https://doi.org/10.46813/2023-143-110

SOME ASPECTS OF ELECTROLYTIC-PLASMA PROCESSING TECHNOLOGY

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A technological device (pilot model) for electrolytic-plasma processing of various surfaces has been developed. Some theoretical calculations and processing recommendations have been done. This technology contributes to significant savings in human and energy resources and achieving the required surface quality of parts, and preliminary processing, and is very usefullbefore vacuum-arc deposition of protective coatings.

PACS: 52.77.-j; 81.20.-n

INTRODUCTION

High-quality polishing surfacesas well as surfaces with specific roughness are extremely needed in many areas including dental and bone implants, traumatology, cranial plates, spinal braces, turbine blades of aircraft engines made of titanium alloys, sheets, foil and wire used for fastening tissues, nerves, suturing, prostheses,parts of fuel and heat exchange, elementsof nuclear power systems,parts of accelerating structures of colliders, etc.

Traditionally, mechanical and electrochemical methods are used to polish products made of various alloys. The disadvantages of mechanical methods are low productivity, susceptibility to the introduction of foreign particles, difficulties in processing complex geometric shapes. For electrochemical technologies, these materials are difficult to process, and their polishing processes require the use of toxic electrolytes. Traditional electrochemical polishing of titanium and niobium alloys are carried out in acid electrolytes consisting of toxic hydrofluoric (20...25 %), sulfuric nitric and perchloric acids. The disadvantages of such solutions are their high aggressiveness and harm to production personnel and the environment.

Over the last years, an environmentally friendly method of electrolytic-plasma processing (EPP) of metal products has been intensively introduced into production [1, 2]. The new method makes it possible to process metal and semiconductor products made of stainless and carbon steels, copper and aluminum alloys, brass, zinc, titanium, and silicon in aqueous salt solutions. Along with high productivity, the electrolytic-plasma technology has higher technical characteristics: the speed of processing the product, the class of cleanliness of its surface, the absence of the introduction of abrasive particles, degreasing the surface. Plasma-chemical electrolysis is an economical technology without using strong and toxic acids having only electrolyte of salt composition with low concentrations.

Surface treatment of metal products can take place in a liquid at constant or alternating voltage. Variants with the addition of pulsed potentials are also possible. In this case, there are two characteristic phenomena:

1) electrolysis in a liquid medium using different electrical potentials between the product material and the opposite electrode;

2) electric (plasma) discharge produced in a steam gap near the surface of the product.

The effect of the formation of a steam gap around the immersed product occurs only at a potential of more than 200 V. It creates conditions for reducing the current density and high field strength, which contributes to more efficient metal etching.

It should be noted that the terminology, EPP and coating of metals and alloys has changed with ongoing research in this direction[3]. Different terms have been used for the same technique. In the future, the term “electrolyte-plasma” or “plasma-electrolyte” was assigned to this method of processing the various surfaces.

In “electrolyte-plasma” processing, rather low potentials and moderate currents are used in comparison with explosive technologies. It should be added that during processing, minimal concentrations of salt reagents are used, which do not pose a danger to the environment and living beings [4].

Plasma phenomena are significantly different from the main processes in electrolysis, due to both the enhancement of physical and chemical processes in the product. Thus, thermal and diffusion processes, new plasma-chemical reactions, and transport of macroparticles become possible during electrolysis. These processes are used in various electrolysis applications such as plasma heat treatment, melting, welding, cleaning, pickling and polishing [5, 6]. Processing times are significantly reduced in comparison with electrochemical polishing, as well as with vacuum processing.

In this research, a technological device for EPP ofvartious surfaces has been developed and some theoretical calculations and useful recomendations have been done.

