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IMPACT OF IONIC NITRIDING ON WEAR RESISTANCE OF X12 STEEL IN CORROSIVE – ABRASIVE MEDIUM

The paper contains the results of experimental research of the impact of technological parameters of steel x12 ionic nitriding on the hardness and of the depth of nitration and its wear resistance in corrosive – abrasive medium. Regression equations that describe the impact of technological parameters of nitriding process on the properties of surface layer are obtained.

Key words: *wear, nitriding, extruder, steel.*

Introduction. Nitriding in glow discharge is the efficient technology of metals surface modification, that enables to modify the properties of surface layers (hardness, depth, phase composition, gradient of properties change) in wide range, that is very important for the improvement of operation characteristics of construction elements [1, 2]. Very promising is the technology and equipment for chemical and heat treatment of machine parts and tools in glow discharge in hydrogen – free media (mixture of nitrogen with argon) [3, 4]. Characteristic feature of the given technology is exclusion of hydrogenic embrittlement of metals in the process of diffusive saturation and increase of ductility characteristics of surface layers at the expense of different phases relation [5]. Properties of nitrided layer are controlled by 4 technological parameters: temperature of diffusive saturation, pressure in vacuum chamber, composition of saturating medium and time of nitriding. Theoretical and experimental studies [6] showed, that all the above-mentioned technological parameters of nitriding process have the impact on the properties of nitride layer. To provide maximum wear – resistance of friction couples in abrasive environment, surface layers must have high hardness and maximum depth. Besides, as the research showed [7], wear resistance of steels in abrasive medium is greatly influenced by metastable phases in the structure of the material.

Problem set up. Study of the impact of technological parameters of steel x12 ionic nitriding on the hardness, depth and wear resistance of nitrided layer in corrosive –abrasive medium.

Main material. Ionic nitriding of the specimen, made of steel x12 was carried out in hydrogen – free media at special installations [4], developed by Khmelnytskiy National University. Theoretical and experimental studies of ionic nitriding process of metals [3, 5, 6] show that for the greater part of structural steels high hardness is achieved at the temperatures of 560 – 580 ^{O}C, and maximum depth of nitride layer is obtained, when the process of diffusive saturation lasts 6 – 8 hours. That is why, in order to reduce the number of experiments in the process of study the properties of nitride layer and wear of nitrided specimen two factor rotatable design of the second order [8]. In the process of study the following factors changed: composition of saturated medium within the range of 29 – 71 %, pressure in vacuum chamber within the range of 55 – 225 Pa. Duration of nitriding and the temperature were fixed and were 240 min and 570 ^{O}C, correspondingly.

Study of wear resistance of the specimen was carried out in the medium of the ПС68-30 polymer, filled with glass melt, at the special friction machine [9], that simulated the extruders operation conditions.

Mathematical model of the investigated values dependence on the technological parameters of nitriding process is written by regression equation – polynomial of the second order [8]:

$$y = b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_{12} \cdot x_1 \cdot x_2 + b_{11} \cdot x_1^2 + b_{22} \cdot x_2^2, \qquad (1)$$

where $b_1, b_2, b_3, b_{12}, b_{11}, b_{22}$ – coefficient of regression; x_1, x_2 – variable factors, that take into account the impact of the pressure in vacuum chamber and content of argon in saturating medium, $x_1 = \frac{P-140}{60}$, $x_2 = \frac{Ar\% - 50}{15}$.

Table 1 contains the results of experimental research of hardness and depth of nitride layer of steel x12, depending on the modes of ionic nitriding in hydrogen – free media.

