Electrical Smoothing of the Powder Bed Surface in Laser-Based Powder Bed Fusion of Metals

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Abstract: Achieving a homogeneous and uniform powder bed surface as well as a defined, uniform layer thickness is crucial for achieving reproducible component properties that meet requirements when powder bed fusion of metals with a laser beam. The existing recoating processes cause wear of the recoater blade due to protruded, melted obstacles, which affects the powder bed surface quality locally. Impairments to the powder bed surface quality have a negative effect on the resulting component properties such as surface quality and relative density. This can lead either to scrapped components or to additional work steps such as surface reworking. In this work, an electric smoother is presented with which a wear-free and contactless smoothing of the powder bed can be realized. The achievable powder bed surface quality was analyzed using optical profilometry. It was found that the electric smoother can compensate for impairments in the powder bed surface and achieve a reproducible surface quality of the powder bed regardless of the initial extent of the impairments. Consequently, the electric smoother offers a promising opportunity to reduce the scrap rate in PBF-LB/M and to increase component quality.

Keywords: additive manufacturing; powder bed fusion; powder bed surface quality; powder bed leveling; electrical smoothing

1. Introduction

Additive manufacturing has established itself as an industrially used manufacturing technology, particularly in aerospace technology, medical technology and general mechanical engineering [1]. Powder bed fusion of metals with a laser beam (PBF-LB/M) is the most widely used additive manufacturing process for metallic components, as it provides high component quality (in particular high surface quality and high relative density) and high detail resolution in comparison to other additive manufacturing processes [2].

In PBF-LB/M, a layer of metal powder is applied to a build plate using a contact-based recoating device. A laser beam is used to apply thermal energy to the metal powder layer, causing the metal powder to melt (see Figure 1) [3]. The subsequent cooling and solidification of the molten metal powder creates a solid material bond with the layer underneath [4]. After the laser exposure, the build plate is lowered by one layer thickness and metal powder is applied and levelled again. This process is repeated until the component is completely built up layer by layer [1]. The metal powder is levelled to a defined layer thickness by a linear or rotating movement of a recoater blade attached to the recoating device. Elastomer blades, steel blades, carbon fiber brushes or ceramic blades are usually used [5–7]. Elastomer recoater blades are generally used in industrial appliances due to their comparatively low cost.

Weber emphasizes that achieving repeatability and consistent component properties (in particular surface roughness, relative density and geometric accuracy) is a key aspect for the industrial application of additive manufacturing [8]. In this context, repeatability is
understood as the ability to achieve consistent component properties during production under the same process conditions (e.g., the same machine with the same process parameters) and the same measurement method [9]. This is the prerequisite for exploiting the potential of the PBF-LB/M, such as the economical production of small quantities and the ability to easily customize parts [8,9].

Figure 1. Schematic representation of the PBF-LB/M manufacturing process.

To accomplish this, it is crucial to achieve a homogeneous and uniform powder bed surface, as well as a defined and constant layer thickness [6,9–11]. The flowability of the powder material, the recoating speed, the selected layer thickness and the type of recoater blade are decisive parameters for powder application [12,13]. If these parameters are selected appropriately, the metal powder can be applied repeatedly with a constant layer thickness without affecting the surface of the powder bed. In an industrial environment, however, variations in the morphology of the metal powder, as well as the surface roughness and distortion of the already solidified material, lead to unpredictable impairments of the layer thickness and the powder bed surface [12,14]. This can cause the recoater blade to collide with component areas protruding from the powder bed, resulting in damage to the recoater blade (see Figure 2) [15].

Figure 2. Example of damage to a recoater blade.

The damage to the recoater blade is transferred to the powder layer during the subsequent recoating processes, leading to localized effects on the layer thickness and the powder bed surface [16]. This can be observed in the form of grooves or powder accumulations, as shown in Figure 3.

These local effects are also accompanied by either a locally reduced or increased layer thickness. In the case of a locally reduced layer thickness, excessive volume energy input
occurs at constant laser power, scan speed and hatch spacing. Conversely, in the case of a locally increased layer thickness, an insufficient volume energy input occurs at constant process parameters [6]. Both cases lead to increased porosity (and thus to an impairment of the mechanical properties) as well as to impairments of the surface microgeometry in the form of an increased surface roughness of the manufactured components (see Figure 4). In addition, the deviations in layer thickness can lead to a successive increase in surface roughness and distortion of the already solidified material, ultimately causing a process interruption [17]. As a consequence, this leads either to scrapped components or (in the case of minor impairments) to additional work steps such as surface reworking. Consequently, this results in increased component costs and longer throughput times, thereby restricting the economic potential of PBF-LB/M [18].

