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Development of technology for high-speed branding of titanium alloys

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Abstract. Electrochemical stamping produces an oxide film on the titanium surface, which slows down the stamping process. In this paper, the task was set to develop technological methods that accelerate the process of stamping titanium alloys. Studies have shown that markings obtained from an electrolytes given in the work and according to the regime described in the work are stable, clear, contrasting, different in color from the base metal. The resulting marks have withstood repeated sterilization by boiling in water and a moisture resistance test.

Introduction

In industry, the technology of marking has found wide application, almost all types of products are stamped [1,2,3]. This is necessary to identify the manufacturer of the product and protect it from counterfeiting.The technology of laser marking became very popular, because of the low cost of creating an image. However, the development of laser technology did not lead to the disappearance of other methods of stamping, such as electrochemical and impact stamping.Electrochemical stamping technology has high productivity and has been recommended in mass production, where individual marking is required for each part [4]. This technology is well developed for stamping steels, but there is a problem with working with titanium alloys. Oxide film, which slows the process of stamping, is formed on the surface of titanium during electrochemical stamping[5,6,7,8]. The task of developing technological methods that accelerate the process of stamping titanium alloys was posed in this paper.

Main part

As a result of the reactions that occur on the electrodes during the passage of an electric current, the electrons are released at the anode, and are bound at the cathode. Anode processes can proceed in two ways: with dissolution or without dissolution of the anode metalIn the case of a soluble anode, the oxidation reaction, which causes the passage of current at the anode, consists in the release of metal ions into the solution according to the general equation:

$$Me \rightarrow Me^{n+} + ne$$

Anodic dissolution of the metal occurs. The insoluble anode will not transfer any ions to the electrolyte. During the anodic oxidation reaction, the metal does not dissolve. The reaction required for the passage of current from the anode occurs at the boundary of the "metal-solution" phases. The releasing electrodes passing into the metal.Anodic oxidation reactions on insoluble anodes

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depend on the composition of the electrolyte and can have very different character. The release of oxygen on insoluble anodes, which passes through the equation in alkaline electrolytes, is of particular importance:

$$4OH^- \rightarrow 2H_2O + O_2 + 4e$$

and acid electrolytes by the equation:

$$4H_2O \rightarrow 4H^+ + O_2 + 4e$$

The behavior of the anodes depends on the anode potential. Many anode reactions can occur simultaneously. Often on soluble anodes with a low current density, there is only one reaction - dissolution of the metal. With increasing current begins to stand out oxygen, resulting in the original anode becomes from soluble to insoluble. As a result of the analysis of literature data and carried out experimental work on the marking of stainless steels, it was revealed that the most productive, providing high quality of the marked marks is the non-stencil method.

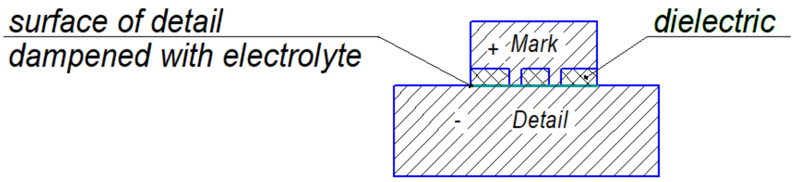

Fig.1. Diagram of the non-stencil method.

The main features of this method is the absence of an artificial integral (gap) between the part and the electrode.

Main factor that determines the process of branding, is a prerequisite of same surface levels of dielectric substrate and electrode. Electrodes with image of brand sign are made of a printing alloy, electrode is poured with an insulating material (one of the fast-hardening plastics: noracryle, styracryl, protakril, etakril, etc.). After solidification, insulating layer from mark of stucco is ground to the same surfaces level of the dielectric substrate and electrode. The process of marking is carried out by imposing head on surface of a DC source connected to various strips of electrolyte pre-wetted with electrolyte.

The process proceeds through following stages: at some initial instant of time an instantaneous maximum current of 3-5 A / cm^2 flows through electrolyte layer, which causes an instantaneous electrochemical reaction; on the parts surface the main metal oxides layer having a large resistance is formed, and a gas shell forms at electrode surface, which sharply reduces the electrical conductivity of interelectrode gap; initial value of the current drops sharply and decreases almost to zero within a short time; the process is terminated.

Formed as a result of an instantaneous electrochemical reaction, the metal oxides strongly bind to the base metal and form the sign itself.

