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LABORATORY INSTALLATION FOR ELECTROLYTIC-PLASMA TREATMENT OF STEEL

Abstract. A laboratory installation for electrolytic-plasma treatment (EPT) of metals and alloys has been created. A detailed description of the device and the operation of the installation are given. The laboratory tests of the installation were carried out, the optimum modes of EPT steel were determined. The disadvantage of traditional heat treatment – gas carburizing with subsequent hardening is the formation of hogging and internal cracks, as well as the high labor intensity and energy intensity of the carburizing process itself. In connection with this, it is urgent to search for alternative methods of chemical-thermal treatment. One of the promising methods is the electrolyte-plasma hardening of the surface layer of the parts. Hardening of the surface layer of the part is achieved as a result of cyclic, very rapid heating and cooling of the surface of the hardened sample in the plasma layer, which temperature is from 6000 to 30,000 K., created between the liquid electrode (electrolyte) and the cathode surface (sample). Rapid cooling (hardening) of the surface layer of the part takes place in the flow of electrolyte. In the process of thermal influence, the surface layers of the metal are saturated with carbon from the ions of the plasma of calcined soda, phase transformations of steel, which leads to local consolidation.

The high efficiency of the pilot plant is revealed - the energy costs and the duration of the chemical heat treatment are sharply reduced, as well as the ecological clean method of hardening.

Key words: steel, tool, phase, structure, properties, electricity, plasma, electrolytic-plasma treatment.

Introduction. The three-cone bit is an especially important drilling tool that destroys the rock by creating high contact stresses from axial force to the bit. For the manufacture of cutters it is used the cemented, low-alloy heat-resistant steel 18ХН3МА-Ш, which contains: 0,16-0,18% C; 3.3% Ni; 0.9% Cr; 0.51% Mo; 0.44% Mn; 0.34% Si; 0.05% Al; and impurities, up to 0.008% S; 0.012% P; 0.015% N; 0.01% O; 0.01% H. All these alloying elements provide high strength steel. At this, nickel simultaneously with the increase in strength of steel contributes to the increase in its impact strength, and molybdenum - to increase its heat resistance [1]. According to the drilling specifications, the details of this steel at temperatures from -70 to +450 ^{0}C should produce at least 270 m of the well.

To ensure the required performance of the bit, taking into account the heavy shock loads and increased operating temperatures (up to 200 °C), under the conditions of production of Vostokmashzavod, JSC, they are subjected to chemical-thermal treatment: gas carburizing at the temperature of 960 °C followed by quenching at the temperature of 880 °C. The hardness of the surface layer of the parts reaches up to 58 ... 63 HRC. The hardness of the core is not more than 45 HRC. The disadvantage of such heat treatment is the formation of warpage and internal cracks, as well as the high labor intensity and energy intensity of the carburizing process itself.

Consequently, it is urgent to search for alternative methods of chemical-thermal treatment [2]. One of the promising methods is the electrolytic-plasma hardening of the surface layer of the parts. However, in Kazakhstan and in the near abroad, pilot-industrial or laboratory plants for electrolytic-plasma treatment are not produced.

The aim of this work was the design and manufacture of a laboratory installation for electrolytic-plasma treatment (EPT) of steel, the principal scheme of which is presented in Fig 1.

The device and operating principle of the EPT installation. The EPT installation (Figure 1) consists of a constant current source 1, a control panel 2, a clamping and mounting mechanism 3, a conical nozzle 4 with an inserted stainless steel anode, a working bath 5 made of dielectric plexiglass, 4 liters in volume [3]. A pump 6 with a regulated electrolyte supply operating in corrosive media was also used, and a dielectric tank 7, 5 liters in volume. The electrolyte from the tank 7 is fed by the pump 6 to the cone shaped nozzle 4 into which the anode of stainless steel 12X18H10T is inserted [4]. When the electrolyte is circulated, the bath is cooled to the required temperature (20±1 °C). The used electrolyte from the working bath is fed back to the tank.

