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Hydrogen nitrogening in great discharge with AC power

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Abstract

The paper substantiates and experimentally shows the possibility of anhydrous nitriding in a glow discharge (BATR) with AC power supply (AC), as well as the possibility of switching the shape of pulses, changing their polarity, which is solved by introducing a glow discharge nitriding device with a power source alternating current of a given frequency. The analysis of the results of metallographic studies of the modified layer indicated the presence of a more uniform gradient of hardness in depth (gradient decreased by 1.7 - 3.5 times), which increases the wear resistance of parts and quality indicators of strengthening parts while reducing processing costs and installation costs. At BATR in CCR with supply of current of industrial frequency the installation for realization of process becomes cheaper. The latter factor will contribute, among other aspects, to the wider introduction of BATR technologies. The use of alternating current affects the course and results of nitriding, as periodic changes in the polarity of the electrodes of the chamber contributes to the cleaning of the surface from the adsorption layer, which positively affects the nature of nitrogen saturation (gradient of microhardness times), contributes to a significant change in the phase composition of the surface modified layer and allows to expand the technological capabilities of nitriding in the direction of obtaining the required performance characteristics of working surfaces, in particular tribological characteristics

Key words: nitriding, alternating current, cyclic-switched discharge

Substantiation of hydrogen nitrogenation in a glow discharge with ac power

To date, research continues on the theoretical foundations, improvement of technologies and structures and types of equipment for technological processes of anhydrous nitriding in the glow discharge (BATR) [1]. Widespread use of BATR in industry has led to the exclusion of ammonia from gaseous media and, thus, to a fundamental improvement in the working conditions of equipment and maintenance personnel, environmental friendliness of the process [2]. In turn, this has led to an expansion of the range of performance indicators in accordance with the requirements and conditions of the friction contact load [3, 4]. Much of the research is devoted to methods of providing discharge in fundamentally different hardware implementations of power supplies [4]. In addition to nitriding with a constant power supply from a DC source, installations with additional heating from special screens or thermoradiation heaters are used, which reduces the relationship between electrical parameters of the technological mode and mode factors, especially temperature, because the energy factor is not only glow discharge. The development of new theoretical approaches is based primarily on the basic principles of gas discharge physics [5, 6]. The technological process has become multi-stage, in which it consists of macro- or microphases, which also significantly affects the results and productivity of the processing process. Fundamentally different nitriding results are achieved due to the introduction of cyclic-switched discharge (CCR), in which compared to the period of time sufficient to extinguish the transition from the glow discharge to the arc, the power supply to the camera electrodes is interrupted. In addition to simplifying control systems in CCR installations, the positioning of parts in the chamber is simplified, as the presence of gaps between parts and equipment for placing parts in the chamber no longer plays such a significant role. However, given the fact that the power supply to the electrodes of the chamber when using alternating current is not all the time, but in a much shorter period, the processing productivity decreases to about the same extent. Voltage and current emissions at the beginning and end of the power cycle are a problem, which can cause local damage to the

treated surface [7]. The aim of the research is to analyze the possibilities and conditions for simplifying the design of nitriding installations in the glow discharge, as well as the possibility of using as a power supply electrodes discharge chamber cyclic-switched or alternating current industrial frequency (HF). The structure and functional purpose of the individual components (for example, a three-chamber installation) are shown in Fig. 1. In the installation, when the process is powered by direct current, the power supply must include the following components: voltage regulator (set the voltage at the input to the power supply system); step-up transformer (under the influence of the control signal from the voltage regulator changes the voltage up to values of about 1200 V - at the end of the surface cleaning phase by cathodic bombardment; rectifier that converts alternating current into conditionally constant output voltage includes ripples of greater or lesser magnitude compared to the rated voltage, ballast rheostat for redistribution of electric current at the input of the chamber. With cyclic-switched power supply, there are significant voltage emissions at the beginning and end of the pulse up to values that can cause local surface damage. In addition, perhaps the most important argument, the discharge control system is significantly complicated by the mandatory inclusion of control pulse generators operating at a frequency of 1 - 5 kHz, as well as CCR significantly reduces the productivity of the modification process [2, 4].

