

## The Peculiarities of Austenite Nickel-Chromium Steel Nitrogenization

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The influence of nitrogenization on steel 08X18H10 structure, hardness and wear resistance in subnormal discharge is investigated. Due to metallographic, roentgen and microroentgen-spectral analysis application it is established that increase of processing time in the upper part of nitride zone influence on nitride dissociation processes followed by reduction of hardness. The industrial tests showed that the nitrogenization enables to increase coal concentrate dewatering screen resistance in 1.5-2 times.

Keywords: NITROGENIZATION, SUBNORMAL DISCHARGE, DEWATERING SCREEN, WEAR RESISTANCE

### Introduction

Austenitic stainless steels, e.g. 18-8, 18-10 are widely used in ore-dressing, food-processing and chemical industry for production of details which are applied in corrosive effect conditions. Low wear resistance of these steels is their significant disadvantage. Different methods of surface hardening, particularly surface impregnation, are frequently used for wear resistance increase. However, passive film presence on the surface, low diffusion coefficient and formation of chemical compound layers in the definite systems, which are almost impenetrable for diffusion, complicate this task essentially.

Nitrogenization of stainless steels, primarily in the subnormal discharge, is the most prevailing method of surface impregnation [1-4]. While analyzing published materials, we noticed that nitrogenization of nickel-chromium steel is worse than that of other stainless steels [3-5]. Diffusion layer on these steels has less thickness that is especially noticeable with the increase of nickel content in the steel [4]. In this case nitrogenization effect on wear resistance is studied comparatively poorly.

In this work we investigated the effect of nitrogenization mode in subnormal discharge on the structure, hardness and wear resistance of steel 08X18H10.

### Results and Discussion

Cold-worked plate samples were nitrogenized in the installation HHB-6.6-И1 in the mixture of nitrogen and argon of different content. The processing temperature came up from 450 to 700 °C, period 1-50 h. Before the nitrogenization during the half of an hour there was performed samples cleaning by cathode spraying under the potential difference 1100-1300 V. Transversal metallographic samples were made on the obtained samples, on which structure and microhardness distribution along the layer deepness were studied. Phasic roentgen analysis was done on the device «ДРОН-3» in the iron radiation. The distribution of main alloying agents was studied on the analyzer «Camebax». Nitrogen content was determined on the apparatus TC-300. For this purpose the surface layer 0.5 mm thick was separated from the nitrogenized sample. The defined value was converted into the nitrogen concentration in the nitrogenized layer, the thickness of which was known. The density of the nitrogenized layer required for calculation was determined by the formula

$$\rho_{N_{\text{layer}}} = (\rho_{\text{steel}} + D_{\text{steel}} + \rho_{\text{steel}} - \Delta\rho_N)/D_N,$$

where  $\rho_{N_{\text{layer}}}$  is a density of the nitrogenized layer;  $\rho_{\text{steel}}$  is a density of the initial steel;  $D_{\text{steel}}$ ,  $D_N$  is the part of initial metal and nitrogenized layer in the sample in accordance;  $\Delta\rho_N$  is a

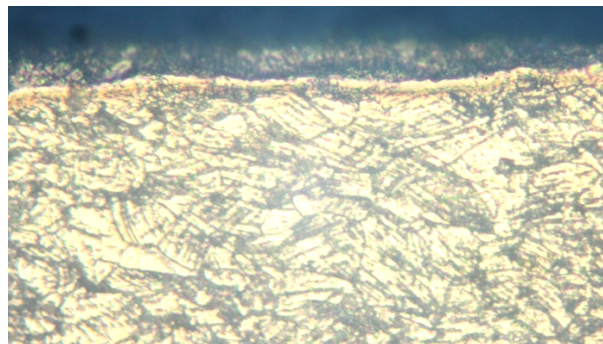
difference in the density of initial and nitrogenized steel.

The density of nitrogenized sample was determined hydrostatically, nitrogen content in the initial steel was neglected.

