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Comparison of Selective Laser Melting Post-Processes based on Amplitude and Functional Surface Roughness parameters

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Abstract

The rising interest of Metal Additive Manufacturing (MAM) for tool production has requested major attention to post-processing techniques. As a matter of fact, MAM-based process chains for tool productions aims to disrupt process chains based on conventional manufacturing technologies by enabling greater design flexibility, efficient material usability and lightweight design, lead time reduction and maximization of the tool functionalities by optimal design solutions such as topology optimization. In order to complete the transitions towards MAM, at first, tools geometrical specifications have to be met for the same quality standards of conventional manufacturing technologies. In this study, a comparison among different post-processing technologies is aiming to provide a quantitative understanding of the final geometrical characteristics of a MAM-based 316L steel component post-processed using different techniques: Glass Blasting, Vibration Deburring, Functional Coatings (Sol-GEl), Dry-Electro Polishing, Optimized Abrasion, Electrochemical Polishing and Plasma-Electrolytic Polishing. The characterization is based on average amplitude surface roughness parameters (S_a, S_{sk}) and functional surface parameters (S_k, S_{pk}/S_k S_{vk}/S_k). The results show the possibility to achieve a final surface roughness amplitude roughness below 1 µm using the considered Plasma Electrolytic Polishing and Dry-Electro Polishing processes.

Metal Additive Manufacturing, Post-Processing, Surface roughness

1. Introduction

The development of Metal Additive Manufacturing (MAM) is resulting in multiple opportunities for manufacturing. However, there are still major challenges to overcome. One of them is understanding the surface finish that can be achieved on MAM components. In this study, the surface finish obtained by applying different post-processing technologies, are compared to those of the as printed parts [1]. The results indicate reference benchmark values for the surface finishing of MAM components.

2. Sample design and metal printing process details

Metal printing of a Stainless steel 316L (1.4404) sample was performed using Laser Powder Bed Fusion (L-PBF), using an SLM©280 machine, from SLM Solutions Group AG, with 2x 700 W lasers. The powder material was atomized with nitrogen gas to spherical particles size 10-45 µm with an apparent density of 4.57 g/cm³. Chemical properties follow the ASTM F138/A276. The sample design, sizes and dimensions are shown in Fig. 1. A total number of eighteen samples was printed.

3. Post-Processing technologies benchmark

Preliminary glass blasting and vibration deburring were performed on all printed parts prior one of the selected post-process was performed. The considered post-processes are briefly described here below.

3.1. Glass Blasting

Glass blasting is a well known, effective and inexpensive process. For these reasons, it is extensively used as MAM post-process technology [2]. In this study, glass particles (150-250 µm) were shot at high pressure (5.5 bar) on the sample surface. The employed equipment was supplied by Pers Group A/S, Denmark.

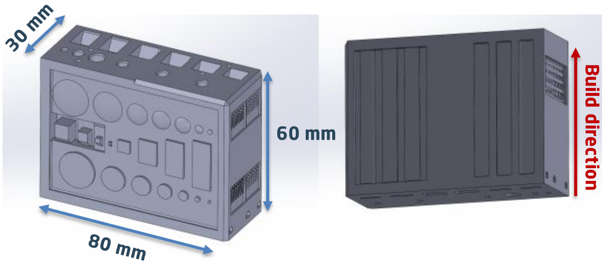

Figure 1. 316L Additive Manufactured sample design

3.2. Vibration Deburring

Vibration deburring is an inexpensive, easy to control and automate process. It consists of actuating a vibratory bath where abrasive pallets and samples are sunk together[3]. For this study, the vibration deburring bath lasted for 120 min using solid pallets of 6.5 mm x 5.6 mm.

3.3. Optimized Abrasion

Another abrasion process based on intermittent blasting was adopted. In this case, compressed air served as a medium for a mix of suspended electro fused ceramics beads and a detergent. The machine used is a DECI Duo from PostProcess© Technologies, Buffalo, USA. The process lasted for 1.0 h, spraying the jet at 5 mm/s and rotating the sample at 5 rpm.

3.4. Functional Coatings (Sol-Gel)

For parts where surface wear might be a limitation, a surface re-coating can extend the tool lifetime. The investigated coating is a hybrid inorganic-organic silane (Sol-Gel) [4]. The coating has a pencil hardness of 5H (Wolff-Wilborn pencil hardness test, ISO 15184:1998). The coating is cured at 185 °C for 1 h to finally result in a transparent 5-10 µm thick film.

3.5. Electrochemical Polishing

Electrochemical Polishing (ECM) is a well-known process that exploits anodic dissolution of the sample in an electrolytic bath. In ECM the electrolytic-metal surface interface area regulates the material removal rate (MRR). For this reason, features sharpness is in most of the cases compromised. Previous cases of ECM on L-PBF AM parts have shown the opportunity to reduce the average amplitude surface roughness S_a below 5 µm [5-7].

