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Experimental investigation on Selective Laser Melting of Glass

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Abstract

Although laser-based Additive Manufacturing (AM) processes have been investigated extensively for use with different materials, fabrication of 3D glass objects using Selective Laser Melting (SLM) technology is not well developed even though it has many applications. As such an experimental investigation on the process parameters of glass powder using SLM process was conducted and the results are summarized in this paper. Multiple 3D objects were fabricated and analyzed. Lastly Scanning Electron Microcopy (SEM) of the manufactured objects as well as effect of process parameters on dimensional accuracy, surface quality, and the density of the fabricated parts are presented in this paper.

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1. Motivation / State of the Art

Selective Laser Sintering/Melting (SLS/SLM) is a powder based Additive Manufacturing (AM) method that uses a laser to create three-dimensional parts by local sintering/melting of powder particles based on CAD data. The individual layers are selectively melted and sequentially processed on top of one another. Regarding this, the build platform is lowered after each layer by a certain value, namely the layer thickness, depending on the material properties and the desired part characteristics. The object is fabricated within the powder bed thus it is always supported by the previous layers or by the surrounding loose powder [1]. SLS/SLM process has been investigated for different materials such as metals, polymers and ceramic for various applications; however, SLS/SLM of glass material is not as well developed due to the complications related to the repetitive and relatively fast cooling cycles of the layers present in this fabrication method. With respect to the SLS/SLM of ceramic and glass different

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approaches could be applied. One of the common approaches used for AM process of ceramic and glass parts is binder based sintering/melting. In this method the ceramic/glass powder is attached to a solid binder. The layer is formed by melting the binder while the structural powder, namely the ceramic, is not melted and is engulfed by the surrounding liquefied binder material driven by capillary forces. Depending on the application, the binder remains in the part or could be removed in a furnace process afterwards. Based on this, the component could be sintered in a furnace in an additional step after the printing process whereby the strength and density of the component is increased. Regarding this different structural materials as well as binding agents have been tested. It is reported that this method could also be used to manufacture porous components [2], [3].

Solid State Sintering (SSS) is another approach which uses a laser beam to bind the powder particles directly by diffusion of the atoms in solid state. With regards to this, Phenix system France developed an SSS system which uses a high temperature processing chamber in addition to a Nd:YAG laser to selectively sinter the powder [4].

Direct Laser Sintering (DLS) of zirconium silicate powder which is based on transient liquid-phase sintering has been studied at Fraunhofer Institute for Production Technology (IPT). It is reported that a part density of up to 50 % can be achieved. The process among other applications has been used successfully for the production of molds and cores for investment casting [5]. IPT has also investigated the direct sintering of borosilicate powder for filter fabrication of various porosity classes. It is reported that the test geometries resulted in a density of 48.6 % of the theoretical density and a dimensional accuracy of 98 %. Appearance of cracks is also reported which is reduced by thermal post-processing which additionally results in a slightly denser part up to 54.4 % [6].

Laser micro sintering procedure has been developed at the Laser Institute of Central Saxony in Mittweida. It is reported that different materials such as Aluminum oxide and silicon carbide have been processed by applying q-switched laser pulses. The components are characterized by good surface finish and geometrical accuracy [7], [8].

Based on previous research by the authors on melting of silica composite materials, in this study SLM of Soda-Lime glass powder is investigated [9], [10]. Even though Soda-Lime glass is manufactured extensively for various industries using conventional manufacturing techniques, no extensive research has been published on AM of Soda-Lime glass. The aim of this study is to investigate the prospect of direct sintering and/or melting of common Soda-Lime glass powder using SLM process in order to determine its feasibility for various applications. The quality of the as-processed fabricated parts are investigated to determine the suitability of parts for use without post processing. The specific composition of the powder can be further optimized for various applications depending on the specific required characteristics.

2. Experimental set-up

For this study a SLM machine equipped with a Yb:YAG fiber laser with a maximum power of 100 W and a wavelength of 1070 nm is used. The study is conducted using Soda-Lime glass powder since it is one of the common glass types used in conventional glass production techniques. Spherical powder particles were selected as the powder wiper on the SLM machine functions more effectively and accurately when used with spherical as opposed to granular particles. Additionally the material distribution thus the melt pool will be more homogenous. SEM image of powder particles is shown in figure 1.