Study on parts ion-plasma nitriding

I H Israphilov, V V Zvezdin, D I Israphilov, M A Chernova
Department of Energy and Information, Naberezhnochelninsky Institute (branch)
Kazan (Volga Region) Federal University, pr. Mira 68/19, Naberezhnye Chelny,
423810, Russian Federation

E-mail: DIsrafilov@kpfu.ru

Abstract. Nitriding is used in various industries to improve the operational reliability of a wide range of products: cylinder liners, crankshafts and camshafts, spindles of machine tools, stamping and cutting tools, turbine parts, etc. Durability and performance of instruments is largely determined by the surface condition and its properties. One of the most effective ways of hardening the surface is ion-plasma nitriding.

1. Introduction
The physical nature of the processes of ion-plasma nitriding atmospheres same. However, qualitative and quantitative characteristics of the individual stages of these processes have their differences that affect the structure and kinetics of formation of the nitrided layer.

Ion nitriding process in hydrogen-containing media (ammonia, a mixture of nitrogen and hydrogen) is well studied in domestic and foreign literature [1 - 5]. Hydrogen, being a good reducing agent, has a significant effect on the kinetics of formation of the nitrided layer, intensifying the process. However, as noted previously, the presence of hydrogen in a saturating medium ko-lichestvah significant causes embrittlement of the surface (particularly the sharp edges) and softening base under certain conditions, leads to a reduction in strength and durability of the structural elements. Addition of hydrogen in argon saturated environment enhances the ductility of the nitrided layer [2, 5]. Substitution of hydrogen with argon saturating medium (a mixture of nitrogen and argon) excludes hydrogen embrittlement of the nitrided layer, but this changes the energy of ion nitriding.

Nitriding is used in various industries to improve the operational reliability of a wide range of products: cylinder liners, crankshafts and camshafts, spindles of machine tools, stamping and cutting tools, turbine parts, etc. Durability and performance of instruments is largely determined by the surface condition and its properties. One of the most effective ways of hardening the surface is ion-plasma nitriding.

The aim is to create a nitriding surface layer with high hardness, wear resistance, enhanced fatigue strength and corrosion resistance. Nitriding subjected finished products past mechanical and final heat treatment.

Nitriding has several advantages over cementation. Advantages are a higher hardness and wear resistance of the surface layer, maintaining their high properties when heated to 500C, and high corrosion properties. In the nitrided layer are residual compressive stress, which increases fatigue strength. Furthermore, after the nitriding hardening is not required, thus avoiding defects of the accompanying hardening.
2. Experimental study

The plasma accelerates the reaction, increasing the energy of nitrogen ions, further activating them as a result of cathode sputtering. Plasma nitriding meets environmental requirements, operates a large number of plants for its implementation. A feature of the plasma nitriding is that the process can be controlled much easier compared to the nitriding in a gaseous medium. Requirements to reduce running costs, reduce the temperature and increase the durability of the product during industrial processes become mandatory. In connection with this process, you always get the hardened layer at medium and low temperatures, are widely used in various saturating atmospheres.

At low temperature nitriding steel in various saturating media occurs mainly nitrogen diffusion and the structure and phase composition of the diffusion layer are determined phase diagram of iron - nitrogen. When the high-temperature nitriding steel (> 600 °C) as a saturating medium used only nitrogen, and ammonia.

A method of forming a wear-resistant coating on the surface of articles made of structural steel includes ion nitriding in a plasma environment of the reactive gas - nitrogen surface cleaning components and nitriding. Cleaning of the surface nitriding is carried out at a pressure of reactive gas $5 \cdot 10^{-3} - 2 \cdot 10^{-2} \text{mm Hg. \ v.}$, the negative bias voltage $V$ and 300-1000 parts of ion current density $2 - 8 \text{mA / cm}^2$ for 30-90 min, cleaning is performed in a plasma of inert gas - argon at a pressure of $3 \cdot 10^{-4} - 7 \cdot 10^{-4} \text{mm Hg}$ and a current density of $3 - 5 \text{mA / cm}^2$. The method allows to intensify the process and increase the operational durability of dies experiencing high specific loads during friction.

When nitriding the surface layer formed of compression stress, which increases fatigue strength of components.

Structure and properties of the hardened layer azotiruemych details depend on the following technical factors: the voltage between the electrodes, the composition of the gaseous medium, degree of dilution, operating temperature, duration of the process, the mutual arrangement of parts and electrodes. Azotiruemye workpieces are mounted in a chamber connected to the negative electrode chamber is sealed and evacuated to a pressure of 1 mm Hg. Art. After evacuation of the air chamber is purged with a working gas for 5-15 minutes at a pressure of 10 mm Hg, then evacuated chamber to a pressure of 0.2 - 0.4 mm Hg, the voltage applied to the electrodes and excite glow discharge. When the voltage 1100-1400 V this stage, the cathode sputtering.

Nitriding temperature is usually 470-580 °C, strain 400-1100 V, vacuum of 1-10 mm Hg. Working pressure is limited by the properties of the glow discharge. At a pressure below 1 mm Hg ion energy sufficient to heat the workpiece to a working temperature at a pressure above 10 mm Hg, violate the stability of the discharge, glow discharge moves in an arc, which is accompanied by the appearance on the surface of the molten craters.

