CREATING NANOSTRUCTURED SUPERHARD AND HEAT-RESISTANT SURFACE LAYERS ON CARBON TOOL STEEL AT INFLUENCE TO INTENSE ELECTRON BEAMS

СОЗДАНИЕ НАНОСТРУКТУРИРОВАННЫХ СВЕРХТВЕРДЫХ И ЖАРОПРОЧНЫХ ПОВЕРХНОСТНЫХ СЛОЕВ НА УГЛЕРОДИСТЫХ ИНСТРУМЕНТАЛЬНЫХ СТАЛЯХ ПРИ ВОЗДЕЙСТВИИ ИНТЕНСИВНЫХ ЭЛЕКТРОННЫХ ПУЧКОВ

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Absract: *The saturation of the surface layers of metals and alloys boron is conducted with the purpose of increase of their surface hardness, wear resistance, etc. Multicomponent layers containing in its composition borides of refractory metals, as a rule, formed by the methods of chemical-thermal processing in the interaction boriding component with refractory or by saturation boron refractory impurities metal or alloy.*
In this work, we studied the features of formation of vanadium and iron borides on the surface of instrumental steels U8A and R18 under the influence of intense electron beams in continuous and pulse modes.
KEYWORDS: ELECTRON BEAM, BORIDES, ALLOYS, MICROHARDNESS, X-RAY DIFFRACTION, STRUCTURE, THE SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS (SHS)

1. Introduction

The surface layers saturation of metals and alloys from boron spend with the purpose of increase of their surface hardness, wear resistance, etc. Application of electronic heating with high (> 10^9 W/m^2) specific capacity in vacuum owing to fast not inertial achievement of limiting heats and ease of regulation of heating in a wide range of temperatures opens sample opportunities for creation of boride layers.
In [1] it was informed about formation of strengthening coating of TiB_2, CrB_2, VB_2, W_2B_5 on carbonaceous steels under influence of an electron beam on boron compound reactionary daub in vacuum. The assumption of an active role of a surface metal has been made at electron beam alloying of self-heating synthesis products which initiated by an electron beam and proceeding in reactionary daub of steochemetric mixtures.
In this work, we studied the features of formation of vanadium and iron borides on the surface of instrumental steels U8A and R18 under the influence of intense electron beams in continuous and pulse modes.

2. Layers based on the boride VB_2 on steel U8A

Vanadium boride layers VB_2 (and forth, and borides of iron Fe_2B and FeB) at the same time synthesized and formed on the surface of cutting plates size 12×12×5 mm with roughness Rz = 4.41 ÷ 4.02 microns of instrumental steels U8A and R18. Samples were prepared by applying the reactionary daubs on the pre-prepared (well-fat) surface of the steel. In the composition of the daubs consisted of 1:1 by volume stoichiometric mixture oxide, boron containing and carbon component and organic binder - solution 1:10 glue BF-6 in acetone. As initial substances used amorphous boron, charcoal (birch) and oxides V_2O_3, Fe_2O_3. Processing of samples was conducted within 2-5 minutes with the power of electron beam 150-300 watts. The pressure in the vacuum chamber did not exceed 2×10^{-3} Pa [2, 3].
X-ray diffraction revealed that in the boride layer on steel U8A observed prevalence of carbide phases (cementite). This can be explained only by the deviation from stoichiometry by evaporation of the intermediate boron oxide. Application of the protective layer of amorphous oxide B_2O_3 (1:1 by volume reactionary daub: daub based B_2O_3) allowed to form a more uniform boride layers. It was found that the weight of the crystalline phases in the samples is 92.3%, and the amorphous phases – 7.7%, while the crystallite size ranges from 15 to 70 nm.

