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STRUCTURE AND PHASE COMPOSITION OF THE SURFACES RECOVERED BY ELECTROSPARKING COATINGS. RESULTS OF MICROSTRUCTURAL AND X-RAY DIFFRACTION ANALYSIS

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Розглянуто дослідження структури та фазового складу поверхонь відновлених електродуговим напиленням під час транспортування часток, що розпилюються повітрям та продуктами згоряння пропаново-повітряної суміші. Показано, що при електродуговому напиленні структура покриття являє собою гетерофазну систему, що складається з двох або більше фаз, розподілених між собою границею розподілу, що відрізняються між собою за хімічним складом та властивостями. Це в свою чергу дозволяє отримати відновлювальні поверхні з необхідним комплексом експлуатаційних властивостей і тим самим вирішити проблему управління ресурсом відновлювальних деталей покриттями з залізовуглецевих сплавів завдяки управлінню структурно-фазовими перетвореннями в цих покриттях у процесі їх нанесення на відновлювальну деталь.

Ключові слова: електроіскрове покриття, якість, структура, фазовий склад.

The investigation results of structure and phase composition of surfaces recovered by electrosparking spraying at transportation of spraying particles by air and combustion products of propane-air mixture have been discussed in the article. It was shown that the structure of coating at electrosparking spraying represents itself heterogeneous system consisting of two and more phases separating between each other by interface and differ by chemical compound and properties. This allows to obtain recovered surfaces with set complex of operating properties and to solve the problem of resource control of recovered details by controlling spraying of recovered coatings from iron-carbon alloys regulating its structure-phase changes.

Keywords: electric-arc coating, quality, structure, phase composition.

Introduction

The surface structure recovered by electrosparking coatings, differs on the structure from structure of initial materials of a coating [3, 5, 9]. The reason of such distinction is, first of all, coating formation process on a recovered surface.

The transportation conditions of sprayed particles and formation of coating by electrosparking method which is differ from other methods of gas thermal spraying [2, 3, 5, 9].

The structure of electrosparking coatings is connected with their following features [5]:

– Superfast crystallization of the sprayed drops of alloy which leads to high density of defects of a crystal lattice (dislocations, vacancies) in coating particles;

– A structure of a coating particle which reflects conditions of crystallization with development of front of growing crystals in a direction opposite to heat removal, i.e. it is perpendicular to a surface of coating layer formation;

– Presence of a pores and a branching network of boundaries (Fig. 1);

– Intensive interaction of the elements which are a part of a coating with environment and working gases at its spraying, in particular, with oxygen that leads to change of phase composition and properties of coatings.

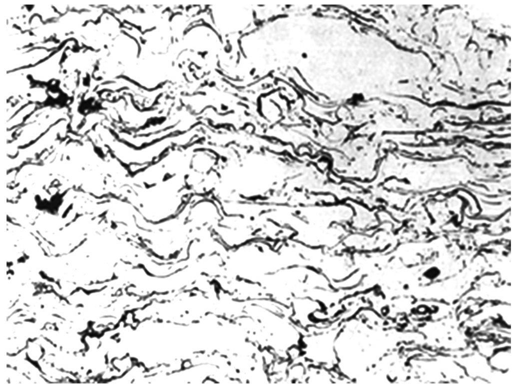

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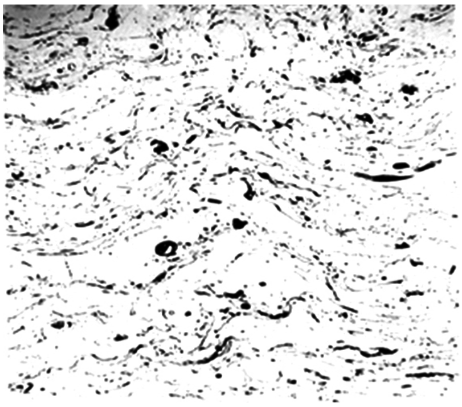
Fig. 1. The structure of electrosparking coating

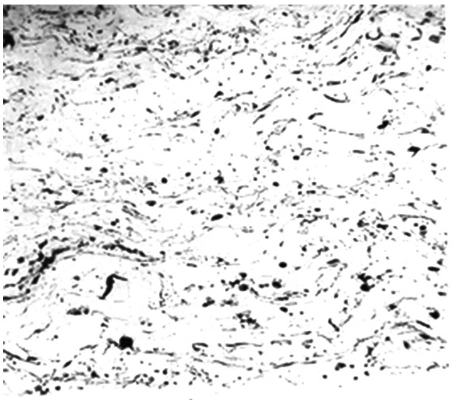
The light sites on Fig. 1 represent a metal surface of particles from which the oxide film is removed in the process of microsection manufacture by the mechanical way, dark threadlike and pointwise oxides, black points – a pores.

