Ion-plasma nitriding as a method of instruments and parts durability

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Abstract: Improvement of the machines, parts, devices reliability as well as improvement of their quality and operation are topics of interest at the present time. Solution to these problems is related to hardening of the product surface layers in the first place. This article deals with parameters of nitriding process using the example of 38XM steel which is applied in essential parts of turbine installations and compressors operating at temperatures up to 400°C. The article also provides the results of nitriding at different modes.

1. Introduction:

Physical entity of ion-plasma nitriding processes in gas environment is identical. However quality and quantity characteristics of particular phases of these processes have their differences which affect the nitrided case development structure and kinetics. Besides the nitrided machine parts obtain increased corrosion resistance in damp atmosphere and other atmospheres with low corrosive power. Their ability to maintain high hardness and durability at high operating temperatures are also significant. Main technological advantage of nitriding is low temperature of process (400-500 degrees) which is the reason of insignificant volumetric changes and deformation of machined parts and instruments. [2]

2. Nitriding stages:

The process of ion-plasma nitriding includes 4 stages: cleaning, heating, aeration and cooling.
After vacuum degassing of the chamber and filling it with working gas to 0,5-0,8 mbar cathode cleaning of parts begins during which discharge rate is permanent and makes 10-20% of its maximum value, coefficient of electrical pulses charge is 50% and pressure is permanent within 0,5-0,8 mbar. This stage is used for initial heating and additional cleaning of parts. Low current and low filling ratio prevent the appearance of electric arcs at cold and contaminated parts. Cleaning stage takes 5-20 minutes.
Cleaning leads to heating which consists of 6 steps. Heating rate, target temperature, pressure, frequency, filling ratio and composition of working gas are specified for each step. The currency is specified by temperature regulator. Heating process of parts leads to step-by-step (graded) pressure and filling ratio increase. During each step they may be persistent or may increase with temperature raise. At the last step of this stage the parts are heated to the defined nitriding temperature and its final parameters – temperature, pressure, filling ratio and gas ratio usually correspond to operating parameters of saturation mode. When nitrogen and hydrogen are used as working gas mixture their proportion may be changed from 1:1 to 1:10. When specified nitriding temperature is reached the

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isothermic saturation process begins. Temperature, filling ratio, pressure and gas ratio are permanent. Their values are 480-500°C, 80%, 2,0-8,0 mbar and 3:1 – 6:1 accordingly.
Nitriding mode takes 5-20 hours depending on design-engineering requirements and performance characteristics of hardened products.
At the end of isothermic saturation parts may be cooled down in discharged atmosphere of working and inert gas. If necessary slow cooling may be used under conditions of plasma burning with decrease of discharge power as well as atmosphere pressure of working gases. When temperature 150°C is reached the chamber is opened and the parts are cooled down.

3. Nitriding process:

Composition and properties of hardened layer of nitrided parts depend on the following technological factors: current between electrodes, composition of gas atmosphere, degree of its exhaustion, operating temperature, process duration, relative position of parts and electrodes.
Nitriding temperature is usually 470-580°C, current 400-1000 V, exhaustion 1-10 mm of mercury. Operating pressure is limited by properties of glow discharge. At the pressure lower than 1 mm of mercury the energy of ions is insufficient for heating of machined part to operating temperature, at the pressure higher that 10 mm of mercury the discharge consistency is interrupted, glow discharge develops into arc discharge accompanied by development of melted microcraters on the surface. At the pressure 2 mm of mercury and temperature 520 °C and 6 mm of mercury and 620°C accordingly the maximum depth of diffused layer is reached. Increase of current also affects the depth of layer.
Change of current intensity within a broad range (0,5-20 mA/cm2) does not affect the nitriding process.
Ammonia, nitrogen and mixture of nitrogen and hydrogen are used as nitrogen containing gases. Nitrogen plasma does not allow the presence of oxygen because it may decrease activity of operating atmosphere, hydrogen insignificantly affects the growth of layer.