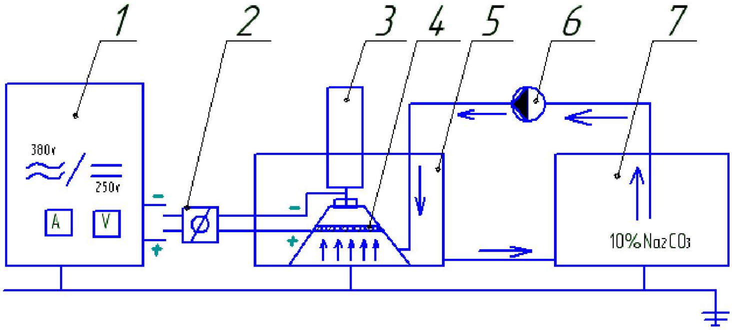


Figure 1 – Scheme of the electrolytic-plasma treatment installation: 1 – constant current source; 2 – control panel; 3 – clamping and mounting mechanism; 4 – Nozzle for electrolytic-plasma processing; 5 – working bath; 6 – pump; 7 – electrolyte tank

The test sample (part) serves as a cathode. It is installed on the mechanism of the clamp 3, which allows to regulate the required depth of immersion of the cathode in the electrolyte [5].

Source of power. The discharge is ignited by a direct current source 1-ИПН160 / 600-Ш, connected to an industrial network (380 V, 50 Hz), with output parameters: voltage U=250 V, current I = 1 kA. Semiconductor rectifier ИПН-160/600-Ш consists of a three-phase power transformer with smooth regulation of operating current (up to 600 A), rectifier block and ballasts [6]. The source provides a switch for obtaining an open circuit voltage: 80, 120, 160 V. The power supply of the plasma arc has a steeply falling external current-voltage characteristic [7]. The power source is controlled by the "Start" and "Stop" buttons on the front panel, as well as by the remote control panel 2. A fuse is used to protect the control circuits from short circuits [8]. Remote control panel allows to smoothly and accurately adjust the main energy parameters of the plasma jet (electrical parameters, flow of plasma-forming and transporting gases) [9].

Nozzle 4 (plasmatron) is a gas discharge device serving for electrolytic-plasma treatment. A nozzle (anodic) node is joined to the cathode node through an electrical insulating unit. The negative terminal of the DC source is connected to the sample (part) - the cathode, and the positive to the nozzle - to the anode [10]. Between the poles, an arc arises that maintains the level of ionization.

The nozzle is the most important element of the EPT installation, the design of which depends on the length of the arc, the stability of its combustion, and the speed and nature of the jet. The cone shape of the nozzle leads to the increase in the arc voltage and the significant increase in the current density in the arc column. The plasma jet is still compressed by a magnetic field created by the flux of charged particles in the plasma itself. Compression of the plasma jet leads to the increase in its temperature. The heated ionized gas stream is carried out at high speed from the nozzle as a bright, luminous plasma jet [11].

In the electrolytic-plasma treatment, depending on the conditions for the appearance of the electric arc and the parameters of the plasma layer, as well as on the composition of the electrolyte and the number of EPT cycles, the chemical and phase composition, the structure and properties of the surface layer of the metal are changed [12].

Hardening of the surface layer of the part is achieved as a result of cyclic, very rapid heating and cooling of the surface of the hardened sample in the plasma layer [13, 14], created between the liquid electrode (electrolyte) and the cathode surface (sample). Rapid cooling (hardening) of the surface layer of the part takes place in the flow of electrolyte.

When conducting electrolytic-plasma treatment of parts on the installation, strict compliance with safety requirements must be strictly observed: grounding, extraction, use of special clothing, protective glasses and dielectric gloves [15].

Results of laboratory tests of the installation. The general view of the EPT installation is shown in Figure 2. In laboratory tests, the electrolyte, a 10% aqueous solution of calcined soda, Na_2CO_3, with known values of viscosity and resistivity, was chosen as the working medium. This electrolyte does not form toxic compounds during the electrolytic-plasma discharge. In the process of working with this electrolyte, technological solutions were found that ensure the absence of emissions into the atmosphere and high ecological parameters of the electrolytic-plasma treatment installation. In the future, a particularly important search direction should be the choice of electrolytes, which allow saturating the surface of products with special alloying elements [16].