The surface oxide film bordering light metal sites is faltering and pointwise. It is a consequence of that the metal particles having high temperature, at flight in jet are oxidized uniformly, but at the moment of particles blow at a firm surface the film cracks and organizes a faltering and pointwise head loop in section.

The area occupied by dark sites, is more at the electrosparking coatings received at spraying of coating material particles by air (Fig. 2), than at the electrosparking coatings received at dispersion of particles by combustion products (Fig. 2).



a



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b

Fig. 2. Microstructure of surfaces recovered y electrosparking coatings received at spraying by air (*a*) and combustion products of propane-air mixture (*b*)

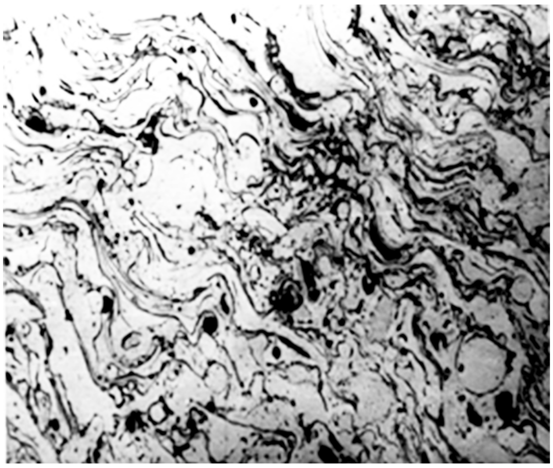
The thickness of oxide films is much less at dispersion of particles by combustion materials of propane-air mixture Fig. 3, which inform about smaller oxidation of these coatings.

The dark interlayers between metal layers on microstructures (Fig. 1–3) are oxides.

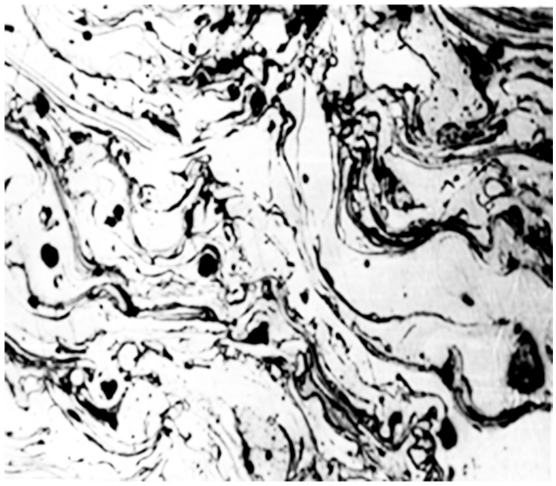
Electrosparking coating is the original material received as a result of blow, deformation and extremely fast crystallization of small (5–100 microns) particles of the metal sprayed on recovered surfaces of details.

The sprayed particles transported by a high-speed jet of combustion products, in the process of collision with a recovered surface are mushroomed and mixed up [3, 5, 9].

The sprayed particles forming a coating are exposed to difficult thermochemical processing: to melting, interaction with a sprayed jet, to evaporation, blow, a spreading. These processes occur simultaneously. The crystallization front moves in a direction of the fused particle.



a



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b

Fig. 3. The microstructure of coatings obtained by spraying of combustible products of propane-air mixture (*a*) and air (*b*)

The solidified material of a particle is exposed to pressure from side of no crystallized melt of a particle and is laying through which this pressure is transmitted to a recovered surface [3, 5, 9].

As a result after complete solidification the particle saves the spread shape (Fig. 4). At blow about a recovered surface particles have a various condition and take the shape mostly strongly deformed, but also there are particles of the round shape. These are particles which have stiffened in flight, not capable to the big plastic deformations.

Sequentially being imposed against each other, particles create an electrosparking coating which has a strongly pronounced stratified structure (Fig. 5). Lamination gives elasticity to coatings [3, 5, 9].