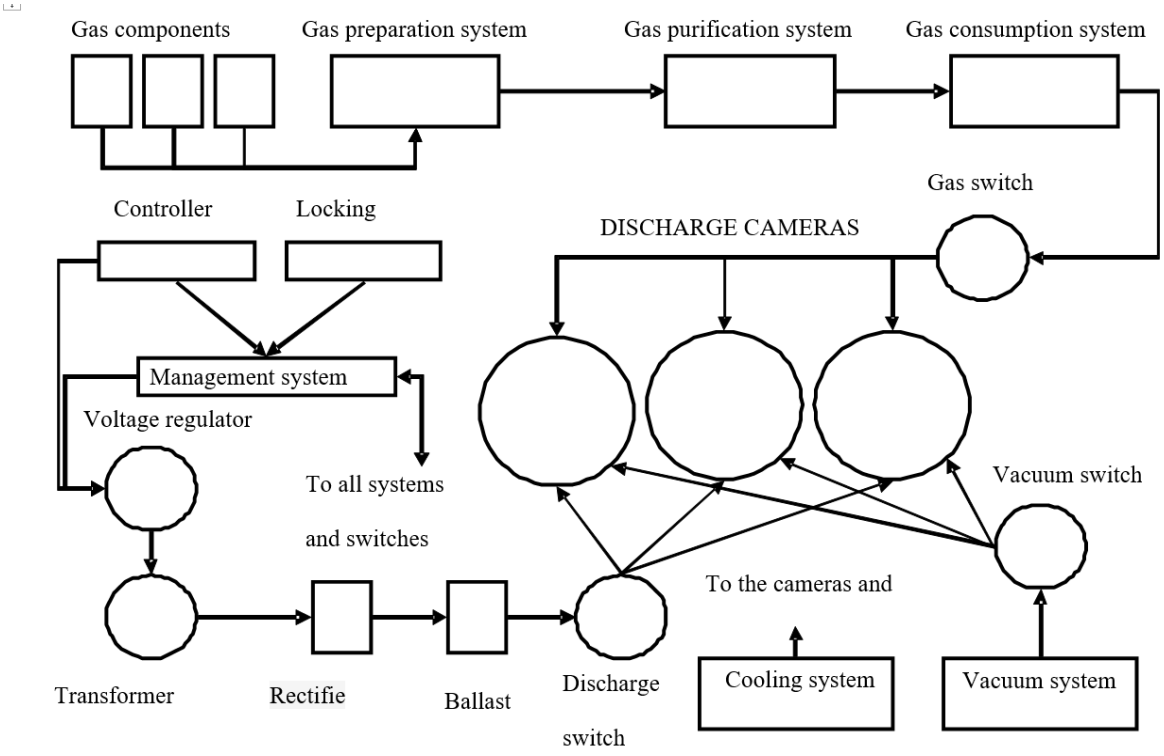

Fig. 1. Block diagram of a three-chamber installation

The above-described power structure of nitriding installations in the glow discharge is most suitable for single-phase processes, when the whole technological process takes place at constant technological parameters. However, it should be borne in mind that the main task of the power supply is not to maintain the specified electrical characteristics of the discharge, but to ensure a stable temperature on the surface of machined parts, which primarily affects the formation of a given phase-structural composition of the surface. Prospects for the practical application of anhydrous nitriding in a glow discharge with AC power supply (BATR HRT) are determined taking into account this circumstance as a determinant, because with variable current amplitude, respectively, in the period when the camera electrodes are negative voltage is no longer heated the cathode, which serves as a cage, and the anode or component of the installation, which acts as an anode. It is obvious that with such a design solution it is necessary to ensure reliable insulation of the anode from the housing, because in case of violation of such insulation there will be a real threat of electric shock. In the case of using BATR SPC power supply of electrodes is a single-phase current, the design of the transformer is significantly simplified, and the cost is reduced by at least three times. Similarly, it would be logical to manufacture and apply a single-phase voltage regulator, which in combination with a single-phase transformer will inevitably have a positive impact on the cost of the entire installation. This will reduce depreciation costs, which will also have a positive impact on cost. The lack of a rectifier and a ballast rheostat makes a certain contribution to reducing the cost of installations. From this analysis there is a question of reaching the temperature of the nitrided surface necessary