1. EXPERIMENTAL SET UP

Structurally, the device for EPP consists of a cylindrical bath with a frame and a mechanism for moving the carriage for hanging samples (Fig. 1). The frame and suspension are made of insulating materials. The sample is fixed on the suspension of the lift carriage. In order to be able to set technological modes before the start of the process, power systems are launched and the operating voltage is pre-set. The system will not start until a command comes from the thermostat that the bath has dialedset temperature. Only after that you can start the timer and the operating mode will turn on.

Fig. 1. Some structural elements of EPP device

In the proposed scheme, in order to eliminate excessive wear of the contact groups of the starter, switching the power variator, it is switched on once before the operation cycle, and the currentless switching of the bridge allows many cycles during operating period. The control panel monitors the status of the system, operating voltage, current and thermostat status.(Fig. 2). A predetermined time interval is set using of a timer.

Fig. 2. Control panel of EPP device

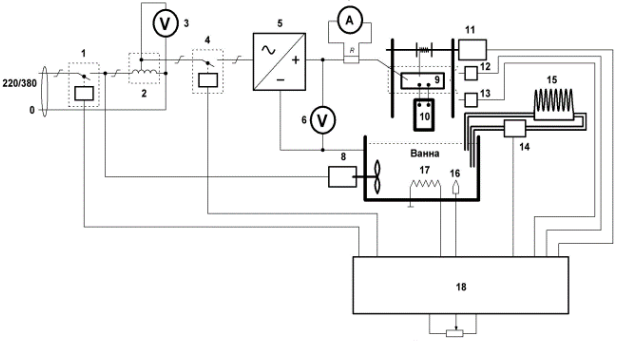

Fig. 3. Principal scheme of EPP device:
1 – main magnetic switch; 2 – three-phase adjustable autotransformer; 3 – input voltage voltmeter;
4 – mode magnetic switch; 5 – Larionov's rectifier;
6 – load voltmeter; 7 – load ammeter; 8 – circulator;
9 – carriage; 10 – sample; 11 – lift;
12 – upper level sensor; 13 – upper level sensor;
14 – water pump; 15 – radiator;
16 – temperature sensor; 17 – heater;
18 – control block

The feeding mechanism prividessmooth descent of the sample and, as it lowers, the etching process begins. At the same time, the solution is heated in the bath and, as the temperature rises, the cooling mode is switched on to the set temperature, by forced circulation through the cooling radiator (Fig. 3). The temperature maintenance mode is important because that the rate of etching depends on the temperature. The circulator creates mixing of the solution in the bath to equalize the temperature throughout the volume.

After the set time has elapsed, the timer starts the lifting mode until the limit switch is activated, which turns off the power. Afer that theprocessing cycle is complete. Before removing the sample it rinsed with water from the electrolyte. When switching to etching another metal, a complete replacement of the electrolyte with a different composition is required.

2. RESULTS AND DISCUSSION

The main technological effect of EPP is to reduce the height of the microroughness of the treated surface. The nature of the smoothing of the microrelief and the formation of gloss during electrolytic-plasma polishing has not yet been elucidated in many respects. It is monitored the periodic occurrence of spark discharges between the electrolyte cathode and the protrusions of the metal anode. At the same voltage in the near-electrode zone, the electric field intensity E is distributed over the treated surface in accordance with its microrelief (1). At the i-th microsection, the tension is equal to:

$$E_i = grad\ U\ \frac{U}{\delta_i}, \qquad (1)$$

i.e., the distribution of tension, as it were, repeats the shape of the microrelief. The exact similarity of the relief will be preserved only if the treated surface has the same electrical properties, which is possible with its chemical and structural homogeneity. The presence of impurities, structural defects and grain boundaries violate this homogeneity, but in this case, the distributionof the electric field strength correlates with the height of microroughnesses.

When a product is immersed in an electrolyte, a thin vapor-gas cushion is formed around the product, and the electric field strength increases sharply to a level where chemical, covalent, metallic and other bonds are destroyed, alternating redox processes occur, which convert the elements in the surface layer into compounds, easily separated from the surface. Some recommendations on polishing one square decimeter are given below: Current ~ 20 A, voltage ~ 250 V. Power – 5 kW. Duration (assume 6 min = 0.1 h). Total specific energy consumption 5x0.1 = 0.5 (kW·h) / Dm.sq.