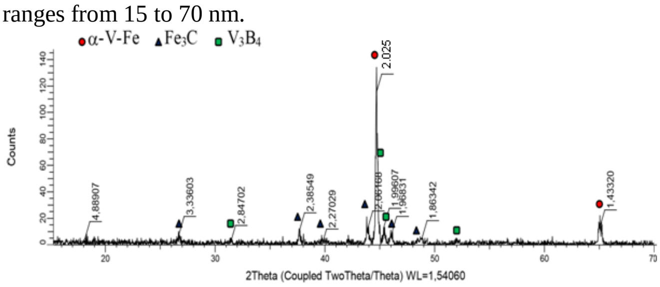
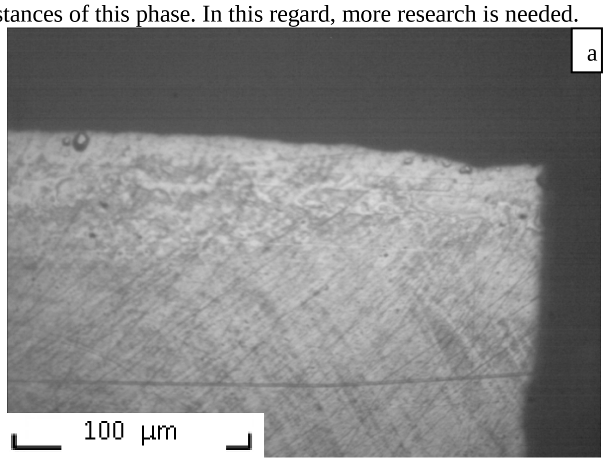


Figure 1. *X-ray pattern of layer based VB_2, formed on steel U8A*

On X-ray patterns of all investigated vanadium boride layers can be observed reflections of refractions belonging vanadium ferrite α-Fe-V, the corresponding phase α-Fe_9V space group *Im3m*, with a cubic lattice parameter a = 0.2878 nm and cementite Fe_3C (PDF 00-003-0989), space group *Pbnm* with rhombic elementary cell with parameters a = 0.4518, b = 0.5069 and c = 0.6736nm, z = 4 (Figure 1).
On X-ray patterns of vanadium diboride layers found boride V_3B_4 (PDF 03-065-2551, space group *Immm*, with elemental rhombic cell with parameters a = 0.303, b = 1.318 and c = 0.2986 nm, z = 2). Education vanadium diboride VB_2 radiographically not detected, although there are reflexes, light intensity related to the interplanar distances of this phase. In this regard, more research is needed.



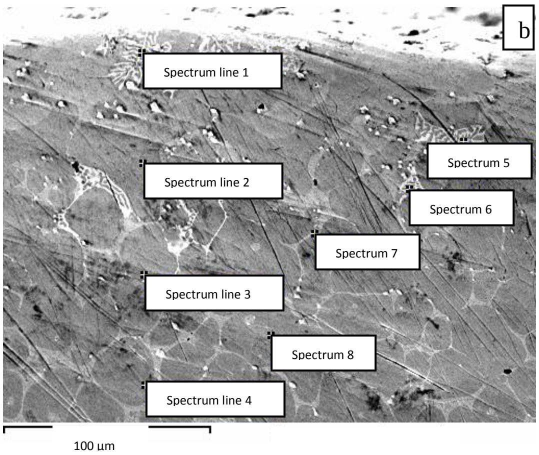


Figure 2. *General view (etched layer) (a) and structure (b) layer VB_2 on steel U8A*

Figure 2 shows a general view (Figure 2.a) and the structure of the boride layer VB_2 on the surface of cutter plate steel U8A (Figure 2.b). Layer thickness reaches up to 500 µm.

