STRENGTHENING OF SURFACE LAYERS OF STEELS AND ALLOYS BY BORIDE COATINGS FORMED UNDER THE CONDITIONS OF AN EXTERNAL MAGNETIC FIELD

Prof. Dr. Chernega S., Grinenko E., Krasovskiy M.
National Technical University of Ukraine "Igor Sikorsky Kiev Polytechnic Institute", 03056, Ukraine, Kiev, Polytechnique st., Bldg. 9, e-mail: smchernega@ukr.net;

Abstract: *It was dedicated to solution of scientific and technical problem to increase the level of physical and mechanical and operational properties of the surface of steels by forming strengthened layers diffusion boriding and complex saturation boron and copper in a magnetic field.*

KEYWORDS: *BORON, BORIDING, BORON LAYER, COPPER, STRUCTURE, DIFFUSION, MICROSTRUCTURE, MICROHARDNESS, EXTERNAL MAGNETIC FIELD.*

INTRODUCTION

Diffusive multicomponent boriding quite energy consuming process, therefore to reduce energy consumption necessary to use methods for intensification the process saturation. One of these methods is the application of an external magnetic field (EMF), the so-called magnetic thermo chemical treatment [1-3].

To solve this problem, we used a complex diffusive saturation of the surface layer of carbon steel boron or boron and copper at simultaneous action of EMF.

The aim of this work was to study diffusive boride coatings and coatings obtained after saturation with boron and copper on carbon steel,

MATERIALS AND EXPERIMENT

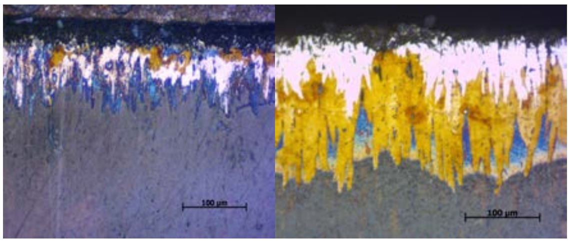
The paper presents the results of the study of the influence of external magnetic field (EMF) on the structure, phase and chemical composition, microhardness, growth kinetics, roughness, crack resistance and wear resistance of boride coatings obtained with complex boron or boron and copper saturation.

RESULTS AND DISCUSSION

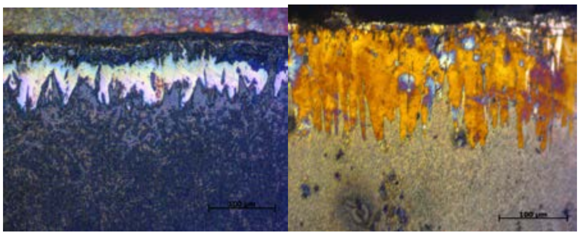
It was found that the use of EMF in diffusion saturated for 2 hours allows to increase the thickness of the diffusion boride layer in 1,5-2 times, compared with the coatings obtained without the action of EMF with a saturation time of 2 hours. So for 2 hours of diffusion saturation with EMF on medium carbon steel the thickness of the coating reached up to 200 μm (Fig. 1, c), compared with the boron layers obtained without

EMF - up to 110 microns (Fig. 1, a). It has been shown that the use of EMF can reduce the duration of saturation of steels and alloys by 2 times. So the thickness of the diffusion boride layer on medium carbon steel without the action of EMF grows to 160 μm for 4 hours of diffusion saturation.

The same pattern is observed for boride coatings obtained with complex boron and copper saturation. So with a whack for a while
For 4 hours without EMF, coatings with a thickness of 165 - 200 μm are formed (Fig. 1, r), whereas, when diminished under the action of EMF, 2 hours of diffusion saturation, borate phases grow in the thickness 180 – 225 μm. Investigation of the microhardness of the boride phases after boring at the simultaneous action of EMF showed that the microhardness of the phase of FeB is 19-20 GPa, and the Fe_2B phase is 17 - 18 GPa, without the action of a magnetic field, FeB - 17 - 18 GPa, Fe_2B - 15-16 GPa . At complex saturation with boron and copper using EMF, we obtain boride layers with a microhardness - for phase (Fe, Cu) B - 17 - 18 GPa, and for phase (Fe, Cu) 2B - 15-16 GPa, without magnetic field action (Fe , Cu) B - 15.5 - 16.5 GPa, and for the phase (Fe, Cu) 2B - 13.5 - 14.5 GPa. Thus, there is an increase in the microhardness of FeB, Fe_2B and (Fe, Cu) B, (Fe, Cu) 2B phases at 1.5-2 GPa, obtained under magnetic field conditions, which is probably due to the shredding of the block structure boride grains up to 38.3 nm compared to 66.1 nm for the FeB phase obtained without the action of EMF. At complex saturation with boron and copper, we observe a decrease in the microhardness of boride layers compared to boring.