Figure 3. Grooves transferred to the powder bed surface by damage to the recoater blade (a) after exposure via laser beam and (b) after powder application.

Figure 4. Scrap components with surface damage due to unsuitable powder application by a damaged recoater blade.
Furthermore, the contact-based powder bed levelling process used by current recoating systems places high demands on the flowability of the metal powders used [19–21]. Metal powders with low sphericity and consequent low flowability lead to a reduced powder bed density in a contact-based powder bed levelling process and thus to delamination and increased porosity of the component [22]. This restricts the choice of metal powders used to gas-atomized, spherical metal powders with a narrow particle size distribution (typically between \(d_{10}=15 \, \mu \text{m}\) and \(d_{90}=60 \, \mu \text{m}\)) [23–25]. However, there is an increasing interest in the use of cheaper, non-spherical, water-atomized metal powders with a wider particle size distribution to reduce material costs and increase resource efficiency of PBF-LB/M [20,26–28].

For the mentioned reasons, further efforts are required to develop innovative recoating and powder bed levelling solutions in order to fully exploit the potential of PBF-LB/M. This publication presents a technical process that enables non-contact powder bed levelling and compensates for local impairments of the layer thickness and the powder bed surface.

For this purpose, an electric smoother was developed, consisting of an electrically insulated metal plate (see Figure 5). An alternating voltage of 5 kV at a frequency of 50 Hz is applied between the electric smoother and the build plate. This generates an alternating high-voltage electric field between the electric smoother and the powder bed. The electric field causes polarization of the particles and the formation of dipoles [29]. Through the so called dielectrophoresis (DEP), a force \(F_{\text{DEP}}\) acts on the polarized particles that is dependent on the absolute permittivity of the surrounding medium \(\varepsilon_{\text{M}}\), the frequency dependent Clausius-Mossooti factor \(\text{CM}\) relating to the polarizability of the particle and medium, the particle radius \(r\) and the root mean square of the electric field \(E_{\text{RMS}}\) [30]:

\[
F_{\text{DEP}} = 2\pi\varepsilon_{\text{M}}r^3\text{CM}\left(\nabla E_{\text{RMS}}^2\right)
\]  

(1)

Figure 5. Schematic representation of the functionality of the electric smoother.

Up to now, DEP has mainly been used in biomedical applications, for example to separate micro- and nanoscale particles or cells, which indicates a high stability and reliability of the mechanism [31]. In this work, the DEP is used to induce movement of the powder particles, enabling their repositioning and thus eliminating impairments within the powder bed. This non-contact and wear-free working principle compensates for local deviations in the layer thickness and powder bed surface. The influence of the electrical smoothing process on the topographic characteristics of the powder bed surface in different process situations is analyzed in the subsequent sections. Following Peta et al., the surface roughness parameters according to ISO 25178-2 are used to describe the topographic characteristics of the surface [32,33].
2. Materials and Methods

2.1. Experimental Setup and Framework Conditions

An experimental setup was developed by modifying a commercially available machine typically used for additive manufacturing of polymer parts via material extrusion (MEX), see Figure 6. The print head of the MEX machine was removed and replaced with the electric smoother. To carry out the experiments, a sample tray filled with metal powder is positioned in the center of the building platform. The control of the Y-axis of the MEX machine enables the electric smoother to pass over the powder pocket, whereby the travel speed of the traverse can be varied from 0 to 500 mm/s. The vertical distance between the electric smoother and the powder pocket can be varied by controlling the Z-axis.

![Figure 6. Experimental setup: modified MEX machine with attached electric smoother.](image)

The MEX machine was installed in an enclosure in the form of a glovebox. The glovebox enables the creation of an argon atmosphere during experiments to simulate the conditions of the PBF-LB/M process while ensuring occupational safety. The control unit of the MEX machine was positioned outside the glovebox to avoid interference and contamination with metal powder.

