DC electric discharge in processes surface polishes of metal products

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Abstract. An electric discharge of direct current between the jet anode and the metal cathode is studied in the processes of local surface treatment of metal products at atmospheric pressure. The oscillations of the current and voltage of the discharge, the power invested in the discharge are investigated. The surface temperature of the medium in the combustion zone of the discharge was investigated. The microrelief of the product surface was studied before and after electrolyte-plasma treatment.

1. Introduction

Over the past 30 years, there has been an increasing interest in plasma sources in which one of the electrodes is a liquid (non-metallic) electrode. This type of discharge is finding ever wider practical application for solving various production problems. Discharges with liquid electrodes are used in plasma technologies for applying high-quality heat-shielding, anti-friction, dielectric and anti-corrosion coatings, as well as for heating products made of metals and alloys in an electrolyte.

Despite the great potential for using discharges with liquid electrodes in plasma chemistry, electronics, mechanical engineering, and metal processing, this type of discharge is still poorly understood. There are many "white spots" in understanding the physics of processes, the mechanisms of breakdown and maintaining a discharge with liquid electrodes. There is no consensus on the nature of these discharges, similar to the classification of a gas discharge plasma with traditional (solid) electrodes [1–3]. The absence of such a classification is due to the fact that discharges with liquid electrodes [4 – 17] are very diverse, depending on the types and configurations of the electrodes, applied voltage, external pressure, velocity and nature of the flow, composition and concentration of the electrolyte. At the same time, a theoretical description of discharges with liquid electrodes is also difficult, since more than 30 equations for the liquid, gas, and plasma phases must be taken into account to create adequate mathematical models. Such systems are extremely difficult to solve numerically, even taking into account the capabilities of modern electronic computers (computers), so today theoretical research is limited to mathematical modeling of highly simplified models.

The aim of this work is to experimentally investigate direct current electric discharges ignited between a jet anode and a metal cathode in the surface treatment of metal products at atmospheric pressure. The results of experimental studies can be used both for constructing various mathematical models for quantitative or qualitative interpretation of the data obtained, and for engineering methods for
calculating plants and processes for the implementation of plasma-liquid systems of direct current electric discharges in a practical plane.

2. Experiment

Studies of low-temperature plasma of direct current electric discharges ignited in the inter electrode gap between the jet anode and the metal cathode were carried out using modern approaches and diagnostic equipment.

1. A study of the forms of electric discharge burning was carried out using high-speed video recording on the Casio EX-F1 aperture, with a video recording speed of 600 and 1200 frames per second. To suppress the intrinsic luminescence of the plasma, a DKSSh-250 arc xenon lamp with a power of 250 W was used.

2. Thermography of the electrode surface in the discharge burning zone was carried out with a FLIRA 6500 SC thermal imager, and ALTAIR v.5.91.010 software was used to process the obtained data.

3. Studies of fluctuations in current and voltage of a direct current discharge were carried out by a digital oscilloscope "GDS - 806S" and "GOS - 6030". To study the discharge at the time of breakdown and combustion, a device based on photodiodes with a microcircuit was connected to an oscilloscope.

4. The roughness parameters of the samples before and after electrolyte-plasma treatment were carried out using confocal laser scanning microscopy using Olympus LEXT OLS 4100 brand equipment.

5. Evaluation of the surface microrelief of the products before and after processing was carried out using a Carl Zeiss AURIGA microscope with an INCA X-MAX energy-dispersive spectrometer. An increase of 100-5000 times was used.

The types and forms of electric discharge burning between the droplet (Fig. 1a-b), inkjet (Fig. 1c-d) and solid electrodes at atmospheric pressure during the processing of the surface of a metal plate were studied. A 7% solution of NaCl in tap water was used as a liquid electrode.

Figure 1 - DC electric discharge (a - b) - between the drop anode and the metal cathode at a pressure p = 10 ^ 5 Pa, cathode diameter d_k = 3.5 mm, jet length l_c = 15 mm, jet velocity v_c = 0.05 m / s, voltage U = 650 V, discharge current I = 1.2 A; (c - d) - between the jet anode and the metal cathode at d_c = 3.5 mm, l_c = 40 mm and v_c = 0.15 m / s, U = 480 V, I = 2.1 A.

With the potential applied to the electrodes U = 500 V, an electric discharge between the jet anode and the metal cathode is formed in the form of current pulses up to 2.4 A with sections of voltage drop corresponding to the discharge up to 400 V at a current pulse frequency of up to 110 Hz, the width of the current pulse in this case is τ = 3-9 ms. The power invested in the discharge can reach P≈ [10] ^ 3 W.
Thermograms of the surface of the jet anode and the metal cathode were studied under the conditions of combustion of a direct current electric discharge. It was found that the temperature of the jet from the nozzle rises in the direction of the discharge combustion zone to 100 °C. The surface temperature of the metal cathode cyclically varies from 45 to 95 °C, which is due to the passage of the heated liquid from the combustion zone of the discharge.

The surface of a metal sample (M1 grade copper) was studied, which was used as a cathode before and after exposure to direct current electric discharge at atmospheric pressure. It was established that the surface of the initial sample (Fig. 2a) is a rough structure, regularly covered with microinhomogeneities of various diameters, and organic and inorganic contaminants. The roughness parameters of the initial sample correspond to class 7.

After electrolyte-plasma treatment, the surface of the samples is smoothed, cleaned of impurities. The roughness parameters of the sample after electrolyte-plasma treatment increases to grade 8.

![Figure 2](image)

Figure 2 - The microrelief of the surface of the metal cathode before and after electrolyte-plasma treatment for 30 seconds.

3. Conclusion

1. The types and forms of combustion of an electric discharge between a droplet, a jet anode and a metal cathode at atmospheric pressure are established.
2. It was found that the discharge is formed in the form of current pulses up to 2.4 A, with sections of voltage drop up to 400 V corresponding to the discharge at a current pulse frequency of up to 110 Hz, the current pulse width being equal to \( \tau = 3 \sim 9 \text{ ms} \).
3. It was found that the temperature of the jet from the nozzle rises in the direction of the discharge combustion zone to 100 °C. The surface temperature of the metal cathode cyclically varies from 45 to 95 °C.
4. It has been established that a discharge with a jet anode and a metal cathode can be successfully used to smooth and clean the surface microrelief of products. The roughness parameters of the sample increase by 1 class.

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