Proceeding from the results of the research, according to two factor rotatable design of experiments carrying out the empirical mathematical dependences of surface hardness (H_{100}) and depth of nitrited layer (h) on the content of argon in saturating medium and pressure in vacuum chamber of the studied steels described by regression equation (2 and 3) have been obtained.

h(μm) = 130.4 +49.6 x1 - 22.5 x2 -7.0 x1x2 -10.4 (x1)2 -5.6 (x2)2, (2)

H100(MPa)=9050+284.8 x1-301.2 x2-150 x1 x2-56,5 (x1)2-320.2 (x2)2. (3)

Table 1

Dependence of microhardness and the depth of nitrited layer on the modes of ionic nitriding of various steels

Number of mode	Technological parameters of nitriding		Steel X12	
	P, Pa	Ar,%	Microhardness H_{100}, MPa	Depth of nitrited layer , μm
1.	200	65	9700	134
2.	200	35	9500	192
3.	80	65	7800	50
4.	80	35	7000	80
5.	140	71	8600	88
6.	140	29	8450	150
7.	225	50	8350	178
8.	55	50	7250	40
9.	140	50	7800	130
10.	140	50	7780	128
11.	140	50	7900	133
12.	140	50	7850	131
13.	140	50	7910	127

Graphs of dependence of nitrided layer hardness on technological parameters of nitriding process in hydrogen – free media of steel x12 (Fig. 1) are constructed on the base of regression equations.

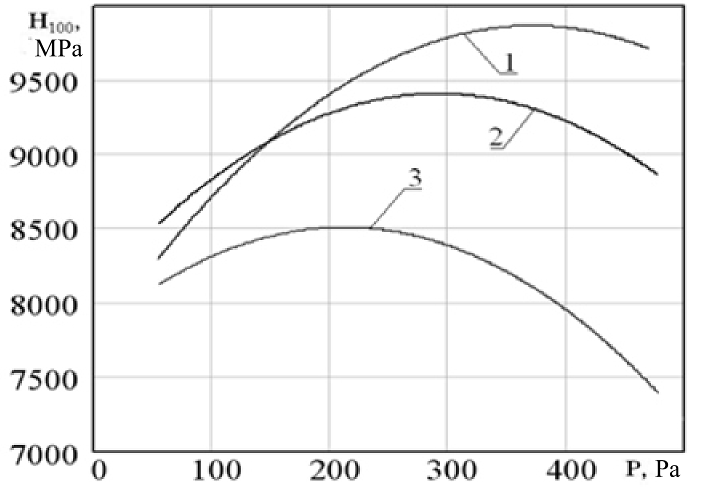

Fig. 1 Dependence of the hardness of nitrided layer surface on technological parameters of ionic nitriding process in hydrogen – free media of steel x12
1 – Ar 35%, 2 Ar 50%, – 3 – Ar 65%

It is seen from Fig. 1 that technological parameters of ionic nitriding greatly influence the hardness of nitrided layer surface. Dependences of surface hardness on the pressure in vacuum chamber and volume content of argon in saturation medium (mixture of nitrogen with argon) are of extreme character with the expressed maximums. For different steels there exist optimal values of these parameters, when the highest microhardness is achieved. For steel x12 maximal micro hardness is achieved, when the value of pressure is 360-370 Pa and content of argon is 38 – 42 %.

Modes of ionic nitriding influence greatly the character of microhardness distribution along the depth of nitrided layer, as it is seen in Fig. 2. Nitriding modes 1 for steel x12 provide high hardness of the surface due to formation of nitride layer and large gradient of microhardness change along the depth of nitrided layer. In case of mode 4 of steel x12 nitriding microhardness of its surface is far less because nitride zone is absent, in this case change gradient of the hardness along he depth of nitrided layer is the least.

Thus, changing nitriding mode, we may change not only the hardness of the surface but also distribution of the hardness and its gradient along the depth of nitrided layer.

