

The investigation of Volkan Dügmeci dealt with the focus of mechanical tests on lattice structures. In particular with the properties of lattice structures during shear loads. To give concrete statements about the results the micro structure was analyzed in detail. According to that deformed struts are the results of misorientation of crystallites that are an indication for internal stresses and which are finally responsible for the mechanical properties. [9]

The mechanical properties of lattice structures are mainly specified by their unit cell. A systematically investigation of the scientists Mager Vouicu et al. describes the properties of lattices based on the size of their unit cell. This for example showed that a cell size greater than 1mm leads to special flexibility, however at the same time it leads to decrease loading properties. [10]

The above mentioned investigations describe part aspects and tests which deal with the topic of lattice structures. However they show the great variety of parameters that have an effect on lattice structures. The following described investigation ties up to the before mentioned and expends those with new aspects.

1.1. Experimental setup

The following mentioned specimens, which are used for this investigation, were generated with the SLM machine M1 Cusing. This system uses a fibre laser with a laser power up to 400W. For the process the used parameters are not changed within the whole experimental set up. This is due to the fact to keep a constant quality of the produced parts. Stainless steel 316L is the Material, which is used for the set up and which has an average grain size of 30-60µm. The adjustments of the parameters are based on previous made investigations and are defined as an optimum. Further the exposure strategy is based on a scanning speed of 1450mm/s for outlines and 1400mm/s for the surface exposure with a constant laser power of 180W. The hatch distance is set to 80µm.

The fundament of every periodic lattice structure are the struts. They determine the value of the mechanical properties, the performance and finally the quality. Concerning the struts conclusions have been made in previous