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The effect of layer thickness at selective laser melting

V.S. Sufiiarov[a], A.A. Popovich[a], E.V. Borisov[a], I.A. Polozov[a]*, D.V. Masaylo[a], A.V. Orlov[a]

[a] *Peter the Great St. Petersburg Polytechnic University, 195251, Polytechnicheskaya, 29, St. Petersburg, Russia*

Abstract

Selective laser melting technology involves various parameters which may influence properties of the resulting part. This study presents the correlation between powder layer thickness and relative density, microstructure and mechanical properties of nickel-based superalloy produced by selective laser melting. It is shown that the microstructure of the bulk material consists of columnar dendritic cells. The size of these cells depends on the layer thickness used during SLM. Tensile strength and elongation at break also depend on the powder layer thickness during SLM. Samples build with 30 µm layer thickness demonstrate higher strength and lower elongation at break than those build with 50 µm layer thickness. It is also established that the horizontally build samples show higher strength properties and lower plasticity compared to the vertically build samples.

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* Corresponding Igor Polozov.
E-mail address: polozov_ia@spbstu.ru.

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1. Introduction

Heat-resistant nickel alloys are widely used in gas turbine building to produce components for hot parts of turbines. One of the most common heat-resistant alloys is Inconel 718 [1-2]. High strength and corrosion resistance of this alloy at room and elevated temperatures have found application in nuclear power, oil and gas industries. Apart from good performance, this material is inclined to work hardening, which causes difficulties in mechanical treatment of blanks. In this respect, it is reasonable to produce elements from Inconel 718 alloy which are maximally close to the geometry of a final part and do not require mechanical treatment.

One of the most promising and efficient trends in manufacturing complex-shaped parts without special equipment and molds includes additive technologies. Additive technologies represent a group of technologies, whose common principle is manufacturing pieces through layer-by-layer addition of material. In terms of production of pieces made of metals with complex geometry, the most advanced additive technology is selective laser melting (SLM). The essence of this technology is layer-by-layer melting of metal powder for obtaining continuous solid-phase structure [3].

Recent researches have focused on using of additive technologies for manufacture in aviation [4,5], medicine [6,7], and repair and restoration capabilities of worn parts [8].

A number of papers [9-11] present research into how layer thickness influences the microstructure and properties of samples obtained on the basis of the SLM technology. However, no research has been done into comparison of the characteristics of samples manufactured with the use of layer thickness equal to 30 µm and 50 µm for Inconel 718 heat-resistant nickel alloy. The authors of this paper have already done research into the characteristics of the samples produced on the basis of SLM with layer thickness of 50 µm [12]. The results of this research will be used to compare them to the characteristics of the samples obtained at the layer thickness of 30 µm.

Thus, the objective of this paper is to do research into the effect of layer formation thickness at selective laser melting on density, microstructure, phase composition and mechanical properties of the manufactured pieces.

2. Experimental procedure

The samples were made on a SLM 280HL selective laser melting system produced by SLM Solutions GmbH. The plant is equipped with two ytterbium fiber lasers, with a maximum power of 400 and 1000 W, characteristic length of emission – 1070 nm, scanning speed up to 15 m/sec. Maximal overall dimensions of pieces are limited by the working area of the system, which is 280x280x350 mm. The system operates in the atmosphere of inert gas (nitrogen or argon), which is selected depending on the powder material to be used.

Inconel 718 heat-resistant alloy powder was used as a source material. It was obtained through gas atomization of liquid alloy [13,14] and was supplied by LPW Technology. The chemical composition of Inconel 718 alloy powder is presented in Table 1.

Table 1. Chemical composition of Inconel 718 Alloy powder (measured by SEM EDS)

Element	Ni	Cr	Fe	Nb	Mo	Ti	Al	Co	Mn
Contents, % wt.	51.4	19.4	18.5	5.3	3.4	1.0	0.7	0.1	0.1

Particle size distribution was determined using the laser diffraction method on the Analysette 22 NanoTecPlus device with a full-scale range of 0.01-2000 µm.

The surface morphology and particle microstructure studies were conducted using the TESCAN Mira 3 LMU scanning election microscope (SEM) working at 4-106x zoom with an accelerating voltage of 200 V-30

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