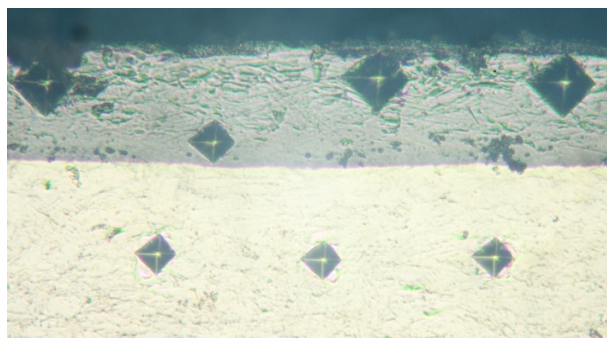
Wear resistance of the nitrogenized samples was determined in the conditions imitating hydroabrasive wear which is distinctive for mineral processing equipment details. The abrasive medium was presented by the carborundum grit

suspension with the grit 0.2-0.5 mm in the 3% sodium chlorine solution.

The nitrogenized layer consists of 2 zones: nitride and diffusional (internal nitrogenization zone). With the increase of the processing time diffusion zone forms firstly. It looks like a light stripe (phantom) because of low picklability (**Figure 1a**). Crystal boundaries, slide curves and compound crystals stay visible in this zone. Then nitride zone forms, which obtains grey colour under natal pickling (**Figure 1b**).



**a**

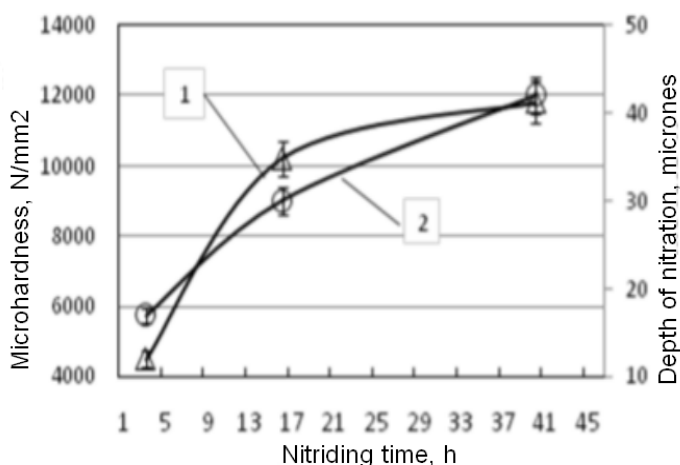


**b**

**Figure 1.** The nitrogenized layer on the sample processed under 580 °C, 1 h (a) and under 620 °C, 6 h (b), pressure 80-95 Pa, x 520

General depth of the nitrogenized layer increases accordingly to the increase of the processing time (**Figure 2**). Either maximal microhardness rises. However the measuring of the depth distribution along the layer depth showed that the microhardness of the upper part of the nitride zone decreases. However, measuring the distribution of microhardness over depth layer showed that with increasing duration of treatment over 2-3 h

microhardness of the top of the nitride zone continuously decreases (**Figure 1b, 3**). Raising the temperature of processing contributes to further decrease in hardness (**Figure 3**). Maximum hardness falls on a layer 5-10 microns thickness, which borders the diffusion zone. Towards the surface hardness decreases, minimum values are reaching of 500-700 N/mm<sup>2</sup>. In the nitride area pore and crack formation was not observed.



