The research of anodic microdischarges in plasma-electrolyte processing

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Abstract. The article is devoted to the topic of anodic microdischarges in plasma-electrolyte processing. The aim of this work is to research the conditions of anodic micro-discharges during the plasma-electrolytic treatment and the influence they have on the surface of metals. As a result of experimental researches, was made a mechanism of influence anodic microdischarges on the surface of the electrode, burning of anodic microdischarges occur in the voltage range of 40-100 W.

1. Introduction

Recently, the discharge of liquid electrodes has found wide application in chemical engineering, materials processing technologies and in other fields of science and technology [1, 2]. With these types of discharges, there is the possibility of formation of surface micro relief [3, 4]. This is due to the fact that the classical methods of treating the surface of electrical steel have disadvantages [5]. In this regard, an urgent need to develop and research new energy-efficient, environmentally friendly and cost-effective methods of treating the surface, based on the use of liquid discharges from the electrodes. The purpose of this study was to examine or testify the conditions of anodic micro-discharges during the plasma-electrolytic treatment and the influence they have on the surface of metals.

2. Experimental

Was developed and constructed an experimental setup to study the anodic microdischarges, the conditions of occurrence and their impact on the metal surface (fig.1).

The experimental setup operates in the range parameters of the voltage U = 0 ÷ 250 B, current I = 0 ÷ 50 A, pH = 1-12 and T = 20-110 ^{0}C. It consists of a current source 1, the electrolytic cell 2, the electrode system 3, of the oscilloscope 4, additional resistance 5, voltmeter 6, and ammeter 7. Camera installation is made in the form of a "tee", two 10 mm diameter tubes, welded together at right angles to each other. The length of the tube base was 80 mm, perpendicular to the tube 30 mm. The power supply provides a regulated constant voltage supply for the power connection to the electrode system. The anode was made in the form of a rectangular plate of width 5 mm, a length of 8 mm and a thickness of 1 mm. The cathode was made of copper in the form of a ring with a diameter of 8 mm and a width of 5 mm. The camera was mounted on a working microscope stage IIB-2, contained in a horizontal position. Through the camera installation was pumped electrolyte. Then, lens was applied to the wall of the plant and focused on the surface of the plate - the anode with a movable microscope tube. Was carried out observation of occurrence anodic microdischarges and their record on the camcorder Sony DCR-TR V60E.

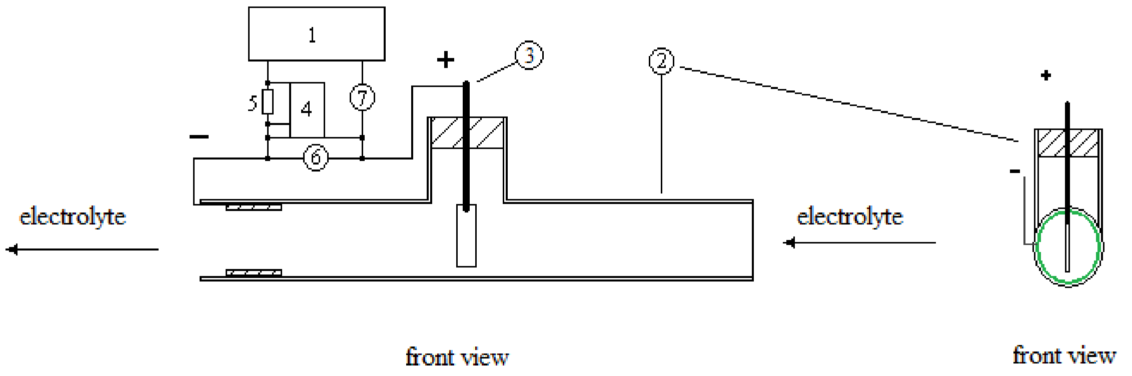

Fig. 1 Functional scheme of the experimental setup, intended to fix the ignition anode microdischarges.

Pumping and purification system is filled with the investigated electrolytes the necessary concentration and composition. In a study of electrolytic cathodes used aqueous solutions of NaCl, Na2CO3, Na2SO4, NaOH, KOH, HCl, H2SO4, concentration up to 15%.
Investigations were performed on specimens made of steel 12X18H9T, steel #3, electrodes E46-ANO-4-d-UD-A (Fe -99%, C -0.1%, Mn-0, 52%, Si - 0,15%), copper and graphite. Samples of the electrode after the plasma electrolytic process were investigated using a scanning electron microscope.