The metal powder MetcoAdd Ti64 (OC Oerlikon Corporation AG, Pfäffikon, Switzerland) made from the titanium alloy Ti-6Al-4V was used for the experiments. Before the experiments were carried out, the metal powder was characterized. A Camsizer XT (Microtrac Retsch GmbH, Haan, Germany) particle sizer and a Hallflowmeter (Landgraf Laborsysteme HLL GmbH, Langenhagen, Germany) were used to ensure that the experiments results can be subsequently compared. The metal powder has the characteristic percentiles $d_{10} = 19.2 \, \mu m$, $d_{50} = 32.0 \, \mu m$ and $d_{90} = 42.5 \, \mu m$ (see Table 1). The particle size distribution is shown in Figure 7. The metal powder particles have a high sphericity (see Figure 8). The flow rate according to DIN EN ISO 4490 is $35.3 \, s$ [34]. The filling density according to DIN EN ISO 3923-1 was determined at 57.3% and the tapping density according to DIN EN ISO 3953 at 63.1% (see Table 1) [35,36].
Table 1. Results of the characterization of the used MetcoAdd Ti64 metal powder.

<table>
<thead>
<tr>
<th>d₁₀ in µm</th>
<th>d₅₀ in µm</th>
<th>d₉₀ in µm</th>
<th>Flow Rate in s (DIN EN ISO 4490)</th>
<th>Fill Density in % (DIN EN ISO 3923-1)</th>
<th>Tap Density in g/cm³ (DIN EN ISO 3953)</th>
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</thead>
<tbody>
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<td>32.0</td>
<td>42.5</td>
<td>35.3</td>
<td>57.3</td>
<td>63.1</td>
</tr>
</tbody>
</table>

Figure 7. Particle size distribution of the used MetcoAdd Ti64 metal powder.

Figure 8. Scanning electron micrographs of the used MetcoAdd Ti64 metal powder at (a) 500× and (b) 200× magnification.

2.2. Experimental Design and Execution

In order to investigate the influence of the electric smoother on the properties of the powder bed, the metal powder is manually filled into sample trays, which have a pocket in the center. Any excess powder extending beyond the tray edges is carefully scraped off with a steel recoater blade. This process replicates the contact-based coating process of the PBF-LB/M and mechanically smoothes the powder bed surface. Three different sample tray designs are used to determine the powder bed surface roughness in different PBF-LB/M process situations before and after electrical smoothing (see Figure 9). There are sample trays with a shallow pocket (length × width × depth/40.0 mm × 40.0 mm × 0.1 mm; see Figure 9a), sample trays with a deep pocket (40.0 mm × 40.0 mm × 5.0 mm; see Figure 9b) and sample trays with a deep pocket (40.0 mm × 40.0 mm × 5.0 mm) with an obstacle in...
the center of the pocket. The obstacle is a screw (M3 × 35; see Figure 9c), which represents a body that protrudes 0.1 mm from the powder bed surface (e.g., a component protrusion as a result of distortion during the PBF-LB/M process). After the metal powder has been filled in the sample trays, four grooves are manually applied to the powder bed surface with a stiff wire for the sample tray with the shallow pocket. The grooves represent possible impairments of the powder bed surface in the PBF-LB/M process (see Figure 3). In summary, the following PBF-LB/M process situations are represented by the sample tray designs:

- Shallow pocket: single powder layer with local impairments
- Deep pocket: multiple stacked powder layers
- Deep pocket with an obstacle: multiple stacked powder layers with a protruding body

![Illustration of the three sample tray designs: (a) shallow pocket, (b) deep pocket and (c) deep pocket with an obstacle.](image)

Figure 9. Illustration of the three sample tray designs: (a) shallow pocket, (b) deep pocket and (c) deep pocket with an obstacle.

In addition to the variation of the sample tray designs, which represent different PBF-LB/M process situations, the parameters vertical distance between the powder bed surface and the electric smoother and the travel speed of the electric smoother are examined in a full factorial design of experiments (see Table 2). The vertical distance is varied between 0.5 mm and 5.0 mm and the travel speed between 15 mm/s and 50 mm/s.