4. Impact of nitriding parameters:

Besides typical factors for all nitriding methods such as duration of treatment and temperature other factors may affect the nitrided layer, for example presence of gas in plasma, width of glowing edge etc.
Data provided about reactions of plasma nitriding shows that temperature does not affect the diffusion mechanism. Nitrogen content at the temperature of 400°C depends on the same parameters as at the temperature of 500 or 600°C. This shows that the temperature range is very large and limited only by physicochemical processes within the metal. Thus, for example, although nitrogen diffusion at the temperature lower than 350°C is very weak it allows to obtain the nitrided layers of shallow thickness.
Plasma nitriding at low temperatures. Nitriding in plasma of glow discharge within the range of temperatures 400-500°C corresponds to modern engineering development providing maintenance of high strength of machined parts core [4].
Figure 1 using 38XM steel as an example shows comparison of test piece strength changing curves after plasma nitriding at the temperature of 450°C and 570°C. After 46 hrs of processing at the temperature of 450°C (curve 5) the depth of nitriding is almost same as after 24 hrs of processing at the temperature of 570°C although the character of their hardness change is different.

In case of processing at temperature of 450°C the hardness of surface is almost 150 HV higher. If for example the hardness of surface HV2 and plasma nitriding temperature relation is analyzed (Figure 2) it shows that (under condition of equal thickness nitrided layer) if the temperature of nitriding decreases the surface layer hardness increases.

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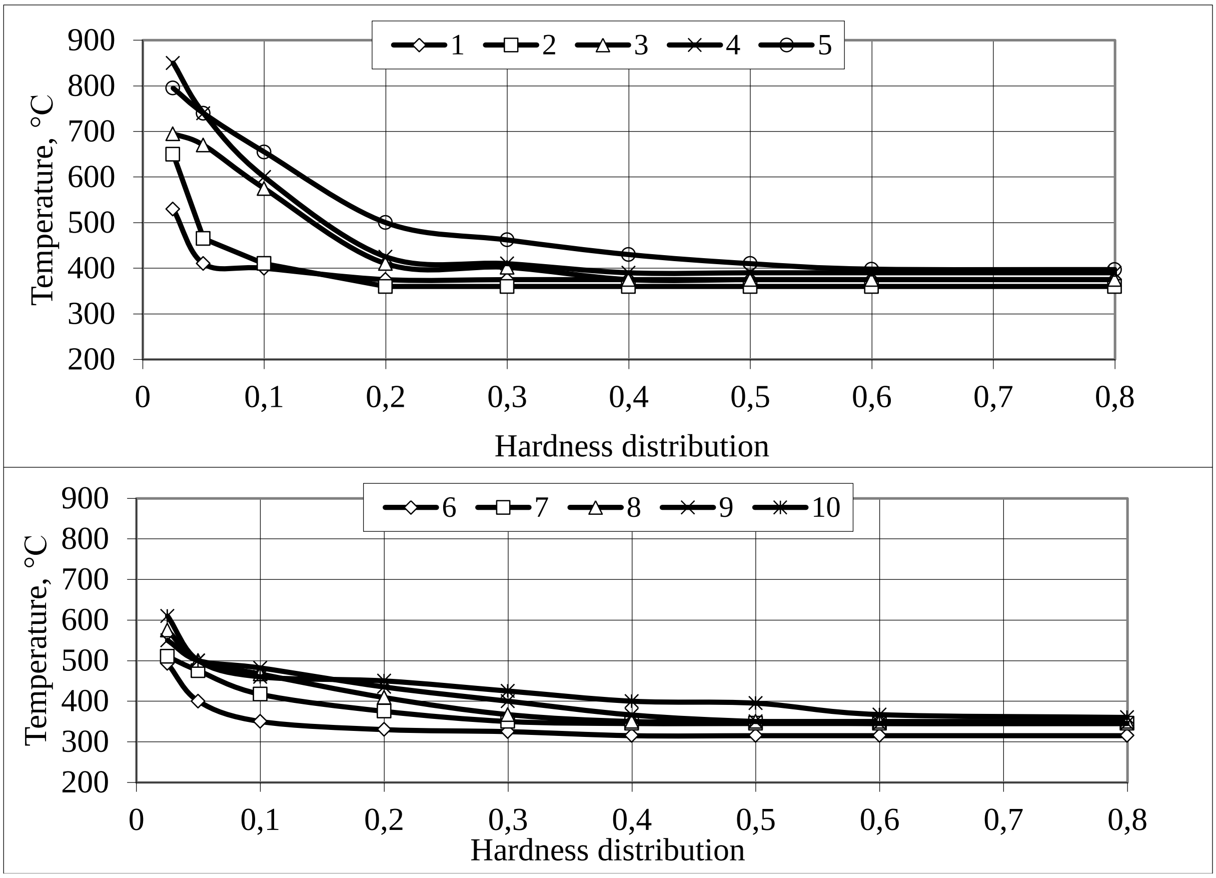

