Research and development of the inert gas atomization of the wire by means of arc spraying

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Abstract. The paper presents brief information on the theory and technology of electric arc wire spraying. The construction for spraying of four groups of wire materials is shown. Carbon and stainless steel, pure copper and titanium wires were atomized. A model of wire atomization during process of electric arc spraying is described.

1. Introduction

The method of electric arc spraying was originally developed by M. U. Schoop in 1910. But this process got commercial acceptance during 1960s. The technology of the electric arc spraying is the most economical among the methods of thermal spray processing. This is due to the high deposit efficiency of the material and the higher productivity of the spraying process. Traditionally, the electric arc spraying is used to protect large structures, such as bridge or tank surfaces. Currently, all major manufacturers of equipment for thermal spray processes have installations for electric arc spraying. For example, the world leaders Praxair S. T. Technology and Oerlikon Metco is used in a variety of situations from high-volume, low-cost applications to high-quality aircraft coatings that have replaced plasma.

Therefore, the theory and practice of electric arc spraying is discussed in detail in the fundamental works on thermal spray processes [1], as well as in specialized monographs [2]. It is known that the melting of wire metal is carried out by means of an electric arc. Liquid metal is sprayed with a gas stream (usually air). The flow of the droplets is formed. The droplets are transferred to the substrate and form a coating. The conditions of the dispersion process form a stream of narrow-fraction droplets. Therefore, the electric arc spray technology can be used to produce spherical powders of a narrow fractional composition.

In this paper, we consider a method of electric arc spraying to evaluate the possibility of obtaining spherical powders for the additive industry. The properties of powders have high influence on the results of additive manufacturing. Traditional atomization methods have known limitations. Therefore, it becomes relevant to study the process of atomization of wire materials using an electric arc spraying with an inert gas.

The purpose of this work is to develop the relevant equipment and to study the process of atomization of wire materials with different chemical compositions.

2. Materials and Method

Four types of materials were used for electric arc spraying (Table. 1). The selected materials are used in additive manufacturing.
The wire with a diameter of 0.8 mm was used for electric arc spraying of the low carbon steel and copper.

The spraying equipment is the twin-wire arc spray system C-16-CT(M) (GMBh "Thermal-Spray-Tec", Moscow, Russia) with the arc spray gun. Figure 1 shows open scheme of the arc spray gun. The maximum power of the inverter is 29 kW. The arc spray gun has cylindrical nozzle with diameter 4.5 mm. The spray gas is the argon. The wire feed mechanism has push/pull scheme.

**Table 1. Materials for twin-wire arc spray atomization**

| Material      | Chemical composition | Fractional composition | Application               |
|---------------|----------------------|------------------------|---------------------------|
| Low carbon steel | 0.9%C, 1.6% Mn, 0.8 %Si, Fe - base | <170                  | Mechanical design         |
| Stainless steel | 0.12%C, 18%Cr, 10 %Ni, 0.9% Ti, Fe - base | <180                  | Mechanical design in the corrosion conditions |
| Cupper        | Cu                   | <200                  | Electrical products, heat transfer [3, 4] |
| Titanium      | Ti                   | <250                  | Aircraft, medical applications |

Figure 2 shows a schematic diagram of the spraying chamber for twin-wire electric arc spraying. The spraying is carried out in a closed chamber. There is a viewing window at the top of the chamber. A gas stream with liquid droplets and solidified particles passes through a cylindrical section, which is 5 m in length. The solidified powders are separated in cyclones. The purified gas is removed to the exhaust. In the first cyclone, large particles are collected. In the second cyclone, small particles are collected. To improve the classification of atomized powders, the number of cyclones can be increased.
3. Results and Discussion
A model of the electric arc spraying process is shown in Figure 3. There are three zones in the spray process. In the first zone the wire is melted by means of an electric arc. In this zone the material is in a liquid state and is drawn out by the gas flow. In the second zone liquid droplets are formed. Under the action of surface tension forces the droplets become spherical. In the third zone the drops are solidified. The process of formation of liquid drops in the second zone is periodic. The voltage of the electric arc changes with the length of the liquid section in the first zone. Therefore, the voltage in the secondary circuit of the power supply has a variable value. Consequently, in the second and the third zones, there are periodic increase and decrease of the number of drops and solid particles, respectively (figure 4).
The analysis of the effect of spray modes on the fractional composition showed that we had a normal distribution of particles as a result of electric arc spraying. Increasing the electric current and the wire feed speed increases the average fraction of the large powders. Increasing the voltage leads to the increase of the fine fraction. Increasing the gas flow rate reduces the size of the atomization powders.

Before spraying, the chamber was purged with argon. The additional vacuuming of the chamber was not performed. Therefore, during the spraying process, the powders were oxidized. For this reason, the chamber must be free of oxygen before spraying. Consequently, the design of the spray chamber requires modernization.

In addition, experiments have shown that using a smooth 4.5 mm nozzle leads to high gas consumption. Therefore, it is necessary to change the design of the spray gun.
4. Conclusion
The tests on wire atomization by means of the electric arc spraying were carried out. It is shown that the proposed process made it possible to obtain spherical powders of a narrow fractional composition from various electrically conductive materials.

A model of the electric arc spraying is proposed. The video footage confirming the variable frequency of the spraying process is presented.

The main directions of improving the spray technology and of selecting the optimal parameters for obtaining the required fractional composition of spherical powder are determined.
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