RESEARCH OF POSSIBILITIES OF LASER POLISHING OF THE SURFACE OF ALUMINUM

ALUMĪNIJA VIRSMAS LĀZERPULĒŠANAS IESPĒJU PĒTĪŠANA

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Abstract: *The report considers the possibility of reducing the roughness after laser polishing of Aluminum plates. A CHANXAN CX-20G fiber laser with a wavelength of 1064 nm is used for the research. As a result of the experiment, 4 matrices were marked with a fiber laser on 3 samples for each series of the experiment. Then, using a multifunctional microscope, the roughness of the treated and untreated aluminum surface was measured. At the end of the research, conclusions were made about the changes in roughness in the course of this experiment.*

Key words : *aluminum laser processing, fiber laser, laser polishing, surface roughness.*

Introduction

When using various kinds of solid materials, the roughness of the surface has a significant effect on their properties. Surface roughness is one of the most important characteristics of materials and affects wear resistance, contact rigidity, corrosion resistance and other functional characteristics of the surface. [1], [2], [3] Wear resistance determines the ability of the surface layers of parts to resist fracture during friction-sliding, friction-rolling, as well as micro displacements caused by vibrations. Wear of parts leads to a loss of accuracy, a decrease in efficiency, a decrease in strength, an increase in dynamic loads, which are a consequence of an increase in mates, an increase in labor. [4] By treating the surface of aluminum with different tools and applying different surface treatment methods, the greatest or the smallest roughness can be obtained. To obtain a smooth surface, such processing methods are used as mechanical grinding, mechanochemical polishing, chemically activated mechanochemical polishing, ion-beam polishing, etc. Currently, another technique is available to improve the surface roughness - this is the process of laser polishing. The principle of polishing is based on the focused radiation of a laser beam, which melts a microscopic layer of the surface material, as well as on the basis of melting the material with a laser, the laser polishing process allows the initial topography to be smoothed. This method, in comparison with other existing ones, allows processing surfaces of complex shapes, provides a higher processing speed and ease of automation of the polishing process. [5] [6], [7], [8] Carrying out a research of the possibility of the influence of laser processing parameters on the roughness of the surface of aluminum is an urgent task aimed at optimizing the parameters of laser processing of the roughness of the surface. The aim of the research is to determine the effect of fiber laser parameters: power P, speed v and distance between lines dx on the average roughness of the aluminum surface.

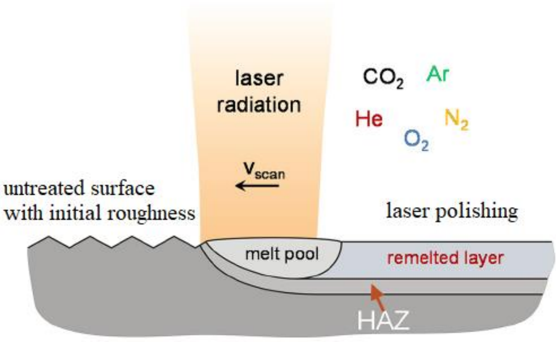

Fig.1.laser polishing process

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1. Equipment

For experiments and measurements were used: fiber laser system CHANXAN CX-20G, 3D laser scanning microscope OLYMPUS LEXT OLS500.

The technical parameters of the CHANXAN CX-20G laser system are shown in Table 1.

The CHANXAN CX-20G laser system is shown in Fig.2.

Fig.2. fiber laser system CHANXAN CX-20G

Table I

CHANXAN CX-20G TECHNICAL PARAMETERS

Name	Value range	Units
Focus shift	-100...100	mm
Average power	0-20	W
Impulse frequency	20-200	kHz
Processing Area	300*300	mm
Wavelength	1064	nm
Laser type	Fiber laser	
Operating mode	impulse	

Fig.3. 3D laser scanning microscope OLYMPUS LEXT OLS500 [9]

Measured using an MPLFNN10XLEXT objective with 236x magnification, magnification and the following specifications were provided by the manufacturer:

- Measuring step Z : 2 μm
- Measurement accuracy in the Z axis: 0.15 + L / 10 μm
- Resolution along the X axis : MAX - 0,14%; MIN – (-0,2016)%
- Resolution along the Y axis: MAX – 0,1211%; MIN – (-0,1547)%

2. Material for research

Aluminum is a soft, lightweight, silvery-white metal with high thermal and electrical conductivity. Melting point 660 ° C. Aluminum is widely used as a structural material. The main advantages of aluminum in this quality are lightness, pliability to stamping, corrosion resistance (in air, aluminum is instantly covered with a strong film of Al2O3, which prevents its further oxidation), high thermal conductivity, and non-toxicity of its compounds. The main disadvantage of aluminum as a structural material is its low strength, so it is usually alloyed with a small amount of copper and magnesium (the alloy is called duralumin). [10]

Table 2.