In this case, during the marking process, practically no etching occurs and the signs obtained in this way have the same level with the surface of the parts. Titanium is one of the highly corrosive materials. This is explained by the presence on its surface of oxide films that are resistant in many corrosive environments. The basic electrochemical indices are such that titanium can be considered a metal having a high propensity to passivation than iron, nickel, chromium and stainless steels.

Titanium is stable in atmospheric conditions, waters of different composition, alkalis, solutions of many salts, some organic acids, food environments, oxidizing acids, etc. Corrosion resistance of titanium alloys with multiple boiling or autoclaving is much better than in chromium steels and nickel-base alloys.

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In the experiment, we used: an electrochemical marking device, a sterilizer, an electric tile, a set of stamps, a stamping fixture, a climatic chamber 3001. For the experiments, the PME-2 instrument was modernized. The principle of the PME-2 device is based on the use of the anodic dissolution process. Structurally PME-2 is made as a separate portable device. Autotransformer, board with rectifier, board with relay, rectifier unit, zener diode, located on the chassis of the front of the device. On the front panel of the device there are installed: a voltmeter, changing the output voltage, an ammeter measuring the load current, a signaling device for switching the device on, a signal lamp indicating the end of the voltage supply to the output terminals, a delay time switch, an output voltage regulator, a switch, output terminals, delay time.The PME-2 device is a power rectifier consisting of an autotransformer Tp and a rectifying bridge at D_1-D_4; with the time relay assembled on the lamp L_2 and the control circuit on the relay P_2. The time relay, assembled on the lamp L_2, works as follows. When you press K_{H1}, relay P_1 is activated. At the same time, the load and the delay circuit are switched on via the contacts P_1^1 and P_1^2. The contact P_1^3 is then opened and the capacitor C_3 starts charging. When the lamp L_2 is ignited, the relay P_2 is triggered and for a moment opens its contact P_2

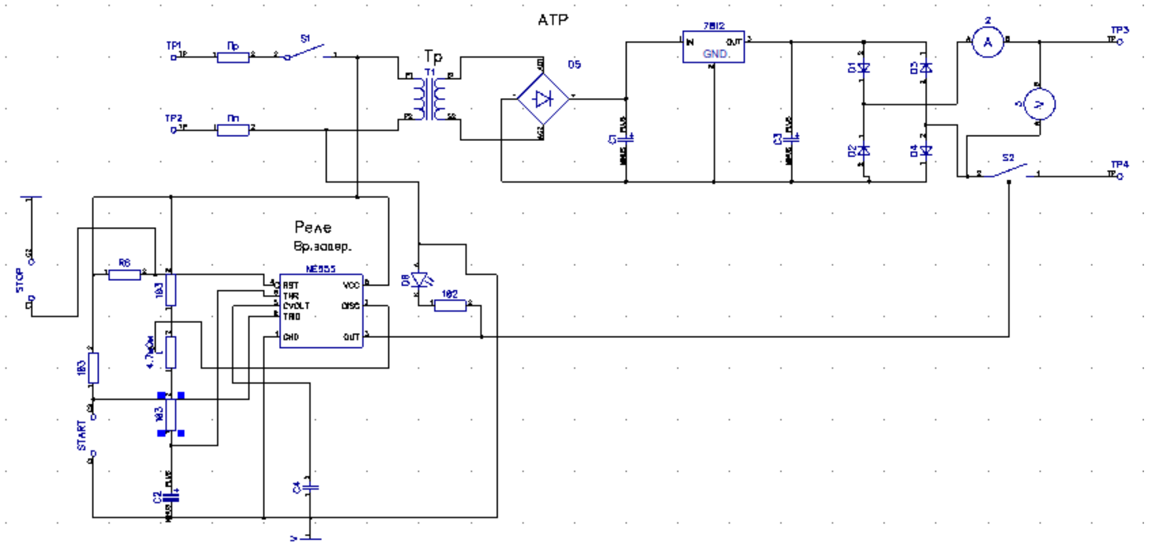

Fig.2. Electrical diagram of the modernized branding device.

Titanium staining by electrochemical method is difficult due to the ability of titanium to permanently passivate the surface. For this reason, the selection of the electrolyte constituted considerable difficulties. In past articles, there was an indication of the use of tap water as an electrolyte for branding titanium. Titanium labeling using tap water as an electrolyte was tested by us first. The received signs were clear, but very light and not sufficiently stable.

In this regard, work was carried out to find new electrolytes, giving a clear and contrast image. The experiments were carried out on plates of OT-4 alloy with preliminary mechanical polishing.

