Improving the operating properties of parts of titanium alloys by surface hardening in high density plasma of glow discharge

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Abstract. The computer model that allows predicting the temperature distribution during local ion nitriding with hollow cathode effect (HCE) and depth of the diffusion zone after the treatment of part “lever of downhole profilometer” was developed. The influence of the HCE on the temperature distribution for the part was studied.

1. Introduction

Ion nitriding in glow discharge is one of the most common methods machine parts surface hardening [1,2]. Usually parts are subjected to local wear and therefore their operating properties are determined by hardening of work surfaces.

Nitriding of titanium alloys is more difficult due to formation of solid nitride layer that noticeably slows diffusion process. Using hollow cathode effect (HCE) allows intense sputtering nitriding layer by argon ions during the process [3,4]. But it leads to uneven heating of part to be treated. It is known that the temperature is the critical factor affecting the nitrogen diffusion into steel and diffusion zone formation of the nitrided case [5,6]. To ensure effective saturation, treatment is usually carried out at temperature about 700°C. Nowadays, modeling heating and diffusion processes during nitriding is an important task. Investigating and understanding processes occurring in the near-surface material of the part would give the possibility of using optimal process parameters and increasing nitriding efficiency.

In this paper the results of computer modeling of ion nitriding process with HCE of part “lever of downhole profilometer” are presented.

2. Methods of study

Calculations were performed with a help of differential equations solver software. Theoretically model of ion nitriding process is based on heat equation and Fick’s equation [7].

The part to be modelled is lever of downhole profilometer. Titanium alloy VT6 is used for this part. Lever is subjected to intense local wear due to friction on downhole walls. Thus, only operating area of part surface is affected by HCE.

To determine the influence of ion nitriding with HCE on depth of hardened layer, samples of VT6 alloy were nitrided. Sputtering was performed in argon during 15 min at pressure of 10 Pa of argon, temperature of the surface was not larger than T=250°C. Ion nitriding was carried in solution of argon, nitrogen (Ar 85%, N₂ 15%). Samples were nitrided in plasma of glow discharge at the temperature T=700±10°C during 8 h.

Olympus GX-51 microscope was used to obtain the microstructure photos. Measurements of microhardness were carried out on microhardness tester Micromet-5101.
3. Results and discussing

Temperature distribution was obtained as the result of model calculation. Temperature of the lever surface after 8h of local ion nitriding with HCE is presented at figure 1. Temperature of operating surface is about 700°C.

![Figure 1. Calculated temperature distribution of the lever surface during nitriding process.](image1)

Calculations show maximum of temperature difference between affected and unaffected by HCE zones of about 33°C.

Heating temperature curves in two points of part surface are presented in figure 2 (point 1 and point 2, figure 1), obtained by modelling.

![Figure 2. Temperature curves of points 1 and 2 of lever surface.](image2)

Presented graph (figure 2) shows that time of reaching process temperature is about 2 minutes.

To study diffusion processes and estimate case depth of nitride layer after treatment, distribution of nitrogen concentration through surface layer was investigated (figure 3).
Modelling shows that distribution of nitrogen concentration in surface layer of material was obtained to estimate hardened case depth (figure 3). Modelling shows that nitriding with HCE during 8 hours leads to formation of 130-160 μm hardened diffusion layer.

Figure 4 shows microstructure of nitrided case of alloy VT6 after ion nitriding with HCE.

![Microstructure of nitrided case of alloy VT6 after ion nitriding with HCE](image)

**Figure 4.** Microstructure of nitrided case of alloy VT6 after ion nitriding with HCE (I – nitride layer, II – diffusion zone, III – core material).

20 μm depth solid nitride layer (I) and diffusion zone (II) are observed. Microhardness profile was obtained to determine the depth of hardened case (figure 5).
Hardened case depth is about 120 µm. Thereby, a good agreement between modelling and experimental data were obtained.

4. Conclusions
Presented computer model allows predicting the temperature distribution in Lever of downhole profilometer during local ion nitriding with HCE and depth of the diffusion zone after the treatment.

Lever heats up to process temperature 700°C during about 2 minutes, after that the surface temperature remains constant to the end of the process. Maximum of temperature difference on lever surface is 33°C because of uneven heating rate of different surface areas.

It is established that case depth after ion nitriding with HCE of VT6 alloy is about 120 µm.

References
[1] Zinchenko V M 2001 Surface engineering gears methods of chemical-thermal treatment (Moscow: Publishing House of the MSTU N.E. Bauman)
[2] Kozlovski I S 1970 Chemical heat treatment of gears (Moscow: Mashinostroenie)
[3] Budilov V V, Agzamov R D, Ramazanov K N 2007 Technology ion nitriding in glow discharge with a hollow cathode Metal science and heat treatment 49 358–361
[4] Budilov V V, Ramazanov K N, Khusainov Yu G, Zolotov I V 2014 Perspectives of using of hollow cathode effect for local ion nitriding of parts from steel 16Kh3VFMB-Sh Vestnik UGATU 62 32–36
[5] Gerasimov S A, Kuksenkova L I, Lapteva V G 2012 Structure and wear resistance of design steels and alloys (Moscow: MGTU im. Bauman)
[6] Lakhtin Yu M, Kogan Ya D 1976 Nitriding steel (Moscow: Mashinostroenie)
[7] Kogan Ya D, Kolachev B A, Levinskiy Yu V 1987 Constant interaction of metals with gases (Moscow: Metallurgiya)
[8] Isachenko V P 1975 Heat transfer. Textbook for high schools (Moscow: Energiya)