PREPARATION OF METAL POWDERS FROM SILVER MELT FOR 3D PRINTING BY MELT DISPERSION METHOD

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ABSTRACT

The development and introduction of additive technologies in modern industry is due to the need of production in reducing waste, reducing the anthropogenic load on the environment and improving the environmental friendliness of production, reducing labor costs and improving technical and economic indicators, automation of the technological process in obtaining products for various purposes. The increase in the number of technological solutions that allow 3D printing is due to the mass interest in this issue, the availability of modern technologies and materials that make it possible to design, test and use printers in experimental and production conditions. The purpose of this work is to develop technological parameters for obtaining metal powder from silver melt for 3D technology by dispersion method. In the course of the work it was found that the formation of particles is significantly influenced by the breaking angles of the silver melt with high-pressure water. Studies have shown that to obtain particles whose shape is close to spherical, with a diameter of 45–500 microns, it is effective to use the splitting angles α=45°, β=42°. Upon receipt of the powder with the corners split α=30°, β=45° и α=β=45° are formed irregular particles on the surface and discovered oxygen in the amount of 1.16 is 7.80 %.

Keywords: dispersing; metal powder; silver; additive technologies

INTRODUCTION

The development and introduction of additive technologies in modern industry is due to the need of production in reducing waste, reducing the anthropogenic load on the environment and improving the environmental friendliness of production, reducing labor costs and improving technical and economic indicators, automation of the technological process in obtaining products for various purposes [1-5].

The most promising methods of obtaining a metal powder size from 20 to 2000 microns, used in 3D printing, can be attributed to the dispersion of the melt by gas spraying using inert gases. The disadvantage of this method is the presence of gas pores in individual granules, formed as a result of the slamming of gas bubbles in the process of spraying the melt jet [6-11].

Dispersion of molten metal by high-pressure water jet eliminates the formation of gas pores and obtain a powder particle shape close to spherical, due to the action of surface tension forces. Previous studies [6, 11, 12] have shown that one of the main parameters of the process that determines the size and shape of the powder particles is the angle of supply of breaking water to the melt jet.

Therefore, the purpose of this work is to develop technological parameters for obtaining metal powder from silver melt for 3D technologies by dispersion method.

MATERIAL AND METHODS

To obtain experimental batches of metal powder, a silver melt containing 99.99% Ag and a facility for dispersing precious metals were used (Fig. 1), which allows to obtain powders of sizes 20-1000 microns. To spray the melt, a V-jet nozzle consisting of 4 nozzles was used. Melting of the charge was performed in an induction melting furnace. The melt temperature before dispersion was 1473 K, at a melting temperature of 1234.9 K. to avoid crystallization of the melt in the drain crucible and in the metal pipe, the crucible was heated to a temperature of 1273 K. The diameter of the drain hole of the crucible - 2 mm.

Studies of the shape and size of the powder particles were carried out using a scanning electron microscope JEOL JSM-7700F with a resolution of up to 0.6 nm.

The chemical composition of the metal powder particles was determined by micro-x-ray spectral analysis using a JEOLJSM 6610 scanning electron microscope equipped with an Oxford Instruments energy dispersion spectrometer.

The granulometric composition was carried out by the sieve analysis method [13] using a vibrating screening machine RETSCH AS 200 BASIC on sieves 0045, 01, 025, 05.

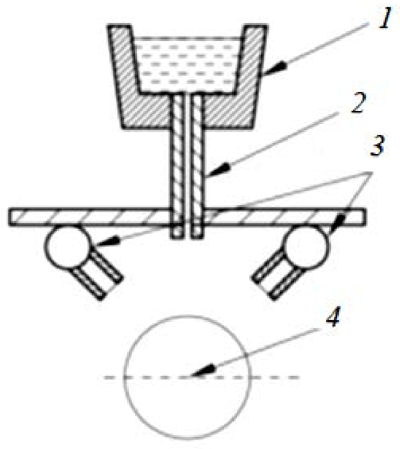
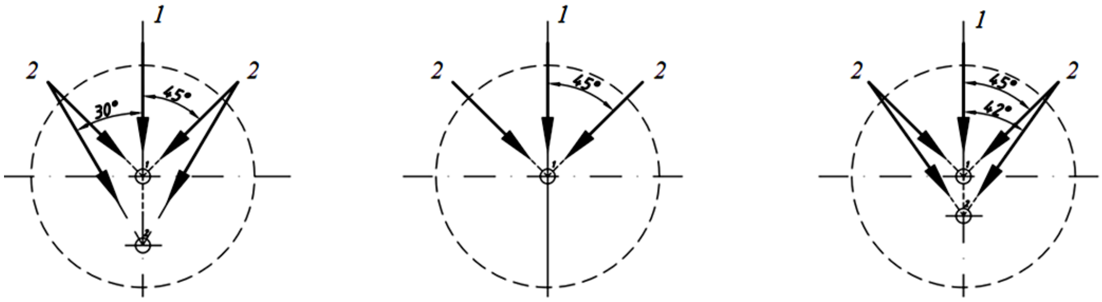