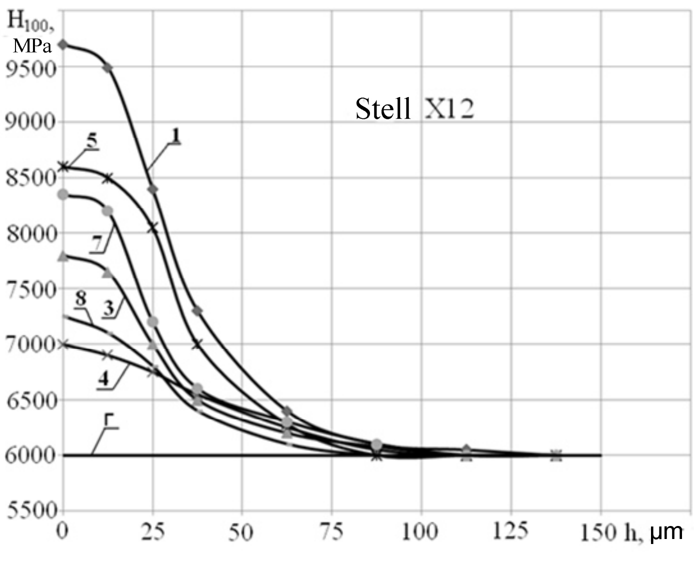

Fig. 2. Distribution of the hardness along the depth of nitrided layer of steel x12 after ionic nitriding, applying modes 1 - 8 (Table 1). Г – steel X12 after hardnening from the temperature 1150°C

Applying equation (1) and data from the Table 2, graphs of dependence of nitrided layer depth for the investigated steels depending on the composition of saturating medium and pressure in vacuum chamber can be built, on the base of these graphs optimal modes of ionic nitriding that provide maximum depth of hardened layer are found. Optimal modes of nitriding were achieved for steel x12 at the pressure 310 – 320 Pa and 12 – 17 % of argon content. The greatest depth of nitrited layer at optimal mode for steel x12 is 225μm.

On the base of investigation results, according to two factor rotatable design emperical mathematic dependence (4) of steel x12 wear on technological parameters of ionic nitriding is obtained:

$$U_{(\mu m)} = 87{,}7 - 33{,}5\,x_1 - 6{,}6\,x_2 + 2{,}0\,x_1 x_2 - 0{,}5\,(x_1)^2 + 22{,}2\,(x_2)^2 \qquad (4)$$

On the base of the equation (4) the graph (3) of wear dependence on technological parameters of ionic nitriding of steel is constructed. It is seen from the graphs (Fig. 3) that minimal wear for steel x12 is achieved at the pressure in vacuum chamber 200 Pa and volume content of argon 52 – 55 %.

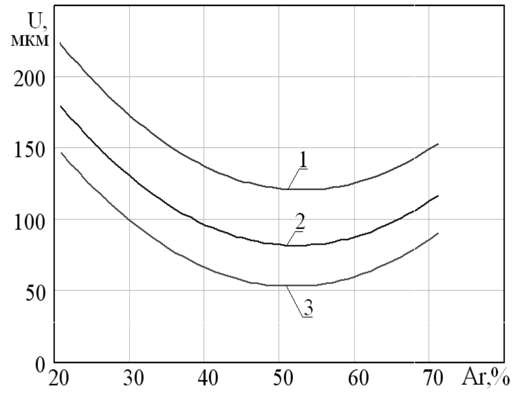

Fig. 3. Dependence of the wear on technological parameters of ionic nitriding process in hydrogen-free medium of steel X12 at the pressure: 1 – 80 Pa; 2 – 150 Pa; 3 – 200 Pa

Optimal mode of ionic nitriding by the criterion on maximum wear resistance for the studied steel x12 is: temperature T=570 ^{O}C, time of diffusive saturation τ=240 min, pressure P=200 Pa, content of argon in saturation mixture Ar%= 53 %.

Conclusions. Thus, study of steel x12 after nitriding has shown, that ionic nitriding in hydrogen free media allows to change the properties of the surface layer in wide range, that can be optimized by operation properties, we are interested in, and also optimize technological parameters of strengthening process by the criterion of maximum wear resistance.

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