# Increased Laser Polishing Rates of LPBF Components

## High path overlaps to reduce surface features at laser polishing of LPBF components with high process speeds

**Lucas-H. Beste, Florian Schadewald, Tim Radel, Brodan Richter, Patrick J. Faue, Frank E. Pfefferkorn, and Frank Vollertsen**

The production of components using laser powder bed fusion (LPBF) offers a wide range of applications. The selective local energy input and layer-by-layer melting of powder particles allows high design flexibility and a wide range of component geometries. It is often necessary to apply post-processing steps in the process chain to meet the design requirements. Besides metallurgical reasons, which may, for example, require a heat treatment, a subsequent treatment may be necessary due to the surface topography. During the LPBF process, partially-melted powder particles often remain on the surfaces. Additionally, the layer-by-layer melting of the powder particles can contribute to the waviness of the surface. Therefore, LPBF components usually have a process chain with post-processes such as machining, grinding, mechanical polishing, shot peening and similar techniques. Laser polishing is an alternative that allows complex surfaces to be polished contact-free and non-abrasively without tool wear. Thus, it is not only possible to smooth the surfaces by remelting, but also to reduce the porosity close to the surface. Typical polishing rates are in the range of a few mm²/s. The melt pool dynamics and the associated waviness limit the melt pool size and processing speed and therefore the achievable polishing rates. Nevertheless, an increase of the polishing rate is desirable.

The polishing rate depends on beam diameter, process speed and path overlap. According to the literature different approaches to increase the polishing rate are possible. For example, this problem can be countered by beam shaping or adjusted intensity distribution. Within this study, the approach of using high process speeds in combination with high path overlaps is investigated. It is based on the hypotheses that the high path overlaps can limit the resulting waviness and therefore enable high polishing rates.

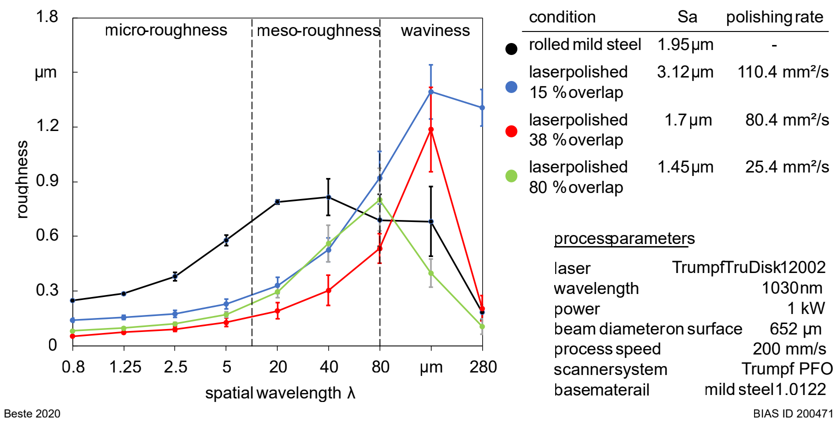


**Fig. 1** Roughness as functions of the spatial Wavelength λ of rolled mild steel 1.0122 surface and of laser polished surfaces with different path overlaps

The laser polishing was done with a TruDisk 12002 by Trumpf with a cw-wavelength of 1030 nm. The beam diameter on the material surface was 652 µm and the laser power was set to 1 kW. The influence of the path overlaps on the surface topography of mild steel 1.0122 was analyzed. Subsequently, the obtained results were transferred to cuboids made of CoCr-alloy (Stellite-21), which were produced via LPBF. The process speed was set to 200 mm/s, while the path overlap was varied between 15 % and 80 %. With the results obtained here the LPBF components were processed afterwards. For this purpose, the laser polishing parameters were a process speed of 1000 mm/s, a power of 1.25 kW, and path overlaps of 80.5 % and 90 %. Surface topography measurements were made by confocal microscopy to analyze the results of the laser polishing process. These microscopic images were processed using a fast Fourier transformation (FFT) to determine the amplitude of the spatial wavelengths of the surfaces with a focus on the waviness as well as the micro- and meso-roughness.

The results of the FFT analysis of the surface topography measurements are shown in Fig. 1 for the mild steel surfaces and in Fig. 2 for the CoCr-LPBF-manufactured surfaces.

The mild steel 1.0122 surfaces show significant influence of the overlap rate. A path overlap of 15 % leads to an increased surface roughness Sa, while the surface roughness then decreases with growing path overlap. Hence, the lowest surface roughness for these experiments is achieved with a path overlap of 80 %. The spatial wavelengths show that the micro- and meso-roughness decrease to similar levels below 0.25 µm depending on the overlap. Regarding the long wavelength surface features, there is a much more significant dependency on the path overlap. For these wavelengths, the waviness was reduced using a path overlap of 80 %, while path overlaps of 15 % and 38 % lead to significant increases of the high spatial wavelengths.

