Analysis of the powder material and the structure of samples obtained from an aluminum alloy by selective laser melting

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Abstract. By selective laser melting, samples were synthesized from the powder material of the AlSi10Mg alloy. All samples are made of aluminum alloy metal powder. Granulometric analysis data and particle morphology were studied to determine the suitability of the powder used in the selective laser melting. To identify structural defects, the samples were polished from the end and from the side of the building platform. Using a metallographic microscope, the porosity of samples made at a flow rate from $7.28 \times 10^5$ to $2.23 \times 10^6$ was analyzed. The geometric shape matching of the initial three-dimensional model was analyzed using the holes in the samples as an example. The results of particle size analysis, sphericity of particles of powder material, as well as metallographic analysis of samples can be used to improve the performance of parts obtained from AlSi10Mg aluminum alloy by selective laser melting.

1. Introduction
Layer-by-layer production of products by selective laser melting is increasingly being applied in various industries in the manufacture of products from different materials [1-5]. This is explained by the fact that this method is distinguished by the possibility of forming complex geometric objects, as well as by the economy when using the material [6]. Also, the selective laser melting method allows the production of substantially lightweight parts with lower material costs, while not neglecting the outstanding characteristics [7, 8]. However, this method has its disadvantages, for example: structural defects in the finished product and the difference between the real geometric shapes from the 3D model [9-13]. Structural defects also include porosity in parts and final products. This work is aimed at identifying the dependence of porosity on the power flow during processing in bulk samples obtained from AlSi10Mg aluminium alloy, as well as analysing the deviation of the geometric shape of the synthesized samples from the initial three-dimensional model.

2. Source material analysis
To study the morphology of particles, conducting particle size analysis and images of the powder were obtained using a scanning electron microscope (Figure 1).

Most of the powder particles have a spherical shape, which meets the requirement of raw materials for the selective laser melting method. At the same time, there are a small number of satellites and oblong oval particles.
Granulometric analysis of the fractional composition of the powder revealed that the average particle diameter \( (d_{50}) \) [14] has a value within 30 μm (Figure 2).

The largest diameter of the measured particles was 49.2 μm. The detected size distribution of granules falls within the range commonly used in materials for the manufacture of parts by selective laser melting.

3. Volumetric sample formation and porosity

To Selective laser melting used an ytterbium fiber laser at a wavelength of 1.07 μm. The protective atmosphere during building was nitrogen gas.

Samples were formed with a layer thickness of 20, 30 and 40 μm. During the experiment, a matrix of powder treatment modes was compiled. The formation of samples occurred at various values of the flow rate. The scanning strategy “Island scan strategy” (Figure 3) was used, patented by Concept Laser GmbH [15].
Figure 3. Laser beam scanning strategy «Island scan strategy».

The processing area is divided into equal squares 5x5 mm, then the laser beam scans with a change of direction by 90 degrees in adjacent sections. This scanning strategy allows you to reduce thermal stresses in the material during processing, as well as reduce possible interference between coater and islands [16,17].

Using an integrated microscope camera, micrographs of thin sections of the surface of samples made of aluminum alloy were obtained (Figure 4). Micrographs of the samples contain tracks, typical of all products obtained by selective laser melting [18-20]. Using an integrated microscope camera, micrographs of thin sections of the surface of samples made of aluminum alloy were obtained (Figure 4). Micrographs of the samples contain tracks, typical of all products obtained by selective laser melting [18-22].

Figure 4. Micrographs of thin sections of the surface of the samples: a) Power flow $9.55 \times 10^5$ J/m²; b) Power flow $2.23 \times 10^6$ J/m².

4. Results and discussion

Below is a graph of porosity values for different flow rates in samples with a layer thickness of 20, 30 and 40 μm. The graph is based on measurements of the total pore area in the samples.
When analyzing the graph and microphotographs, it was found that the smallest porosity for samples with a layer thickness of 20 and 30 μm corresponds to the flow power \(1.70 \times 10^6\text{J/m}^2\), for samples with a layer thickness of 40 microns - \(1.91 \times 10^6\text{J/m}^2\).

The deviation from the given geometry was determined by measuring the shape of the holes in the samples and comparing the obtained values with the values of the 3D model. The shape was measured using an optical microscope and an image analysis program. The hole diameter in the original 3D model is 10 mm (Figure 6).

Below (Figure 7, 8), the measurement data are shown in the X and Y directions, as well as a comparison of the results with the diameter of the original 3D model.
Figure 7. The graph of deviations of real sizes from the 3D model for X.

Figure 8. The graph of deviations of real sizes from the 3D model for Y.

The deviation of dimensions in X is explained by shrinkage of the material due to rapid heating and cooling. Compensation for dimensional deviations in this direction is possible due to the processing of the contours of each layer during the manufacture of the part.

As can be seen from Figure 8, the smallest deviation was at a layer thickness of 20 μm, from this we can conclude that the deviation in Y is more dependent on the thickness and uniformity of the applied layers.

5. Conclusions
In the course of the work, data were obtained on the particle size distribution and morphology of the particles of the powder material of an aluminum alloy. The size distribution and shape of the granules satisfy the material requirements for the selective laser melting method.

The dependence of the porosity of the samples on the power of the laser radiation flux was revealed. The data on the processing regimes with the lowest porosity for layers with a thickness of 20, 30, and 40 μm are presented.

Deviations in the geometry of the samples were recorded and measured depending on the power of the laser radiation flux to the processed material. For X deviations, the greatest role is probably played by the shrinkage of the molten material due to rapid heating and cooling. Moreover, the deviations in Y are more dependent on the layer thickness.
6. References

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