The study the erosion of the electrodes under the influence moving electric arc

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Abstract. The paper presents the results of experimental study of the processes of interaction of a moving arc with electrodes pulsed plasma generator in the range of parameters $I = 60 \pm 500$ A, $U = 30 \pm 70$ V, $G = 0 \pm 155$ l/min, $d_E = 4 \pm 14$ mm and $L_E = 2 \pm 20$ mm. In this article the results of the study traces left by moving arc on the electrode surfaces are described, and the impact velocity of the arc on the form and sizes these traces, ranging $V_D = 7 \pm 130$ m/s. We show the research results of the heating and erosion of the electrodes under the influence of high-current arc moving.

1. Introduction

Near-electrode effects in plasmator with moving arc a significant impact on the formation and burning of electric arc in a pulsed plasma generator.

Near-electrode effects - the processes in gas discharges in the plasma with inhomogeneous concentration, temperature, and other parameters, concluded between the electrode and the almost homogeneous plasma. In contrast to the homogeneous plasma positive column where the current flows under the influence of an electric field in the near-electrode parts importance processes the transfer of charged particles due to diffusion and under the influence of a temperature gradient. Very close to the electrode distribution the electron and the ion by speed are generally different from the Maxwell distribution.

The complexity of the near-electrode effects is determined not only the variety of conditions in which they take place, but also a necessity in many cases regarded as effects near the electrode, and in the electrode at the mutual influence on each other. This fact characterizes the composition and properties of the electrode plasma. For example, the existence and self-renewal of pulsed arc defined the formation electrode spots and of erosion material electrode. Consequently, one of the main proposition in the study of near-electrode effects, is research of the spots left by moving arc on the electrode surface [1, 3].

2. Experimental studies of spots

In the pulsed plasma generator the arc ignited at the end of the electrode, it is run by a magnetic field and leave traces on the surface of the electrodes.
We give a qualitative description of the traces (Fig. 1). Depending on the geometric dimensions ($d$), the interelectrode gap ($L$) and the mode of arc traces at the electrodes are essentially different. For example, for high currents ($I \geq 150 \text{A}$) and velocities ($V \geq 20 \text{m / sec}$) (Figs. 1 b and c) traces on the cathode are a plurality of grooves parallel to the direction of movement of the arc. Obviously, while there are a large number of spots which have a high mobility and move with an arc. When moving many spots run in the footsteps of other spots.

Figure 1. Photographs of traces on the electrodes from steel 20 (from above cathode):

- $a$ - $d=8 \text{mm}$, $L=8 \text{mm}$, $I=120 \text{A}$, $U=46 \text{V}$, $V=7.5 \text{m/s}$;
- $b$ - $d=8 \text{mm}$, $L=4 \text{mm}$, $I=230 \text{A}$, $U=36 \text{V}$, $V=25 \text{m/s}$;
- $c$ - $d=8 \text{mm}$, $L=4 \text{mm}$, $I=380 \text{A}$, $U=38 \text{V}$, $V=35 \text{m/s}$;
- $d$ - $d=8 \text{mm}$, $L=5 \text{mm}$, $I=1500 \text{A}$, $U=70 \text{V}$, $V=130 \text{m/s}$;

$U$ – arc voltage

Flow pattern of the electrode spots movement greatly influence the temperof the flow in the conducting channel of the arc. Trajectory of motion spots, probably approaching particle trajectories conducting gas in the arc column. Spots move in the direction of the arc, while run away laterally from the axis of symmetry and disappear, reaching the edge of the arc column. Besides the basic branching on the cathode surface seen small branching. The formation of this small structure, presumably due to the high mobility microspots. Tends to form microspots at the edges fused spots where due to the destruction of electrode material formed sharp edges and leads to increased gradients of the electric field, which facilitates electron emission.

At low speed of the arc up to 10 m/s traces are continuous (Fig. 1 a). By increasing the speed of movement on the surface of electrode, the arc leaves traces of irregular shape which do not have the preferred orientation (Fig. 1 b - d). Because of the oxide film near electrode spots have low mobility, moving behind the arc. As a result of the breakdown between the arc and the wall formed a new spot and between spots remain gaps. At low speeds, trace is small. With increasing speed discontinuities between separate traces increase and reach 5 mm. It is connected that at lower speed the air between the arc and the wall succeeds to warm more and shunt between the electrode and the wall of the arc occurs at a lower breakdown voltage, i.e. with a smaller displacement of the arc relative to a substantially stationary spot.
At the anode, for small speeds, there is also the continuity of the trace (Fig. 1 a). By increasing the speed of the arc gaps appear between spots, which have a circular shape (Fig. 1 b and d) or a form of the drop, elongated in the direction of motion (Fig. 1 c). The number of spots increases with increasing current, and the size of each spot is greatly reduced.

