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THE VT1-0 AND Zr-1%Nb ALLOYS OXIDATION IN THE CONTROLLED RAREFIED OXYGEN-CONTAINING MEDIUM

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Summary

The possibility of strengthening of VT1-0 titanium and Zr-1%Nb zirconium alloys by solid solution in rarefied controlled environment, oxygen containing, was shown. The impact of differences in partial pressure of oxygen on the gradient of strengthening nearsurface layers, weight gain and surface roughness of VT1-0 and Zr-1%Nb alloys was investigated.

Keivords: titanium-zirconium alloys, oxygen containing medium

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Introduction

Through a combination of unique physical and mechanical properties of titanium and zirconium alloys are widely used in various industries [1-4]. A common feature of these metals is high reactivity with interstitial elements (in particular oxygen), which leads to saturation solid solution hardening of near surface layers of the metal. It should be noted that the saturation of these materials and hence solid solution hardening occurs during processing or operational heating, thermal or chemical-thermal treatment (CTT) [5-11]. In this case, the metal layer is formed by a subsurface gas saturated certain depth with a gradient of oxygen concentration, and then the hardness gradient. Since the gas-saturated layer is characterized by increased hardness, it is called a hardened layer. That is, we have to deal with so-called solid-solution strengthening near surface layers of metal. Gas-saturated layer affect the performance properties of products in general, so when choosing a mode of heat treatment (temperature-time gas-dynamic parameters and environment) should take into account the interaction of these alloys with the elements of the Incarnation and to predict the consequences of its impact on the performance of the article. In recent years, interest in this subject is growing again, due to an extension of the construction materials, the exhaustion of the traditional and the search for new methods to increase the performance properties of the products.

Purpose - to establish patterns of treatment effect in a controlled oxygen-containing environment on physical and mechanical properties of VT1-0 titanium and Zr-1%Nb zirconium alloys.

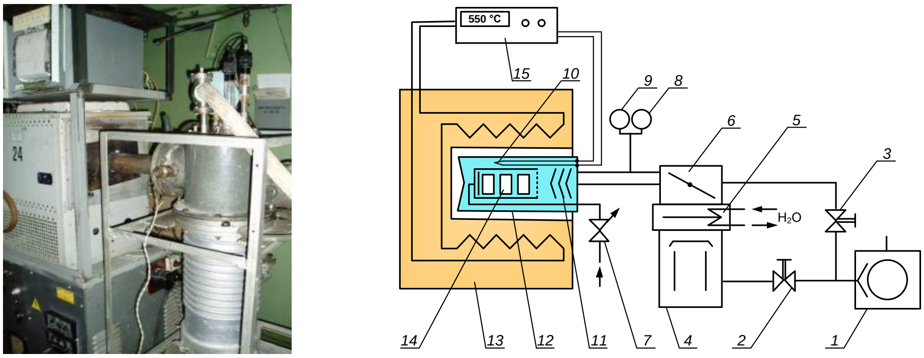
MATERIALS AND METHODS

As prototypes used plate thickness ~ 1 mm of technically pure titanium alloy VT1-0 and zirconium alloy Zr-1%Nb.

Subsurface gas-saturated layer is formed by diffusion saturation of oxygen containing gas environment controlled by different modes (Table. 1). Chemical heat treatment of alloys VT1-0 and Zr-1%Nb performed on laboratory thermal equipment (Figure 1) without sinters the reaction chamber.

Table 1 Regimes chemical-thermal treatment VT1-0 and Zr1%Nb alloys

Number	Regimes chemical-thermal treatment	Conditional denotation
1	$\boldsymbol{T}$ = 750°C, τ = 5 h, $\boldsymbol{P}_{O2}$=2.6·10^{-2} Pa	***P1***
2	$\boldsymbol{T}$ = 750°C, τ = 5 h, $\boldsymbol{P}_{O2}$=2.6·10^{-3} Pa	***P2***
3	$\boldsymbol{T}$ = 750°C, τ = 5 h, $\boldsymbol{P}_{O2}$=2.6·10^{-4} Pa	***P3***