Thus, the structure of an electrosparking coating is represented the heterophase system consisting of two and more phases, seperated among themselves by section boundary (Fig. 6) and differ among themselves by a chemical compound and properties [5].

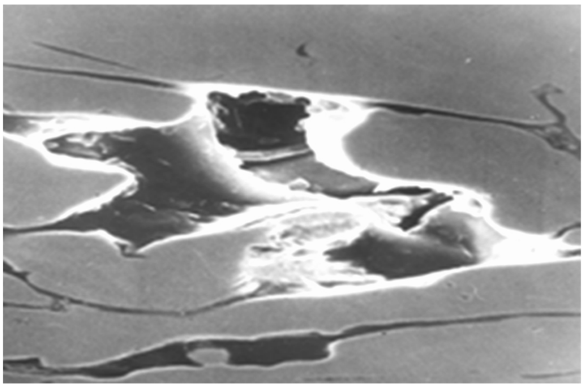

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Fig. 4. The morphology of hardened particles after blow

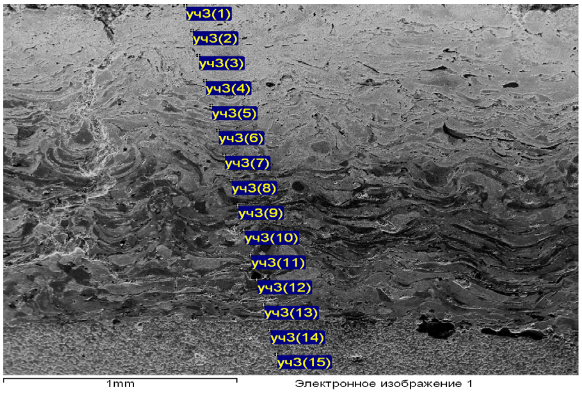

Fig. 5. The fragment of coating on restored surface obtained at spraying of steel wire

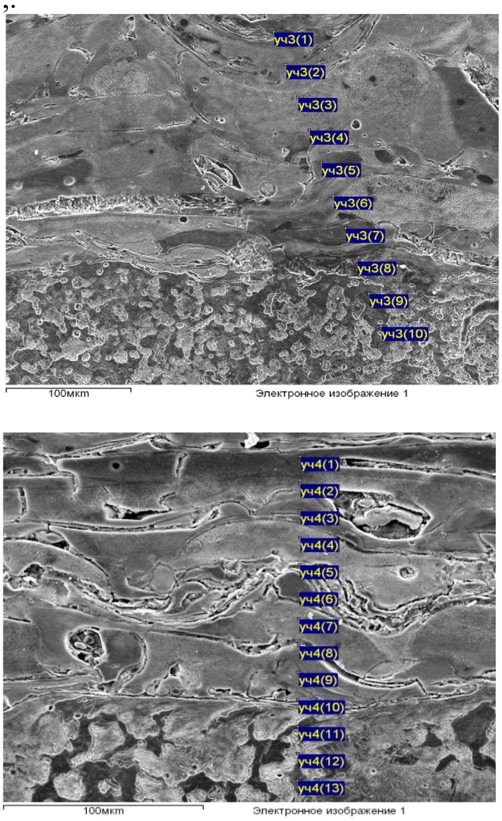

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Fig. 6. The microstructure of electrosparking coating

The structure of electrosparking coatings from a wire steel 40X13 which was used in the research process, represents the stratified system consisting of prolonged pellets — lamels (Fig. 7) which phase composition corresponds to a hard chrome solution in α-iron, with fine-dispersed additives of compounds of oxides and iron and chrome carbides [4–9].