As nitrogen gas is used, ammonia, nitrogen and a mixture of nitrogen and hydrogen. In the presence of oxygen nitrogen plasma is unacceptable, since it reduces the activity of the working environment; hydrogen has little effect on the growth of the layer. Changes in the concentration of hydrogen in nitrogen-hydrogen mixture in the range of from 1:9 to 9:1 does not affect the parameters of the diffusion layer. Ion nitriding can be carried out in a hydrogen-free plasma. To control the composition of the nitride zone on carbon in the working atmosphere are introduced carbonaceous gases.

Ion nitriding process is realized in two steps: 1) cleaning the surface of cathode sputtering; 2) saturation.

Electrical and vacuum discharge parameters during the cathodic sputtering ensure activation and destruction of a surface oxide film, and a second step to provide surface heating temperature diffusion activity of the gas phase to maintain a concentration gradient of nitrogen on the surface and adjustment process on the phase composition of the diffusion layer.

Cathode sputtering is carried out for 5-60 minutes at a voltage of 1100-1400 V and a pressure of 0.1-0.2 mm Hg. During cathodic sputtering surface temperature of items exceeding 250 °C. The operating parameters of the process upon saturation: $U = 400-100 \text{V}$, the pressure of 1-10 mm Hg.
After surface treatment for 5-60 min regime cathode sputtering voltage lowered to the working and the pressure was increased to 10.1 mm Hg. When the pressure decreases the length of the cathode glow, which is uniformly distributed over the surface of the part, repeating its outlines. Cathode sputtering may be carried out in a hydrogen atmosphere, the use of which is particularly advantageous during nitriding austenitic steels. Use of a hydrogen plasma nitriding process prior to feeding the ammonia accompanied by decarbonization surface (especially intensively flowing along the grain boundaries) that when a slight fall improves ductility hardness of the diffusion layer.

Operating process temperature (470-580 °C) is achieved in 15-30 minutes. The heating rate is determined by the ratio of the surface and the mass of details.

After isothermal holding parts are cooled to room temperature under vacuum. In this cooling rate as compared with the above heating furnace, since the ion treatment is only heated product, and heating the walls of the container (working chamber) due to heat radiation and convection under vacuum negligible.

Equipment for ion nitriding and regulation should provide for stable maintenance of electrical and vacuum discharge characteristics. Installation for nitriding in a glow discharge consists of four functional systems: electrical, vacuum, gas distribution and automatic control of the process parameters. The control system includes a digital controller for controlling the entire operation of the unit and provides the following controls:
- Pressure in the chamber;
- The temperature of the parts;
- Heating rate;
- The composition of the gases.

The control system consists of a master controller and slave nodes (transmitters and drivers) connected through a highly reliable communication network. The controller receives data from the transmitters, the software executes in real time and sends commands to drivers who drive machinery installation.

Block software controls the data collection, the work pressure regulators, current and temperature, logic control, data logging, control of the technological process, error detection and visualization. Long-term memory of the controller 50 to store the history of technological regimes and technological processes. In the history includes the most important parameters - temperature, pressure, current, voltage, gas flow and time. Software running on the system Windows98 / XP, the PC communicates with the main controller. Software display the current setup parameters to the computer display, maintains a history of technological processes in the database and is reviewing the data in graphical and tabular form.

### 3. Results of experiment

The plasma generator excites the pulse glow electrical discharge of the following parameters:
- Voltage 500 - 800 V
- The maximum pulse current of 25 - 250 A
- The pulse rate (adjustable) 5 - 10 kHz
- The fill factor (adjustable) 50 - 80%

The plasma generator and equipment supply and protection of: - electrical filters, circuit breakers, contactors, power transformers and power thyristor rectifier - housed in a metal cabinet IP-54 air cooling.

### 4. Conclusions

Changes in current density in the high range (0.5-20 mA / cm2) does not affect the nitriding process. Improving technical efficiency and technological complex is to optimize the process parameters, depending on the dimensions and weight and geometric details. It is because of these characteristics
depends on the uniformity of the density distribution of the ionized gas on the surface of the
cOMPonent, since the intensity of the glow discharge plasma in the nitrogen atmosphere is increased
by the sharp edges of parts.

References
[1] Arzamasov BN, Bratukhin AG, Eliseev YS, Panayiotou TA. Ionic chemical heat treatment of
alloys in gas media (Moscow: Izd.MGTU them. NE Bauman, 1999) p 400
[2] Liakhovich LS. Case hardening alloys (Moscow.: Metallurgy, 1981) p 420
[3] Lahtin YM, Arzamas BN. Case hardening (Moscow.: Metallurgy, 1985) 256 p.
[4] VG Kaplun, Shepherd IM. Plasma diffusion processes of surface modification of materials,
technology and equipment (Proceedings of the scientific-practical Symposium "Equipment
itehnologii heat treatment of metals and alloys in engineering" - Kharkiv (Ukraine),
OTTOM. -2000) p 145-154.
[5] Israphilov DI 2007 Management of a plasma technological complex for heat treatment of parts
with specified strength characteristics (Naberezhnye Chelny: Kama state engineering and
economic academy) p 141