**Figure 2.** Dependence of the maximum microhardness (1) and the depth of nitration (2) on the nitriding time

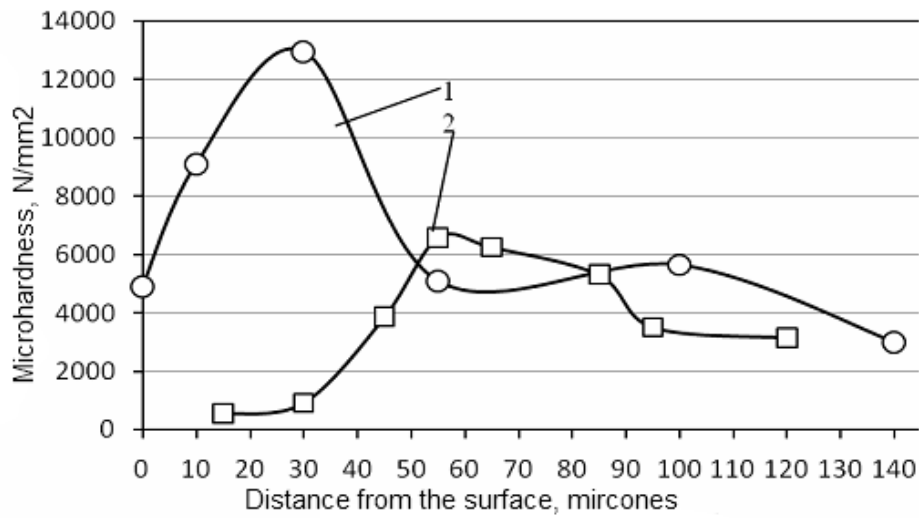
For comparison, samples of chromium steel 12H17 were nitrogenized by similar modes.

Microhardness measurements showed that at the top of the nitride zone of these steels hardness can

be reduced. However, the magnitude of reduction is 2000-4000 N/mm<sup>2</sup> with hardness in nitride zone 11000-13000 N/mm<sup>2</sup>. The depth of the layer is approximately equal to the depth of the chromium-nickel steel layer.

Such behavior of the hardness of the nitrided layer of chromium-nickel steel can be explained by the mechanism of layer formation [6, 7]. In accordance with this mechanism, nitrogen diffusing into the surface layer of the sample appears during the resolving of nitride laid-down

on the surface of the working space of the furnace. Nitrides formed by the reaction of metal atoms evaporated from the sample and nitrogen surface. Nitride, laid-down on the surface, is the layer with low hardness. However, according to this mechanism it is impossible to explain the monotonic increase in hardness of the sample surface before the diffusion zone (**Figure 3**). Apparently, the drop in hardness is the result of some processes in the nitride zone, which run parallel with the increase of the layer.



**Figure 3.** The change of microhardness over the samples depth of nitration treated by different modes 1 – 450 °C, 50 h; 2 – 630 °C, 5 h

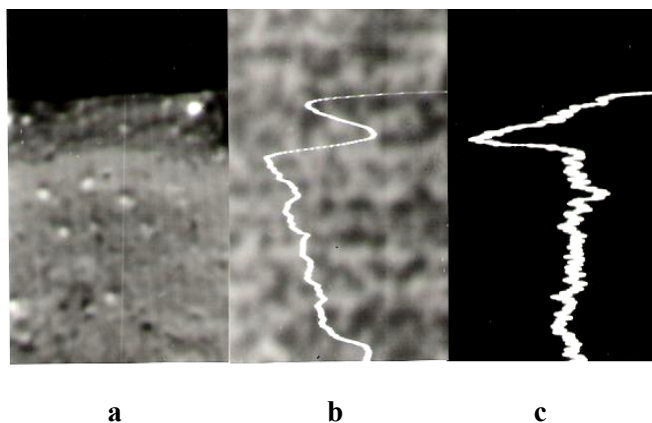
In order to study the phase and chemical composition of the nitrided layer samples were X-rayed. Determining the distribution of nitrogen in the depth of the layer was not possible. However, the analysis showed the presence of high concentrations of chromium in the nitride layer zone with a maximum microhardness (**Figure 4**).