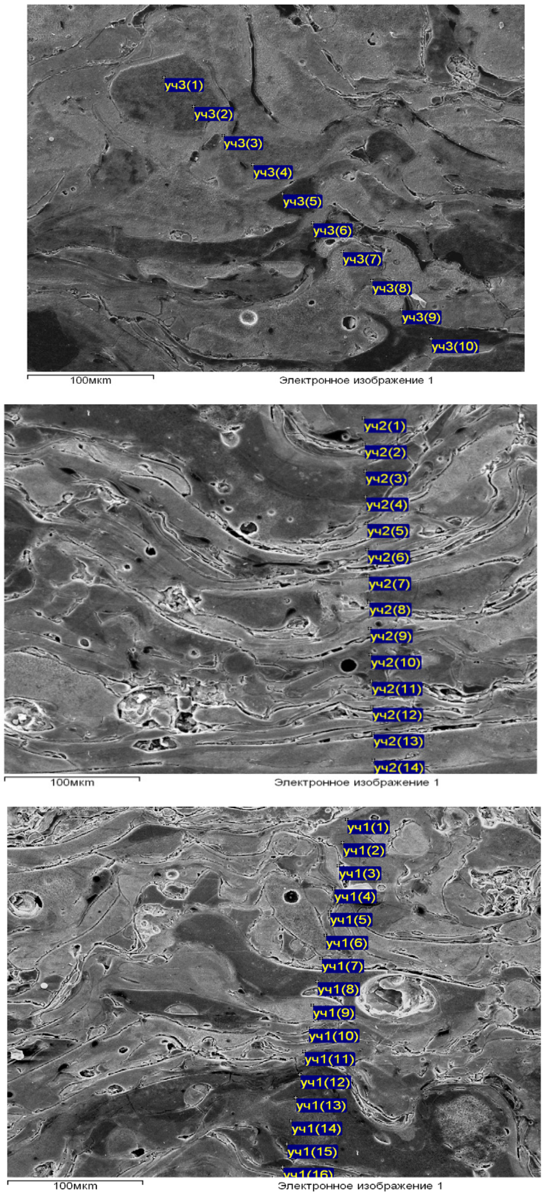

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Fig. 7. The lamellar structure of electrosparking coatings

Thus, electrosparking coating have lamellar structure of crystallized particles of metal and oxides, and oxides are settle down, as a rule, on boundaries of lamels. Formation of fragile oxides and intermetallids, along with formation of hardening structures, create premises for application of an electrosparking spraying method of coatings at restoration of details of aviation ground equipment and essentially expand their spectrum [3–5].

If for a compact material two types of boundaries — intergranular and phase-to-phase are characteristic, for coating three more varieties of boundaries are added: between the deformed particles; between layers; the boundary separating a coating and a base metal. For structure of the electrosparking coatings received by dispersion of particles by combustion products of propane-air mixture, small presence of visible boundaries between particles, small volume of a pores and additives, absence of not deformed particles in a coating (see Fig. 1, 2 and, 4) is characteristic. There are adjacent particles, not seperated by a surface film of oxides in coatings: the electrosparking coatings received by dispersion by combustion products have a lot of such particles (see Fig. 1*b*, 2*a*), than at the coatings received by dispersion of a compressed air (see Fig. 1*b*, 2*a*). It occurs when films of oxides at blow are failed, uncover pure metal of particles. It is observed in these places spot welding of pure surfaces of metal parts. The particle of the spraying metal stops to be deformed, if following sprayed particles of the small sizes and force of their pressure is insufficient for a plastic deformation. On Fig. 3 the morphology of hardened particle after blow about a cold recovered surface is shown. The particles sprayed by air, are covered by oxide film in flight which is cracked after blow about a recovered surface. The surface of the particle sprayed by combustion products with a great speed in the protective warmed up environment, is almost free from oxides [5, 9] that is confirmed by results of other researches [3].

At research of the surfaces recovered by electrosparking coatings, and comparison of their structure and properties the conclusion has been done that the better surface is obtained at its restoration by dispersion of wire steels 40X13 by combustion products of propane-air mixture (see Fig. 1–2, 4). The porosity is essentially decreased.

Possible ways of obtaining recovered surfaces with a demanded complex of operation properties and resource increasing of aviation ground equipment is restoration of their surfaces by electrosparking coatings from iron-carbonaceous alloys and control of structurally-phase transformations in these coatings during planting process on a recovered surface.

The phase composition of the electrosparking coatings received at dispersion of wire steel by a compressed air is defined by method of the X-ray analysis:

– 40X13 — α-phase (martensite), γ-phase (austenit), oxides Fe_3O_4 and FeO (Fig. 8*a*). FeO content in a coating from a steel 40X13 is rather insignificant;

– Св-08 — α-phase and oxide FeO (Fig. 8*b*).