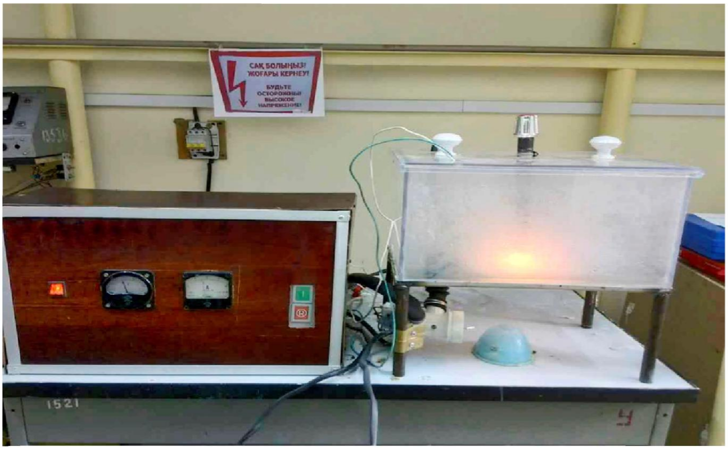
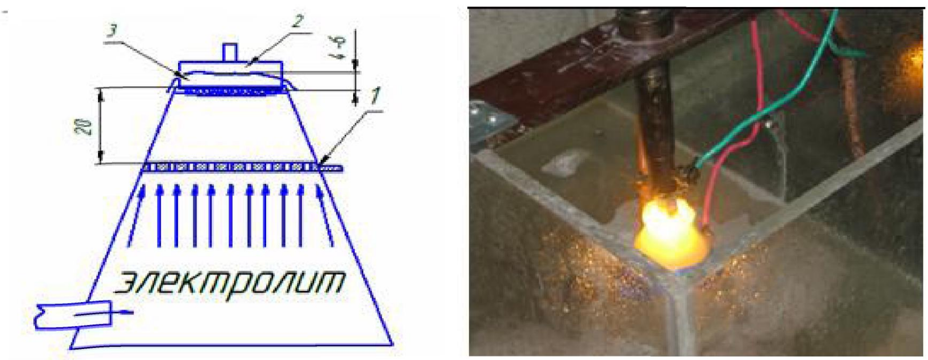


Figure 2 – General view of the laboratory EPT installation

The method of carrying out experimental studies [17] of the effect of the electrolytic-plasma treatment on the changes in the quality parameters of steel during its operation was as follows (Figure 3): cathode 2 - the sample is immersed in the electrolyte to a depth of 4-6 mm. Anode 1, which has the shape of a disk with a diameter of 50 mm and a thickness of 2 mm with drilled holes Ø4 mm, is made of stainless steel [18]. Plasma 3 occurs between the cathode and the liquid electrolyte.



Nozzle circuit Processing

Figure 3 – Electrolytic-plasma treatment of the sample

When the electric potential is turned on, a rapid warm-up occurs, and when it is turned off, the surface layer of the detail is cooled rapidly above the phase transformation temperature. Subsequent repetitions of the heating and cooling cycle make it possible to carry out a mode of thermo-cyclic surface treatment [19].

When a constant voltage is applied between two cathode electrodes (a hardened sample) and the anode (electrolyte), a layer of plasma generated by electric discharges arises [20]. As a result, an intense heating of the surface layer of the sample takes place. The current flowing through the plasma sheath can provide heating of the active electrode from 100 °C up to the melting point of its material [21]. After the power supply is turned off, the plasma is extinguished, which provides access to the heated product to the electrolyte and its rapid cooling (hardening) [22]. The rate of hardening also increases due to the heat removal in the massive substrate. To eliminate the melting of the surface, a pulsed heating mode has been developed. Since the duration of a pulse with a voltage is limited by time, surface overheating with EPT does not occur [23].