On the copper electrode has a similar tendency, i.e. at low speeds of movement of the arc, traces are continuous, with increasing velocity traces consist of separate spots. With increasing speed traces consist of separate spots. But because of a lower melting point of copper erosion surface more intensively.

3. The erosion of the electrodes

The study the erosion of the electrodesto determine service life of the electrodes and the plasmatron as a whole. To determine the erosion of the electrodes is necessary to estimate the amount of heat introduced into the electrodes. To measure the heat flux supplied to the electrodes used in the K-type the thermocouple and the multimeter, thermocouples close up in the electrodes. The study of thermal fields in the electrodes was carried out using analytical methods [4].

As a result of running a single arc electrode temperature was increased by $\Delta T$. By raising the temperature determines the amount of heat given from the arc to the electrode. After reaching the maximum temperature of the thermocouple changed slightly for a few seconds, which suggests that there is no leakage of heat. In Figure 2 is a plot of heat from the arc at the electrode from current, which it is seen that the amount of heat introduced to the anode far exceeds the heat losses at the cathode. Consider the reasons for such behavior.

![Figure 2](image)

Figure 2. Dependence the heat to the electrodes ($Q_H$) of the arc current ($I$), the electrode material Steel $20d=8\text{mm}$, $L=8\text{mm}$; ●-anode, ▲-cathode

![Figure 3](image)

Figure 3. Dependence the erosion of the electrodes ($m$) of the arc current ($I$), the electrode material Steel $20d=8\text{mm}$, $L=8\text{mm}$; ●-anode, ▲-cathode

The arc moving under its own magnetic field belong to the species of the arc with cold cathode and the cathode spot. The current in such arcs flows through one or many small, fast and disorderly moving appearing and disappearing spots on the cathode. The current density is very high in spots, $J_0 = 10^4 - 10^7 \text{A/cm}^2$. For a short time the localization of spots metal in this location is strongly heated, broken, vaporized but next to the spots and generally remains relatively cold cathode.

In the spot enters the ion current. Ions bring kinetic energy, which acquired in the cathode fall. Together with the potential energy released during neutralization, it goes into heating the metal. This, together with the strong field causes the emission and on the other hand, the evaporation of the metal. Couples create in the case of a vacuum gap the environment which is ionized emitted electrons accelerated in the cathode fall. This, in turn, is the source, the ion current. The evaporation process of localized hot center depends on the outflow direction heat energy to adjacent layers of metal and other components of energy balance.
The voltage drop in the anode region is created as a result of the extraction of electrons from the arc column and acceleration when entering them into the anode. In the anode region has substantially only an electron current, due to the small amount of negatively charged ions having lower speed than the electron. An electron gets on the surface of the anode, gives the metal not only kinetic energy but also the energy of the work function, so an anode receives energy from the arc column, not only in the form of electron beam, but in the form of thermal radiation. Consequently, the anode temperature is always higher, and it generates more heat.

Quantitative evaluation of erosion of the electrodes was carried out by determining the mass change of the electrodes under the influence of a moving arcing using a laboratory scale (Fig. 3).

The analysis found that in the range with increasing current decreases erosion of the electrodes and thus increases the number of pulses which produce a pulsed electrode of the plasma generator prior to their destruction. The reason for this is that during the growth of the current speed increases, changing the impact of the arc on the electrodes and thereby reduces the erosive effect of moving the arc. Shared resource electrodes, for example, current 360A is 50 hours.

4. **The conclusion**

The arc in the electrode region exists due to thermionic emission of the atoms and electrons with the surface, which ultimately affects the stability of the arc. In turn, the severe erosion of the electrodes can reduce the life of the plasmatron. In this connection, it is necessary to select the operating mode of the plasmatron such that movement of the arc accompanied by micro grafting. On the mode of movement of the arc strongly influenced the speed of the arc, thus changing the speed of the arc, you can choose the best mode of arc, get a steady stream of plasma on output and increase the service life of the plasmatron [5,6].

**References**

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