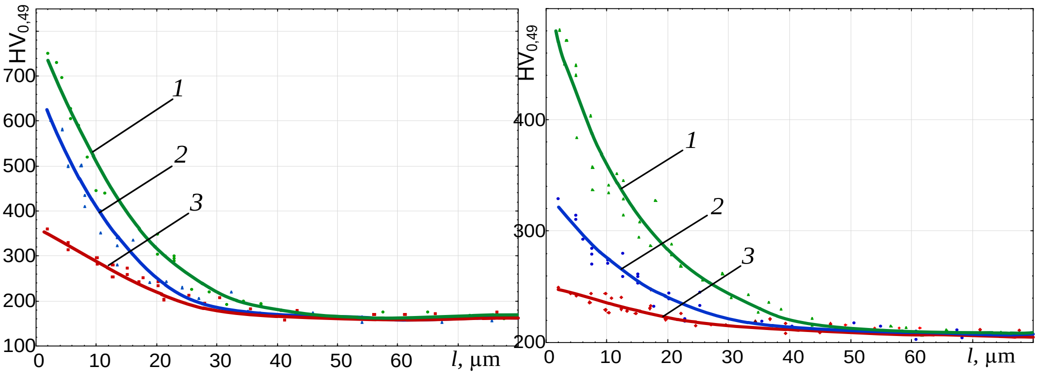
a *b*

Figure 1 – General view of (*a*) and a schematic diagram of chemical-heat treatment (*b*). 1 – backing vacuum pump; 2 – stopcock; 3 – the stopcock buy a pass; 4 – diffusion vacuum pump; 5 – trap diffusion pump; 6 – controlled valve; 7 – leak valve; 8 – thermocouple vacuum gauge; 9 – high ionization vacuum gauge; 10 – thermocouple; 11 – the system of screens; 12 – the reaction vial; 13 – furnace; 14 – container with a samples; 15 – heating furnace control system.

Determining the mass increase ΔM, μg/mm^2 prototypes obtained by weighing them before and after the chemical and thermal processing on the electronic precision weight firm «Voyager» to within 0.0001 grams to measure surface roughness before and after the chemical-thermal treatment using standard profilometer model 176021. Micro hardness samples determined PMT-3M device for loading 50 g sample Metallographic study was performed by scanning electron microscope (EVO 40XVP with microanalysis system INCA Energy).

RESULTS AND DISCUSSION

The results show (Fig. 2, Tab. 2) surface hardness after various modes of treatments varies: VT1-0 alloy range from $HV_{0,49}$ = 340 ± 35 to $HV_{0,49}$ = 850 ± 45 and for Zr1%Nb alloy from $HV_{0,49}$ = 245 ± 35 to $HV_{0,49}$ =550 ± 40. Given that the solubility of oxygen in the α-titanium is 33% at, and α-zirconium – 27% at and at a temperature of $\boldsymbol{T}$ = 750°C diffusion coefficients of oxygen are about the same, so after CTT gradient of hardness in the surface layer of titanium is greater than zirconium.



a *b*

Figure 2 – The distribution of hardness in the surface layer of the alloy VT1-0 (*a*) and Zr-1%Nb (*b*) after treatment regimes: 1 – ***P1***, 2 – ***P2***, 3 – ***P3.***

Patterns of weight gain VT1-0 alloys and Zr-1%Nb are similar: the value decreases with decreasing oxygen partial pressure (P1 → P2 → P3). Thus, for alloy VT1-0 recorded 1,842 → 1,458 → 0,372 µg/mm^2, respectively, and for the alloy Zr-1%Nb – 1,657 → 0,932 → 0,201 µg/mm^2 (table 2), respectively.

Table 2 – The effects of different modes of chemical-thermal treatment on the characteristics samples of the VT1-0 and Zr-1%Nb alloys.