The composition of electrolytes is given in Table 1. Work was carried out on the selection of voltage and time of labeling with various electrolytes. It was found that for marking titanium alloys, an increased voltage is required compared to stainless steels. The voltage is 10-12 volts. This is due primarily to the presence of a passive film on the titanium surface, which has a significant ohmic resistance, as well as high ohmic resistance of the electrolytes themselves. Marking time is 0.1 sec.

Marking modes are shown in Table 1.

Table 1.The composition of electrolytes and the marking modes by electric method on the device.

№	Composition of electrolytes	Marking modes		Characteristics of the sign
		U, V	T, s.	

1	C_2H_5OH 10%, NaCl 0.2%, NH_4Cl 0.2%, distilled water.	10-12	0.1	The sign is dark brown or dark blue, clear
2	C_2H_5OH 10%, NaCl 0.2%, distilled water.	10-12	0.1	The sign is clear brown light
3	NaCl 0.2%, distilled water.	9-11	0.1	The sign is dark brown, clear
4	C_2H_5OH – 15%, NaCl0.2%, CH_4N_2O 0.4%, distilled water.	10-12	0.1	The sign is dark brown, clear
5	C_2H_5OH – 15%, Tap water	10-12	0.1	Sign clear, light brown
6	Tap water	10-12	0.1	Sign light, unstable

The development of additive production technology allows you to create individual things quickly and for short lines. The flagship of this technology is the technology of selective laser melting. To create a stigma-electrode this technology is very attractive. We used a ProX 300 machine with a pressing roller. The model of the three-dimensional stamp is loaded into the installation, into which it is divided into layers with a thickness of 40 μm. Each layer has its own profile. On the platform using a roller, a layer of metal powder 17-4 PH with a thickness of 40 μm is deposited. The laser scans the corresponding profile for each layer.

The grown product is cut off from the surface of the platform, and its working part is poured with the recrystal-65.

A series of stamps with the signs "USSR" and "Stainless" was tested. Tests have shown that sharp, contrasting signs are obtained when setting about 500 characters. When stating more characters, the image turns out to be vague, fuzzy, and the brand itself is rendered useless.

Studies have shown that when marking titanium, the resistance of the stamping electrode was lower than when marking stainless steels (500 characters for titanium and 5,000 marks for stainless steels).

But, considering that the stigma grown with the SLM installation can be re-polished and re-used, as well as the low cost of stamping, we can assume that when replacing the stamping method with electrochemical method, an economical effect will be obtained.

Studies have shown that the markings obtained from the tables given in Table 1. 1. electrolytes, and according to the above regime - stable, clear, contrasting, excellent in color from the base metal. The resulting marks have withstood repeated sterilization by boiling in water and a test for moisture resistance.

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References

[1] Knaislová A, Novák P, Pruša F 2016*Preparation of Ti-Al-Si alloys by powder metallurgy* Manufacturing Technology 16(6) pp 1274-78

[2] Ong JL, Lucas LC, Raikar GN 1993*Electrochemical corrosion analyses and characterization of surface-modified titanium*Applied Surface Science

[3] Zhao H,Andrawes B 2017*Mechanical properties of NiTiNb shape memory alloy subjected to a harsh corrosive environment* Journal of Materials in Civil Engineering

[4] Kashapov R N, Kashapov L N, Kashapov N F 2017 *Analysis and development of methods for obtaining metallic powders for selective laser melting* IOP Conference Series: Materials Science and Engineering Vol 240 Is 1 **012071**

[5] Kashapov R N, Kashapov L N, Kashapov N F 2015 *The research of anodic microdischarges in plasma-electrolyte processing* IOP Conference Series: Materials Science and Engineering Vol 86 Is 1 **012019**

IOP Conf. Series: Materials Science and Engineering **412** (2018) 012092 doi:10.1088/1757-899X/412/1/012092

[6] Kashapov L N, Kashapov N F, Kashapov R N 2013 *Research of the impact acidity of electrolytic cathode on the course of the plasma-electrolytic process* Journal of Physics: Conference Series. Vol 479 Is 1 **012011**
[7] Kashapov L N, Kashapov N F, Kashapov R N 2014 *Influence of plasma-electrolyte discharge to the glass surface* Journal of Physics: Conference Series. Vol 567 Is 1 **012024**
[8] Kashapov L N, Kashapov N F, Kashapov R N, Denisov D G 2016 *Plasma electrolytic treatment of products after selective laser melting* Journal of Physics: Conference Series Vol 669 Is 1 **012029**