**Table 2. Parameter settings of the used design of experiments.**

<table>
<thead>
<tr>
<th>Vertical Distance in mm</th>
<th>Travel Speed in mm/s</th>
<th>Sample Tray Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>15</td>
<td>Shallow pocket</td>
</tr>
<tr>
<td>1.0</td>
<td>25</td>
<td>Deep pocket</td>
</tr>
<tr>
<td>2.0</td>
<td>35</td>
<td>Deep pocket with an obstacle</td>
</tr>
<tr>
<td>5.0</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

The experiments are carried out using the following steps:

1. Preparation and positioning of the sample tray on the built platform;
2. Flooding the enclosure with argon to simulate the conditions of the PBF-LB/M process and to prevent the metal powder from reacting with oxygen as a result of the high voltage applied;
3. Switching on the electric smoother and passing over the sample trays with the defined parameters;
4. Switching off the electric smoother;
5. Flooding the enclosure with atmospheric gas and removing the samples;
6. Metrological analysis of the metal powder in the sample trays.

To ensure that the powder bed is not affected by the manual removal of the samples from the experiment setup and transportation to the profilometer, preliminary tests are carried out for the investigation on the influence of the sample handling. For this purpose, the powder bed surface is recorded after preparation, after multiple times of handling and after electrical smoothing and evaluated in terms of surface quality.
2.3. Metrological Analysis of the Powder Bed in the Sample Trays

The evaluation of the influence of the electric smoother is based on a metrological analysis of the surface of the powder bed in the sample trays using the profilometer VR-5200 (Keyence Deutschland GmbH, Neu-Iseringbrug, Germany). The surface of the powder bed is measured using the VR-Series Viewer software (Version 3.3.2.2337; Keyence Deutschland GmbH, Neu-Iseringbrug, Germany) with a magnification of 12× and a sampling interval of 21 µm, resulting in an image with a size of 2248 pixels in x-direction and 2236 pixels in y-direction. The measurement data is then imported into the software VR-Series Analyzer (Version 3.3.3.282; Keyence Deutschland GmbH, Neu-Iseringbrug, Germany). Height profiles with the edge area of the sample tray as the zero plane are derived from the measurement data obtained without the use of metrological filters.

Additionally, the surface of the powder bed is characterized using the surface roughness parameter Sa, which is measured using an L-filter of 2.5 mm. Therefore, the measurement data is evaluated within the measuring area shown in Figure 10a (30.0 mm × 30.0 mm). For the sample with a deep pocket and an obstacle, the measuring area around the screw is excluded (see Figure 10b).

![Measuring area](image1.png)

(a) Measuring area of the samples with a shallow pocket and a deep pocket and (b) measuring area of the sample with a deep pocket and an obstacle.

3. Results and Discussion

3.1. Investigation on the Influence of the Sample Handling

Figure 11 shows examples of the profilometer images before and after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 50 mm/s. The results of the metrological analysis of the surface roughness of the powder bed after preparation, after multiple times of handling the samples and after electrical smoothing is shown in Figure 12. The surface roughness remains almost constant after multiple times of handling the samples. The initial roughness of $S_a = 16.64 \mu m$ of the powder bed in the sample with a shallow pocket, which is comparatively high due to the grooves applied into the powder bed, was reduced by around 1% as a result of multiple times of handling. The sample with a deep pocket was also hardly affected. The sample with a deep pocket had a roughness of $S_a = 3.25 \mu m$ before and $S_a = 3.23 \mu m$ after multiple times of handling. It can therefore be assumed that the manual removal of the samples from the experiment setup and transportation to the profilometer has no significant influence on the experiment results.

Electrical smoothing of the sample in the preliminary experiment reduced the surface roughness $S_a$ by 66% to 5.52 µm. The grooves inserted during sample preparation were completely compensated by electrical smoothing, so that a homogeneous powder bed surface can be seen afterwards (see Figure 11b). For the sample with a deep pocket, the surface roughness $S_a$ increased by 88% to 6.12 µm. After electrical smoothing, the surface roughness $S_a$ is almost similar for the sample with a shallow pocket and the sample with a deep pocket ($S_a = 5.52 \mu m$ and $S_a = 6.12 \mu m$ respectively). This indicates that the smoothing process enables a constant and reproducible surface quality of the powder bed surface,
independent of previous local impairments of the powder bed surface and the powder bed height.

![Profilometer images of a sample with a shallow pocket](image1.png)

**Figure 11.** Profilometer images of a sample with a shallow pocket (a) before and (b) after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 50 mm/s.