Comparison of the concentration of chrome and iron distribution, as well as the microhardness over depth of nitration suggest rising diffusion of chrome in the layer with the maximum nitrogen content. Moreover, the diffusion flow is directed, apparently, from the surface into the sample. This conclusion is supported by a layer-by-layer X-ray analysis. The first survey conducted directly on the surface of the nitrided sample. Then the surface layers were cleansed by aqua regia. The value of the remote layer was determined by measuring the sample thickness with a «Mitutoyo» micrometer with an accuracy of 1 micron. The thickness of the nitride zone of the samples was 30 microns. The relative content of the phases was estimated by the integrated

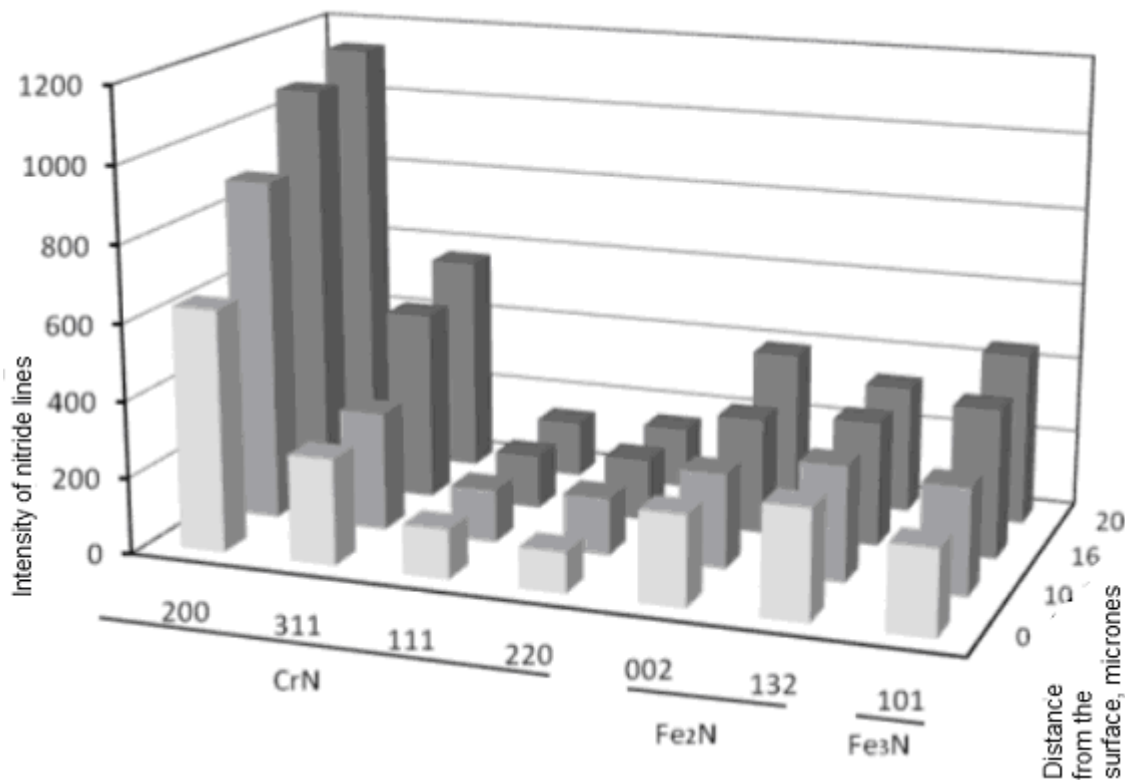
intensity of the lines. In the direction from the surface into the nitride zone nitride content increases (**Figure 5**). Mostly it is typical for nitride CrN.

Taking into account the data on the distribution of hardness over the depth of the samples layer nitrided at different modes (**Figure 3**), it would be logical to assume that with increasing of thickness of the nitride zone the average content of nitrogen in it should decrease.

Determination of the concentration of nitrogen in the nitrogenized samples (**Table 1**) showed that with increasing thickness of the nitride zone, the nitrogen content in it decreases. The increase of duration and, especially, temperature results in reduction of concentration of nitrogen. With the consideration of a fiber X-ray analysis, we can assume that it occurs as a result of the collapse of nitrides and nitrogen excretion in atomic and molecular form. The nitrogen, apparently, is removed into the atmosphere from the top of the nitride zone.