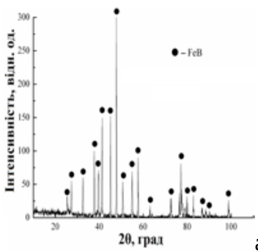
a b



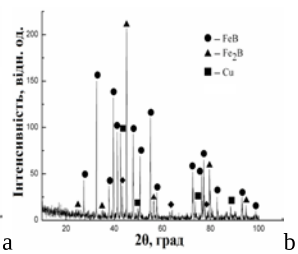
c d

Fig.1 Microstructures of complex boride coatings on steel 45 obtained in different physical - chemical conditions: a – boriding without action EMF, the duration of saturation 2 hours, x200;b – boriding in EMF, the duration of saturation 2 hours, x200; c – complex saturation with boron and copper without action EMF, the duration of saturation 2 hours, x200; d – complex saturation with boron and copper with simultaneous action EMF, the duration of saturation 2 hours, x200, (thermal etching)

The study of the phase composition of boride coatings obtained in different physical and chemical conditions was carried out. It was shown that in the case of boronization without EMF in the surface layer of boride coating to 15 - 20 μm, the FeB phase (Fig. 2, a), and with complex boron and copper saturation without the action of EMF - the FeB, Fe2B, and Cu phases (Fig. 2, b).



a



b

Fig.2. X-ray diffraction picture taken from the surface of the carbon steel 45 *with boride coatings obtained without action EMF after: a – boriding, the duration of saturation 2 hours; b – complex saturation with boron and copper, the duration of saturation 2 hours complex saturation with boron and copper without action EMF, the duration of saturation 2 hours*

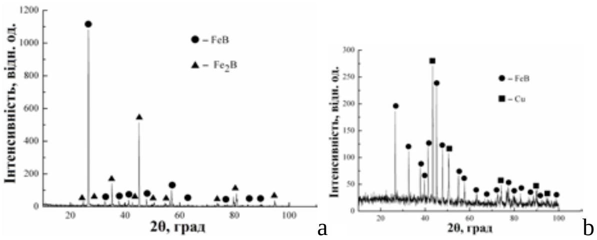


Fig.3. X-ray diffraction picture taken from the surface of the carbon steel 45 *with boride coatings obtained after: a – boriding at the simultaneous action EMF, the duration of saturation 2 hours; b – complex saturation with boron and copper with simultaneous action EMF, the duration of saturation 2 hours. Diffraction peaks Cu correspond crystallographic planes: (111) (200) (220) (311) (222)*

The diffractograms (*Fig.2, Fig.3*) were taken from the surface of steel 45 with boride coatings obtained after boriding (a), complex saturation with boron and copper (b) without the action of EMF and boriding (c), dimming (d) under the action of EMF.

When applying EMF in boride layers, the decrease in the volume of the phase of FeB and on the diffractograms of the surface layers of the boride coatings, and the presence of the FeB and Fe2B phases is observed in the diffractograms (Fig. 3, a). After complex saturation with boron and copper, under the action of EMF, the phases of FeB and Cu (Fig. 3, b) are fixed. An overlay of EMF leads to a redistribution of the quantitative ratio of boride phases in the surface layers, changes in the periods of the crystal lattice, and a decrease in the volume of the elementary lattice of the phase of FeB. Local microscopic analysis has established a discrete distribution of copper in a surface layer of FeB phase up to 20 microns of coating. Copper impregnations can accumulate in the pores of boride coatings and surround their walls (Fig. 4, a, Table 1). An overlay of a magnetic field at a complex saturation with boron and copper leads to an increase in the diffusion coefficient of copper in the surface layers of boride coatings from 7.8 · 10-11 cm^2 / s to 4.1 · 10-10 cm^2 / s, which leads to a faster penetration of copper in surface layers of the phase of FeB. Therefore, copper with this method of saturation penetrates to a depth of 30 micrometer (Fig. 4, b, Table 2), compared with 20 micrometer in the traditional complex saturation with boron and copper without EMF.