Figure-1. Diagram of dispersion of a metal melt:
1-melting chamber; *2*-metal pipe; *3*-spray nozzles; *4*-spray area

RESULTS AND DISCUSSIONS

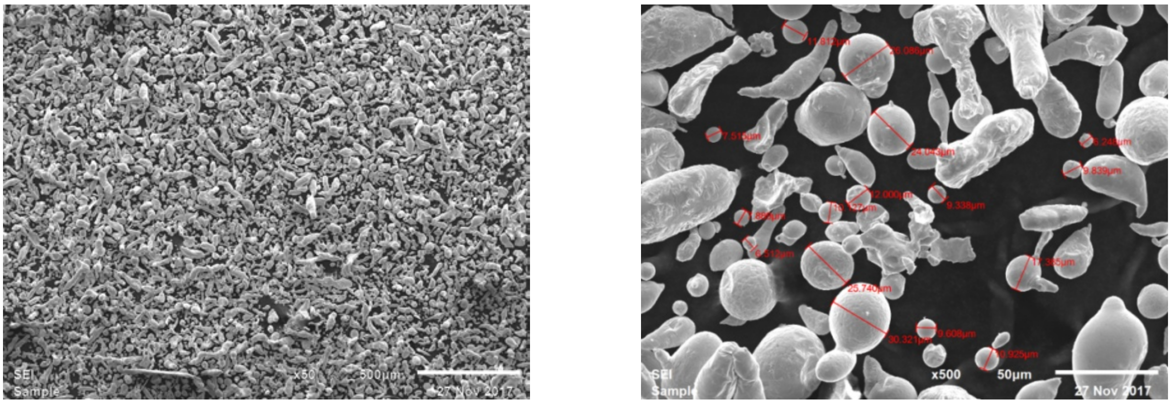
Preparation of experimental batches of metal powder was carried out at different angles of partition (Fig. 2): first batch – corners α=30°, β=45°, the second batch-traditional technology of spraying at angles α=β=45°, the third batch-two-stage crushing α=45°, β=42°. The speed of water flows directed to the melt is 100–150 m/s, at a pressure of 15–25 MPa, providing a cooling rate of 103–104 °/s.



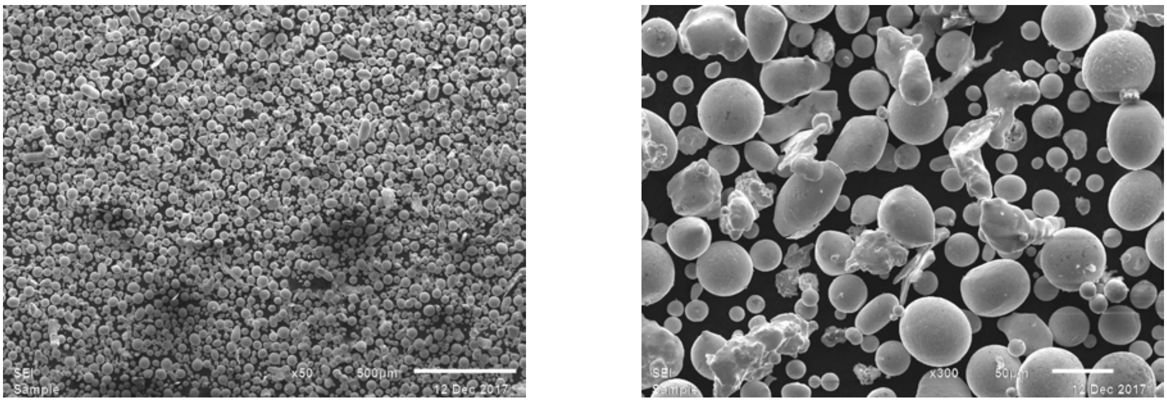
a *b* *c*

Figure-2. Diagram of the angles of the nozzles for the dispersion of the molten metal:
1-melt supply; *2*-water supply: *a* – α=30°, β=45°; *b* – α=β=45°; *c* – α=45°, β=42°