Physical properties of aluminum

Density, (kg / m^3)	2,7
Melting point Tm, ° C	660
Boiling point Tboil, ° C	2327
Latent heat of fusion, J / g	393,6
Thermal conductivity l, W / m • deg (at 20 ° C)	228
Heat capacity Cp, J / (g · deg) (at 0–100 ° C)	0,88
Linear expansion coefficient α × 10-6, 1 / ° C (pr ° C)	24,3
Specific electrical resistance ρ × 10-8, Ohm × m (at 20 ° C)	2,7
Ultimate strength σ in, Mpa	40-60
Elongation δ,%	40-50
Brinell hardness HB	25
Normal elastic modulus E, GPa	70

3. Experiment methodic

Using a fiber laser, 4 matrices were marked on 3 samples for each series of experiments. The matrix consists of 7 columns and 5 lines, forming 35 rectangles(see Fig.4.). For each series of experiments, the same values of power P, speed v and different values of the step dx are used. Power P takes on the values 60%; 70%; 80%; 90%; 100%. Marking speed v = 50; 100; 150; 200; 250; 300; 350 mm / s. The constant is the step between the lines dx = 0.01; 0.02; 0.04; 0.06 and frequency f = 20 kHz for each series, respectively, while the speed v and power P varied with the marking of each series. A multifunctional microscope is used to measure the average roughness Sa of each rectangle and to measure the average roughness of the untreated surface. The average roughness is measured in micrometers μm. One measurement is made for each rectangle. On the untreated surface, 5 measurements were made for each batch. For each sample, based on the results of 5 measurements, the arithmetic mean of the average roughness of the untreated surface was calculated. Absolute, relative, and root mean square errors are calculated for each measurement on the raw surface.

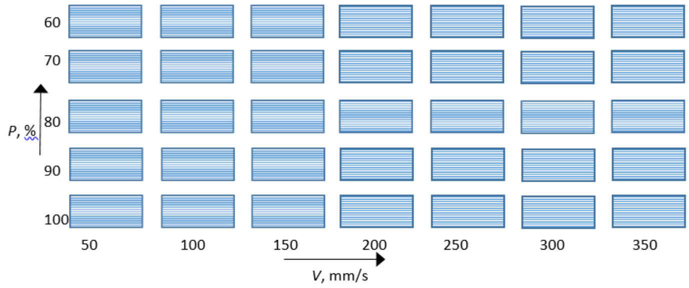


Figure 4. The matrix

4. Experimental research results and discussions

In the course of the work, were made the calculations of the errors of the roughness results of the untreated surface.

According to the formula (1), the absolute error of the average roughness of the untreated surface is calculated

$$\Delta X = X - X_i \qquad (1)$$

Where X is the average and X_i is the single measurement.

ΔX = 1,088 – 1,049 = 0,039 μm

According to the formula (2), the relative error of the average roughness of the untreated surface is calculated

$$R = \Delta L / L \qquad (2)$$

Where ΔL is absolute error and L is the number obtained during the measurement.

R= 0,039 / 1,049 = 0,037 μm

R= 0,037 *100% =3,7 %

The formula (3) calculates the mean square error of the average roughness of the untreated surface

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}} \qquad (3)$$

Where X_i is the single measurement and $\bar{X}$ is the average of measurements. Where n – is quantity of measurements.

σ = (0,015/(5-1)) / 1^2 = 0,004 μm

From the data obtained on the basis of the experiment, graphs were constructed that show the dependence of the average roughness Ra on the power P and speed v and step between the lines Δx.(See Fig.5, Fig.6.,Fig.7.)

- For speed v = 350 mm / s the roughness is close to that of the untreated surface for the three powers;
- For power P = 60% the roughness varies from 0.85 μm to 1.08 μm for the speed range from 50 mm / s to 350 mm / s;
- For power P = 80% the roughness varies from 0.72 μm to 1.05 μm for the studied speed range;
- For power P = 100% the roughness varies from 0.63 μm to 1.01 μm for the studied speed range;

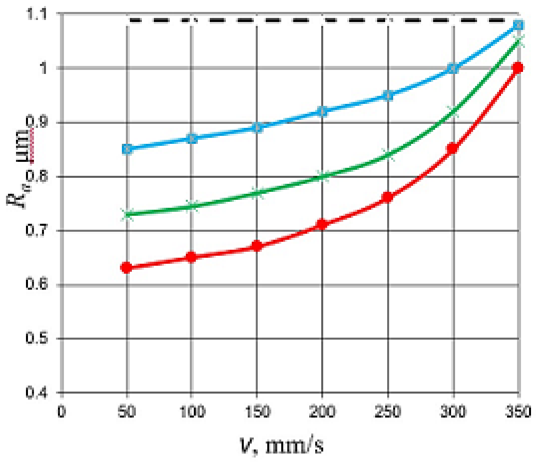
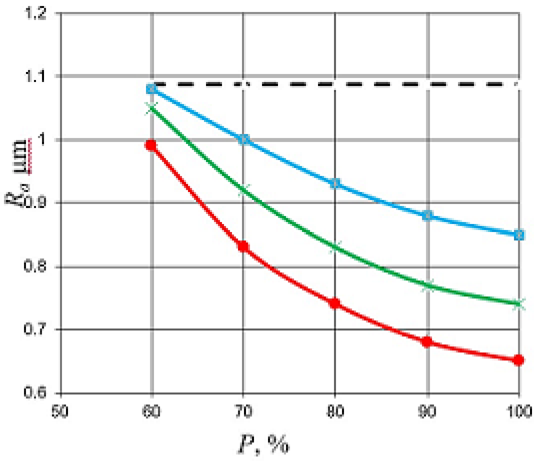


