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SELECTION OF PARAMETERS FOR LASER SURFACE TEXTURING OF TITANIUM ALLOYS

DOBÓR PARAMETRÓW LASEROWEGO TEKSTUROWANIA POWIERZCHNI STOPU TYTANU

Abstract
This paper shows a parameters selection method providing an ablative laser treatment removal of materials. A laser for generating laser beams of ultraviolet light in picosecond pulses at a frequency to 400 kHz was used in the experiment. The quality of the marks was examined by scanning electron microscopy. On the basis of the analysis, it is recommended to conduct micromachining at a frequency of 100 kHz and exposure times within the range of 62.5 ms to 125 ms.

Keywords: laser surface texturing, titanium alloys

Streszczenie
W pracy przedstawiono metodę doboru parametrów mikroobróbki laserowej zapewniającą ablacyjne usuwanie materiału. W eksperymencie zastosowany został laser generujący wiązkę promieniowania ultrafioletowego w impulsach pikosekundowych z częstotliwością do 400 kHz. Jakość wytworzonych śladów została oceniona metodą elektronowej mikroskopii skaningowej. Na podstawie przeprowadzonej analizy rekomenduje się prowadzenie mikroobróbki przy częstotliwości 100 kHz i czasie oddziaływania impulsów lasera od 62, 5 ms do 125 ms.

Słowa kluczowe: laserowe teksturowanie powierzchni, stopy tytanu

1. Introduction

Due to biocompatibility, high resistance to corrosion in the tissue environment, the most similar mechanical properties to natural bones and density among the previously used materials, titanium alloys are the most promising group of materials used for joint endoprosthesis [1]. Poor tribological properties are the limitations in the use of titanium alloys. The wear products may cause for e.g.: allergic and inflammation reactions, osteolysis and finally the loosening of the implant [2].

Laser surface texturing has enormous potential for structuring biomaterials [3]. Laser micromachining is one of the methods of limiting wear and friction of biobearing [4, 5]. It also has a beneficial effect on cell adhesion, distribution of biological fluids, osseointegration and endurance on the bone-to-implant direct contact [3, 6, 7].

The selection of parameters for laser surface texturing involves the use of appropriate radiation wavelength, which affects the ability of the material to absorb radiant energy and the possibility of focusing of a laser beam. The efficiency and depth of penetration of radiation into the surface are smaller for a smaller radiation wavelength. It is also important to choose the fluence, which has an impact on the shape of surface texture elements and the homogeneity of the radiation interaction. At higher fluence, the heterogeneous nucleation of bubbles with steam leads to normal boiling. The length of a laser pulse is another aspect of laser micromachining. In general, since the duration of the pulse is shortened, the energy is rapidly accumulated in the material, which leads to its faster excretion. The ablation processes with femto- and picosecond pulses is called cold laser ablation, because the heat-affected zone is not observed in the material [8, 9, 10].

Laser surface texturing is considered by performance and accuracy of the process. The accuracy of micromachining can be considered in terms of the precise geometry of texture elements and a removal of the material [8, 9]. One of the main advantages of a laser as a tool for surface treatment of materials is the possibility of precise control over energy deposition place and level. The desired modification of the material is achieved due to the appropriate selection of laser processing parameters [10].

The analysis of laser processing parameters influencing morphology on the surface of the element made of Ti6Al7Nb is the aim of the study.

2. Materials and methods

The analyses were conducted on samples made of Ti6Al7Nb. The chemical composition of the alloy was in accordance with ISO 5832-11: Fe max. 0.25%, O max. 0.2%, N max. 0.05%, C max. 0.08%, H max. 0.009%, Al 5.5–6.5%, Nb 6.5-7.5%, Ta max. 0.5%, remainder Ti.

The experiment was carried out by using a stand for microprocessing equipped with a TruMicro 5000 model 5325c picosecond laser with max 5 W average power, pulse energy up to 12.6 μJ and quality of the radius of $M^2 < 1.3$. The maximum pulse frequency is 400 kHz and can be modified by the introduction of a pulse divider taking the values of 200 kHz, 133, 33 kHz, 100 kHz, 80 kHz, 66, 66 kHz, etc. The radiation wavelength of a TruMicro 5325 c laser is 343 nm. It consisted in evaluating the impact of laser pulses on the processed material by changing the frequency of pulses and their duration. The energy value of a single pulse was

12.6 μJ at 100% of power. The exposure times were within the range of 12.5 ms to 250 ms. As a result, changes in the number of individual pulses acting on the sample in the range of N = 78 to N = 100 000 were obtained (table 1). During the processing of a sample, beams were placed in the focus, and the processing zone was shielded with argon.

Table 1. List of selected laser microprocessing parameters of samples tested

f [kHZ]	**t [ms]**				
	12, 5	**25**	**62, 5**	**125**	**250**
400	5000	10 000	25 000	50 000	100 000
200	2500	5000	12 500	25 000	50 000
100	1250	2500	6250	12 500	25 000
50	625	1250	3125	6250	12 500
25	312	625	1562	3125	6250
12, 5	156	312	781	1562	3125
6, 25	78	156	390	781	1562

f – frequency of laser pulses [kHz]; *t* - the exposure time [ms]

The assessment consisted in observing the shape and form of the obtained trace of the impact of the laser beam on the material and in identifying processes such as melting of the material, loss with no signs of melting and the outbreak of the material. The surface morphologic observations were carried out by scanning electron microscopy (NovaNanoSEM 450, FEI).

