NITRIDING, OXIDATION AND CARBURIZATION OF TITANIUM AND STEELS IN NON-SELF MAINTAINED GASEOUS DISCHARGE

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The samples of stainless steel (SS), high speed steel (HSS) and titanium (Ti) were exposed to fluxes of ions N^+, O^+, and $C_mH_n^+$ which have been ejected from hollow anode into hollow cathode (vacuum chamber). It has been found that the oxidation of Ti is going faster than the nitriding does. The surface microhardness of samples treated by fluxes of ions in non-self maintained gaseous discharge grows from 1.5 for HSS (except the carburization) to 6 times for Ti and SS.

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INTRODUCTION

Non-self maintained gaseous discharge where the vacuum arc plasma gun is used as a source of supplementary charges has been successfully applied for nitriding of high speed steel cutting tools [1-4]. The hardness of instrument enhance to 1400 HV, the thickness of nitriding layer grows with a speed of 1 μ/min and reaches up to dozens of microns. In [5] it has been reported about the non-self maintained gaseous discharge with a hollow anode. At standard vacuum arc apparatus this type of discharge allows obtaining a dense flux of gaseous ions with a current density of 30÷40 mA/cm^2 and higher. The energy of ions can be varied by changing the voltage between the hollow anode and vacuum chamber.

The goal of this paper is to provide a surface hardening of stainless steel (SS), high speed steel (HSS) and titanium (Ti) through action of directed ion fluxes of N^+, O^+, and $C_nH_m^+$ generated in non-self maintained discharge with a hollow anode.

1. EXPERIMENTAL APPARATUS AND METHOD

The "Bulat", a plant for vacuum arc deposition, has been used for experiments. The scheme for generation of dense flux of ions in non-self maintained gaseous discharge with a hollow anode has been presented in [5]. The specimens of SS, HSS and Ti with dimensions of 20×10×2 (in millimeters) have been attached in various ways to the walls of stainless steel tube with a 25 mm inside diameter and with a length of 120 mm. The first group of samples has been attached to frontal part of tube, so that its surface was oriented normal to the ion flux. The second group was oriented tangentially to ion flux, Fig. 1. Additionally, the third group of samples was placed inside the tube, out of ion flux. The tube could be rotated so that the frontal samples periodically came and went away from ion flux. The temperature of the tube could be varied by applying to it a negative potential of 100÷500 Volts and has been measured with pyrometer Optris P20. The process time for all samples was 20 min. The hardness of the samples has been measured using a PMT-3 hardness tester. The hardness in a depth of the sample has been defined as an average of 10 measurements performed at equal distances from the surface at a microsection of the sample.

Fig. 1. Stainless steel tube with the samples in ion flux

2. RESULTS

2.1. TREATMENT OF SURFACES ORIENTED PERPENDICULAR TO THE ION FLUX

As can be seen from Table, the microhardness of samples treated with the perpendicular to its surface flux of ions grows from 1.5 for HSS (except the carburization) to 6 times for Ti and SS. The oxidation of Ti is going faster then the nitriding does (Fig. 2). A depth of nitriding or oxidization reach up to 10…20 μm, that corresponds to the speed of forming of hardening layer 0,5…,0 μm /min. The back sides of samples are hardening too (see Figs. 3 and 4) despite of its close overlapping to the tube wall.

Microhardness SS, HSS, and Ti after 20 min of exposition to fluxes of N^+, O^+ and $CnHm^+$

Material		SS	HSS	Ti
Initial microhardness, GPa		2.2	9.0	1.9
Microhardness, GPa, after:	Nitriding	14.0	14.0	8.0
	Oxidation	4.5	14.0	11.0
	Carburization	5.6	9.0	9.0

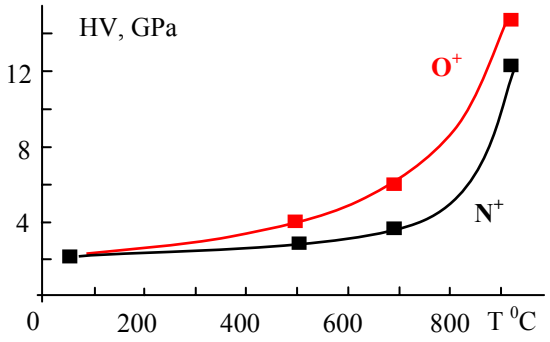

Fig 2. Microhardness of Ti plate versus temperature after 20 min treatment with ions of N^+ and O^+

