

Erosion of electrode metal in the electric discharge under the exposure of the electrolyte stream

Yu I Shakirov, R I Valiev¹, A A Khafizov, R A Valiev and R G Khakimov

Kazan Federal University Naberezhnye Chelny Institute, 68/19 Mira Street,
Naberezhnye Chelny, 423810, Russian Federation

E-mail: rivaliev87@mail.ru

Abstract. The discharge between solid and liquid electrodes under the normal atmospheric conditions (SATP) was investigated. As electrodes, the metal materials and unsaturated salts solutions are used. Such discharge takes place in the range of voltage from 510 V to 525 V, a current from 0.2 A to 6 A, a electrolyte liquid flow rate from 2 cm³/s to 14 cm³/s, an electrolyte stream length from 5 mm to 40 mm. Increasing the flow rate of electrolyte liquid increases the discharge current. There are minimum and maximum critical values of the electrolyte flow rate of beyond which the existence of discharge is impossible. Specific values of the critical flow rate of the electrolyte depend on the nature, composition and stream length of the electrolyte. The electrical discharge between the electrolyte stream and a metal electrode is followed by erosion of the electrode material. The technique for local removal of metal by means of such a discharge is developed and the optimal values of erosion treatment parameters are determined. By using the discharge, technical processes of cleaning surface, deburring, drilling and cutting of metal materials were implemented.

1. Introduction

In the recent years, special attention is given to the study of the processes occurring in the electric discharge between solid and liquid electrodes [1 – 4]. The implementation of the plasma with various liquid and solid materials usage allows modifying and synthesizing products with a wide range of properties [5 – 7]. However, the absence of developed technologies delaying the implementation of these processes in production.

The usage of the electrolyte stream as a liquid electrode is attractive in terms of the local treatment of material by plasma. Such a discharge is accompanied by erosion of solid electrode material which can be successfully used for surface cleaning, deburring, drilling, cutting metal materials. Implementation of controlled erosion is limited by lack of studies of the processes occurring in the discharge between the solid electrode and the electrolyte stream.

The determination of electrical characteristics of the discharge, establishing their influence on the electrical and hydraulic properties of the electrolyte have a great importance for the development of erosion treatment technology.

2. Experiment

The discharge was done at atmospheric pressure between the liquid cathode and the solid anode with the values of voltage and current not exceeding 1 kV and 6 A, respectively. Experiments were

¹ To whom any correspondence should be addressed.



conducted with using various electrode materials. The aqueous solution of sodium chloride, copper sulphate, ammonium nitrate with different concentrations and industrial water were used as electrolytes. Copper, iron, titanium, and their alloys are used as the solid material of the electrodes. At the same time the solid electrode was used as an object of erosion machining.

For the erosion machining, electrolyte stream is directed to a certain area of the solid electrode. A stream of electrolyte is supplied through the ferrule with the dielectric nozzles. Current is fed to this ferrule. Stream length (L) is defined as the distance from the ferrule to the surface of the solid electrode. The diameter (D) of the stream depends on the size of the holes of the dielectric nozzles. To conduct the experiments a special tool to manage the supply (flow rate) of the electrolyte and to adjust the size (diameter and length) of its stream was made.

3. Results and their discussion

After getting out of the nozzle, electrolyte stream becomes a main element which supplies current to the metal electrode. It is known [8] that the electrical conductivity of the electrolyte is higher, as the higher the concentration of salts is in the solution, but it is seen only till a certain critical concentration. Typically, these values are slightly below the critical limits of solubility. Nevertheless, as shown by our experiments, the presence of undissolved crystal sediment in the electrolyte leads to instability of the discharge. These circumstances have been resulted into the choice of the unsaturated sulphate solutions as the electrolyte: from 5% to 15% for the NaCl, CuSO₄, NaNO₃. Another factor affecting the rate of current passage is the average rate of the electrolyte flow (or liquid flow rate Q).

The parameters such as power and electrolyte stream affect the discharge between the solid electrode and the electrolyte.

The critical current values (I_{cr}) and flow rate of the liquid electrode (Q_{cr}) for the occurrence of discharge were experimentally established. When currents and flow rate of the electrolyte are lower than the critical level, the discharge does not light, and there is a conventional electrolysis. The specific values of the critical current and critical flow rate of the electrolyte depend on the nature of the salts and its concentration in the solution, and on the temperature and length of the stream of electrolyte (Figure 1).