![Surface roughness graph](image2.png)

**Figure 12.** Surface roughness $S_a$ depending on handling and electrical smoothing of the samples.

### 3.2. Investigation on the Achievable Powder Bed Surface Quality

The results of the analysis of the surface roughness $S_a$ of the sample with a shallow pocket after preparation are shown in Figure 13. The initial value of the surface roughness $S_a$ of the samples before electrical smoothing is on average 18.32 µm with a standard deviation of 3.18 µm due to the manual insertion of grooves. Regardless of the parameters vertical distance and travel speed, the use of the electric smoother results in a reduction of the surface roughness $S_a$ by at least 12.64 µm. The movement of the particles resulting from the DEP led to a rearrangement of the particles. This enabled complete compensation of the grooves through the electrical smoothing process (see Figure 14). It can be seen that the surface roughness $S_a$ of the powder bed has on the one hand its minimum at a travel speed of 35 mm/s (except at a vertical distance of 0.5 mm). On the other hand, the minimum surface roughness $S_a$ is at a vertical distance of 2.0 mm. The global minimum of the surface roughness in the test series was $S_a = 3.95$ µm, which corresponds to a reduction of 74% compared to the initial value.

In addition to the compensation of the grooves and the associated reduction of the surface roughness $S_a$, a further effect was observed. When passing over the samples, the powder is ejected from the edge area of the sample. This is caused by a turbulence of the
powder, which is visible in the marked area in Figure 15a. The lack of powder can be seen in the height profile (see Figure 14b) of the samples as well as visually (see Figure 15b). Due to the greater lack of powder at the left edge of the sample than at the right edge of the sample and the travel direction of the electric smoother from left to right, it is assumed that the electric smoother moves the powder at least partially in the direction of travel.

![Figure 13. Surface roughness $S_a$ of the samples with a shallow pocket depending on travel speed and vertical distance.](image)

**Figure 13.** Surface roughness $S_a$ of the samples with a shallow pocket depending on travel speed and vertical distance.

![Figure 14. Height profile of the sample with a shallow pocket (a) before and (b) after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 35 mm/s.](image)

**Figure 14.** Height profile of the sample with a shallow pocket (a) before and (b) after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 35 mm/s.

Figure 16 shows the surface roughness $S_a$ determined for the samples with a deep pocket. The initial value of the surface roughness $S_a$ after preparation with a steel recoater blade before electrical smoothing is on average 4.78 $\mu$m with a standard deviation of 0.99 $\mu$m. The results show a superordinate dependence of the surface roughness $S_a$ on the travel speed. In contrast, the vertical distance and thus the electric field strength has a subordinate influence on the surface roughness $S_a$. Irrespective of the vertical distance, the greatest reduction in the surface roughness $S_a$ is achieved at a travel speed of 35 mm/s. With the exception of the parameter combination of vertical distance 1.0 mm and travel speed 15 mm/s, an increase in surface roughness $S_a$ can be observed at all other travel
speeds. For the samples with a deep pocket, a minimum surface roughness $S_a$ of 4.03 µm (reduction of 16% compared to the initial value) was determined at a travel speed of 35 mm/s and a vertical distance of 2.0 mm, which corresponds to the results of the samples with a shallow pocket. This indicates that the smoothing parameters are independent of the height of the powder bed.

Figure 15. (a) Turbulence of powder as a result of electrical smoothing and (b) lack of powder after electrical smoothing.

Figure 16. Surface roughness $S_a$ of the samples with a deep pocket depending on travel speed and vertical distance.

Figure 17 shows an example of the height profile of a sample with a deep pocket before and after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 35 mm/s. As with the sample with a shallow pocket, a lack of powder can be seen in the height profile in the edge area of the sample. The indentations caused by the turbulence of the powder by the electric smoother are visible in a smaller area for the samples with a deep pocket than for the samples with a shallow pocket. As already observed with the samples with a shallow pocket, the powder ejection is more distinctive on the left edge of the sample than on the right edge of the sample, which indicates a displacement of the powder at least partially in the direction of travel by the electric smoother. In addition, due to the smaller distance between the edge area of the sample trays and the electric smoother than between the base of the pocket of the sample trays and the electric smoother, the
electric field is more pronounced in the edge area of the pocket than in the center of the pocket. As a result, the DEP exerts a stronger force on the particles in the edge area of the pocket than in the center of the pocket, which results in a reduced powder bed height in the edge area of the pocket (see Figure 17b).

![Height profile of the sample with a deep pocket (a) before and (b) after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 35 mm/s.](image)

**Figure 17.** Height profile of the sample with a deep pocket (a) before and (b) after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 35 mm/s.