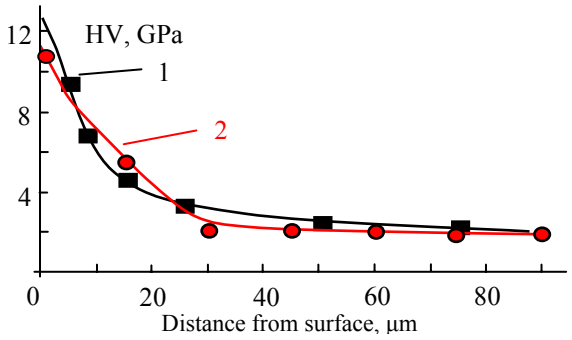

Fig. 3. Microhardness of Ti plate versus a distance from surface after 20 min of oxidation. T=900 ^{0}C. 1 – side turned to stream of ions; 2 – back side

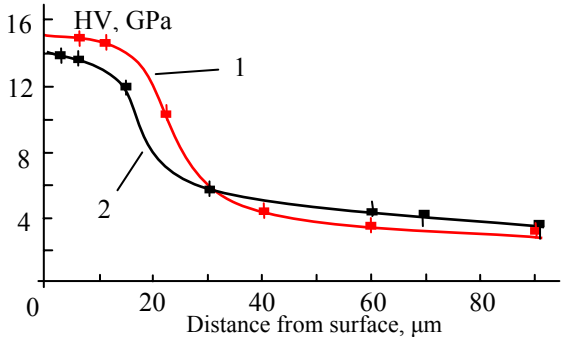

Fig. 4. Microhardness distribution along a depth in stainless steel sample after 20 min of nitriding at 700 ^{0}C. 1 – side turned to stream of ions; 2 – back side

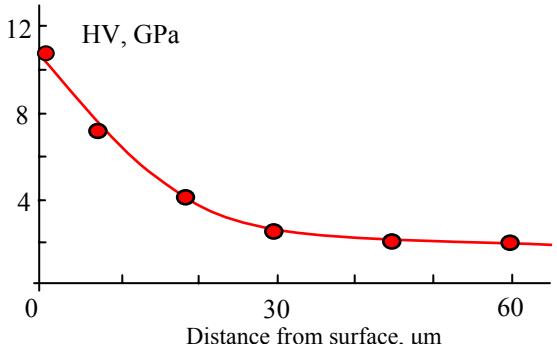

Fig. 5. Microhardness distribution along a depth after 20 min of nitriding at 900 ^{0}C in Ti plate that was rotated periodically leaving the area of N^+ ion flux

2.2. NITRIDING AND OXIDATION IN TANGENTIAL ION FLUX

The Figs. 6 and 7 show that the nitriding or oxidation is more effective if the ion flux is directed tangential to the treated surface. The rate of formation of nitrided layer is about 10 times higher than in the normal to the surface ion flow. Perhaps, it occurs due to less energy load applied to the surface as compared to the case of perpendicular flow. This, in turn, reduces the rate of TiN layer forming at the Ti surface that is an obstacle for the diffusion of nitrogen in titanium.

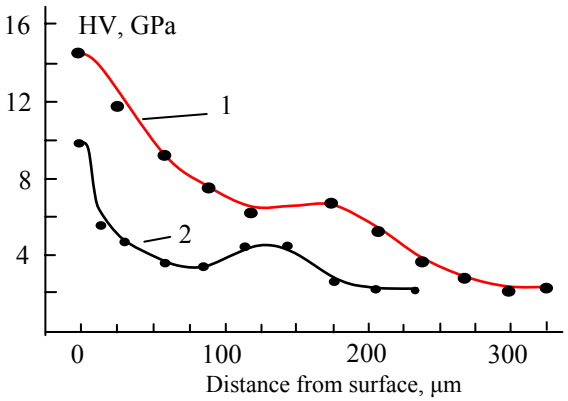

Fig. 6. Microhardness distribution along a depth in Ti sample after nitriding at 900 ^{0}C during 20 min. 1 – the side turned to stream of ions; 2 – back side

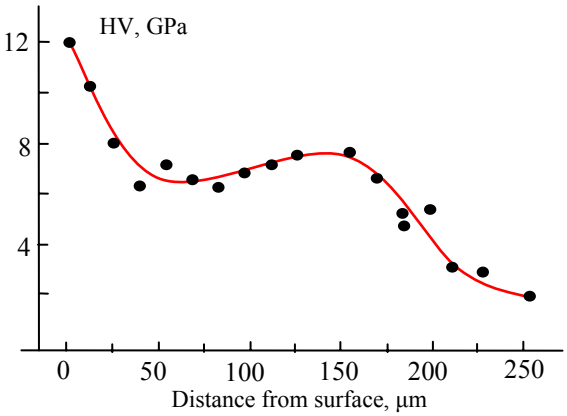

Fig. 7. Microhardness distribution along a depth in stainless steel plate after 20 min of oxidization at 700 ^{0}C

2.3. NITRIDING AND OXIDATION OF INNER WALL OF TUBE

To simulate nitriding (oxidation) of inner wall of titanium tube, the titanium plates was placed inside a stainless steel tube in its center. In this case, near the surface of the sample are neither ions nor the electric field. Nevertheless, the Figs. 8 and 9 testify that the processes of nitriding or oxidation take place even when the treated surface is in the shadow of the ion flux. This confirms a point of view [6] according to which for the successful nitriding (oxidization) it is enough the presence of excited atoms of nitrogen (oxygen) and suitable temperature. A relatively small a depth of the hardened layer indicates that the concentration of excited atoms inside of tube is much lower than that is outside of it.