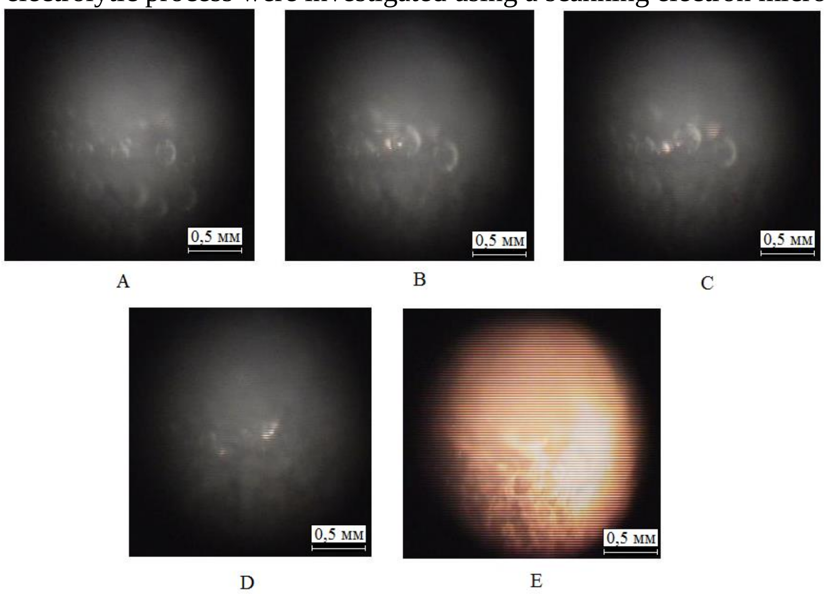

Fig. 2. A series of photos occurrence of anodic microdischarges during plasma electrolytic process.
Were recorded anodic microdischarges in the voltage range from 40 to 90 V. (Figure 2 A - D). Average optical radius of the luminous zone of a single microdischarge was 0.05 mm. These anodic microdischarges are similar to those previously known in /2/ that have the same size. But there are two very strong differences:

1. The material of the anode. In [2], the anode was made of valve metal. The characteristic property of a group of valve metals - forming property in the anodic polarization of a protective oxide layer with high resistance. In our case, it was ordinary steel, the anodic polarization is anodic dissolution of metal.
2. The voltage. In [2], it was 340 V.

A further increase in voltage from 100 to 160 V led to the initiation of a large anode discharge of 0.5 - 1.5 mm, the image of which is shown in Figure 2E.

Based on these studies we propose a mechanism of influence anodic microdischarges on the surface of the electrode. This mechanism involves two action modes of anodic microdischarges on the surface.

The first case - formation of steam jets as a result of evaporation of the electrode. The depth of the hole h_{hole}, formed as a result of evaporation, determined by the law of conservation of energy: the latent heat of $q_{el}\cdot\tau_{ex}$ and delivered during the discharge is expended in heating the material to the boiling point, the transition to the gaseous state, the message is a pair of kinetic energy and heat into the interior of the electrode

$$h_{hole} = \frac{\left(q_{el}\tau_{ex} - 2T_{emit}/\sqrt{\pi}\right)\sqrt{\lambda_{\mathrm{T}}c_{\mathrm{T}}\,\rho_{el}\tau_{ex}}}{\rho_{el}(c_{\mathrm{T}}T_{emit} + Q_{emit} + 0{,}5v_{\mathrm{steam}}^2)}$$

where v_{steam} - speed of the steam jet, Q_{emit} - heat of phase transformation.

Fast entry of a large amount of heat can cause uneven thermal expansion of the electrode material and create a force breaking away from the solid particles of the electrode. Was observed in the case of plasma-electrolytic formation of the microrelief of graphite electrodes.

The second case - the melting the surface layer of the anode, the melt is continuously removed, and the heat flux acts to ever-exposed solid material of the electrode. The depth of hole was determined assuming that the heat source moves along the boundary of the melt. From the conservation law should:

$$h_{hole} = \frac{q_{el}\tau_{ex}}{\rho_{el}[c_{\mathrm{T}}(T_{melt} - T_0) + Q_{emit} + 0{,}5v_d^2]}$$

where v_d - speed of dispersion of the particles melt.

A result of research determined that the burning of anodic microdischarges occur in the voltage range of 40-100 W. A result of research determined that the burning of anodic microdischarges occur in the voltage range of 40-100 W. Based on the analysis of surface morphology of the electrodes and the burning time of anodic microdischarges we propose a mechanism their effect on the electrode surface.

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