The treatment is carried out in an electrohydrodynamic mode in an aqueous solution of ammonium sulfate at a temperature of 70...85 °C and a voltage of 250...350 V. The treatment is carried out for 1...6 min at a current density of 0.1...0.2 A/cm^2. At the same time, the electrolyte is very stable during long-term use, effective at low current densities (less than 0.2 A/cm^2), has the property of self-purification.As the temperature rises, the current consumed decreases, metal removal decreases and the processing time lengthens. When the boiling point of the electrolyte is reached, the polishing process practically stops. Therefore, during operation, the electrolyte must be cooled.

When polishing flat stainless steel surfaces, metal removal rate is about 2 μm/min per side, and from a sharp right-angled edge – about 4 μm/min, i.e. twice as much. This explains the blunting of sharp edges.

Polishing of metals occurs in the voltage range of 250...330 V and current densities of 0.4...0.6 A/cm^2. The duration of polishing is 2...5 min. For a stable anode process to occur, it is necessary that the cathode area be at least 10...15 times larger than the area of the workpieces to be processed.

In practice, aqueous solutions of salts (NH_4Cl, $(NH_4)_2SO_4$, NaCl), acids (H_2SO_4, HCl), and alkalis (NaOH, KOH) are widely used for various types of electrolytic treatment. The qualitative nature of the change in the properties of the listed electrolytes from concentration is shown in Fig. 4.

With an increase in concentration, the coefficients of electrical conductivity of surface tension, kinematic viscosity, and density increase. The curves of thermal conductivity and the contact angle of wetting have a falling character.

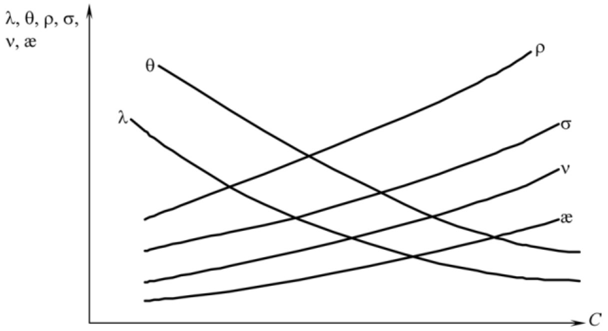

Fig. 4. Dependence of the properties of electrolytes on the concentration of the solution

λ – thermal conductivity of the anode material;

θ – contact angle;

ρ – liquid and vapor densities;

σ – surface tension coefficients, N/m;

ν – kinematic viscosity of the electrolyte m^2/c;

$\varkappa$ – specific electrical conductivity $\Omega^{-1} \cdot cm^{-1}$

CONCLUSIONS

A technological device for EPP of vartious surfaces has been developed. Some theoretical calculations and usefull recommendations for EPP have been done. This technology contributes to significant savings in human and energy resources and achieving the required surface quality of parts, and preliminary processing, before vacuum deposition of protective coatings.

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Article received 06.02.2023

ДЕЯКІ АСПЕКТИ ТЕХНОЛОГІЇ ЕЛЕКТРОЛІТНО-ПЛАЗМОВОЇ ОБРОБКИ ПОВЕРХНІ

І.К. Тарасов, А.В. Клосовський, А.В. Таран, С.П. Романюк

Розроблено технологічний пристрій (дослідну модель) для електролітно-плазмової обробки різних поверхонь. Зроблено деякі теоретичні розрахунки та надано корисні рекомендації щодо процесу обробки. Ця технологія сприяє суттєвій економії людських та енергетичних ресурсів і досягненню необхідної якості поверхні деталей, попередньої обробки, а також є дуже корисною перед вакуумно-дуговим напиленням захисних покриттів.