Fig.5. Dependence of the average roughness R_a on the speed v

- For speed v = 50 mm / s the roughness varies from 0.99 µm to 0.66 µm for the power range from 60% to 100%;
- For speed v = 200 mm / s the roughness varies from 1.04 µm to 0.74 µm for the power range from 60% to 100%;
- For speed v = 350 mm / s the roughness varies from 1.07 µm to 0.85 µm for the power range from 60% to 100%;



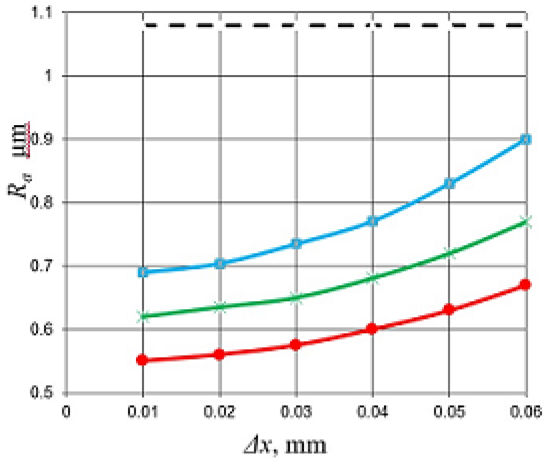


Fig.6. Fig.7.

Fig.6. Dependence of the average roughness R_a on the power P

Fig.7. Dependence of the average roughness R_a on the step between the lines Δx

- For power P = 60% the roughness varies from 0.69 µm to 1.00 µm for the step interval from 0.01 mm to 0.06 mm;
- For power P = 80% the roughness varies from 0.62 µm to 0.77 µm for the studied step interval;
- For power P = 100% the roughness varies from 0.55 µm to 0.67 µm for the studied step interval;

During the experiment, the roughness of all rectangles of 4 matrices was measured and the roughness of the untreated surface was also measured. Figures 8 and 9 show examples of measurements taken with a microscope at 10X magnification. Both figures show the appearance of the surface to be measured and the level of surface smoothness at a certain specified height and other specified parameters. According to this measuring system, the green color of the surface indicates that the level of evenness of this surface fragment is very high. In turn, the presence of different colors on the surface indicates that this fragment of the surface has a non-uniform appearance of evenness. Each microscope drawing is a separate measurement.

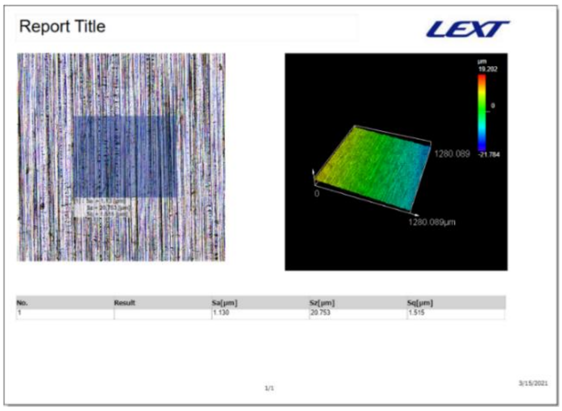


Fig.8.

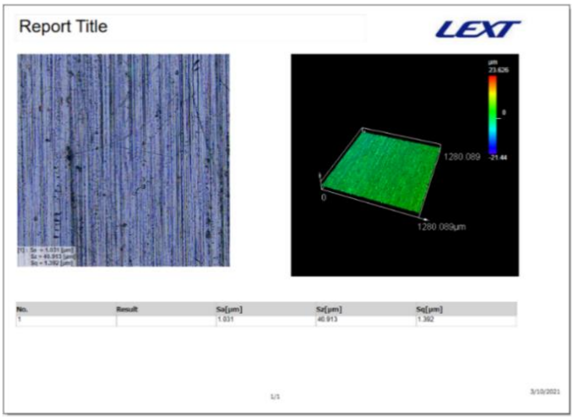


Fig.9.

Fig.8. untreated surface with initial roughness Fig.9. treated surface

Conclusions

- *The roughness of the treated surface is less than the roughness of the untreated surface (Ra = 1.088 μm, with a black dotted line) for the whole studied speed range;*
- *With increasing speed increases the roughness in the area of laser impact for the three studied powers; for power P = 60%, the roughness increases to 78.7% for the speed range from 50 mm / s to 350 mm / s;*
- *With increasing power, the roughness in the area of laser impact for the three studied speeds decreases; for speed v = 50 mm / s, the roughness is reduced to 150% for the power range from 60% to 100%;*
- *By increasing the step, the roughness in the laser impact zone for the three examined powers increases nonlinearly; at power P = 60%, the roughness increases by 69% with a step of 0.01 mm to 0.06 mm;*

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