Figure 1. Influence of nitriding temperature on the value and distribution of hardness (steel 38XM). Plasma nitriding at the temperature of 450°C (1-5) and 570°C (6-10) within: 1 – 1 hr 20 min. 2 – 2 hrs., 3 – 9 hrs, 4 – 22 hrs. 5 – 46 hrs, 6 – 5 min, 7 – 30 min, 8 – 2 hrs 15 min, 9 – 8 hrs, 10 – 24 hrs.

The reason of the higher hardness is fine distributed complex nitrides appearing in perlite at low temperatures at a great amount.[5]

Durability of parts nitrided this way in the result of sliding friction, especially dry sliding, is shown in Figure 3. Degree of wear was defined as relation of mass loss and number of rotations.

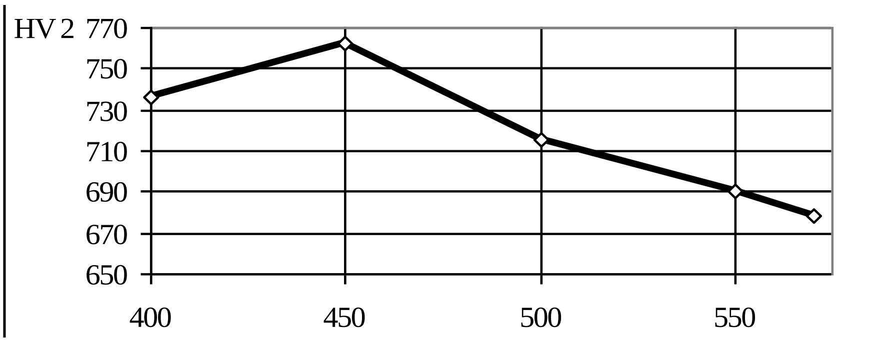

Figure 2. Hardness and temperature relation at equal nitriding depth (method of treatment – plasma nitriding, material steel 38XM).

Nitrided layers obtained at the temperatures of 450, 530 and 580 °C in the result of nitriding length change had the diffusion layer with thickness ~ 0,2 mm and nitride γ-layer with thickness 4-6 micron. Results show that lower wear of test pieces corresponds to lower temperatures of nitriding.

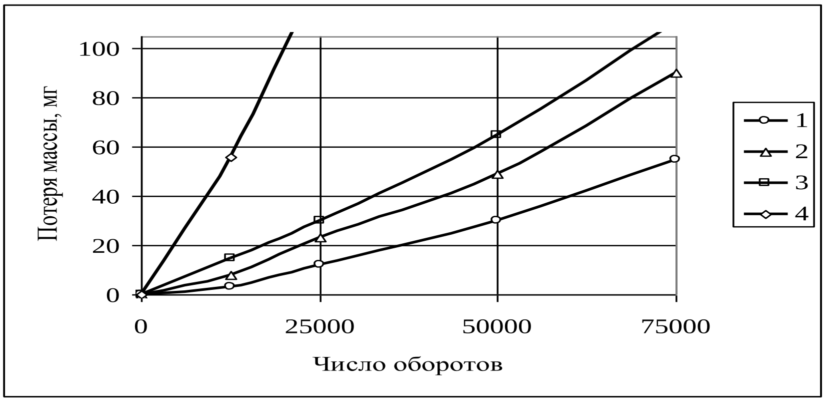

Figure. 3. Wear of steel 38XM after plasma nitriding at different temperatures (F = 196,2 H, vrel= 1,43 m/s, emergency operation test):1, 2, 3 – plasma nitriding at 450°C, 30 hrs; 530°C, 9 hrs and 580°C, 1 hr; 4 – improvement to σв = 1200 N/mm2.

5. Conclusion:

The research shows that nitriding temperature does not affect the depth of appearing hard layer but at the decrease in processing temperature the growth of surface layer hardness is observed. Structural analysis shows than file distributed complex nitrides having higher hardness appear in perlite at lower nitriding temperature. This in its turn affects the part durability which is increased.

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