Study of the effect of scanning speed in selective laser melting on the physicomechanical properties of samples.

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Abstract. In this work, prototypes of aluminum alloy were obtained by the method of selective laser melting at different beam scanning speeds. Images of the powder material were obtained on a scanning electron microscope and the shape and size of the particles were investigated. The microstructure and defects were studied by metallographic analysis. Diagrams of the structure-phase composition of powder materials and samples obtained by the method of selective laser melting were obtained. The physical and mechanical properties of the images were also investigated.

Introduction
Selective laser melting (SLM) is an additive method for obtaining a product, which has a huge variety of parameters on which the quality of the product depends. First of all, the melting parameters of the layers are determined by the melting parameters and characteristics of the starting material. The characteristics of materials include particle size, shape, bulk density, and specific surface area of the powder. The melting parameters are laser power, laser radiation intensity, scanning speed, protective atmosphere [1]. The goal of optimizing SLM parameters is to achieve close to 100% density of the part created with a maximum print speed. For maximum efficiency, it is necessary to take into account the peculiarities of aluminum powders: low fluidity, thermal conductivity, oxide film, high reflectivity [2-5].

The process of obtaining metal powder and the manufacture of parts by the SLM method occurs at metal temperatures above > 600 °C, in order to suppress the formation of an oxide film at such temperatures, it is necessary that the partial pressure is less than 10-50 atm (10-45 Pa). Such values are unattainable, hence the formation of an oxide film in these technological processes is inevitable. In [6], it was shown that in the SLM process, an oxide film is formed on the surface of the molten bath, which changes the wetting characteristics, these changes should be taken into account, because this is one of the reasons for the formation of porosity, and also influences the structure of the created sample when forming. With sufficient laser power, the oxide film is destroyed and absorbed by the molten bath.

Due to the low density of aluminum and the non-sphericity of the granules (including the presence of satellites), aluminum powders are characterized by low fluidity [7]. Oxide particles are formed on the surface of a melt drop when a jet of liquid metal is sprayed with an inert gas, these particles limit surface tension and are the basis for the formation of satellites. The low mass of the granules limits the fluidity of the metal-powder composition due to the domination of the friction forces and the cohesion of the granules caused by the van der Waals interaction forces over the gravitational force acting on the
powder. This feature of aluminum powder can prevent the application of a thin, uniform layer for its subsequent fusion [8].

Aluminum very well reflects the radiation falling on it. For example, it absorbs only 7% of the total energy of radiation incident on it with a wavelength of 1 micron, which is often used in modern lasers. Although there will be more absorption for the powder, due to multiple reflection by absorption, the aluminum powder will still need considerable laser power to overcome the absorption capacity. It is also worth noting that there is a difference between the absorption ability of molten aluminum to play on the border with the melt, which inevitably leads to the formation of temperature gradients. Due to the resulting temperature difference across the bath section of the melt, convection currents appear (Marangoni convection), and this affects the structure and surface of the synthesized material [9-11].

1. Experimental work

В качестве материала использовался порошок AlSi10Mg, изготовленный методом распыления расплавленного сплава нагретым азотом с последующим разделением полученного продукта на фракции необходимого гранулометрического состава. На рис. 1. представлены результаты исследования методом растровой электронной микроскопии.

![Fig. 1. SEM image powder material AlSi10Mg.](image)

The shape of the powder is closer to spherical, there are a number of inclusions of non-spherical shape, relatively smaller in size, relative to the main mass, the size of the fraction varies from 20 to 40 microns.

AlSi10Mg alloy prototypes were obtained on the ConceptLaser M2 cusing selective laser melting unit. This setup is equipped with a diode-pumped fiber-optic laser and an optical system equipped with galvanic scanners. The powder layer was subjected to continuous laser irradiation: the radiation wavelength was 1070 nm, the laser beam diameter on the treated surface was 50 μm. The melting of the powder material occurred at scanning speeds ranging from 1500 to 2300 mm / s, with a fixed maximum power of 400 watts. Melting took place in an inert gas, because Aluminium powder is prone to oxidation.