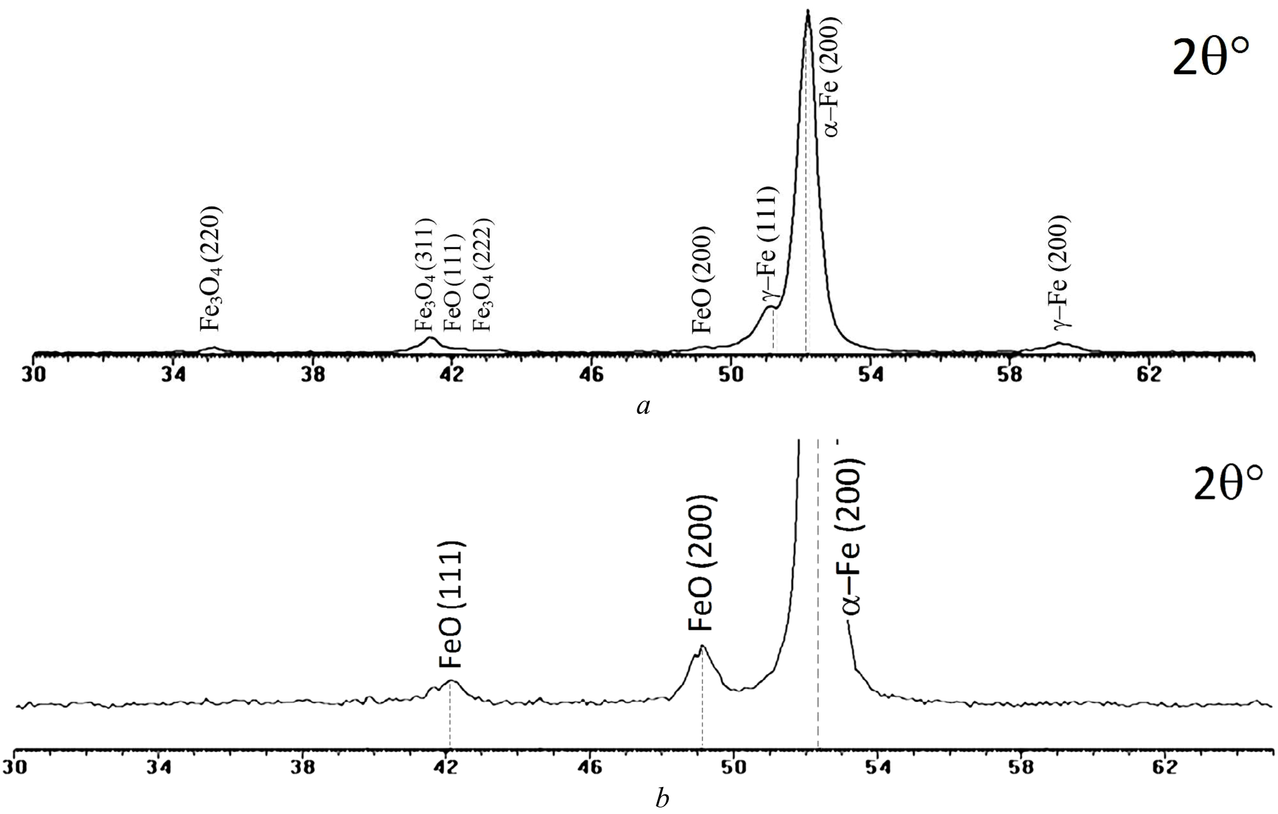

Fig. 8. The fragments of X-ray diffraction patterns (CoKα) of restored surface layers by electrosparking coatings at spraying wire steels 40X13 (*a*) and Св–08 (*b*) by compressed air

It is determined at research of phase composition of the recovered surfaces by electrosparking coatings from wire steels of Св-08 and 40Х13 at their dispersion by combustion products of propane-air mixture that in a recovered surface with a coating from a steel:

– Св-08 contains α-phase, oxides FeO and oxides Fe_3O_4 (Fig. 9*a*). Thus the content in a coating of oxide FeO essentially exceeds content Fe3O4;

– 40Х13 contains α -phase (martensite), γ-phase (austenit), oxides Fe_3O_4 and oxides FeO (Fig. 9*b*).

Unlike a coating from a low-alloy steel Св-08, FeO content is rather insignificant (Fig. 9*a*).

The results of researches of phase composition of restored surfaces of samples with electrosparking coatings from wire steels 40Х13 and Св-08 are shown in Table.