3.6. Dry-Electro Polishing

The Dry-Electro polishing process exploits the principle of ECM. However, solid particles are used as electrolyte instead of a liquid medium. This solution allows varying the MRR by selecting different medium sizes. Moreover, the parts are not submerged into an electrochemical bath avoiding contaminations [8]. The Dry-Electro Polishing process has been performed for 420 min at 30 V using a DLyte100I® machine.

3.7. Plasma Electrolytic Polishing

The Plasma Electrolytic Polishing (PeP) is a variation of the ECM process. It exploits a plasma vapour formation at the skin of the sample part. High voltage ensures the formation of plasma, inducing efficient anodization of the sample [9,10].

4. Surface Roughness measurements and Results

Surface roughness was measured using a confocal microscope Olympus® *lext OLS* 4100, equipped with a 50x magnification objective (Numerical Aperture = 0.95). Three inspection areas were identified for all samples on three different orientations with respect to the built direction as shown in Fig. 2. The measurements were repeated five times and the resulting field of view was a square of 256 µm x 256 µm (1024 x 1024 pixels). Before the analysis, the acquired topographies were levelled using a first order plane fit (Global Levelling using SPIP™ software, Form Image Metrology ApS, Denmark). Amplitude surface parameters according to ISO 25530-2:2012 such as average height S_a and skewness S_{sk} are compared in Fig. 3. Functional parameters (core height S_k its ratio with Reduced Peak Height S_{pk}/S_k, Reduced Valley Depth S_{vk}/S_k) are shown in Fig. 4.

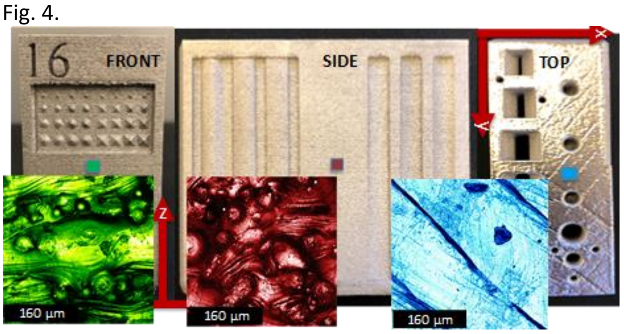

Figure 2. As-printed inspection locations and examples of the respective surface topographies.

5. Discussion

It is interesting to note that the initial vibration deburring reduced the surface roughness by a factor 2.7. The achieved surface is uniform and isotropic with no skewness that is reflected by the equal ratio of S_{vk}/S_k and S_{pk}/S_k. None of the abrasion-based processes selected is capable to reduce the S_a value below 2 µm, indicating that machining and polishing cannot be substituted yet. The most favourable post-processes in terms of S_a roughness amplitude reduction are PeP and Dry-electro polishing with average roughness values below 1 µm. The associated skewness indicates a predominance of valleys in the case of the PeP process. This is confirmed by the higher S_{vk}/S_k in comparison to S_{pk}/S_k ratio for the previously mentioned topographies.

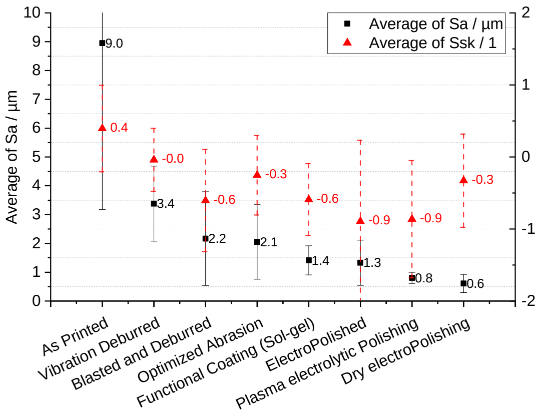

Figure 3. Comparison of S_a and S_{sk}.

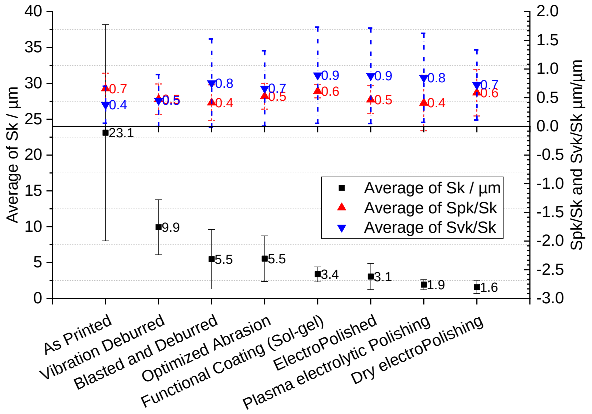

Figure 4. Comparison of S_v, S_{vk}/S_k and S_{pk}/S_k.

6. Conclusions

With the presented post-processing technologies adopted for MAM, S_a reduction can be achieved up to below 1 µm. The analysis of Skewness and functional parameters served as supporting factors in the understanding of peak to valley predominance in the evaluation of the surface topographies surface quality.

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