**Figure 4.** Cross-sectional image of the nitrided sample in reflected electrons (a, x 200), the distribution of iron (b) and chrome (c) on the depth of nitration, x 800



**Figure 5.** Change of the relative integrated intensity of the nitride lines on the depth of the nitride zone

**Table 1.** Nitrogen content in the nitride zone samples treated by different modes

Processing mode			Nitride zone thickness,	Nitrogen content in the nitride zone, %
P, Pa	T, °C	Duration, h		
80	450	50	29	7.91
80	580	3	30	9.53
120	600	3	42	4.12
80	620	3	51	3.31
95	640	6	65	5.42

**Table 2.** Specific wear of samples of steel 08H18N10 with different treatment, g/m<sup>2</sup>

Sample processing	Wear
Without processing	0,3447
Galvanic plating	0,2866
Nitriding in a glow discharge (the thickness of nitride zone is 45 microns)	0,177

In order to prevent the processes that lead to a drop in the hardness of nitride zone, the mode of nitration was changed: temperature, pressure, composition of the gas mixture. However, qualitatively the distribution of microhardness over the nitride zone of the samples remained unchanged (**Figure 3**).

Tests on hydroabrasive wear and tear showed that compared to the initial state resistance of nitrated steel 08X18H10 doubled. For comparison, test samples covered with electrochemically hard chrome 200 microns thick.

Laboratory results were confirmed by industrial tests. Nitrogenization was subjected to centrifuge rotors produced by "Techno Union Ltd.", for the dewatering of coal concentrate. Tests carried out on different concentrators, have shown that the resistance of nitrated rotors increased by 1.5-2 times.

## Conclusions

1. The decrease of the hardness of the nitride zone upper part to a minimum of 500-700 N/mm<sup>2</sup> is observed with the increase of nitriding steel 08X18H10 duration simultaneously with the growth of the nitrogenized layer. In this case the hardness gradually increases to a maximum values which is the distinctive features of the nitride and the diffusion boundary zones.

2. Number of chromy and iron nitrides near the surface of the nitride zone decreases. Dissociation is the most probable reason for it.

3. The nitrogen content in the nitride zone decreases with the increase of the nitride zone thickness.

## References

1. Yurgenson A.A. *Azotirovanie v energomashinostroenii*, M.: Mashinostroenie, 1962, 132 p. \*
2. *Ionnoe azotirovanie ferrito-perlitnoi i austenitnoi*

*stalyei v gazovykh razryadah nizkogo davleniya*, A.D.Korotaev, S.V. Ovchinnikov, A.N. Tyumentsev i dr., FHOM, 2004, № 1, P. 22-27. \*

3. *Vliyanie azotirovaniya na korrozionnyuyu stoikost nerzhavyeyushchih stalyei*, A.G. Andryeeva, L.YA. Gurvich, MiTOM, 1959, № 4, P. 34-40. \*

4. *Azotirovanie austenitnykh stalyei*, A.I. Nikonorova, F.R. Florensova, MiTOM, 1965, № 10, P. 16-18. \*

5. *Sravnienie metodov gazovogo, ionnogo i vakuumnogo azotirovaniya*, N.L.Anichkina, V.S. Bogolyubov, V.V. Boiko i dr., MiTOM, 1989, № 3, P. 9-12. \*

6. *Prikladnaya tehnika obrabotki poverhnosti metallicheskih materialov: per. s nem.*, G. Simon, M. Toma, Chelyabinsk: Metallurgiya, 1991, 368 p. \*

7. Krukovich M.G. *Modelirovanie protsessa azotirovaniya*, MiTOM, 2004, № 1, P. 24-31. \*

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## Особенности азотирования аустенитной хромоникелевой стали

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Исследовано влияние азотирования в тлеющем разряде на структуру, твердость и износостойкость стали 08X18H10. С применением металлографического, рентгеновского и микрорентгеноспектрального анализа установлено, что с увеличением длительности обработки в верхней части нитридной зоны развиваются процессы диссоциации нитридов, которые сопровождаются падением твердости. Промышленные испытания показали, что азотирование позволяет повысить стойкость сит для обезвоживания угольного концентрата в 1,5-2 раза.