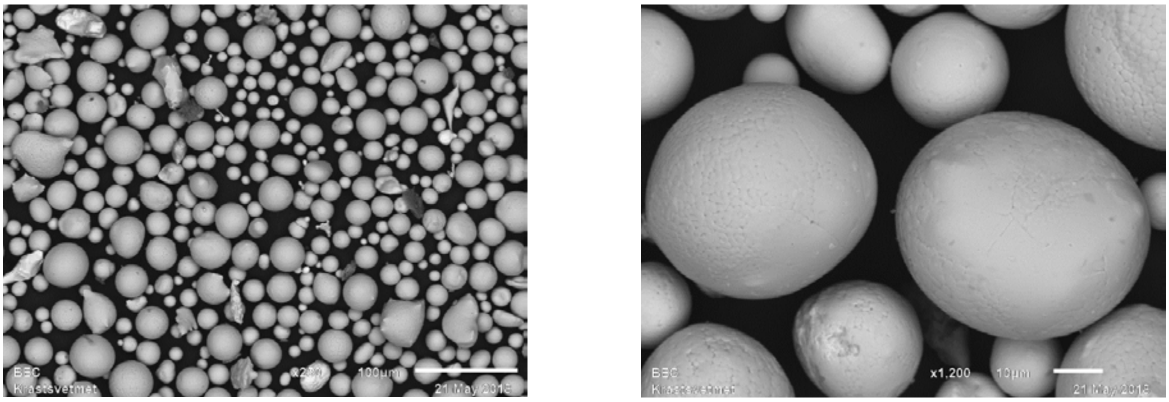
Investigations carried out on a scanning electron microscope allowed to determine the influence of the angle of the melt jet on the shape of the resulting metal powder (Fig.3).



×50 *a* ×500



×50 *b* ×500

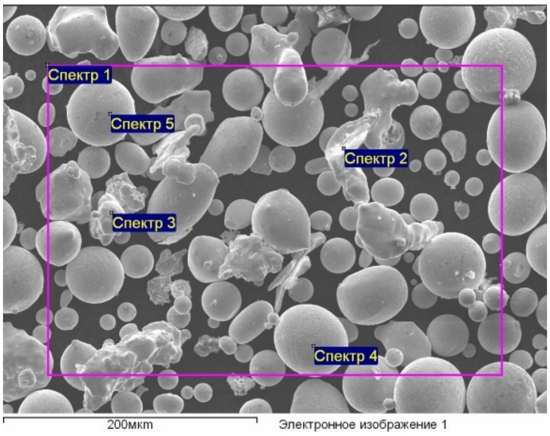


×250 *c* ×1200

Figure-3. Shape of powder particles: *a* – first party; *b*-second party; c-third party

The metal powder of the first batch (Fig. 3, *a*) contains in its composition mainly particles of irregular shape. The shape of the powder particles of the second batch (Fig. 3, b) is both irregular and spherical in approximately equal proportions. Particles of metal powder of the third party (Fig. 3, c) preferably have a spherical shape. This is due to the fact that at given angles of splitting, the contact area of the melt jet with high–pressure water increases, in consequence of which the process of crystallization and spheroidization occurs in the melt-water medium.

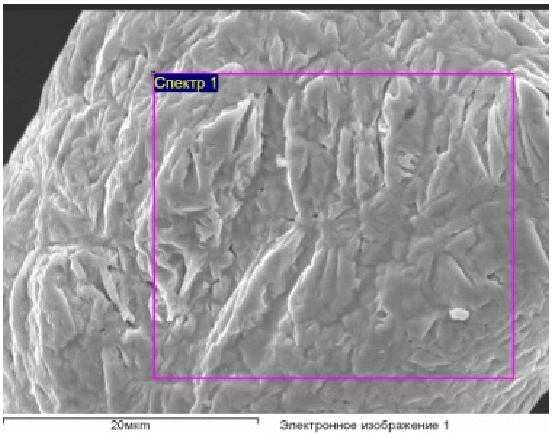
The formation of irregularly shaped particles can occur as a result of the interaction of the melt with oxygen, which leads to the formation of refractory oxide films on the surface of the particles suppressing the surface tension forces. In order to determine the effect of the splitting angle on the chemical composition of the surface of the metal powder particles, an energy dispersion analysis was performed (Fig. 4-6).