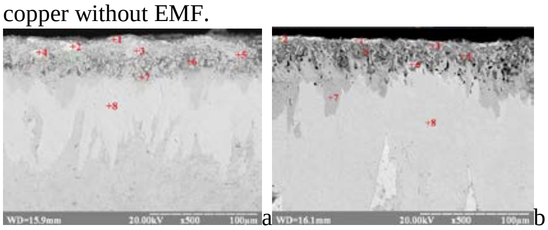


Fig. 4. Structures of a cross-section with a diffusion boride coating obtained with complex boron and copper saturation without the action of EMF (a) and under the conditions of the action of EMF (b) on steel 20 (chemical analysis was determined at points +1,+2, +3, +4, +5, +6, +7,).

Table 1.*The chemical composition of the diffusion layer obtained after complex saturation with boron and copper on steel 20 without the use of EMF*

Eleme nts	Position						
	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	+ 7
	мas. %						
Fe (K)	2,38± 0,06	2,69± 0,07	76,66± 1,50	95,37± 1,65	57,75± 1,09	93,42± 1,71	100± 2,15
Cu (K)	97,62± 1,50	97,31± 1,80	23,34± 0,70	4,63± 0,31	42,25± 1,01	6,58± 0,29	0,00

Table 2.*The chemical composition of the diffusion layer obtained after the complex saturation of boron and copper on steel 20 at the simultaneous action of EMF*

Eleme nts	Positions							
	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	+ 7	+ 8
	мas. %							
Fe (K)	1,33± 0,05	22,09± 0,74	1,40± 0,05	66,29± 2,59	77,44± 2,32	82,76± 2,59	83,28± 2,08	100± 2,60
Cu (K	98,67± 2,53	77,91± 2,19	98,60± 2,47	33,71± 1,34	22,56± 0,87	17,24± 1,59	16,72± 0,53	0,00

The research of roughness of complex boride layers obtained in different physical and chemical conditions has shown that the lowest level of roughness Ra = 0,0553 is achieved at the complex boron and copper saturation using EMF, compared with Ra = 0,0650 with dimming without EMF. When pounding in EMF Ra = 0,0855, compared with Ra = 0,0961 in the absence of EMF.

CONCLUSIONS

The investigation of the crack resistance of diffusion boride coatings obtained in various physical and chemical conditions was carried out. It has been established that the highest cracking strength is achieved in the boride phases obtained in powder environments with the use of copper powder when applied to EMF, and on steel 20, respectively, is 2.23 MPa • m $^{0.5}$, with the shearing stress of 345 MPa. Then, when scattering without the action of EMF, the crack resistance of the steel is 20 - 1.24 MPa • m $^{0.5}$, and the stresses of shearing - 181 MPa. An increase in the magnitude of the stresses in the complex bromide layers is due to the formation of phases of greater viscosity, for which the crack resistance K1C in 1,4 - 1,7 times higher than the output boridephase (FeB, Fe2B).

The study of wear resistance of boride coatings obtained in various physical and chemical conditions was conducted. It has been established that diffusion boride coatings obtained with the use of an external magnetic field have higher tribotechnical characteristics. Thus, the average linear wear in the boride coatings obtained in the EMF is reduced by 2.4 times, and the coefficient of friction is 0.63 versus 0.66. In the case of the production of gloomy coatings obtained in EMF, the average linear deterioration is reduced by 1.8 times, the coefficient of friction decreases to 0.60 compared with 0.64 for gloomy coatings without EMF.

REFERENCES

[1] Chernega S. Structure and properties of surface layers metals on the basis of high solid boride obtained in conditions of an external magnetic field / S. Chernega, I. Poliakov, M. Krasovskiy. // Machines. Technologies. Materials. – Sofia, Bulgaria. – 2015. – No.12. – P. 52 – 55.

[2] S. Chernega, I. Poliakov, M. Krasovskiy. Increasing wear resistance of machines details from carbon and Cr–Mn–N steels of the complex boride coating|// Nonequilibrium phase transformations. – Sofia, Bulgaria. – 2016. – No.3. – P. 31 – 34. – ISSN 2367 – 749X.

[3] Chernega S. I. Poliakov, C. Grinenko, M. Krasovskiy. Increase wear resistance hard alloys T15K6 boride coatings // XII International congress «Machines, technologies, materials 2015». – Bulgaria, Varna, 16 – 19 September 2015. – Vol.II. – P. 109 – 111.