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The Increase in Wear Resistance of Low Carbon Steel by Flux-Cored Wire Surfacing Followed Be Electron Beam Processing

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Abstract. Structure-phase state and tribological properties of the coating deposited on Hardox 450 martensitic low-carbon steel by flux-cored wire Fe-C-Cr-Nb-W and modified by subsequent electron-beam processing were studied. It is shown that the electron beam processing of ~ 5 mm thick deposited layer leads to the formation of ~ 20 µm thick modified surface layer with the main phases of α -Fe and NbC, Fe₃C and M₆C(Fe₃W₃C) carbides. Wear resistance of the weld layer is 70 times higher than the one of the original steel.

Introduction

The production of coatings with high service properties making possible the increase in service durability of the articles in the extreme conditions of high wear, corrosion, mechanical loads and temperatures is the important fundamental problem. The thorough analysis of the relation «wear parameters – hardness - microstructure» is necessary in scientific and practical use of various kinds of surfacing in the critical articles. Only in this case it is possible to produce the articles with high service parameters [1 – 8].

The purpose of the research is the analysis of structure and tribological properties of the layer formed on Hardox 450 steel by electrocontact surfacing of powder wire of system Fe-C-Cr-Nb-W and modified by high intensity pulsed electron beam irradiation.

Hardox 450 steel (weight %): (0.19-0.26 C; 0.70 Si; 1.6 Mn; 0.025 P; 0.010 S; 0.25 Cr; 0.25 Mo; 0.004 B; balance – Fe) was used as a test material. The surfaced electrode 1.6 mm in diameter had the following chemical composition (weight %): 1.3 C; 7.0 Cr; 8.5 Nb; 1.4 W; 0.9 Mn; 1.1 Si, balance – Fe.

The testing techniques of the surfacing by methods of modern physical material science are presented in [1].

The results and their discussion

The formation of the surfaced layer results in the increase in wear resistance of steel. The performed tests revealed the increase in wear resistance of the surfaced layer modified by intense pulsed electron beam by more than 70 times in relation to wear resistance of steel.



Fig.1 shows the variation of friction coefficient in tribological tests of the surfaced layer modified by electron beam. Attention is drawn to the two-stage variation in friction coefficient. At the first stage the friction coefficient value is ~ 0.17 , at the second stage it is ~ 0.5 . The friction coefficient of steel without surfacing is ~ 0.26 . When analyzing the variation in friction coefficient in tribological tests (Fig.1) it can be supposed that the modification of the surfaced layer by the intense pulsed electron beam results in the significant (~ 3 -fold) decrease in friction coefficient of the surfaced layer.

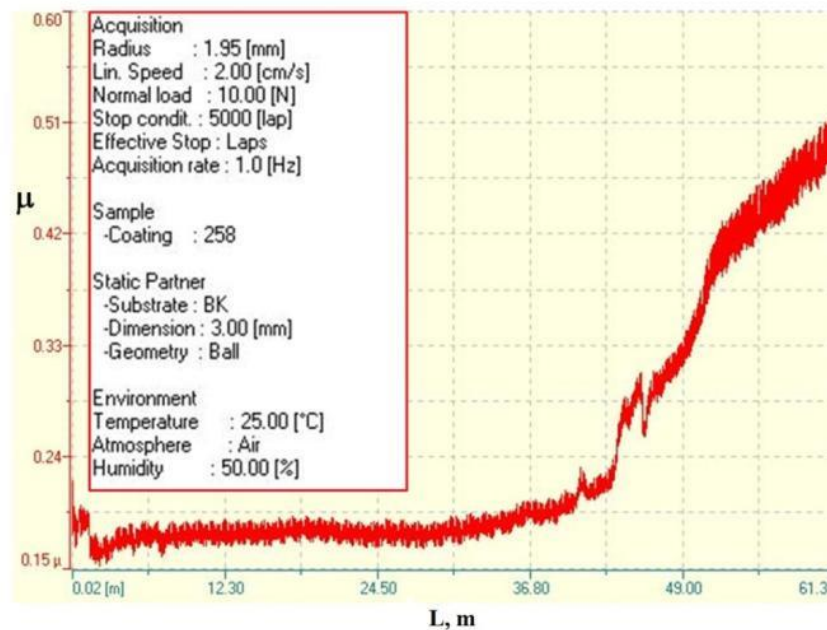


Fig.1 Dependence of friction coefficient on track length of tribological tests. The insert shows the tribological test conditions.