for carrying out the planned technological mode. If this task cannot be performed, additional heaters can be used to ensure the independence of the discharge energy parameters. Thus, it is possible to use technological modes with high discharge voltage or current, which allow to form the necessary under the conditions of subsequent operation of the phase structure of the surface modified layer. The next task of the staging nature is the study of the electrical characteristics of the process, which is associated with the need to establish the magnitude of the ignition voltage of the discharge and its stable combustion in the anomalous mode. It is also necessary to establish analytical or experimental dependences of the parameters of the technological regime, taking into account its energy characteristics and thus establish the limits of energy characteristics necessary for the implementation of the process. The next question is to study the process of formation of a given phase structure in BATR HRC. The essence is that the nitriding process is always a combination of individual subprocesses: the formation of nitrides, surface spraying and diffusion of nitrogen into the depth of the surface layer. With normal nitriding (direct current), an equilibrium is established between the individual sub-processes, usually in favor of nitride formation and diffusion. The process in the conditions of this equilibrium takes place stationary and with different intensity, which depends not only on the energy conditions, but also on the material of nitrided parts. It is known that chromium steels can be nitrided only in gaseous media, where the neutral component predominates. This is because chromium is a nitrogenous material. Already in the initial period of nitriding, a monolayer of nitrogen is formed on the surface, which then acts as a barrier to the penetration of nitrogen into the depth of the surface. Nitriding is almost non-existent and the thickness of the nitride layer is very small. Given the significant relative duration of the half-life of the negative voltage (0.02 s) on the electrodes of the chamber, it is appropriate to hope that under the action of electron flow the nitride monolayer will be destroyed, and in the next half-period when the flow is directed to the cathode (detail) , will promote the intensification of both nitride formation and diffusion of nitrogen into the depth of the surface layer. Therefore, in principle, nitriding in a glow discharge with power supply of industrial frequency is possible. This significantly simplifies and reduces the cost of installation for the process.

Device for increasing the wear resistance of steels by nitriding in ACR with AC

The process of nitriding parts in the glow discharge is mainly carried out using a constant power supply discharge. Thus, when using a discharge with constant power on the outer surface of the part for a relatively short period of time (duration of the nitriding process 4 h), you can get a modified surface with specified properties with high stability of the discharge. The big disadvantage of this process is that parts of complex configuration (with a large number of small holes, with narrow slits, with sharp tops) require proper preparation of these parts for nitriding. All these holes and crevices must be properly closed because they significantly complicate the nitriding process using a constant discharge power supply and can provoke corona and arc discharges, which leads to overheating of the part and in most cases the nitriding process itself becomes impossible. Therefore, one of the options to solve this problem is to use a glow discharge with non-stationary power supply. When using AC industrial frequency, you do not need to create new equipment, but only need to upgrade existing ones. The essence of the modernization is to replace the uninterruptible power supply of the discharge with a source of non-stationary power supply of the discharge with alternating current of a given frequency. Adjusting the switching frequency, or as it is called duty cycle, is the ratio of the cycle period to the signal duration, and the shape of the signal itself makes it possible to influence the results of surface treatment. The influence of the shape and frequency of the discharge power signal on the nitriding process is due to the shutdown of the electric field, which allows to change the flight trajectory of the incident flux particles. That is, the switched off electric field allows the particles to move for some time by inertia along the tangent to their trajectory and allows the particles to penetrate to a much greater depth. And also to influence impossibility of transition of a glowing category in an arc. The use of cyclically switched AC power discharge makes it possible to nitriding parts with slits, with small diameter holes without the use of special equipment and you can not be afraid of corona and arc discharges. As a disadvantage, it should be noted that the nitriding process itself increases at least two or more times. The device for nitriding in a glow discharge with a direct current consists of a power supply to the chamber which contains a thyristor voltage regulator, a rectifier, a transformer, current and voltage sensors, a ballast rheostat, an automatic shut-off unit. The disadvantage of this device is its complexity and significant energy losses on the current converter, the need to use special filters to smooth the current. The work is based on the task of creating a device for nitriding in the glow discharge with AC power, which provides the opportunity to significantly simplify the equipment and, accordingly, reduce its cost. The problem is solved by the fact that the device for nitriding in the glow discharge introduced a source with non-stationary power supply with alternating current of a given frequency [8]. The purpose of the proposed device is primarily to significantly simplify the design of the installation for nitriding in the glow discharge and increase its reliability, as well as to reduce the cost of equipment, which is solved by replacing a constant discharge power supply with non-stationary AC power supply. This increases the reliability of the installation, and also due to a significant reduction in electricity losses reduces the cost of processing nitrided parts. The use of alternating current also affects the course and results of nitriding, as periodic changes in the polarity of the electrodes of the chamber