VT1-0 Alloy							
Processing mode	Micro hardness $HV_{0,49}$			Size hardened layer, µm	Surface roughness *Ra*, µm		Weight gain Δ*M/S*, µg/mm^2
	surface	core	Δ*H*		To treatment	After treatment	
P1	850±45	195±25	655	37…44	0,310±0,034	0,285±0,039	1,842
P2	760±60		570	25…33		0,265±0,032	1,458
P3	340±35		150	22…27		0,300±0,026	0,372
Zr-1%Nb Alloy							
P1	550±40	205±20	345	40…45	0,390±0,034	0,385±0,033	1,657
P2	360±45		155	30…35		0,260±0,030	0,932
P3	245±35		40	21…26		0,196±0,027	0,201

The state of the surface of the alloy VT1-0 and Zr-1%Nb with the electron microscope (Fig. 3) after different treatments. It should be noted that the surface alloy VT1-0 is less sensitive to the partial pressure of oxygen than Zr-1%Nb zirconium alloy.

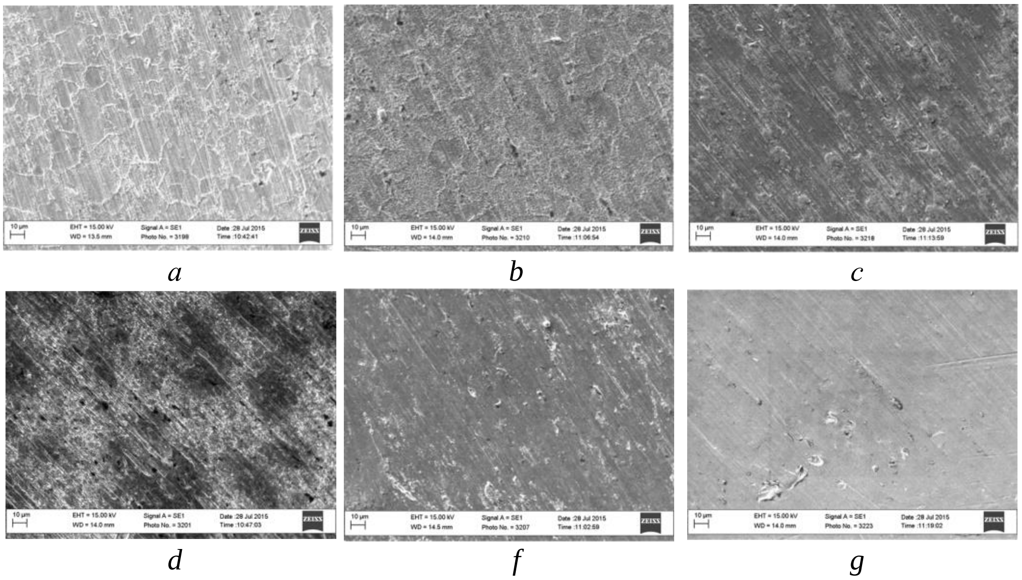


Figure 3 – The surface of samples VT1-0 (*a*, *b*, *c*) and Zr-1%Nb (*d*, *f*, *g*) alloys after treatments regimes: *a, d* – ***P1***, *b, f* – ***P2***, *c, g* – ***P3***.

Proof of this is that after treatment by the regime of P1 ($\boldsymbol{P}_{O2} = 2.6\times10^{-2}$ Pa) on the surface of titanium alloy grain boundaries are shown (Fig. 3a) as a result of faster diffusion through grain boundaries and low rate of formation of continuous oxide film, while the surface of the alloy Zr-1%Nb covered with a solid oxide film and grain boundaries do not appear. (Fig. 3 d).

CONCLUSIONS

The effect of treatment (T = 750°C, τ = 5 h) of VT1-0 titanium and Zr-1%Nb zirconium alloys in a controlled gaseous environment at different partial pressure of oxygen $P_{O2} = 2.6\times10^{-2}...2.6\times10^{-4}$ Pa the forming of hardness gradient of nearsurface layers, weight gain and surface roughness was established. Shown that titanium alloy characterized the larger hardness gradient than the zirconium alloy. Increase in weight two investigated alloys decreased with decreased partial pressure of oxygen at the chemical-thermal treatment.

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