The tests of the installation made it possible to establish the optimal mode of the electrolytic-plasma treatment of tool steel: voltage U=200 V, current I=10 A, processing time 4s, hardening 4s, total time 2 min. It is also possible to carry out electroplating and plasma treatment of alloys based on non-ferrous metals [24].

Conclusion. A laboratory installation for the electrolytic-plasma treatment (EPT) of metals and alloys has been created. A detailed description of the device and operation of the installation is given [25]. The laboratory tests of the installation were carried out, the optimal modes of EPT steel were determined. The high efficiency of the pilot plant operation is shown - the energy costs and the duration of the chemical-thermal treatment are sharply reduced.

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БОЛАТТЫ ЭЛЕКТРОЛИТТІ-ПЛАЗМАЛЫҚ ӨҢДЕУГЕ АРНАЛҒАН ЛАБОРАТОРИЯЛЫҚ ҚОНДЫРҒЫ

Аннотация. Металдар мен қорытпаларды электролитті-плазмалық өңдеуге ЭПӨ арналған лабораториялық қондырғы жасалған. Қондырғы лабораториялық сынақтан өткізіліп, ЭПӨ тиімді режимдері анықталған. Өндірісте қолданылатын газды цементациялау және оның артынан шықтыру әдісінің негізгі кемшіліктері: бұйымның формасының өзгеруі, үлкен ішкі кернеулердің пайда болуы, сонымен бірге аса үлкен қиындығы және энергетикалық шығыны мол. Сондықтан химия-термиялық өңдеудің жаңа әдістері табу аса актуалді болып табылады. Осындай болашағы зор әдістердің бірі – металдың беткі қабатын электролитті-плазмалық өңдеу болып табылады. ЭПӨ кезінде бөлшектің беткі қабатының қаттылығы мен беріктігі температурасы 6000-30 000К ортада циклді түрде, өте тез қыздырудың және тез суытудың нәтижесінде артады.

Тәжірибелік қондырғынының тиімділігі жоғары екендігі көрсетілген. Электроэнергияның шығыны химико-термиялық өңдеу уақыты қысқарады.

Түйін сөздер: болат, құрал-сайман, фаза, құрылысы, қасиеттері, электр тоғы, плазма, электролитті-плазмалық өңдеу.

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ЛАБОРАТОРНАЯ УСТАНОВКА ДЛЯ ЭЛЕКТРОЛИТНО-ПЛАЗМЕННОЙ ОБРАБОТКИ СТАЛИ

Аннотация. Созданалабораторная установка для электролитно-плазменной обработки (ЭПО) металлов и сплавов. Приведено подробное описание устройства и работы установки. Проведены лабораторные испытания установки, определены оптимальные режимы ЭПО стали. Недостатком традиционной термической обработки – газовой цементации с последующей закалкой является образование коробления и внутренних трещин, а также высокая трудоемкость и энергоемкость самого процесса цементации. В связи с этим актуальным является поиск альтернативных методов химико-термической обработки. Одним из перспективных методов является электролитно-плазменное упрочнение поверхностного слоя деталей. Упрочнение поверхностного слоя детали достигается в результате циклического, очень быстрого нагрева и охлаждения поверхности упрочняемого образца в слое плазмы, температура которого составляет от 6000 до 30000 К., создаваемого между жидким электродом (электролитом) и поверхностью катода (образец). Быстрое охлаждение (закалка) поверхностного слоя детали происходит в потоке электролита. В процессе термического влияния происходит насыщение поверхностных слоев металла углеродом от ионов плазмы кальцинированной соды, фазовые превращения стали, что приводит к локальному упрочнению.

Выявлены высокая эффективность работы опытной установки – резко сокращаются затраты электроэнергии и длительность химико-термической обработки, а также экологический чистый метод упрочнения.

Ключевые слова: сталь, инструмент, фаза, структура, свойства, электричество, плазма, электролитно-плазменная обработка.

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