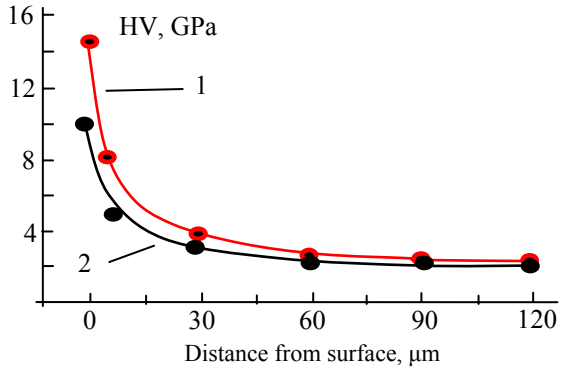

Fig. 8. Ti plate is placed inside of tube. Microhardness distribution along a depth after 20 min of nitriding at 800…900 ^{0}C. 1 – Side turned to the axis of tube; 2 – side turned to the wall of tube

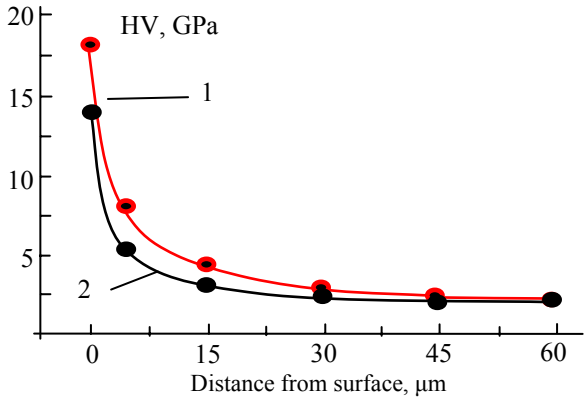

Fig. 9. Ti plate is placed inside of tube. Microhardness distribution along a depth after 20 min of oxidization at 800…900 ^{0}C. 1 – Side turned to the axis of tube; 2 – side turned to the wall of tube

CONCLUSIONS

The most interesting result of this work is an extremely high speed of nitriding or oxidation in tangential flux of ions produced in non-self maintained discharge. It reaches almost 10 μm/min (Figs. 6, 7). Despite the hardness at a depth of 50 μm and dipper is less than at the surface, it continue to be quit high and is near 3…3,5 times more than the origin material has. Thus, by orienting the surface that being treated in the optimal way, we can significantly increase the rate of the process of hardening of material. The results presented suggest that the non-self maintained discharge with a hollow anode may be an effective instrument for giving the useful properties to products from titanium and steels.

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АЗОТИРОВАНИЕ, ОКСИДИРОВАНИЕ И КАРБИДИЗАЦИЯ ТИТАНА И СТАЛЕЙ В НЕСАМОСТОЯТЕЛЬНОМ ГАЗОВОМ РАЗРЯДЕ

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Образцы из нержавеющей стали (SS), быстрорежущей стали (HSS) и титана (Ti) подвергались воздействию потоков ионов N^+, O^+, и $C_mH_n^+$, которые эжектировались из полого анода в полый катод (вакуумную камеру). Найдено, что процесс оксидирования титана идет с большей скоростью, чем азотирование. Поверхностная микротвердость образцов, обработанных потоками ионов в несамостоятельном газовом разряде, увеличивается от 1,5 для быстрорежущей стали (за исключением карбидизации) до 6 раз для титана и нержавеющей стали.

АЗОТУВАННЯ, ОКСИДУВАННЯ ТА КАРБІДИЗАЦІЯ ТИТАНУ І СТАЛЕЙ В НЕСАМОСТІЙНОМУ ГАЗОВОМУ РОЗРЯДІ

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Зразки з нержавіючої сталі (SS), швидкоріжучої сталі (HSS) і титану (Ti) були піддані дії потоків іонів N^+, O^+ і $C_mH_n^+$, які ежектувалися з порожнистого анода в порожнистий катод (вакуумну камеру). Знайдено, що процес оксидування титану йде з більшою швидкістю, ніж азотування. Поверхнева мікротвердість зразків, оброблених потоками іонів в несамостійному газовому розряді, збільшується від 1,5 для швидкоріжучої сталі (за винятком карбідизації) до 6 разів для титану і нержавіючої сталі.