Investigation of parameters of low-temperature gas discharge plasma with liquid electrodes upon receipt of metal powder

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Abstract. Selective laser melting technologies are widely used in various industries and medicine. A gradual increase in the volume of manufactured products requires the creation of new cheap methods for producing metal powders. One of the new methods for producing powders is the plasma-electrolyte method. A feature of this method is the use of gas with liquid electrodes, which allows you to get a metal powder and quickly cool it in a liquid. The question of the influence of discharge parameters on the process of metal atomization remains open. The paper studies gas discharges with liquid electrodes under the conditions of atomization of a metal anode. A gas discharge between a liquid electrolyte and a metal electrode was studied experimentally in the voltage range 300 - 1000 V. Solutions of sodium chloride in distilled water were used as the electrolyte. The conditions are established under which a stable discharge column is formed and metal powder is sprayed. The regularities of the change in the CVC of the discharge depending on the interelectrode distance are determined. A splitting of the spectral lines of the yellow sodium doublet was found in the emission spectrum of a gas discharge.

1. Introduction

The development of additive technologies (AT) made it possible to manufacture metal products by melting the powder and obtaining a uniform solid-phase structure [1]. Additive technologies make it possible to manufacture parts of complex geometric shapes, the receipt of which by traditional methods is impossible. In addition, additive technologies can reduce the time to obtain the finished product [2]. Production can be started as soon as the product is designed. Thus, the time from the design of the product to the receipt of the finished part can be reduced from several weeks to several days. Also, the use of additive technologies can reduce the utilization of the material and, thereby, reduce the cost of production.

ATs make it possible to use a wide range of various metallic materials: nickel, titanium, aluminum alloys, cobalt-chromium, various steels, etc. Using ATs, finished functional products with high mechanical properties can be obtained. The quality of the products obtained depends on many technological process parameters, the correct choice of which is a fundamental factor for obtaining the necessary properties. All this, as well as the wide technological capabilities of the process,
environmental friendliness and a high level of use of the material make these technologies promising both for research purposes and for production needs [3].

One of the new methods for producing metal powders is plasma-electrolyte sputtering [4]. Which consists in using a gas discharge with liquid electrodes. In this case, the sprayed metal electrode is installed above the liquid electrolyte, which performs the function of a cathode [5]. Upon contact of the metal anode with the liquid cathode, the combustion of the electric arc is initiated, then the metal electrode rises vertically to a distance of 5 mm from the surface of the electrolyte. During arc burning, the metal anode melts and the metal sprays under the action of plasma [6]. Liquid metal drops formation is observed, which quickly crystallize in the electrolyte. The goal is to study the parameters of the electric discharge during the metal powder formation.

2. Main part

The gas discharge parameters were studied at the installation, the functional diagram of which is shown in Figure 1. It consists of an electrical power system 1, an electrolytic bath - 2, an electrode system - 3, an oscilloscope - 4, additional resistance - 5, a voltmeter - 6, an ammeter - 7, thermocouples - 8. Using the electrode system, the distance between the anode and the electrolyte solution was monitored. Using the oscilloscope 4, the shape of the applied voltage and current was controlled, and the voltage and discharge current were measured using a voltmeter and ammeter.

![Figure 1. The experimental setup](image)

Combustion of a gas discharge occurs between a cobalt-chrome alloy anode and an electrolytic cathode. The anode is a metal cylinder with a diameter of 3 mm, located above the surface of the electrolyte at a height of 1 to 5 mm. As the electrolytic cathode, aqueous solutions of NaCl and Na₂CO₃ were used with a concentration of 0.1-1% by weight.

To understand the processes occurring at the interface between the plasma and the liquid cathode, it is necessary to know the dependence of the cathodic potential drop on the acidity of the electrolyte and pressure. Spectral studies can give an idea of the charge transfer mechanism and plasma properties, showing the intensity lines of the elements entering the solution as a function of the cathode drop and the acidity of the electrolyte. It was found that the magnitude of the cathode drop is independent of gas pressure. Measurements of the intensity of the spectral lines of metals dissolved in the electrolyte from the acidity of the electrolyte show that for more acidic electrolytes, the intensity can exceed ten times. The cathodic potential drop for pH below 5 drops sharply from 800 V to 500 V.

Analysis of the waveforms shows the presence of ripple current, a strict periodicity of which is not observed. Spectrometric studies have shown that sodium atoms predominantly emit in the discharge.
The spectral composition is dominated by radiation corresponding to the head line of the main sodium series, which is often called the yellow D-line or the yellow sodium doublet. Under gas discharge conditions, each doublet line is split into two components. It can be assumed that the splitting occurs due to the action of a strong magnetic field on sodium atoms. Accordingly, instead of one energy level of an atom, two sublevels can form. From this point of view, a similar splitting of spectral lines in a high-current gas discharge obtained using electrolytes of salts and other alkali metals, in particular potassium, is possible.

3. Conclusion
The question of the discharge nature remains open. For the formation of a metal powder, burning an electric arc with a large energy input is necessary. However, studies show:

1. A decrease in the cathodic drop with a decrease in the acidity of the electrolyte may indicate an increase in the secondary electron emission coefficient.
2. This dependence can be explained by the participation of protons and solvated electrons in the processes of secondary electron emission for the electrolytic cathode.

All this indicates a greater degree to combustion glow discharge sputtering of metal powder, instead of the electric arc.

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