Spectrum	Conten , %	
	O	Ag
Spectrum 1	10.18	80.51
Spectrum 2	7.35	85.90
Spectrum 3	3.82	96.41
Spectrum 4		92.16
Spectrum 5		97.01

a *b*

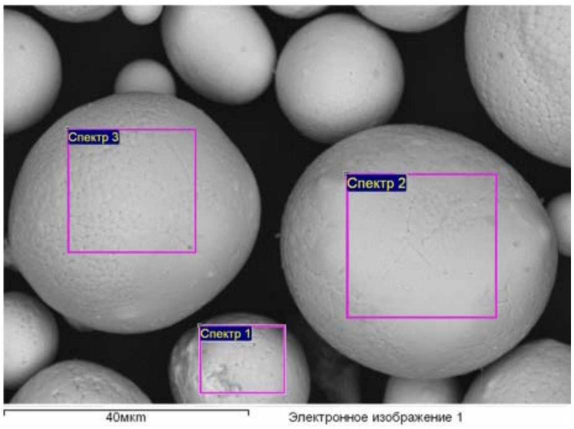
Figure-4. Energy dispersion analysis:
a-spectra for determination of chemical composition of particles; *b*-chemical composition of spectra



Spectrum	Content, %	
	O	Ag
Spectrum 1	7.80	85.04

a *b*

Figure-5. Energy dispersion analysis: *a*-spectrum on an irregular particle; *b*-chemical composition



Spectrum	Content, %	
	O	Ag
Spectrum 1	1.16	98.24
Spectrum 2	-	98.70
Spectrum 3	-	98.18

a *b*

Figure-6. Energy dispersion analysis: *a* – particles of spherical shape; *b* – chemical composition

The obtained results of energy dispersion analysis of the metal powder selected from the experimental batches show the relationship between the shape and chemical composition of the particle surface. Spectra located on irregularly shaped particles: Fig. 4, a-spectrum 2, 3; Fig. 5, a-spectrum 1; Fig. 6, a-spectrum 1-show the presence of oxygen in the amount of 1.16-7.80 % (Fig. 4, b; 5, b; 6, b), while no oxygen was detected on particles whose shape is as close to spherical as possible: Fig. 4, b-spectrum 4, 5; Fig. 6, b-spectrum 2, 3. It is worth noting that the greater the deviation from the spherical shape, the higher the oxygen content.

The granulometric composition of each experimental batch was studied according to the standard procedure on sieves 0045, 01, 025, 05. The results of the particle size distribution are shown in Fig. 7.

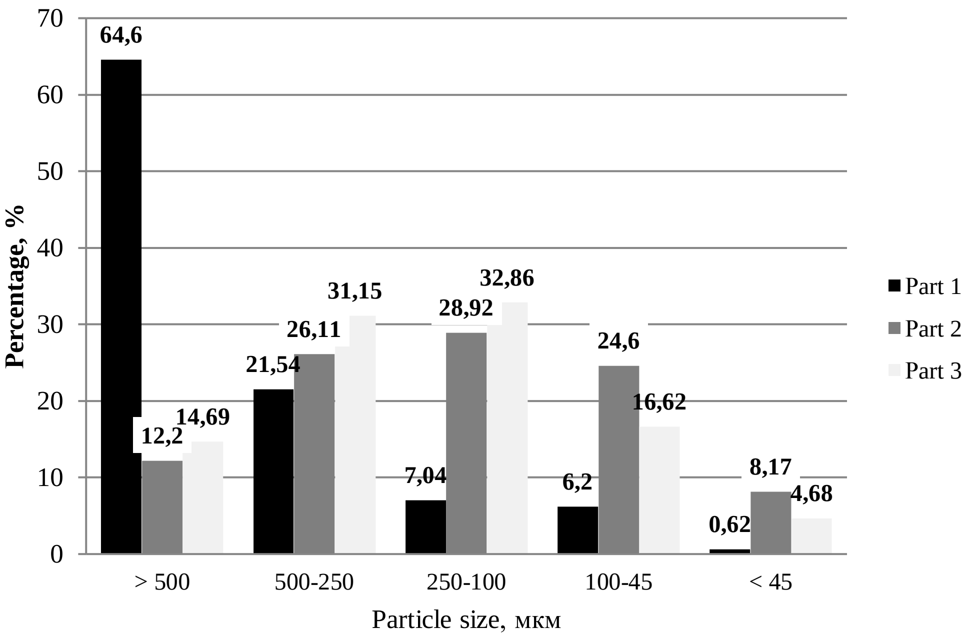


Figure-7. Granulometric composition of experimental batches of powder

According to the results obtained, the metal powder particles of the second batch have a smaller size. Such results allow to draw a conclusion that increase of angles of splitting of a jet of a metal melt to 45 ° leads to formation of particles of a powder of the smaller sizes.

CONCLUSIONS

The use of high-pressure water greatly reduces the formation of gas pores on the surface of the metal powder particles. By results of researches it is established that the size and the form of particles depends on an angle of splitting of a jet of melt, water of high pressure. Powder particles, whose shape is as close to spherical as possible, are formed at the splitting angles α=45°, β=42°. It is worth noting – the higher the oxygen content on the surface of the powder particles, the greater the deviation from the spherical shape. The average size of the particles at the corners of the split α=45°, β=42° slightly more than when the corners split α=β=45° and is in the range of 100-250 μm.

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