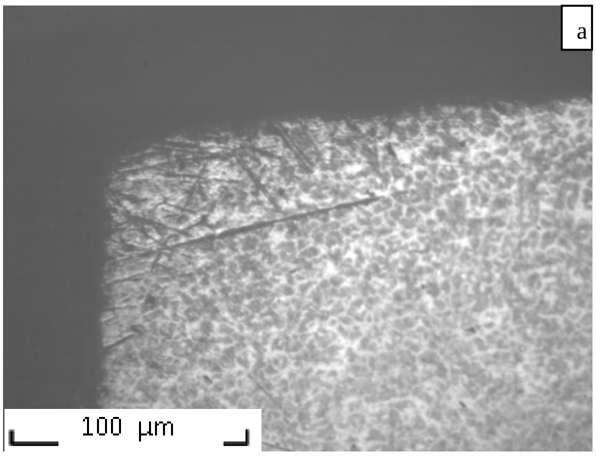
Microhardness testing showed uneven distribution of its thickness in the cross-section. Separate very rare inclusions have microhardness HV≈ 24000 MPa and are located in the surface layers. Next we will see two areas: in the first area microhardness reaches 2500 MPa, and in second - 1500 MPa. The metal base is microhardness 200 MPa.

3. Layers of iron borides Fe_2B and FeB at high-cutting steel R18.

X-ray diffraction (XRD) revealed that in the samples of cutter plate steel R18 after electron beam treatment reflexes following phases are present: the metal substrate - α-Fe and carbide W_3Fe_3C. It was found that the weight of the crystalline phase is 92.7% and the amorphous phase – 7.3%.

Boride FeB located near the surface of the coating. This is evidenced by the results of the investigation of the end surface of the cutter plate steel R18 and X-ray analysis data (scanning electron microscope JSM-6510LV JEOL with microanalysis system INCA (Figure 3).

Application of the protective layer of amorphous oxide B_2O_3 contributed obtaining equilibrium boride layers Fe_2B and FeB.



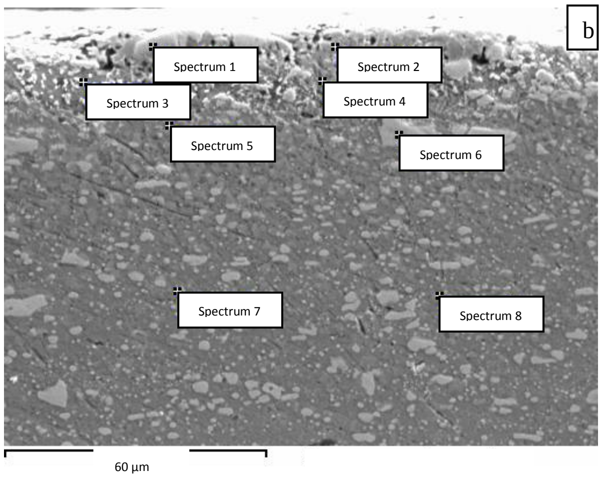
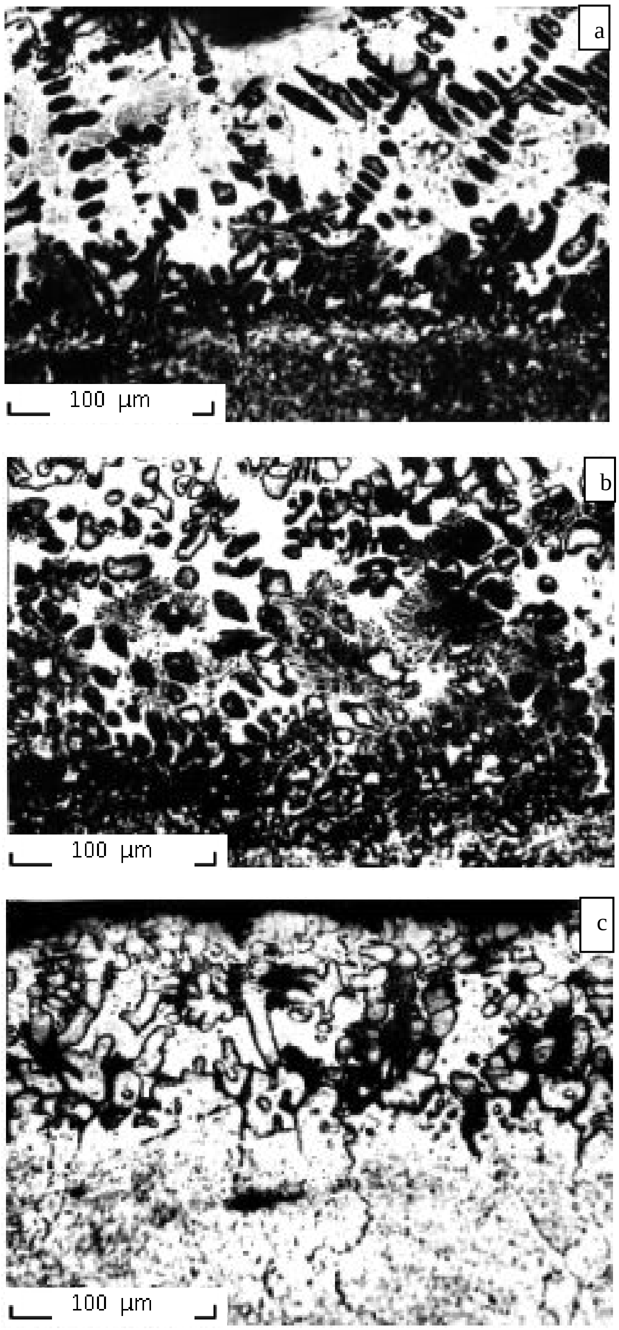


