

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

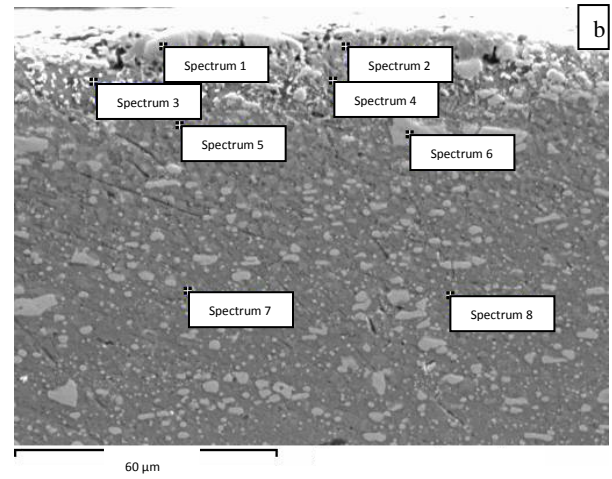


Figure 3. General view (a) and structure (b) boride layer FeB on steel P18

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  $\mu m$ .

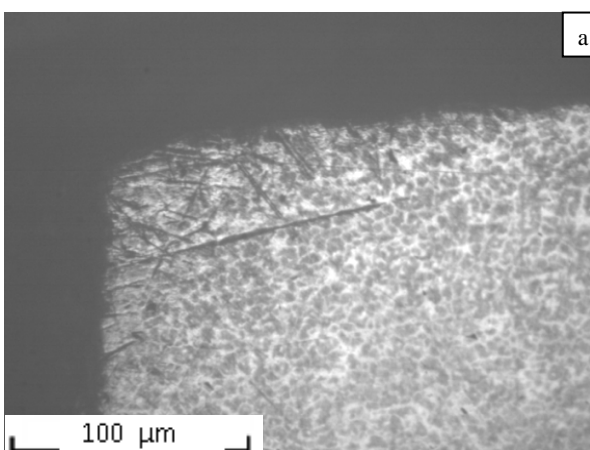
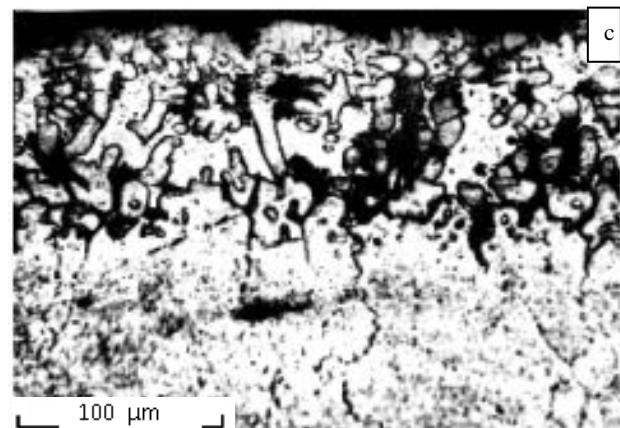
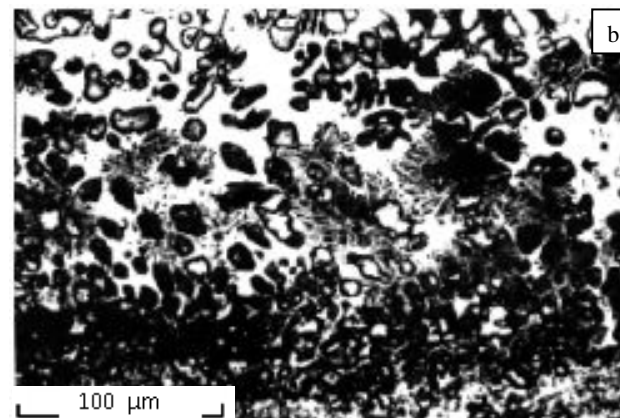
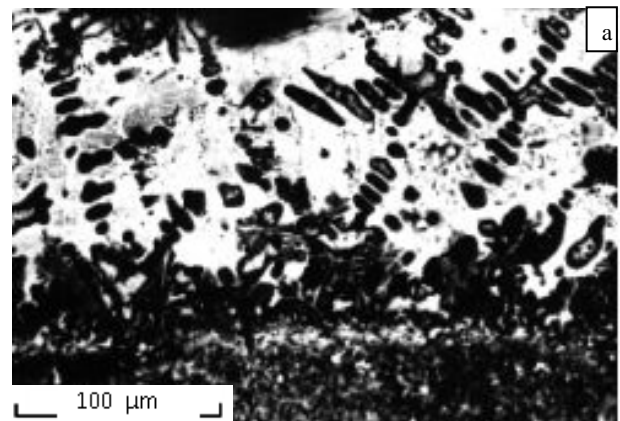
Microhardness testing showed uneven distribution of its thickness in the cross-section. Separate very rare inclusions have microhardness  $HV \approx 24000$  MPa and are located in the surface layers. Next we will see two areas: in the first area microhardness reaches 2500 MPa, and in second - 1500 MPa.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

