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Polishing of metals with femtosecond GHz-burst laser

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Abstract

In this work, we explore the use of a femtosecond laser operating in the GHz-burst regime for metal polishing, both with and without ablation, to enhance micromachining quality. The high number of pulses per burst (800 ppb) combined with high burst repetition rate (800 kHz) allows for ideally distributing the laser energy over metallic samples. As surface melting and smoothing is driven by surface tension forces, this is a critical factor in this process. Recent studies have demonstrated that GHz-bursts of femtosecond pulses are particularly effective for metal polishing, as the pulse-to-pulse delay within the burst is shorter than the material's characteristic heat relaxation time. We will present our results on stainless steel and titanium and point out the best process windows.

Keywords: ultrafast laser processing; GHz-burst mode; laser polishing; metals

1. Introduction

Laser-based polishing is an interesting contactless approach for surface finishing and thoroughly described in a review by Gisario et al., 2022. Recently, burst modes have been explored for polishing (Gaidys et al., 2023). In this contribution, we show novel results of metal polishing with long GHz-bursts.

2. Method

For our study, we used a Tangor 100 (Amplitude) emitting at a wavelength of 1030 nm with a pulse duration of about 500 fs operating in GHz-burst mode with 800 pulses per burst (ppb) at 1.28 GHz. The experimental setup includes an argon-fuelled gas cover to avoid oxidation during the process. A Z-motorized stage (Alio Industries, AI-LM-10000) allows for adjusting the Z-focus position with respect to the metal surface, which was dislocated at 600 µm in order to have a beam diameter of 45.3 µm on the sample surface. A galvo scanner (Lasea, LS-Scan XY20) with a f-theta lens of 100 mm focal length is used to realize the hatch pattern. The metals samples of stainless steel (316L) and titanium TA6V have the dimensions of 25 x 25 mm^2 and a thickness of 0.5 mm and are placed on motorized XY stages (Alio Industries, AI-LM-20000-XY-I-LP) for correct positioning underneath the scanner. The whole experimental setup is controlled by DMCpro software (Direct Machining Control). The surface roughness of the samples was measured by a confocal microscope (Zeiss, Smartproff 5).

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3. Results

We investigated polishing with different doses up to 4.3 J/mm (hatch of 1.2 µm) and measured the resulting surface roughness. Figure 1 shows the results for different burst repetition rates. On the left side, a scanning electron microscope (SEM) image of the pristine surface of a titanium TA6V sample is depicted, and the corresponding value is indicated as a dashed red line in the graph. On the right side of Figure 1, the corresponding SEM images at 1.3 J/mm^2 are shown together with a close up (indicated by a black circle in the graph).

First, the surface roughness Ra remains almost constant up a dose of 2.2 J/mm^2 and increases then for increasing dose with almost the same values for the different repetition rates. We further studied the resulting surface with an increased hatch of a factor of ten and found similar Ra values. These results shows that scalability for higher processing speed is possible. The same trend was observed for stainless steel.

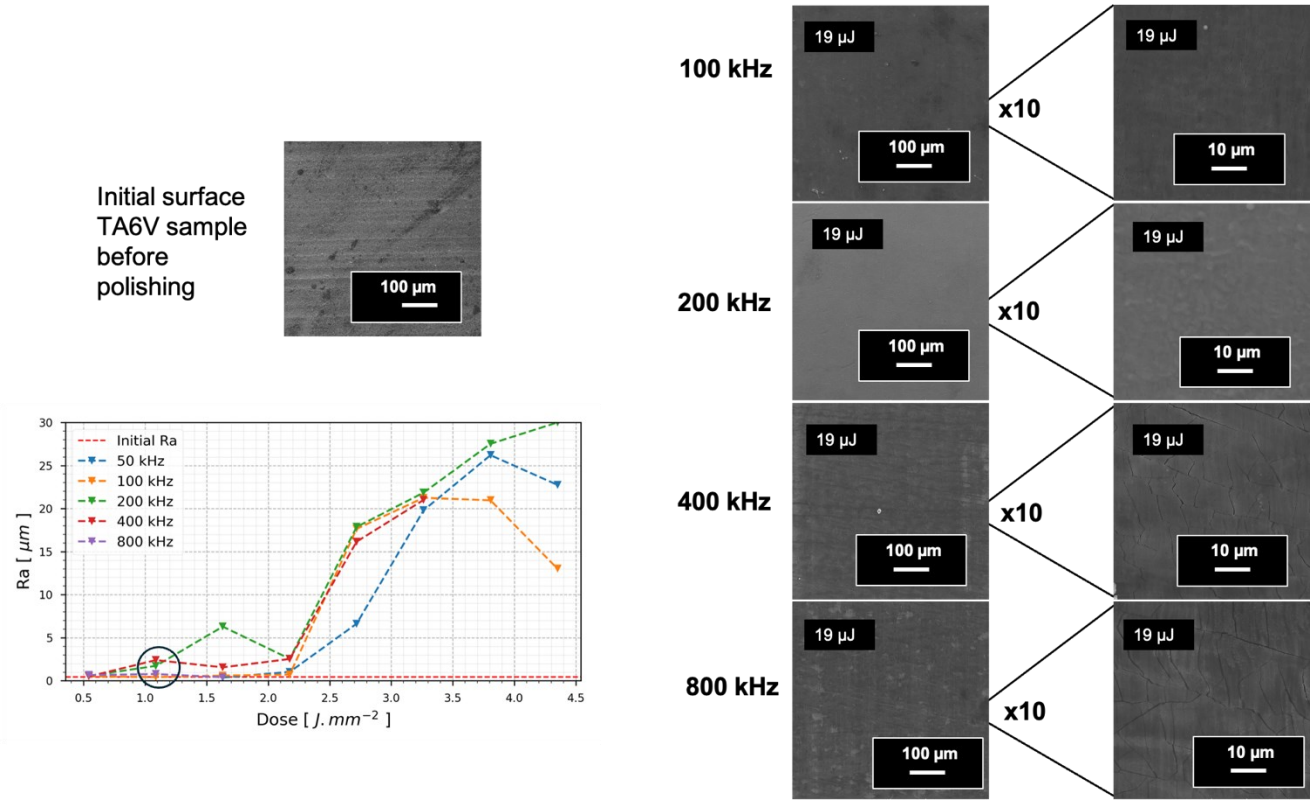

Fig. 1. Left: SEM image of the pristine TA6V sample and evolution of the surface roughness as a function of applied dose; right: corresponding SEM images with close-up at a dose of 19 µJ (indicated by the black circle in the graph).

4. Conclusion

We studied metal polishing with GHz-bursts of 800 ppb and showed that up to a certain dose (about 2 J/mm^2 for titanium TA6V), the surface roughness Ra remains below 5 µm independent of the burst repetition rate. Moreover, hatch increase is possible without degrading the surface quality. These results are encouraging for process upscaling.

References

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