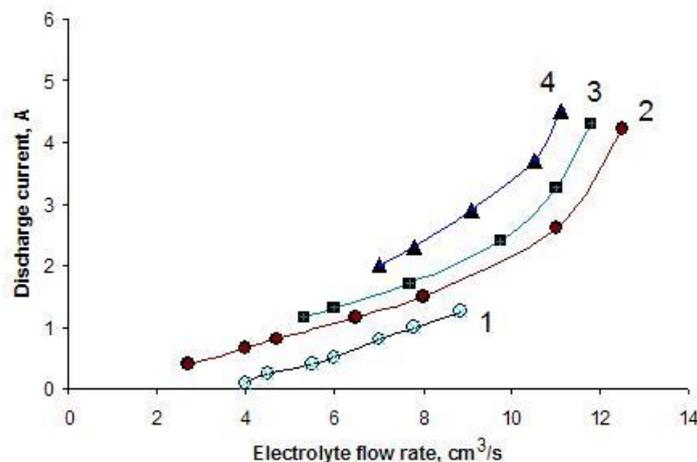


Figure 1. The dependence of the discharge current I on the flow rate of the electrolyte Q at different lengths of the stream L of electrolyte of process water (1 – $L=18$ mm) and 10% NaCl solution (2 – $L=10$ mm; 3 – $L=14$ mm; 4 – $L=22$ mm).

The increasing of the length of stream L increases not only the value of the critical current I_{cr} , but also requires a larger flow rate of electrolyte Q_{cr} for the occurrence of discharge. For example, in the

case of electrolyte of 10% sodium chloride solution, with increasing of stream length L from 10 mm to 22 mm, the critical current values I_{cr} and Q_{cr} electrolyte flow rate increase from 0.35 A to 1.75 A and from 2.7 cm³/s to 6.6 cm³/s, respectively. Such delay is supposed to be due to increased resistance of the stream and the voltage drop on it.

Increasing the flow rate of electrolyte increases the discharge current I , as this increases the number of current carriers per unit of time. However, after reaching a certain Q values, the discharge becomes unstable and the blanking is carried out. Thus, the discharge is characterized by another critical value of the electrolyte flow rate Q_{max} . This is the maximum flow rate of the electrolyte liquid at the given conditions, beyond the increasing of which, the discharge goes to electrolysis. This transition is accompanied by a spike increase of the current, flowing through the stream. Critical parameter Q_{max} , as the I_{cr} and the Q_{cr} , depends on the nature, composition and length of the electrolyte stream.

It should be noted that the electric discharge behaves similarly when using industrial water as an electrolyte. However, it is characterized by low values of discharge of current and blanked much earlier – at low flow rates of electrolyte.

Figure 2 shows the current-voltage characteristics of the discharge between the metal electrode and the electrolyte stream. Specifications are directly proportional and it can be considered almost horizontal. For electrolytes usage with normal atmospheric conditions (SATP), combustion of such discharge is possible in a range of voltage from 510 V to 525 V. It was determined that the location of the lines of current-voltage characteristics in the stress axis is influenced by both, the length of the stream and electrolyte conductivity.

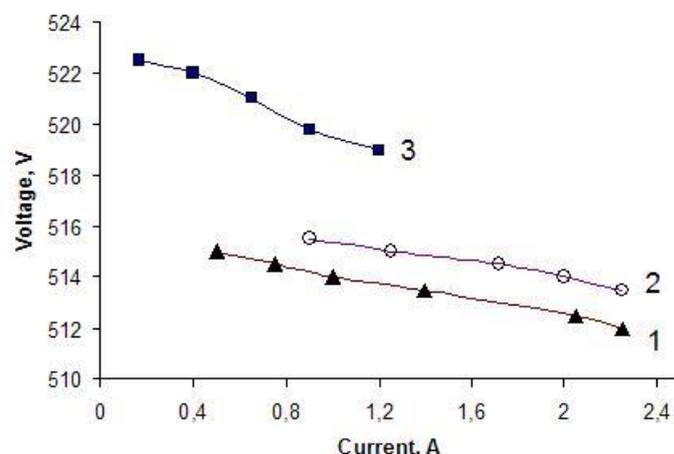


Figure 2. Current-voltage characteristics of the discharge between the metal electrode and the electrolyte stream with diameter of 3 mm for various lengths L of the stream of electrolyte from 10% NaCl solution (1 – $L=10$ mm; 2 – $L=15$ mm) and process water (3 – $L=10$ mm).