Figure 3. *General view (a) and structure (b) boride layer FeB on steel P18*



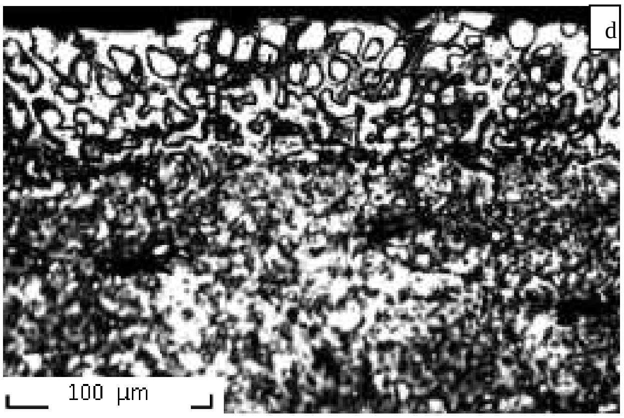


Figure 4. *Structure of the surface layer on the steel R18 after electron beam boriding, a – at the power density of the electron beam J =2.8×10^4 W/cm^2, b – at the power density of the electron beam J=2.5×10^4 W/cm^2, c,d – at the power density of the electron beam up to J =2.2×10^4 W/cm^2*

4. Wear resistance of boride layers on high-cutting steel R18

When the electron beam boriding steel R18 with the power density of the electron beam J =2.8× 10^4 (W/cm^2) layer was formed as a result of deep weld penetration, which determined its structure. Figure 4a shows that when directed crystallization main axis line dendrites oriented in the direction of heat removal. The structure of dendrites (chain separate globules) indicates of the intermittent nature of their education. When power density of the electron beam J=2.5×10^4 (W/cm^2) layer consists predominantly of stellate dendrites (Figure 4b). When reducing the power density up to J =2.2×10^4 (W/cm^2), surface layer also contains stellate dendrites, but their number is not dominant (Figure 4c,d). Microhardness layer is 1100-1860 kg/mm^2. The thickness of layer is 25-100 µm.

