Powder production of from low-alloy steel by flame atomization

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Abstract. The advantages of plasma atomization technology in comparison with other methods of powder production for additive technologies are shown in this paper. Investigations of powders obtained by plasma atomization from welding wire sv-08G2S (similar to ER70S-6) with a diameter of 0.8 mm have been carried out. The size of the powders, their shape, chemical composition, microstructure and microhardness have been investigated.

1. Introduction
The problem of producing powder materials is relevant not only for the development of additive technologies, but also for the completely classical powder metallurgy. A metal-powder composition are used in such high-tech industries as aircraft construction, power engineering, military and space technology, shipbuilding, and instrument making.

At the moment, there are various methods for the production of metal powders, which can be divided into physical-chemical and mechanical.

Physicochemical processes include methods in which the initial material changes its chemical composition. While the mechanical methods of producing metal powders, there is no significant change in the chemical composition of the initial materials. These methods include mechanical destruction of the initial material in a solid state, for example, in special mills, and also the spraying of starting material in a liquid state using a gas jet and a liquid stream.

The melt spraying using various carriers makes it possible to producing metal powders of the correct spherical shape and the required fractional composition. Such powders have the most powerful properties required for additive technologies.

Another type of gas atomization is the plasma spraying technology, which makes it possible to produce high-quality, ultra-pure powder in a wide and controllable range of fractional composition. In the plasma sputtering technology, metal is melted using the plasma. The main of the technology is follows: the sprayed material is taken in the form of a rod or wire, an inert atmosphere is created in the spraying chamber, a plasma jet is supplied to the wire, and the material is consumed at the same time melted and sprayed, which increases the energy efficiency of the technology. The disadvantage of this technology is the need to prepare the starting material in the form of a rod with a diameter of 1-5 mm. However, this technology makes it possible to obtain high quality powders.
Plasma technologies make it possible to produce metal powders of a given granulometric and chemical composition; it is possible to obtain powders from refractory materials.

2. Experimental studies

Researches of powders obtained by plasma spraying were performed in this work. The installation for obtaining metal powders with a given shape and particle size, using the technology of plasma-arc spraying with a water shield, used in additive technologies, characterized by a modular structure of the spray chamber to facilitate its maintenance and repair, the presence of a cooling chamber with a water shield for more efficient cooling sprayed metal particles. The object of research is powders obtained from welding wire sv-08G2S (analogue ER70S-6) with a diameter of 0.8 mm. Sv-08G2S welding wire is one of the most common demanded options due to the fact it has an optimal component composition. It is used for a wide variety of welding and surfacing applications. The chemical composition of the wire is shown in Table 1.

Table 1. Chemical composition

|     | C     | Mn    | Si    | S        | P        | Cu    |
|-----|-------|-------|-------|----------|----------|-------|
|     | 0,05-0,11% | 1,8 -2,1 % | 0,70 - 0,95% | < 0,025 % | < 0,03 % | < 0,25 % |

Figure 1 shows a sample of a plasma spray powder.

![Sample of powder obtained by plasma spraying.](image)

Powders were examined using a scanning electron microscope "VEGA 3 LMH" manufactured by TESCAN, Czech Republic, using an X-ray energy dispersive microanalysis system AZtecEnergy Advanced with a nitrogen-free detector X-max 20 Standart, manufactured by Oxford Instruments. Powders were studied from the surface and in the cross section of particles. The results of these studies are presented in Figure 2.
Investigations of powders microstructure were carried out in the section of particles. The microstructure of the particles is identical and is a low-carbon martensite, in accordance with Figure 3.

The microhardness of the particles was measured in accordance with GOST R ISO 6507-1-2007 using a MicroMet 5104 microhardness tester, at a load of 100 gf.

The microhardness of the powder particles is:
- sample with conditions No. 1 - 294 - 382 HV0.1;
- sample with conditions No. 2 - 250 - 360 HV0.1.

3. Conclusions
The plasma atomization technology makes it possible to obtain high-quality, ultra-pure powder in a wide and controllable range of fractional composition.

The developed installation, using the plasma atomization technology, has advantages over other methods of powder production:
- Energy costs fall by 20-30% in comparison with gas or water spraying, since only a small section of the wire is melted and immediately sprayed, also due to the high plasma temperature, the fluidity of the melt increases, which makes it possible to obtain powders of a smaller fractional composition;
- The gas consumption is reduced by 10-20%, since the sprayed gas is also plasma-forming and, as a result of its increase in volume, more efficiently sprays the molten material;
- A finely dispersed powder structure is formed, which leads to a more uniform distribution of the composition of the material and, as a result, leads to an increase in the strength characteristics of the final products.
- A wide range of sprayed materials, including refractory ones, and obtaining various metal (carbon, stainless and tool steels, aluminum, copper, titanium and other metals) and ceramic (oxides, carbides and nitrides) powders on one device;
- Ability to obtain any volume of powder: from several kilograms to several tons;
- Easy to control the spraying process (fractional composition), by changing the gas-dynamic and energy parameters of the plasmatron.

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