2. Research

Samples were prepared for the study of their microstructure, defects and non-metallic inclusions. The surface of the test specimen should have a roughness of not more than 0.16 microns. The obtained samples were examined on a metallographic microscope with subsequent processing in the Altami Studio software package. In fig. 2 shows photographs of the macrostructure samples. The study was conducted along and across the section:
Fig. 2. Microstructure of SLM samples: 1 - fused at a speed of 1500 mm / s at 50X magnification a) view across; b) view along, 2 — fused at a speed of 2300 mm / s at 50X magnification; a) view across; b) view along.

The samples are observed profiles of thin continuous layers in the form of scaly macrostructures containing a fine-grained structure with inclusions of intermetallic compounds. Intermetallic compounds grow with prolonged cooling. Also on samples at high scanning speeds, pores can be observed to a greater degree than at low scanning speeds.

The structural-phase composition of the powder material and SLM samples was studied by X-ray diffraction on a D8 ADVANCE instrument. In fig. 3 and 4. The results of the phase composition of powders and SLM samples are shown.

Fig. 3. Phase composition of AlSi10Mg powder.
According to the diffraction patterns of Fig. 3 and 4 we can observe which phases are included in SLM AlSi10Mg powders and samples, the composition of each of them and the amount of each phase. It can be observed that in the phase composition of the Al powder there is less by 1-2% than in the SLM samples. The highest amount of Al is observed in the sample at a speed of 2300 mm/s - 97.22%. Also, the differences in impurities are not so great. The appearance in the phase composition of the powders of two elements: SiO₂, the percentage of which is greater, is a chemical modifier added as a deoxidizer, and the second SiO₂ is a pure natural component.

Tensile tests were carried out on a WDW-100E tensile machine. The main task of the tensile test is to construct a diagram that shows the relationship between the force that stretches the sample and its absolute elongation. Prepared samples increased in length from 0.1-0.3 mm after rupture. In fig. 5 shows the patterns of sample breaks.

Fig. 4. Phase composition of SLM samples: A - AlSi10Mg fused at a speed of 1500 mm/s, B - AlSi10Mg fused at a speed of 2300 mm/s.

|          | Al  | O₂ Si | O₂ Si | Fe₂ O₃ | Si   | Mg₂Si | Al₃ O₃.52 |
|----------|-----|-------|-------|--------|------|-------|-----------|
| Powder   | 94.92 | 2.05  | 0.27  | 0.13   | 1.99 | 0.63  | -         |
| 1500 mm/s| 96.61 | -     | -     | -      | 1.57 | 1.01  | 0.81      |
| 2300 mm/s| 97.22 | -     | -     | -      | 1.28 | 0.69  | 0.81      |

Fig. 5. Diagram of the rupture of the AlSi10Mg sample alloyed at a speed of 1500 mm/s.
Fig. 6. Diagram of the rupture of the sample AlSi10Mg fused at a speed of 2300 mm / s.

The diagrams of all samples show the dependence of stress (MPa) and strain (%). The barely noticeable beginning of the curve is the elastic zone. Here only elastic, very insignificant deformations occur. Upon further loading, the curvilinear part of the diagram goes into an almost horizontal section - the yield zone. Here, the deformations grow with almost no increase in load. There is a local narrowing of the sample, in the place of which the gap will subsequently occur. The most extreme point in the diagram indicates the destruction of the sample. The last section of the curve is a local flow zone.

Microhardness was studied by Vickers at loads from 9.807 N to 980.7 N by pressing a diamond tip in the form of a regular tetrahedral pyramid into a sample under the action of a load applied for a certain time, and measuring the print diagonals remaining on the sample surface after the load was removed. From the data obtained, it can be concluded that the highest average microhardness in large areas of the AlSi10Mg sample is fused at a speed of 1500 mm / s. In the middle sections, also in sample AlSi10Mg fused at a speed of 1500 mm / s. But the average value of microhardness in small areas is the highest for sample AlSi10Mg fused at a speed of 2300 mm / s. As the melting rate increases, the microhardness begins to fall sharply.

3. Conclusion

Thus, it can be concluded that with a change in scanning speed, various changes in the physicomechanical properties of the samples obtained by the method of selective laser melting can be observed. The study of the microstructure showed that the change in scanning speed affects the pore formation, but as such, no change in the microstructure is observed. The phase composition did not change significantly. The study of physicomechanical properties showed a deterioration in performance with an increase in speed up to 2300 mm / s.

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