Ion-plasma nitriding of machines and tools parts instrumental steels

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Abstract. Here introduced features of formation diffusion bond during ion nitriding in glow discharge plasma in gaseous mediums (mixture of nitrogen and argon). It is shown, that argon existing in saturated medium changes the nitriding process kinetics and the phase composition of the outer zone. Here presented investigation results on ion-plasma nitriding of instrumental steels, focused on microstructure and tool areas phase composition change, operating in most difficult conditions.

1. Introduction
Physics of ion-plasma nitriding processes in gaseous medium is equal. However, quantitative and qualitative characteristics of separate steps of these processes have their own differences, that shows the influence on structure and the formation kinetics of nitriding case.

Ion nitriding process in hydrogenous mediums (ammonia, mixture of nitrogen and hydrogen) is well studied in Russian and foreign literature [1 - 3]. Hydrogen, being a good deoxidant, has a great impact on the nitriding case formation kinetics, intensifying the process. However, presence of hydrogen in the saturating medium in fair quantities causes surface embrittlement (especially sharp edges) and base weakening, which in certain conditions leads to strength and durability reduction of the construction elements. Adding argon into hydrogenous saturating medium acts nitriding case moldability to rise [4]. Replacement of hydrogen by argon in saturating medium (mixture of nitrogen and argon) excludes hydrogen embrittlement of nitriding case, but hereby the ion nitriding process energetics changes.

Tools strength and service characteristics to a great extend are defined by the surface condition and it’s characteristics. One of the most effective ways for hard facing is ion-plasma nitriding.

2. Nitriding in the glow-discharge plasma
Plasma nitriding meets environmental requirements, a great number of installations is used for this purpose. The feature of plasma nitriding is that the process can be managed much easier in comparison with nitriding in gaseous medium. Processes of ion-plasma nitriding, that allow receiving hardened case in middle and low temperatures, see heavy use in different saturating atmospheres.
During low temperature steel nitriding, in different saturating mediums, there happens preemptive nitrogen diffusion, and the structure and phase composition of diffusion layer defined by constitution diagram iron — nitrogen. During high temperature steel nitriding (>600°C) only nitrogen and ammonia are used as saturating mediums.

3. Method of formation anti-abrasion coating on the surface of products made from structural steel

Method of formation anti-abrasion coating on the surface of products made from structural steel includes ion-plasma nitriding in reagent gas medium — nitrogen, part surface cleaning and nitriding. Surface cleaning and nitriding are performed with the reagent gas pressure 5•10^-3-2•10^-2 mm of mercury, negative bias on parts 300-1000 V and ion current density 2 - 8 mA/cm² during 30-90 min, cleaning is performed in inert gas plasma – argon with the pressure 3•10^-4 - 7•10^-4 mm of mercury and current density 3-5 mA/cm². Method allows to intensify the process and increase drawing dies service durability, which are under high unit loading in the triboprocess.

Modern devices for ion-plasma nitriding (Fig.1) have quite difficult heating system. Impulse voltage simultaneously and independently is fed to active screen and parts, which are under nitriding. This eliminated nearly all defects of traditional charts of ion nitriding, connected with the difficulty of necessary temperatures regulation, low flatness of heat field, arcing. Herewith, the surface cleaning time and heating to operating temperatures are sharply decreased.

While nitriding in coating surface there compression stresses are formed, which increases parts permanent strength.

4. Ion-plasma nitriding technology

Nitriding parts hardened case structure and characteristics depend on the following technology factors: strain between electrodes, structure of gas medium, degree of vacuum, operating temperature, process time, relative position of parts and electrodes. Nitriding parts are set in camera, connecting to negative electrode, camera is pressurized and the air is pumped out till the pressure 1 mm of mercury. The camera view is shown on figure 1.

![Figure 1](image)

a) Installation diagram for ion-plasma nitriding (a) and it's view (b)

1 — hardening product; 2 — water-cooling camera; 3 — active screen; 4 — heating element; 5 — table; 6 — supply of high pressure to the screen; 7 — fan; 8 — supply of saturating gaseous medium; 9 — supply of high pressure to hardening product; 10 — to vacuum pump.

Selection of optimum pressure, which depends on parts configuration complexity and their reasonable positioning (Fig. 2), as with the change of pressure, the length of discharge cathode part changes. With increase of pressure from 1 to 10 mm of mercury the discharge cathode part area decreases from 10 to 1 mm. It must be taken into account to provide steadiness of diffusion coating on the product perimeter.
Temperature of nitriding is usually of 470-580°C, voltage 400-1100 V, vacuum 1-10 mmHg. The operating pressure is limited by the glow discharge properties. With the pressure below 1 mmHg, the ions energy is not enough for heating of the processed part up to the operating temperature; with pressure above 10 mmHg, the discharge stability falls, the glow discharge turns into an arc one, and this process is accompanied by the melted microcraters appearance on the surface (Fig. 3).

Ammonia, nitrogen and a nitrogen plus hydrogen compound are used as nitrogen-bearing gases. Nitrogen plasma cannot contain oxygen as it decrease the operating atmosphere activity; hydrogen slightly influences the layer growth. The change of hydrogen concentration in the nitrogen-hydrogen compound within the limits from 1 : 9 to 9 : 1 does not influence the diffusion layer parameters. Ionic nitriding can be also performed in a hydrogen-free plasma. In order to regulate the composition of the nitride zone by carbon, carbon-bearing gases are added to the atmosphere.

Cathode spraying is conducted during 5-60 min with voltage of 1100-1400 V and pressure of 0,1-0,2 mmHg. During the cathode spraying, the part surface temperature does not go above 250°C. The operating parameters of the process with saturation: U = 400-100 V, pressure 1-10 mmHg.

After the surface has been being processed during 5-60 min in the cathode spraying mode, the voltage will be increased up to the operational one, and the pressure will be increased up to 1-10 mmHg. With the pressure increase, the length of the cathode glow which is equally distributed on the part surface decreases repeating its contours. Cathode spraying can be conducted in a hydrogen atmosphere as well, the use of which is especially appropriate during austenite steel nitriding. The operating temperature of the process (470—580°C) is reached within 15-30 min. Heating speed is defined by the parts surface and their weight correlation.

After isothermal aging, the parts are cooled down to ambient temperature in vacuum. During this process the cooling speed is higher against the oven heating as during the ionic heating only the part will be heated, and the container walls (process booth) is not substantial due to the heat emission and convention in the vacuum conditions.

Steel 4X5MФС is the main steel for various stamps, deformation of steel and non-ferrous metals and for molding types under pressure of aluminum and magnesium alloys with diameter up to 70-80 mm.

Consequently, the 4X5MФC (4X5B2FC) and 4X4VMФC steel forms durability will be higher by 1,5—2 times.

Thus, the nitride layer contains nitride compounds (Fe 2_3-e - phase,- Fe 4 N - /- phase) and internal nitriding zones. Figure 4 shows a photo pf microstructure and a graph showing changes in micro-hardness of the nitride layer of the steel 4X5MФC.
The austenite disintegration in the perlite and transition zones is preceded by the part of carbides emission, which takes place at the granules edges, which leads to viscosity decrease by 30-40 %.

5. Conclusion
Current density change within great limits (0.5—20 mA/sm²) does not influence the nitriding process. Improvement of the ionic-and-plasma nitriding technical efficiency lies in optimization of the technological process parameters based on the weight-dimension and geometry features of a part. This is explained by the fact that these features influence the ionic gas density distribution evenness on the part surface as the plasma glow discharge intensity in the nitride atmosphere increases the sharp part edges.

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