The electron beam processing (EBP) of the surfaced layer results in the formation of the modified surface layer up to $20\text{ }\mu\text{m}$ in thickness. The modified layer differs from the main volume of the surfaced material by the degree of structure dispersion detected on ion etching of the transverse metallographic section. If in the volume of the surface unirradiated by electron beam the sizes of etched structural elements amount to $1.5\text{ }\mu\text{m}$ then after EBP the sizes of high-melting compounds having the low level of ion beam etching vary within 150 to 750 nm (Fig.2)

The phase composition analysis of the surfacing modified layer was performed by methods of microdiffraction analysis using dark field technique. The results of the analysis are presented in Fig.3.

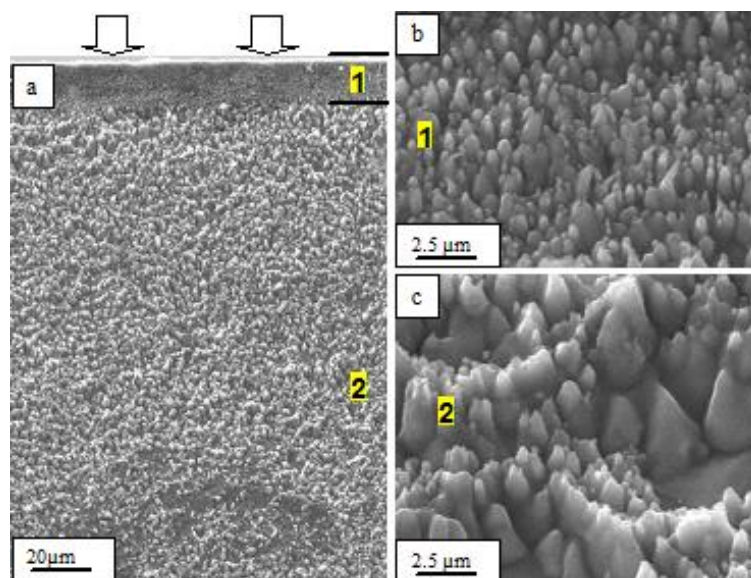


Fig.2 Structure of the surface layer. The transverse metallographic section. The arrows designate the irradiation surface of the surfaced layer by pulsed electron beams. The figures designate: 1 – the layer modified by electron beam processing; 2 – the main volume of the surfacing.