contributes to the cleaning of the surface from the adsorption layer, which in turn leads to a significant change in phase composition of the surface modified layer [9]. The possibility of using the claimed device for conducting BATR on the existing industrial installation was experimentally tested. At the same time, the need for electricity significantly decreased due to the absence of losses for rectification, which also led to a reduction in the cost of processing. Analysis of the results of metallographic studies of the modified layer indicated the presence of a more uniform gradient of hardness in depth (gradient decreased by 1.7 - 3.5 times), which, in turn, increases the wear resistance of parts and quality performance of parts (Ukrainian patent №118327).

Method of nitriding in ACR with AC power supply

The most common method of BATR surface in which the part throughout the process serves as a cathode powered by a DC source. The disadvantage of this method is that its implementation is possible in the presence of an adjustable DC source, as well as special control devices. The problem of developing a method of nitriding in a glow discharge with AC power, which would simplify the process power supply, is solved by powering the process from an AC power source, the voltage should vary depending on the parameters of the technological mode of surface modification. The essence of the proposed idea is that the part and body of the camera or its special shell, which serve as electrodes, receive power of different polarity, and parts of the cage and the body of the camera or its special part, which acts as electrodes, are powered by AC power source , and the voltage varies depending on the parameters of the technological mode of modification of the surface of the parts. Unlike traditional incandescent nitriding methods, in which the part is always the cathode and the chamber shell or its special part serves as the anode, there is a constant threat of the incandescent discharge in the arc, which also complicates the process because the part is damaged locally or the entire surface. In addition, it is impossible to obtain a stable constant supply of the electrodes of the discharge chamber, ie to some extent the process takes place when supplied with non-constant current, although stable polarity. The experiments performed on the existing industrial plant indicate the possibility of implementing the claimed method of nitriding in a glow discharge with AC power supply of industrial frequency. If necessary, the frequency of the current can be easily changed using a simple frequency converter using an electromechanical device. In this case, the process of regulating the parameters of the technological process is significantly simplified, the reliability of technology implementation is increased, which has a positive effect on the cost of processing metal parts [10]. The idea of using industrial frequency AC as a power source for BATR, the possibility of switching the shape of pulses, changing their polarity has led to the development of a number of developments in methods and technologies of nitriding [10, 11].

Main results and conclusions

At BATR in CCR with supply of current of industrial frequency the installation for realization of process becomes cheaper. The latter factor will contribute, among other aspects, to the wider introduction of BATR technologies.

The use of alternating current affects the course and results of nitriding, as periodic changes in the polarity of the electrodes of the chamber contributes to the cleaning of the surface from the adsorption layer, which positively affects the nature of nitrogen saturation (gradient of microhardness times), contributes to a significant change in the phase composition of the surface modified layer and allows to expand the technological capabilities of nitriding in the direction of obtaining the required performance characteristics of working surfaces, in particular tribological characteristics.

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Стечишина Н.М., Стечишин М.С., Мартинюк А.В., Гладкий Я.М. Безводневе азотування в тліючому розряді з живленням змінним струмом

У роботі обгрунтована та експериментально показана можливість проведення безводневого азотування в тліючому розряді (БАТР) із живленням змінним струмом промислової частоти (СПЧ), а також можливості комутації форми імпульсів, зміни їх полярності, що вирішується введенням пристрою для азотування в тліючому розряді з джерелом живленням зі змінним струмом заданої частоти. При цьому аналіз результатів металографічних досліджень модифікованого шару вказав на наявність більш рівномірного градієнту твердості по глибині (градієнт знизився в 1,7 - 3,5 рази), що підвищує зносостійкість деталей та якісні показники зміцнення деталей з одночасним зниженням собівартості обробки та вартості установки

Ключові слова: азотування, змінний струм, циклічно-комутований розряд