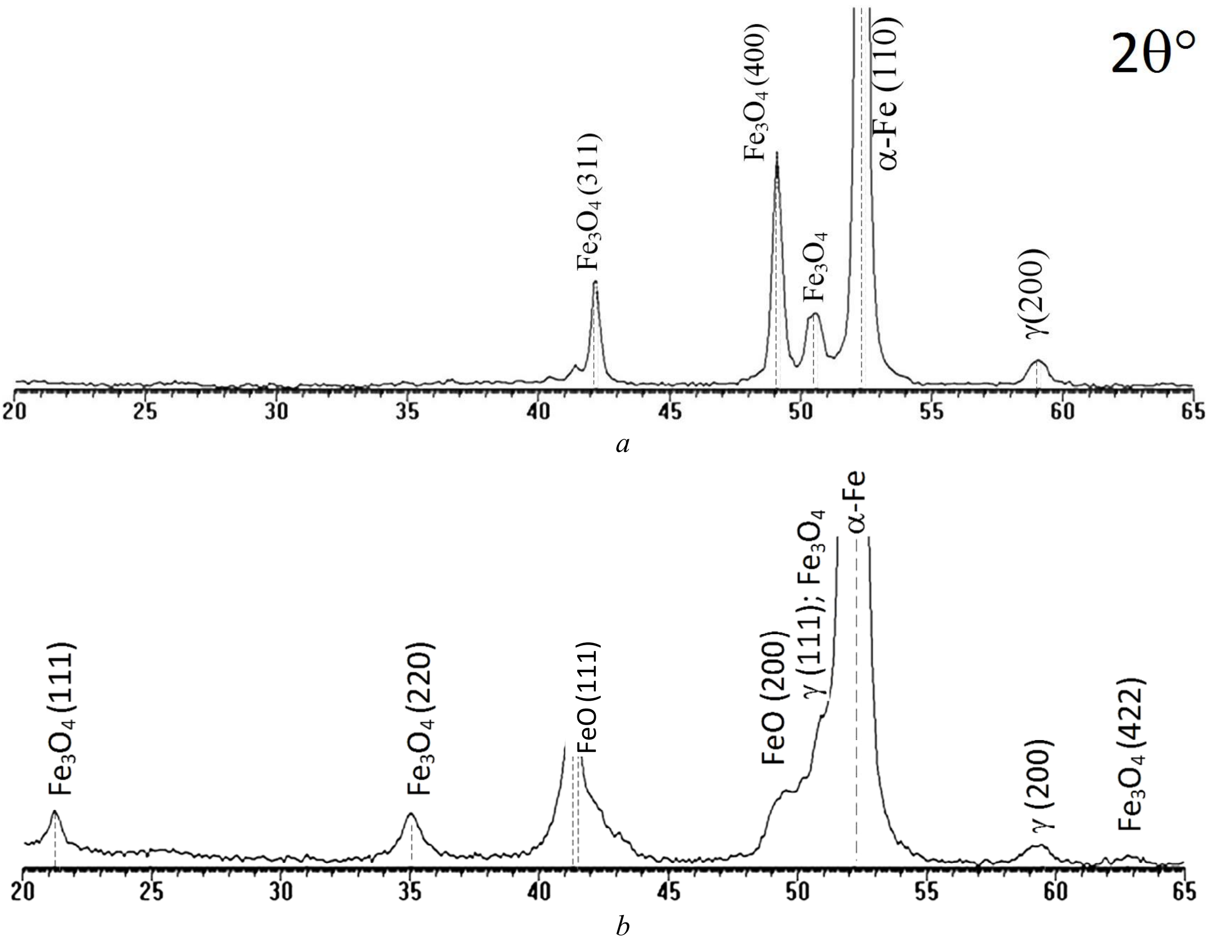

Fig. 9. Fragments of diffraction patterns of recovered surface layers by electrosparking coatings at spraying wire steels Св-08 (*a*) and 40Х13 (*b*) by combustion products of propane-air mixture

Table

The phase composition of coatings from wire steel Св-08 and 40Х13

Coating material	The phase composition of surfaces restored by electrosparking coatings at spraying wire steels	
	By combustion products of propane-air mixture смеси	By compressed air
Св-08	α-Fe; FeO; Fe_3O_4	α -Fe; FeO
40Х13	α-Fe; FeO; Fe_3O_4;γ-Fe	α-Fe; γ-Fe; FeO; Fe_3O_4