3.3. Investigation on the Compensation of Obstacles in the Powder Bed

The surface roughness $S_a$ determined for the samples with a deep pocket with an obstacle is shown in Figure 18. The initial value of the surface roughness $S_a$ after preparation with a steel recoater blade before electrical smoothing is on average 10.09 $\mu$m with a standard deviation of 1.61 $\mu$m. The initial value is higher than for the samples with a deep pocket without an obstacle, as the screw protruding from the powder bed prevents the powder from being levelled evenly by the steel recoater blade. This causes a local elevation of the powder bed surface, resulting in an inhomogeneous layer height (see Figure 19a).

![Surface roughness $S_a$ of the sample with a deep pocket with an obstacle depending on travel speed and vertical distance.](image)

**Figure 18.** Surface roughness $S_a$ of the sample with a deep pocket with an obstacle depending on travel speed and vertical distance.
The local increase in layer height around the obstacle was compensated by electrical smoothing, resulting in an almost homogeneous layer height in the mid area of the samples (see Figure 19b). A lack of powder in the edge area of the sample can be observed as in the previous experiments. The height of the powder bed is also reduced locally in the edge area of the obstacle due to the locally higher electric field strength and the associated higher F_{DEP} on the particles in this area. This effect is partially compensated for by the displacement of the powder in the direction of travel by the electric smoother.

3.4. Surface Structuring after Smoothing

Some parameter combinations (see Table 3) lead to a structuring of the powder bed surface for the samples with a deep pocket and the samples with a deep pocket with an obstacle (see Figure 20). This impairs the surface quality and the homogeneity of the powder bed height. For the samples with a shallow pocket, this structuring of the powder bed surface did not occur with any combination of parameters. One possible explanation for the formation of the depicted surface structure is the escape of inert gas from the powder bed as a result of compaction of a large powder bed height (5.0 mm) at once. The compaction causes the powder particles to move closer together and displace the inert gas in the powder bed, which then escape on preferred paths to the powder bed surface. At a travel speed of 35 mm/s, no structuring of the powder bed surface can be seen regardless of the vertical distance. Consequently, a structuring of the powder bed surface can be avoided by selecting a suitable travel speed.

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Figure 20. Height profiles with structured powder bed surfaces of samples (a) with a deep pocket and (b) with a deep pocket and an obstacle after electrical smoothing with a vertical distance of 2.0 mm and a travel speed of 25 mm/s.

4. Conclusions

This paper discusses the non-contact and wear-free electrical smoothing of the powder bed in the additive manufacturing process PBF-LB/M using DEP. The parameters travel speed of the electric smoother as well as vertical distance of the electric smoother to the powder bed surface were varied under consideration of different process situations. The influence of these parameters on the surface roughness $S_a$ was investigated and evaluated. Furthermore, the suitability of non-contact electrical smoothing to compensate inhomogeneities in the powder bed surface was investigated.

It was found that with suitable parameter settings, a reduction in the surface roughness $S_a$ to approximately 4.0 $\mu$m (samples with a shallow pocket: 3.95 $\mu$m, sample with a deep pocket: 4.03 $\mu$m and samples with a deep pocket and an obstacle: 4.13 $\mu$m) can be achieved, regardless of initial impairments of the powder bed surface or the powder bed height.

In addition, the electrical smoothing process was able to compensate for large-scale impairments of the powder bed (e.g., grooves), which may also occur in PBF-LB/M. Consequently, the electric smoother is a promising development for reducing the scrap rate in PBF-LB/M and increasing component quality (in particular, the relative density and surface quality in the form of reduced surface roughness).
Future research will be dedicated to studying the interaction between the electric smoother and metallic components in the powder bed. Previous investigations have shown that electrical smoothing leads to a local reduction in the powder bed height in the edge area of solids in the powder bed due to local differences in the electric field strength. In order to investigate this effect in more detail, the electric smoother will be integrated into a PBF-LB/M machine in the future. In this context, the influence of the size and distribution of the metallic components in the powder bed on the electrical smoothing process will be examined in particular. Furthermore, the electric smoother will be investigated in conjunction with water atomized metal powders with comparatively low sphericity and low flowability. The availability of water-atomized metal powders for PBF-LB/M could significantly reduce material costs and thus contribute to fully exploiting the potential of PBF-LB/M.

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