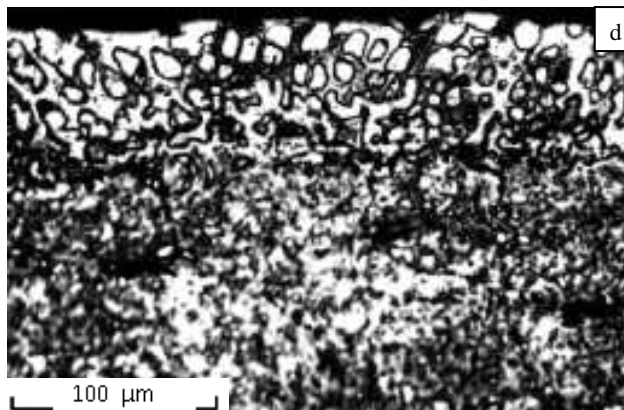
### 3. Layers of iron borides $Fe_2B$ and $FeB$ at high-cutting steel R18.

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 -  $\alpha$ -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.

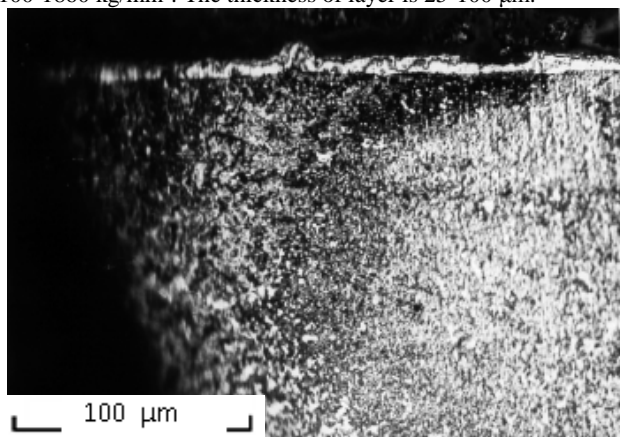




**Figure 4.** Structure of the surface layer on the steel R18 after electron beam boriding, a – at the power density of the electron beam  $J = 2.8 \times 10^4 \text{ W/cm}^2$ , b – at the power density of the electron beam  $J = 2.5 \times 10^4 \text{ W/cm}^2$ , c,d – at the power density of the electron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

#### 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  $J = 2.8 \times 10^4 \text{ (W/cm}^2)$  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  $J = 2.5 \times 10^4 \text{ (W/cm}^2)$  layer consists predominantly of stellate dendrites (Figure 4b). When reducing the power density up to  $J = 2.2 \times 10^4 \text{ (W/cm}^2)$ , surface layer also contains stellate dendrites, but their number is not dominant (Figure 4c,d). Microhardness layer is 1100-1860  $\text{kg/mm}^2$ . The thickness of layer is 25-100  $\mu\text{m}$ .



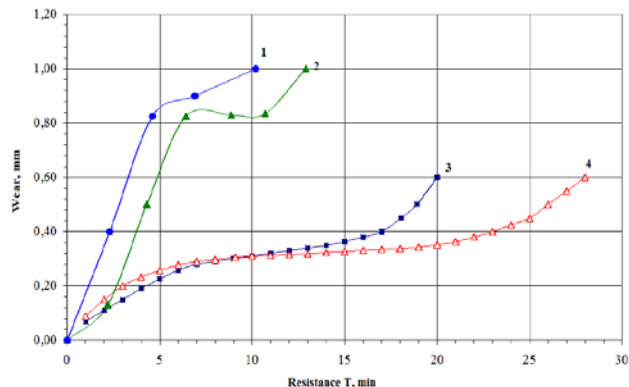
**Figure 5.** The microstructure of cutters from steel R18 after electron beam treatment

After treatment by the electron beam of cutter plate with boron-containing daubs, on the surface formed layer with thickness 8-10  $\mu\text{m}$  (Figure 5). The resulting layer have a specified thickness practically over its entire length. With increasing  $\times 500$  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  $\gamma = 15^\circ$ , the main rear angle  $\alpha = 8^\circ$ , plan approach angle  $\varphi = 45^\circ$ . 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  $\mu\text{m}$  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  $\mu\text{m}$ .

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°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 boriding (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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2. Dashev D.E., Smirnyagina N.N. Features of the process of self-propagating high-temperature synthesis, a structure and strong properties of borides iron layers on the carbonaceous steel 3, generated under a powerful electron beam in vacuum. // News of higher educational institutions. Physics. - 2012. - V. 55. - № 12/2. - pp. 51-54.
3. Dashev D.E., Smirnyagina N.N. Features of the process of self-propagating high-temperature synthesis, a structure and strong properties of borides iron layers on the carbon steels, generated under a powerful electron beam in vacuum // J. Chem. Eng. 2013. - V.7. - № 4. - pp 319-325.