THE INFLUENCE OF THE MAIN PARAMETERS OF THE SLM PROCESS ON THE DENSITY OF VOLUME PARTS

Adzhamskyi Serhii
PhD, senior researcher, Chief designer
Institute of Transport Systems and Technologies of the NAS of Ukraine, LLC «Additive Laser Technology of Ukraine», Ukraine

Kononenko Ganna
Doctor technical science, scientific secretary, materials engineer
Iron and Steel Institute of Z.I. Nekrasov NAS of Ukraine, LLC «Additive Laser Technology of Ukraine», Ukraine

Podolskyi Rostyslav
PhD, researcher, materials engineer
Iron and Steel Institute of Z.I. Nekrasov NAS of Ukraine, LLC «Additive Laser Technology of Ukraine», Ukraine

Safronova Olena
PhD-student, junior researcher
Iron and Steel Institute of Z.I. Nekrasov NAS of Ukraine, Ukraine

Summary. SLM technology is gaining more and more distribution and application in many industries after it was possible to ensure a sufficiently high density of products. The technological parameters of the process significantly affect the quality of the products. Purpose: establishment of rational printing modes of volumetric samples, with a working thickness of the 316L powder layer of 40 microns to achieve a density of volumetric samples of 99.9%. Volumetric samples (10 × 10 × 3 mm) were produced on an Alfa-150 3D printer manufactured by ALT Ukraine LLC. Experimental manufacturing modes: power - 195 W, speed varied in the range of 800...900 mm/s with a step of 100 mm/s, distance between tracks – 0,08...0,11 mm with a step of 0,01 mm. Determination of the density of metal samples was carried out by the metallographic method on an optical microscope CarlZeiss AxioVert 200M mat. It was established that with the thickness of the applied layer of 40 μm metal powder of steel 316L, at a scanning speed of 800 mm/s and a distance between tracks of 0,08 mm during the production of volumetric samples using SLM technology, their density is 99,98%.

Keywords: microstructure, AISI 316L, density, power, scan speed, distance between tracks.

Introduction. With selective laser melting (hereinafter - SLM), the product consists of a set of single layers, which in turn are created from a set of single tracks.
The influence of the characteristics of the melt bath on the quality of construction of three-dimensional parts from various materials has been widely studied [1-4]. The small size of the melt bath leads to a decrease in the productivity of the process due to an increase in the production time. A large melt bath can increase production productivity, but can cause evaporation of the substrate or powder, leading to the formation of pores and an increase in the total number of material defects.

Therefore, the quality of the product, including the final metal density and surface roughness, primarily depends on the characteristics of the melt bath (shape and size) [5], which are largely controlled by the change in the energy density of the laser beam, which is essentially a measure of the energy supplied during the printing process [6-7]. Energy density control can be achieved by changing the relevant controlled parameters [8-10]. Laser power P (W), scanning speed v (mm/s), track distance (melt bath overlap) d (mm) and layer thickness t (mm) are the most important parameters.

Purpose: establishment of rational modes of printing volumetric samples, with a working thickness of the 316L powder layer of 40 μm to achieve a density of volumetric samples of 99.9%.

Material and methods. The research was conducted on samples made of powder material. Samples were printed on an Alfa-150 3D printer manufactured by ALT Ukraine LLC [11-12]. The material used in this study was metal powder with a particle size of 10 to 45 μm. Chemical composition of 316L powder in % by mass: Cr=17,79; Ni=12,63; Mo=2,35; Mn=0,78; Si=0,64; C=0,016. At the same time, the power is 195 W, and the speed is in the range of 800...900 mm/s with a step of 100 mm/s, the distance between the tracks is 0,08...0,11 with a step of 0,01 mm. A total of 8 modes of printing three-dimensional samples (10 × 10 × 3 mm), located at a distance of 10 mm from each other, were investigated. The thickness of the layer used in the experiments is 40 μm, the diameter of the beam is 0,12 mm.

The raw material was examined using a SEM-106 scanning electron microscope (Fig. 1, a) to determine the shape and size of the particles. In fig. 1, b shows the results of the analysis.

![Fig. 1. Particles of the original material 316L at a magnification of 200 (a) and the results of granulometric analysis (b).](image)

Microstructure studies were performed on a CarlZeiss AxioVert 200M mat optical microscope.
The microstructure of test samples made with different process parameters is shown in Fig. 2. In the samples made with the parameters: the distance between the tracks – 0,08 mm and the scanning speed - 800 and 900 mm/s, the minimum porosity of the metal was observed, which was 99,98% and 99,96%, respectively.

<table>
<thead>
<tr>
<th>Distance between tracks, mm</th>
<th>Scanning speed 800 mm/s</th>
<th>Scanning speed 900 mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,8</td>
<td><img src="image1" alt="Microstructure" /></td>
<td><img src="image2" alt="Microstructure" /></td>
</tr>
<tr>
<td>0,9</td>
<td><img src="image3" alt="Microstructure" /></td>
<td><img src="image4" alt="Microstructure" /></td>
</tr>
<tr>
<td>0,1</td>
<td><img src="image5" alt="Microstructure" /></td>
<td><img src="image6" alt="Microstructure" /></td>
</tr>
<tr>
<td>0,11</td>
<td><img src="image7" alt="Microstructure" /></td>
<td><img src="image8" alt="Microstructure" /></td>
</tr>
</tbody>
</table>

Fig. 2. Microstructure of test samples made with different process parameters

In the samples made with the following parameters: the distance between the tracks – 0,09...0,11 mm and the scanning speed – 800 mm/s, slight porosity of the
metal was observed. In the samples with a distance between the tracks of 0.11 mm, unmelted particles of the original metal powder material are located in the pores. The density of the samples was 99.92...99.84%.

In the samples made with the following parameters: the distance between the tracks – 0.09...0.11 mm and the scanning speed – 900 mm/s, lower porosity was observed compared to the scanning speed of 800 mm/s, which was 99.87...99.72%, respectively.

Conclusions. From the results of research, it was established that with a thickness of 40 microns of the applied layer of metal powder of steel 316L, at a scanning speed of 800 mm/s and a distance between tracks of 0.08 mm during the production of volumetric samples using the SLM technology, their density is 99.98%.

It was established that when the distance between the tracks is increased from 0.09 to 0.11 mm with a step of 0.01 mm at a scanning speed of 900 mm/s, the density of the test samples is 99.87...99.72%. It is shown that reducing the scanning speed to 800 mm/s leads to an increase in density to 99.92...99.84% according to the distance between the tracks. Thereby increasing the penetration of the intertrack space.

References:
[9] Аджамский С. В., Кононенко А. А., Подольский Р. В. (2020). Симуляция влияния остаточных напряжений и параметров SLM-технологии на формирование области границ изделия из жаропрочного никелевого сплава INCONEL 718. «Інформаційні технології в металургії та машинобудуванні» (17-19 березня 2020, Дніпро), Дніпро,