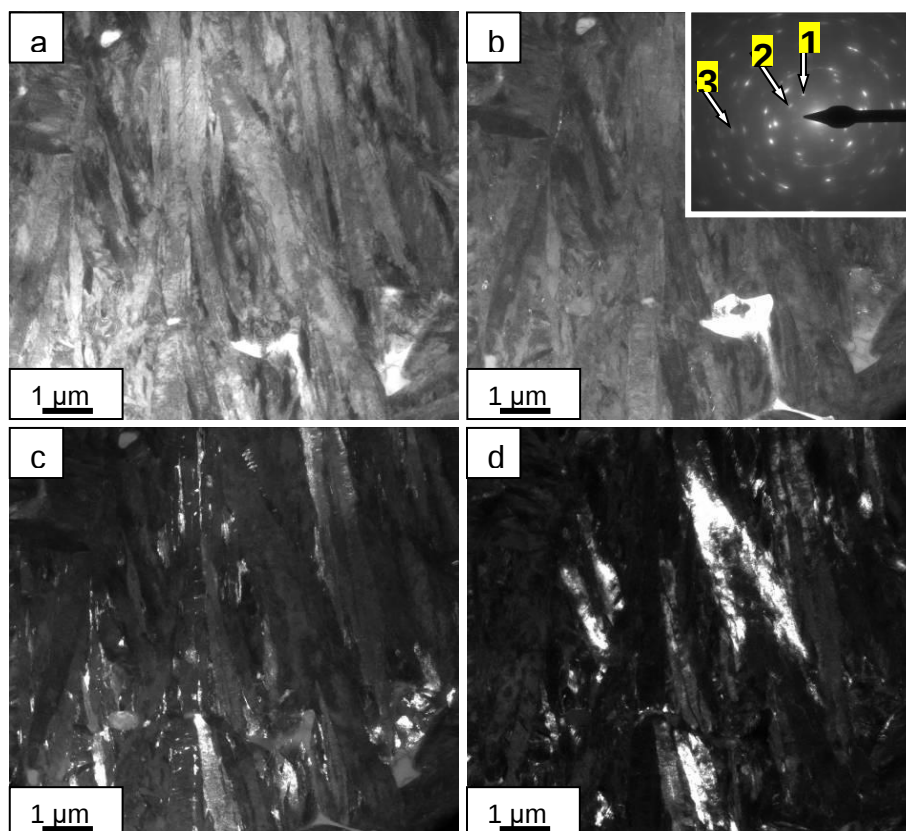


Fig.3. Electron microscope image of surfaced layer structure irradiated by intense pulsed electron beam; a – light field; b-d – dark field obtained in reflections $[511] M_6C(Fe_3W_3C)$ (b); $[110] \alpha-Fe + [102] Fe_3C$ (c); $[024] \alpha-Fe$ (d). The microelectron diffraction pattern (insert in “b”) shows the reflections of obtaining the dark field images 1(b), 2(c), 3 (d).

It is established that the second phase inclusions located at grain boundaries as interlayers are the carbide $M_6C(Fe_3W_3C)$ (Fig. 3, b). In the volume and along the boundaries of martensite crystals the particles of iron carbide Fe_3C (Fig. 3, c) are revealed.

The surface layer structure of the surfacing irradiated by intense pulsed electron beams is characterized by the presence of the facet inclusions located chaotically in the volume of grains (Fig.4). The sizes of these inclusions amount to $2\ \mu m$ and they are niobium carbide NbC .

Thus, by methods of electron diffraction microscopy it is shown that the surface layer of the surfacing modified by intense pulsed electron beam is a multi-phase aggregate with the main phases of α -iron-base solid solution and carbides M_6C , NbC and Fe_3C .

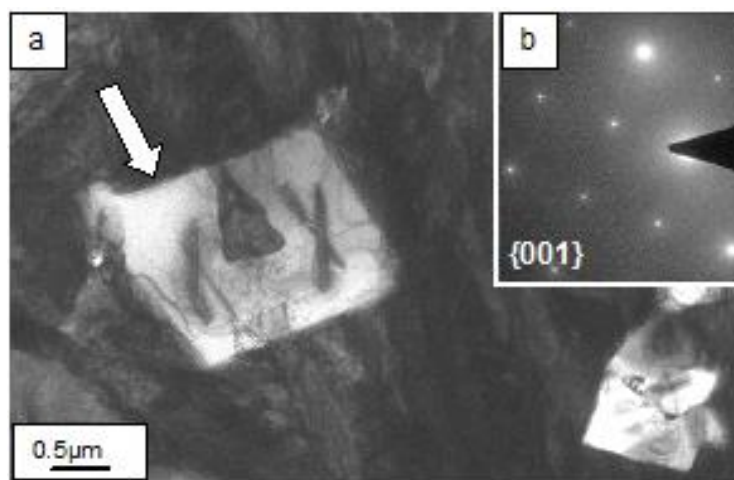


Fig. 4. The structure of the surfaced layer modified by electron beam (a). Microelectron diffraction pattern (b) is obtained from the particle designated by the arrow.

Conclusions

By methods of modern physical material science the investigation of structure and tribological properties of the layer formed on Hardox 450 steel by flux-cored wire Fe-C-Cr-Nb-W modified by EBP were carried out. It is shown that electron-beam processing of the surfacing top layer results in the refinement of structure and variation in the morphology of carbide phase of layer and the significant decrease in its friction coefficient and increase in wear resistance.

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