The practical interest is performed by the fact that the electric discharge between the electrolyte stream and a metal electrode is accompanied by erosion of the electrode material. This phenomenon can be successfully used to solve technological problems, such as surface cleaning, deburring, drilling, cutting of metal materials.

Based on these studies the technique of local metal removal by a discharge, combusting between the electrolyte stream and the solid electrode – workpiece. The technique has been tested on copper, titanium and steel parts. For example, a drilling hole of 2 mm diameter in a copper plate with a thickness of 5 mm at a discharge current of 2 A with a 10% solution of sodium chloride as electrolyte was performed in 8 minutes. The experiment showed that the higher the temperature of melting of the

electrode material, the more time is spent on its drilling. Processing performance can be increased by increasing the discharge current. However, as shown above, when exceeding the critical values of the discharge is being blanked and the process of anodic dissolution is started. It is accompanied by a spike increase in electric power consumption and by a high heating of the electrolyte. In contrast to the processes of drilling and cutting of metal, the cleaning of metal surface requires softer treatment conditions. Apart from current density, the length of electrolyte stream influence on the effectiveness of the erosion treatment. Experimentally, the optimal values of L , which lie in the range from 5 mm to 8 mm, were determined. Outside this range, the discharge stability is being significantly reduced.

4. Conclusions

The parameters such as power and electrolyte flow rate affect the occurrence and combustion between the solid electrode and the electrolyte. Under the normal atmospheric conditions (SATP) and used as the electrolyte the unsaturated sodium chloride solution, copper sulfate discharge combusts in a range of interrelated basic parameters: voltage from 510 V to 525 V, a current from 0.2 A to 6 A, flow rate of electrolyte liquid from 2 cm³/s to 14 cm³/s, an electrolyte stream length from 5 mm to 40 mm.

Increasing of the flow rate of electrolyte liquid increases the discharge current. There are minimum and maximum values of the critical flow rate of electrolyte beyond which the existence of discharge is impossible. The specific values of the critical flow rate of the electrolyte depend on the nature, composition and length of the stream of the electrolyte.

The electrical discharge between the electrolyte stream and a metal electrode is followed by the erosion of the electrode material. Based on these studies, the technique of local metal removal with the help of such discharge is made and the optimal values of erosion treatment parameters are determined. It makes possible to solve the technological problems of surface cleaning, deburring, drilling and cutting metal materials.

References

- [1] Kashapov L N, Kashapov N F and Kashapov R N 2015 The research of anodic microdischarges in plasma-electrolyte processing *IOP Conf. Ser.: Materials Science and Engineering* **86** 012019
- [2] Dautov G Y, Nail K F, Viktor L, Renat G Z, Raphael G T, Fayrushin I and Kashapov R N 2013 Low Temperature Plasma in the Processes of Functional Coating Preparation *J. of Phys.: Conf. Ser.* **479** 79.
- [3] Tazmeev Kh K and Tazmeev A Kh 2015 Gas discharge with liquid electrolyte cathode in the mode of occurrence of the constricted channels *J. of Phys.: Conf. Ser.* **567** 012035
- [4] Tazmeev Kh K and Tazmeev A Kh 2005 Some specific features of heat and mass transfer of gas-discharge plasma with a liquid electrolytic cathode *Heat Transfer Research* **36** 623
- [5] Valiev R A, Shakirov Yu I and Iliukhin A N 2014 Phase and structural conditions of low-temperature plasma interaction products with steel. *J. of Phys.: Conf. ser.* **567** 012040
- [6] Valiev R A, Gaisin F M and Shakirov Yu I 1991 Special traits of powder obtained in discharge between steel electrode and electrolyte *Soviet Powder Metallurgy and Metal Ceramics* **30** 448
- [7] Khafizov A A Valiev R I Shakirov Yu I and Valiev R A 2014 Steel surface modification with plasma spraying electrothermal installation using a liquid electrode. *J. of Phys.: Conf. ser.* **567** 012026
- [8] Amitan G L, Baysunov I A and Baron Yu M 1988 *Spravochnik po elektrochimicheskim i elektrofizicheskim metodom obrabotki* (Leningrad: Mashinosroenie) p 719