Optimizing Selective Laser Melting for Reflective Optics

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This work examines an approach for the optimization of the optical quality of additively manufactured reflectors. Therefore the parameters of a Selective Laser Melting process, which manipulate surface properties are distinguished and varied in order to achieve optimized reflectance and roughness values. Influences are evaluated with specific samples and optical measurement equipment.

1 Introduction

Additive Manufacturing is one of the most attractive techniques when it comes to the production of individually designed components. For example the application of free-form optics enables new strategies for illumination techniques and provides an unprecedented freedom of design for optical components. Desired light distributions can easily be accomplished by implementing these geometries [1]. Nonetheless additively manufactured reflectors lack in a sufficient quality of their optical properties and thus are not suitable for their designated field of application [2,3].

In order to improve surface properties such as surface roughness, different studies have already been published, which focus on the variation of laser power, scan velocity or hatch distance in a Selective Laser Melting (SLM) process [4]. In addition other approaches investigated different printing directions and build orientations. The results are correlations between positioning (angles) and surface roughness [5,6]. However these works do not address optical properties such as reflectivity/reflectance. Furthermore most of the research has been realized using polymers as build material and the parameters have been investigated separately.

This work presents an approach for the determination of an optimized parameter set regarding surface qualities of reflectors. Therefore reflector samples are manufactured with an SLM machine and an aluminum alloy. The samples will be investigated concerning their surface roughness and reflectivity via optical measurement equipment.

2 Methods and Materials

For the experiments an EOS EOSINT M280 machine and AlSi10Mg powder are used. In order to achieve an optimized set of para-meters for the reflectors, the method, shown in figure 1, is used.

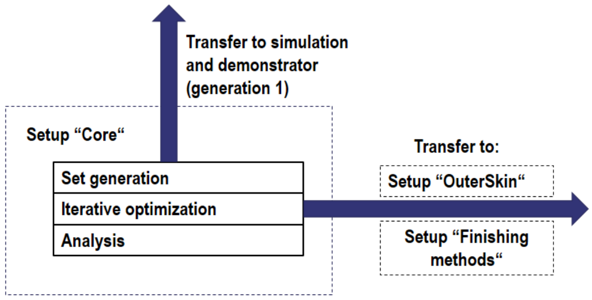

Fig. 1 Excerpt of the methodology for acquiring an optimal printed reflector, only concerning the “Core” settings

The additive manufacturing process is divided into two parts: manufacturing of the core structure and of the outer surfaces (OuterSkin). Inner surfaces are not addressed. A third part is included by examining different post-process techniques. For each part an analysis of parameters that influence the surface properties of the printed component is performed, starting with the “Core” settings. The optimized “core” settings serve as a basis for the optimization procedure of the “OuterSkin” settings. They are also used for the manufacturing of the first generation of demonstrators. To gain the full range of values for each parameter, the first tests were conducted in order to find the maximum and minimum applicable energy density Ψ according to [7]:

$$\Psi = \frac{P}{v \cdot d \cdot h} \tag{1}$$

P resembles the laser power [W], v the scan velocity [mm/s], d the hatch distance [mm] and h the layer height [mm]. In respect to gathered physical limitations of the printing process, parameters are then varied and the printed components are evaluated regarding reflectivity and surface roughness.

3 Results

The Manufacturing of reflector samples using the whole range of available values for laser power, scan velocity, etc. shows, that only energy densities between 8 and 60 J/mm^3 seem to be feasible. For these experiments, the “OuterSkin” treatment is disabled in order to solely examine the influence of the “core” parameters. For this work only laser power and scan velocity are considered. Laser power and scan velocity for the “core” settings prove to have a significant influence on the surface roughness, which has already been shown in previous work [4]. However, by comparing different surface tilts that are provided with the samples it can be assumed that the tilts do not significantly affect the surface roughness (see fig. 2). Furthermore the best roughness values average to 80 µm with a deviation of about 21 µm with laser power of 370W, scan velocity of 1300 mm/s, hatch distance of 190 µm and layer height of 30 µm.

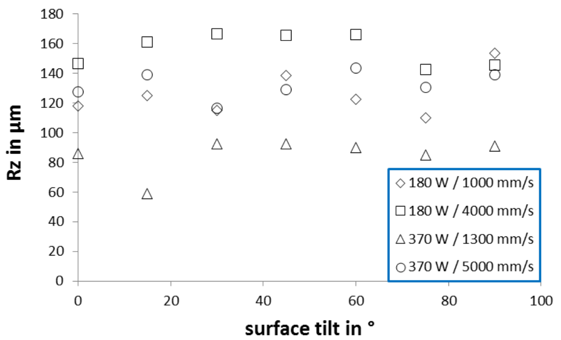

Fig. 2 Surface roughness for differently printed reflector samples using only the “core” settings (same hatch distance and layer height); 0° is parallel to the building plane.

The reflectivity of these samples were measured, but the scattering effects led to acquired intensities beyond the equipment’s confidence interval. The estimated reflectivity is between 10^{-6} and 10^{-8}. Further improvements on the surface quality enable a proper measurement of the reflectivity.

4 Discussion

The physical limitations of the printing process have been experimentally determined. Despite the values for the energy density, some of the samples were processed with sufficient energy density according to equation (1), but were not printed, because the powder was not melted. Thus an extended description of the applied energy is needed, including the whole energy exchange.

The measured surface roughness of a sample with different tilts did not show any mentionable differences. According to [6] the surface quality should change with different tilts depending on the printing direction. The reason behind it is the stepping effect due to the different layers of the component. It is assumed that this effect cannot clearly be seen because the surface roughness itself is too high and therefore dominating the stepping effect. Further investigations of higher quality surfaces should show the named effect.

5 Conclusion

This work presents an approach to effectively optimize the SLM process for reflective optics. The approach is demonstrated with the first step of printing the core structure and vary the corresponding process parameters. An optimal setting for laser power and scan velocity is derived and can be used for further investigations of the influence of the hatch distance, layer height, etc. The reflectivity could not be determined for the first samples due to a high surface roughness and thus to high scattering.

6 Future work

The method will be applied for the last process parameters of the “core“ and “OuterSkin” settings to continuously develop smoother and more reflective surfaces with regards to different surface tilts and rotations. Additionally the concept of the limitations by the energy density will be revised.

Acknowledgements

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