2. Results

Exemplary SEM views of the picosecond laser beam traces of the impact on Ti6Al7Nb were showed in Figure 1.

Small particles, which created a concentric zone of material deposition, are visible on the edges of the microcavities. During the point impact of the picosecond laser carried out at the frequency of 50 kHz or lower for the range of pulses from 1562 to 12500, a bigger number of particles is visible as the range of pulses increase. With a small range of pulses, the energy of laser interaction is sufficient only for the coarse defragmentation of the material and much larger particles are formed as a result of the phase explosion. Moreover, the force of the explosion is not able to discharge defragmented particles to the periphery of the trace and therefore they remain in the centre of the track. For the range of pulses below 2500, the defragmented particles remain in the centre. Regular cavities were obtained using the frequency of 400, 200 and 100 kHz for the full range of pulses. For the range of pulses from 5000 to 100000 and the frequency of 400 kHz and 200 kHz, cavities were irregular in nature and had the shape of a tapering crater. As the number of impulses increases, the depth of the produced cavity increases. For the range of pulses from 6250 to 100 000, corrugations on the sheet of cavities are visible. For frequencies from 6.25 to 50 kHz cavities appear at min. 1562 pulses. Therefore, the use of processing with the frequency of 100 kHz and the range of pulses from 6250 to 12 500 is the most favourable for Ti6Al7Nb.

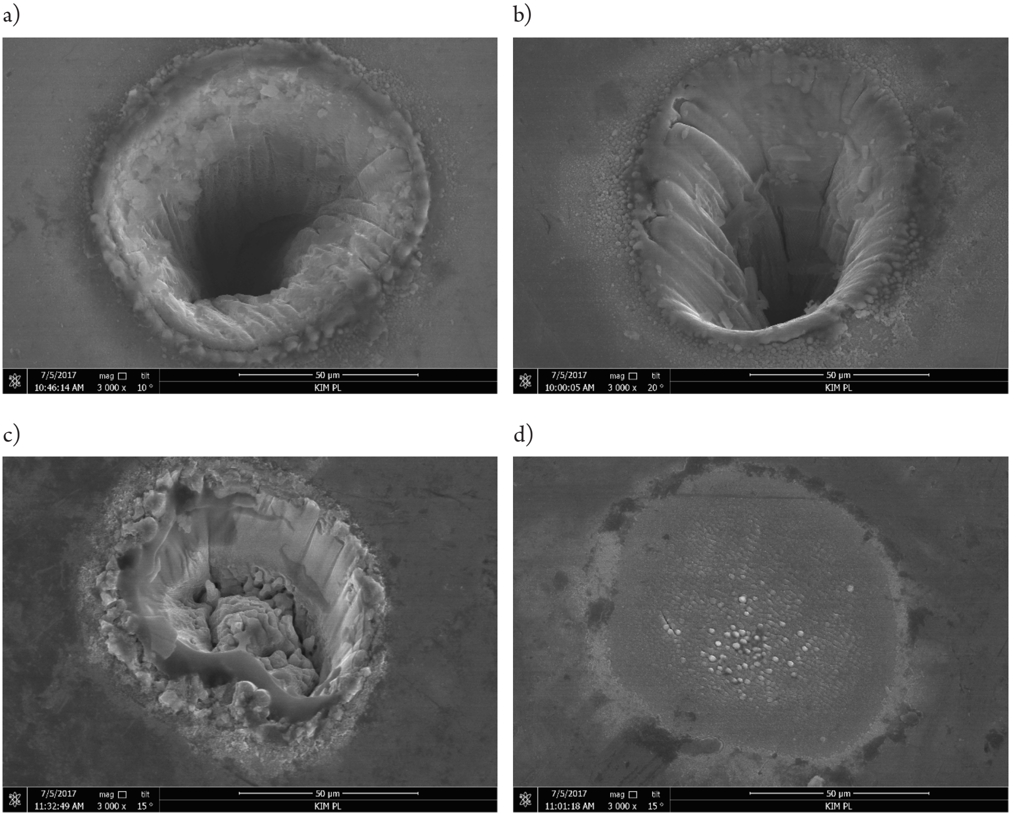

Fig. 1. Selected SEM views of the picosecond laser beam traces of the impact on Ti6Al7Nb: a) 400 kHz, 250 ms, N = 100000, b) 200 kHz, 125 ms, N = 25000, c) 50 kHz, 62.5 ms, N = 3125, d) 6.25 kHz, 12.5 ms, N = 78

3. Conclusions

The results show that using the frequency of 100 kHz and the range of pulses from 6250 to 12 500 is the most favourable for Ti6Al7Nb. A selection of incorrect parameters of microprocessing can cause the insufficient treatment capacity of materials as well as ablation with remelting.

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