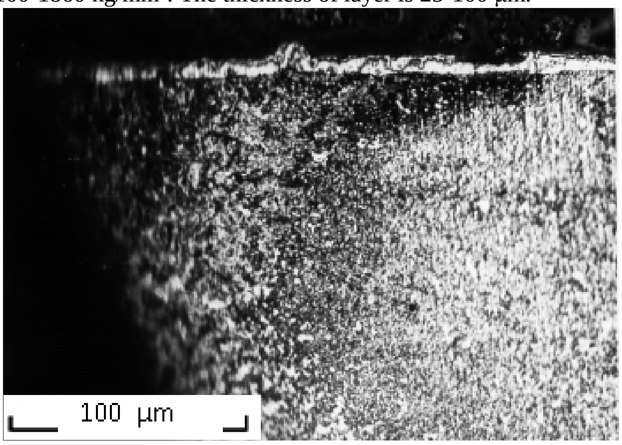


Figure 5. *The microstructure of cutters from steel R18 after electron beam treatment*

After treatment by the electron beam of cutter plate with boron-containing daubs, on the surface formed layer with thickness 8-10 µm (Figure 5). The resulting layer have a specified thickness practically over its entire length. With increasing × 500 shows that the layer contains particles which are located not only within the layer, but also at the boundary layer - base. This suggests that these particles are carbides of alloying elements (tungsten, chromium, molybdenum and vanadium). Layer was firmly held on the metal base. Microhardness layer slightly higher microhardness is 550 bases and HV and 410 HV, respectively.
To assess the tribological properties of the resulting layer tests conducted strength incisors. Tests were performed on lathes 1A616 on the following modes: feed - 0.1 mm / rev, rate speed - 224 rev / min, depth of cut - 1.0 mm. Processed material - steel 45 and sus321. Wear incisors determined by the rear surface with a magnifying glass Brinell. Geometric parameters of incisors: rake angle γ= 15^o, the main rear angle α = 8^o, plan approach angle φ = 45°. Criterion for stability incisors taken the time to reach the limit flank wear of 0.6 mm.
The results are given in figure 6. The figure shows that formation boride layers thickness of 8-10 µm on the front surface, allows to increase the resistance of incisors almost 1.5 times (for processed steel sus321).

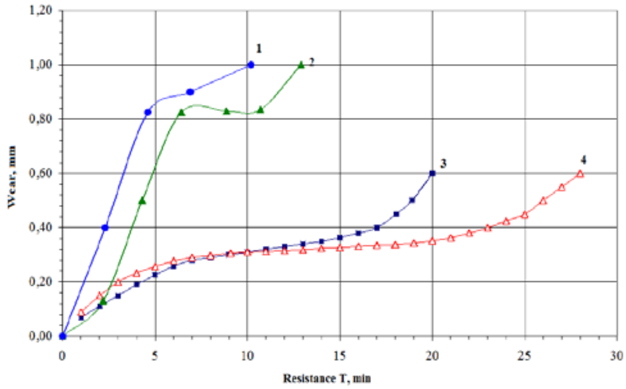


Figure 6. *Kinetics of wear cutters from steel R18 1-R18 hard. (steel sus321), 2-R18 thermochemical treatment (steel 45), 3-R18 electron-beam boriding (steel sus321), 4-R18 hard. (steel 45)*

5. Conclusion

Conditions for the formation, structure and properties boride layers on the surface cutting plates of carbon steel U8A formed during electron beam processing in vacuum were investigated and discussed.It found that at the directional crystallization the main axis of line dendrites is focused in the direction of heat removal. The structure of dendrites (a chain separate globuly) speaks about intermittent nature of their education. Microhardness layer constitutes 1100-1860 HV. The thickness of 25-100 µm.
The formation boride layers thickness of 8-10 microns on the front surface, allows to increase the resistance of incisors almost 1.5 times (for processed steel sus321).
A more significant increase of resistance incisors are associated with increased thickness boride layers. When electron beam boriding thickness of boriding layer can be up to 300 microns, but the temperature processing is 1100-1200^{o}C. The processing time is 2-3 minutes. On this basis, electron-beam boriding cannot be recommended as a final, but as an intermediate processing operation of the cutting tool, for example, before hardening. It should be noted that to achieve the same thickness of a layer when diffusion borating (for example, when borating in sealed containers with safety valve) is required not less than 3 hours.

6. Acknowledgments

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7. Literature

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