Polishing and deburring of machine parts in plasma of glow discharge between solid and liquid electrodes

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Abstract. The most effective way of materials processing in economical and ecological way is utilizing of the low temperature plasma. Modes of operation, in which the speed of polishing was increased in more than 2 – 2.5 times in comparison to electrical erosion method, were found. Roughness was about 0.16 – 0.08 micrometers.

1. Introduction
Cleaning [1, 2] and deburring of surfaces is an important technological operation of many industries. These technologies save energy, reagents, raw materials, time, increase productivity and product quality.

Of great interest are the processes in nonequilibrium discharge plasma [3-6], in which the temperature of the atoms and molecules is close to the ambient temperature, while the electrons have enough energy for excitation, dissociation and ionization of atoms and molecules. The use of such plasma improves the efficiency of many technological processes, such as plasma-chemical deposition of polymer and inorganic films, plasma anodizing, chemical synthesis, etc.

2. The experimental device
To streamline the process of cleaning and deburring, experimental plasma electro thermal installation with liquid electrode was developed [7-12] (Fig. 1). Bath is made of copper plates and has a cooling jacket. It is filled with the investigated electrolytes required concentration. Bath is connected to one terminal of the power source. The upper solid electrode is attached to the other terminal of the source. This electrode is installed on the coordinate device that allows to adjust the interelectrode distance and the coordinates X, Y. the electrolyte used was NaCl, CuSO\(_4\), NH\(_4\)NO\(_3\).

The experimental set-up [13] is designed to study the electrical discharge in a range of settings \(U_p = 0.3 \text{–} 3000 \text{ V}, \) current \(I = 0.01 \text{–} 200 \text{ A}, j = 0.1 \text{ –} 25 \text{ A/cm}^2,\) the interelectrode distance \(l = 0.1 \text{ to } 100 \text{ mm.}\) Cooling system installation serves for cooling the electrolyte. It is fed from the main water supply network and supply of electrolyte is made from a special tank.

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3. Results and their discussion

For the formation of a solid gas-vapor membrane [14], albeit unstable, it is necessary to provide energy in the anode area, sufficient to boil the electrolyte to some extent.

The highest quality of surfaces cleaning (Fig. 2) is carried out, if in the NaCl add boric or citric acid, which reduces sumelocenna electrolyte. It is especially important that the pH not only affects the anodic current density \( j_a \), but also on the parameter \( R_a \) of the surface roughness.

Adding sodium nitrite to serve as a corrosion inhibitor and after treatment, the treated surface is corrosion resistant. Discharge voltage (≈ 120 V) has virtually no effect on the surface quality parameters and the details cleaning rate. The density of the same anode current affects the quality of treatment and duration of treatment. For example, for 20 seconds of current machining, with density of 1 A/cm² at the depth \( h = 5 \cdot 10^{-3} \) m, we obtained the surface roughness of 8th grade. The increase in current density up to 3 A/cm² (at the time of processing 15s) has allowed to improve the quality of surface cleaning. A further increase in current density or the processing time almost does not affect the class of the surface roughness. The temperature of the electrolyte affects the quality of the processed surface. Studies have shown that with increasing temperature of the electrolyte decreases the performance of the process. So we cooled electrolyte using running tap water.

**Figure 1.** Functional diagram of the experimental installation
1 - electrolyte bath; 2 - jacket water cooling; 3 - bubbler; 4 - electrolyte; 5 - item; 6 - air compressor; 7 - filter; 8, 9, 11 - shut-off valve; 10 - pump; 12 - tank heat exchanger; 13 - extractor hood; 14-exhaust fan; 15 - power supply; 16 - axis scanner; 17-thermometer; 18-conductors; 19 - return valve.

**Figure 2.** Connection terminal:
a) before processing; b) after processing
The results are shown on (Fig. 3) of dependence studies of parameter $R_z$ of the machined surfaces parts quality made of copper M1 and steel 25XHBA when processing discharge with liquid electrode (electrolyte temperature 300 K) depending on the current density on a solid electrode. It is seen that there is no noticeable improvement in the quality of the surface with increasing current density more than $3 \times 4 \text{ A/cm}^2$.

Methods of deburring and finishing increase the roughness class up to 8\text{1}, and diamond processing [15], paste polishing [16], electrochemical treatment [17] allow to achieve a roughness class of 13\text{14}. These methods are not always reliable, they are characterized by low productivity, complexity and irregularity of the removal of the edges, i.e. the surface geometrical characteristic forming process is difficult to manage.

Effective deburring (Fig. 4) is achieved remaining after the machining of complex configuration parts edges, an electric discharge between the workpiece and the liquid electrode. The area of the gas-vapor layer starts to expand with the speed of $0.005-0.01 \text{ m/s}$. Current is growing, and in $8-12 \text{ sec}$, under critical conditions, the layer is broken by the explosion, then the process repeats. With $h = 10^3 \text{ m}$, the surface area of the layer reaches $0.012-0.5 \text{ m}^2$, and the discharge current - 200A. Studies have shown that the process of removing the burrs should be carried out at $4 \text{ A/cm}^2 < j < 13 \text{ A/cm}^2$, a voltage of $80 \text{ V} < U < 120 \text{ V}$.

**Figure 3.** The quality of surface after treatment by plasma discharge with liquid electrode. The pressure $P = 105 \text{ Pa}$, the temperature of the electrolyte $T_e = 300 \text{ K}$, curve 1 - $U = 120 \text{ V}$ and the processing time $t = 40 \text{ sec}$ for copper M1; curve 2 - magnetic core steel 25XHBA, $U = 90 \text{ V}$, $t = 60 \text{ sec}$

**Figure 4.** Complex Configuration Part Processing
(a) before processing; b) after processing
As a result of processing samples weight change was observed. The average weight change of a copper sample when the duration of treatment is $t_{обр} = 25$ seconds is $\Delta P_{м} = 380$ milligrams, for a sample of steel for the same processing time it is $\Delta P_{ст} = 350$ milligrams (Fig. 5)

The analysis of the above dependences has shown that the weight change of a copper samples and electrical steel processing is 27 seconds and is almost the same.

![Figure 6. Mass change of steel and copper parts](image)

Thus, provided that the weight change $\Delta P$ of the workpiece after processing does not exceed the permitted limit, taking into account the installation performance and to achieve the desired (requested) quality of surface treatment, the required length of time treatment will be 20 - 35 seconds.

4. Conclusions
For machining the rectified voltage $U = 400 - 550$ V power source is required with power up to 100 kW. The voltage discharge has virtually no effect on the surface quality parameters and the speed of cleaning components. Due to the analysis the conditions were established under which the deburring performance increases in 2 - 2.5 times in comparison with the electroerosive method, while the roughness is reduced to 0.16 - 0.08 micrometer (roughness class of 8 - 9).

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