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Some aspects of the nitriding process of parts in machine construction

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Abstract. Nitriding is the most common and effective surface hardening method. Such chemical-thermal treatment is capable of increasing surface hardness, contact endurance, wear and seizure resistance, as well as heat resistance and corrosion resistance of a wide range of machine parts. This process of surface hardening has found its application in many branches of modern mechanical engineering. The operational requirements for the parts led to the need to replace high-temperature methods of chemical-thermal treatment (carburizing, high-temperature nitrocarburizing, etc.) for hardening processes at lower temperatures (500-650° C), namely nitriding. This replacement was facilitated by the latest technological developments in the field of various nitriding methods. The scientific developments obtained to date make it possible to gradually eliminate such disadvantages of nitriding as a significant duration of the process, increased fragility of the surface layer, insufficient values of contact endurance, and labor intensity of the process [1, 2].

1. Introduction

Nitriding is the most common and effective method of surface hardening. Such chemical-thermal treatment is capable of increasing surface hardness, contact endurance, wear and seizure resistance, as well as heat resistance and corrosion resistance of a wide range of machine parts. This process of surface hardening has found its application in many branches of modern mechanical engineering. The operational requirements for the parts, came to the conclusion to replace high-temperature methods of chemical-thermal treatment (carburizing, high-temperature nitrocarburizing, etc.) for hardening processes at lower temperatures (500 - 650 ° C), namely nitriding. This replacement was facilitated by the latest technological developments in the field of various nitriding methods. The scientific developments obtained to date make it possible to gradually eliminate such disadvantages of nitriding as a significant duration of the process, increased fragility of the surface layer, insufficient values of contact endurance, labor intensity of the process [1 - 3]. Despite the fairly widespread use of the nitriding process in the practice of various areas of mechanical engineering, there are still a lot of unresolved issues associated mainly with the mechanism of structure formation in the formation of a diffusion layer [2 - 6]. It is the structural features of the nitride layer and the matrix itself that determine the performance of machine parts and, consequently, the choice of steels, pretreatment technologies and the nitriding technology itself. Therefore, today the prediction and modeling of the formation of structure and properties in the diffusion layer during nitriding is a rather urgent problem [7 - 9].

2. Modeling the processes occurring during nitriding

Modeling the processes occurring during nitriding is the most effective method for developing a technological process. The use of computational methods makes it possible to obtain rather promptly information about the main properties of the hardened layer, about the rate of diffusion and structures of forming processes, about the formation of nitride and carbon nitride layers with varying temperature and time regimes. Simulation of various nitriding processes makes it possible for a simple and prompt solution of many technological problems to control and manage saturation modes of diffusion layers, predict the final results and the possibility of developing innovative processing modes. At the same time, taking into account the complexity and high cost of carrying out a large number of experiments makes mathematical modeling of nitriding processes a particularly promising research method. Mathematical models describing the dependences of the depth of the nitride layer and surface hardness on the values of temperature and duration of chemical-thermal treatment of steel during ionic nitriding can be represented as a polynomial of the second degree [1, 3]:

$$y_i = b_0 + a_1x_1 + a_2x_2 + a_3(x_1^2 - \beta) + a_4(x_2^2 - \beta) + a_5x_1x_2 \quad (1)$$

where - a_i are the estimated coefficients, β – is the parameter calculated depending on the number of points of the core of the compositional plan 2n-p, the shoulder of "star" points α and the number of points in the plan by the formula:

$$\beta = \Sigma_{j=1}^{N} \quad (2)$$

The procedure for estimating the coefficients of the model, checking its adequacy and statistical analysis of accuracy are given in [1, 2]. The resulting model of the depth of the hardened layer, depending on the normalized values of temperature and duration of chemical heat treatment, has the form:

$$y = 295{,}55556 + 42{,}5085 \cdot x_1 + 280{,}056 \cdot x_2 - 9{,}211 \cdot x_1^2 + 33{,}289 \cdot x_2^2 + 13{,}75 \cdot x_1 \cdot x_2$$

The procedure for estimating the coefficients of the model, checking its adequacy and statistical analysis of accuracy are given in [1, 2]. The resulting model of the depth of the hardened layer, depending on the normalized values of temperature and duration of chemical heat treatment, has the form:

$$y = 295{,}55556 + 42{,}5085 \cdot x_1 + 280{,}056 \cdot x_2 \quad (3)$$

The mathematical model describing the effect of the temperature and duration of nitriding on the values of the surface hardness of the nitride layer, in general form, is represented as follows

$$y = 9{,}8 - 0{,}8335 \cdot x_1 + 1{,}30026 \cdot x_2 + 0{,}09853 \cdot x_1^2 - 0{,}80147 \cdot x_2^2 - 0{,}75 \cdot x_1 \cdot x_2$$

Checking the significance of the coefficients showed that the coefficient *a3* can be considered insignificant, therefore, the model is converted to the form:

$$y = 9{,}8 - 0{,}8335 \cdot x_1 + 1{,}30026 \cdot x_2 - 0{,}80147 \cdot x_2^2 - 0{,}75 \cdot x_1 \cdot x_2 \quad (4)$$

Response surfaces in factor space in a given planning area are presented in [2, 3].

3. Wear on the nitride surface

One of the reasons for the failure of many parts is the wear of the working surfaces during operation in friction units. To solve this problem, expensive materials are used, which are necessary for the manu-facture of parts, with high hardness, wear resistance, etc. Experimental data on the determination of the hardness and thickness of nitride surface layers of steels of different grades by the nanoindentation