The phase composition of the surfaces restored by electrosparking coatings by dispersion of wire steels Св-08 and 40Х13 by a compressed air (see Fig. 8) is close to phase composition of the corresponding surfaces restored by the same coatings by dispersion of the same wire steels, but only by combustion materials of propane-air mixture (Fig. 9). At spraying of wire steels by a compressed air in process of an electrosparking spraying rather lower temperature of the spraying particles and their big size are characteristic that leads to greater burn out in them of alloying elements and to oxidizing spraying layers in comparison with the layers received at spraying of these wire materials by combustion products of propane-air mixture. The data of X-ray analysis testifies about lower concentration of oxidizing products in the coatings received by electrosparking spraying of wire steels by combustion products. Besides for coatings from a steel 40X13 the extend content in them of carbon and oxides (see Fig. 8*a* and 9*b*) and the highest level of hardness and a microhardness (Fig. 10, a curve *1*) is characteristic. It is possible to see that depth of hardening is spreaded practically to all area of a coating and makes ≈0,2–0,25 mm (Fig. 10). The increased microhardness of a coating from a steel 40X13 is caused by high concentration of carbon in it. It is interesting to underline that crackings in a layer are not registered.

The specified features promote to following changes of structure in surface layers of an electrosparking a hard solution of carbon in α-Fe, and also additives of carbides (see Fig. 8*a* and 9*b*). Thus presence coating from a steel 40X13 — formation of the structures containing at a coating from a steel 40X13 of high-tensile phases of a martensite and carbides (see Fig. 8*a* and Fig. 9*b*) will ensure increased microhardness and wear resistance of the recovered surfaces [6–9], and consequently, their resource.

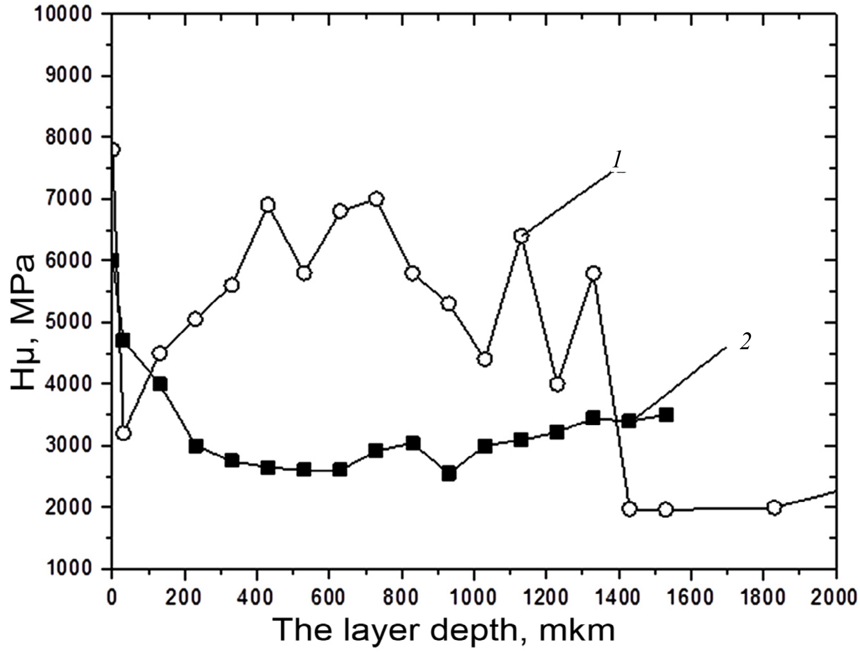

Fig. 10. The distribution of microhardness by depth of electrosparking coatings from steel 40X13 (curve *1*) and steel Св-08 (curve *2*)

Conclusions

Thus, it is established on the base of conducted researches that at restoration of surfaces by an electrosparking spraying:

– Wires from steels of Св-08 the layers with rather low level of a microhardness (Fig. 10*a* curve *2*) which is caused by small concentration of oxides are formed;

– Wires from steels 40X13 the layers with a high microhardness (Fig. 10*a* curve *1*) which is ensured with high concentration of alloying elements (chrome and carbon) are formed.

The reason of higher microhardness of the surfaces restored by electrosparking coatings from a steel 40X13 (Fig. 10) is higher concentration in them of alloying elements (chrome and carbon) at complete dissolution of chrome carbides at wire melting and saturation of melt drops by carbon from a flame, in comparison with steels of Св-08 (see Fig. 8–9).

The absence of particles of carbides Cr_3C_6 testifies about this.

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