The results of the laser polished LPBF surfaces show a reduced surface roughness $S_a$ at both 80.5 % and 90 % path overlaps compared to the as-built surface. The examination of the different spatial wavelength sections has shown that the micro- and meso-roughness as well as the waviness are reduced compared to the initial surface depending on the overlap.

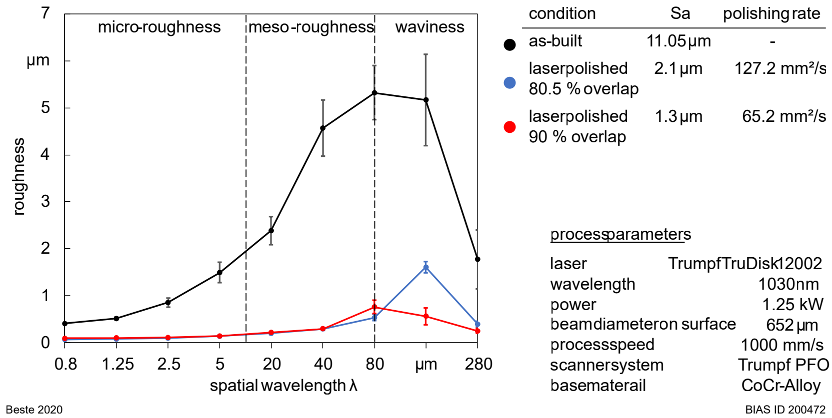


Fig. 2 Roughness as functions of the spatial wavelength $\lambda$ of LPBF manufactured CoCr-component surfaces in the as-built- and laser- polished condition with different path overlaps

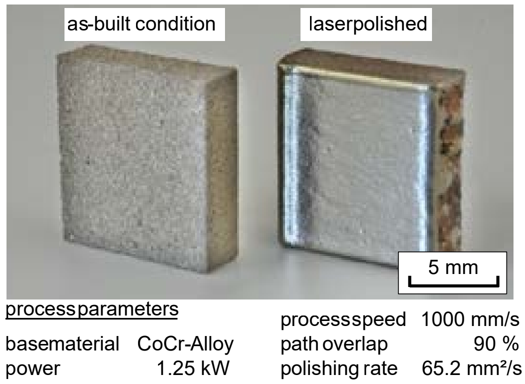


Fig. 3 Two cuboids of CoCr-alloy (Stellite-21) produced via LPBF; The cuboid on the left side is in the as-built condition, the cuboid on the right side was laser-polished

For both polishing rates, the micro and meso-roughness are reduced to 0.1 µm, while the waviness can be reduced to 1.6 µm at a polishing rate of 127.2 mm²/s and up to 0.76 µm for a polishing rate of 65.2 mm²/s. An image of an as-built and a polished LPBF-cuboid made of CoCr-alloy is shown in Fig. 3.

The results show that a high path overlap can lead to a reduction in waviness on rolled surfaces and on the surfaces of components based on LPBF. In combination with high process speeds, the polishing rate can be increased while the resulting waviness due to the melt pool dynamics can be limited.

Overall, it is shown that the long wavelength surface features created during the laser polishing process by high process speeds can be limited by a high path overlap (90 %) in such a way that not only the micro- and meso-roughness but also the waviness of LPBF-components can be reduced at high polishing rates. The evaluated scan strategies give the opportunity to perform subsequent treatment of LPBF-surfaces via laser polishing in a high mm²/s range.

*

The authors would like to thank the Deutsche Forschungsgemeinschaft (DFG) for funding the project "NSF-DFG: Laser Finishing of the Multi-Scale Surface Structure of Additive Manufactured Parts" (Project No. 386371584) and the U.S. National Science Foundation (Grant No: CMMI-1727366).

DOI: 10.1002/phvs.202100009

L.-H. Beste,
F. Schadewald,
T. Radel, and F. Vollertsen
BIAS – Bremer Institut für angewandte Strahltechnik GmbH,
Klagenfurter Str. 5, 28359 Bremen,
phone: +49 421 218-58129
e-mail: beste@bias.de
Web: www.bias.de

B. Richter, P. J. Faue, F. E. Pfefferkorn:
University of Wisconsin-Madison,
1513 University Ave.,
Madison, WI 53706, USA
Web: www.wisc.edu