Surface hardening of components by automatic plasma electrothermal installation with molten cathode

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Abstract. An automatic installation for surface hardening of components has been designed. It enables to enhance the effectiveness of technological process and to provide the stability of quality indexes.

1. Introduction
The success achieved in the field of surface hardening of materials by plasma current shows high efficiency of this method and requires further development.
Automating the process of heat treatment of components in mechanical engineering can improve the efficiency of technological process (TP). To obtain the desired mechanical properties of metal surfaces modern technologies of hardening are applied [1; 2; 3; 4; 5]. Plasma methods of wear resistant coating or physico-chemical modification of the surface layer of components can reduce the duration of TP, power consumption, save the basic geometric dimensions of components [6; 7, 8, 9].
Problem statement. Ensuring the stability of quality indexes of component a surface, as well as strong economic performance requires the use of TP in automated control systems. On this basis, a promising way to improve technological plasma electro thermal installation (TPETI) for components heat treatment is development of the head of TPETI, automatic control systems (ACS).

2. Basic part.
The electrical characteristics of the discharge generated between a hard anode and molten cathode have been researched. Experimental investigations of electric discharge between a metal anode and electrolytic cathode at atmospheric pressure were held in a wide range of current I=0.5-10A, voltage U=0.5 kV, interelectrode distance l=5-50 mm, the diameter of the anode da=5-40 mm for various composition (technical and purified water, solutions of CuSO4, NaCl in technical water) and electrolyte concentration.
In experiments, as a metal anode, steel of various grades (Steel 3, St35, St45) and copper of different geometric form (solid cylinder, hollow cylinder, hollow truncated cone, solid cone) were used.

The most important parameter of the electric discharge is the value of density of a current on the anode [10; 11]. As it can be seen from Fig. 1, with the increase of the discharge current up to I=1A a decline of current density can be observed. There is an growth of the spot on the surface of a metal anode. At the critical value of I=1A is the spot covers the lower part of the cylindrical electrode. At the further increase of the discharge current the area of the anode spot is not changed. This fact explains the growth of density of the current on a metal anode with the increase of the discharge current. The change of the interelectrode distance does not affect the nature of the density of a current. (Figure 1, curves 1 and 2). Comparing the curves 1 and 2, you can see that the increase of interelectrode distance leads to some reduction of current density.
Dependence of current density on the metal anode from the current of the discharge for different interelectrode distances: 1 - 1=5 mm; 2 - 1=15 mm

With the help of Excel and MathCad software for discharge between electrolytic cathode of technical water and metal anode the generalized criteria equation in the following form has been worked:

\[ \frac{U \cdot I^{0.5}}{I} = 5752 \left( \frac{I}{I^{0.75}} \right)^{-1.1} \]

The dependence of \( \frac{U \cdot I^{0.5}}{I} \) from the parameter \( \frac{I}{I^{0.75}} \) represented in Fig. 2.

The maximum standard deviation of the experimental values of voltage discharge from the obtained equations is less than 10%, so these criteria equations can be used in the calculations of plasma installations with electrolytic cathode. To solve the set tasks the head of TPETI has been developed (Fig.3). It is made of quartz glass, which is water-cooled. The plasma gas, which is shown by arrows, is delivered to the channel. The discharge occurs between the cooled copper anode and electrolyte.

Technological process of plasma thermo strengthening can be used in the processing of outward of cylindrical surfaces for such details as a worm, a roller, a windrow.

The efficiency of the process of plasma thermo strengthening depends on the thermo physical properties of the processed metal and technological factors [12]: the energy potential of the plasma jet, rotation speed of the component, the gap between the part and the head of TPETI, the intensity of water cooling and the temperature of the plasma jet (approximately 10000°C).
Hollow cylindrical components made of steel 45 have undergone plasma processing. Metallographic and durometric analyses were performed on the samples in the form of plates cut from the component perpendicular to the plasma process.

In this case the results of studying the structure and microhardness edgewise and in depth of the hardened layer were the criteria of assessment hardening. It is shown that the character of changes in the microhardness in the depth of the hardened zone virtually identical for different modes of plasma processing characterized by the presence of three basic sections.

![Graph](image)

Fig. 4. The character of the distribution of microhardness in the depth of the thermo hardened layer depending on the modes of plasma processing: 1.2 - change of the gap between the cylinder and TPETI and the component; 3.4 - changes in electric current intensity.

![Graph](image)

Fig. 5. The character of distribution of microhardness edgewise of the zone of heat treatment depending on the electric current intensity.

3. Conclusion. The developed head and control system ensures the stability of parameters of surface hardening components quality. For optimal hardening of working surfaces of cylindrical components, you need to choose the modes of processing, which would ensure the minimum width and depth of the transition zone. In addition, the necessary condition for high-quality processing is the stability of parameters of heat-treated plots microhardness, which provides high service properties of the processed surface.

4. References
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