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Structure formation of abrasive-resistant coatings

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Abstract

The paper presents the results of the study of abrasion-resistant coatings obtained by surfacing on alloying compositions Fe-Cr-Mo-V-C and Fe-Cr-B4C-Mo-C.It is established that with the increase of chromium in alloying compositions from 2% to 10%, the hardness and wear resistance of coatings increases due to the formation of a significant amount of complex alloyed carbides.The microhardness of the structural components of the deposited coatings correlates with the percentage of carbido-forming elements. Chromium-based coatings with the addition of vanadium, molybdenum and boron have shown high wear resistance under abrasive wear.

Key words: electric arc surfacing, alloying compositions, carbide inclusions, alloyed structures, microhardness.

Introduction

With the use of surfacing, parts are made that have special service characteristics of working surfaces, as well as their initial dimensions and operational properties of worn surfaces are repeatedly restored.Arc surfacing methods have become the dominant use in production practice. One of the most common methods is surfacing in shielding gases. And the development of surfacing technology using alloying elements is very important.

The main contribution to the wear resistance of the material is made by harder components, which are often carbides. Hence the desire to increase the amount of carbides in the structure of wear-resistant alloys. Sometimes their number is increased to 90% [1,2]. It is established that wear resistance is affected not only by size but also by the shape of carbides [3].

Grinding of carbide inclusions (for example, as a result of accelerating the crystallization of cast iron) increases wear resistance. Moreover, carbides in the form of isolated inclusions most intensively increase wear resistance. Less wear-resistant alloys have the structure of which contains ordinary cementite - an unstable phase. Under conditions of friction during operation, according to the modern theory of friction and wear, in the microzones of molecular adhesion there are so-called "high-temperature" points at which the substance can even pass into a plasma state. Under the influence of temperature, the wear-resistant components of the surface layer, in particular cementite, disintegrate, which leads to accelerated wear of working surfaces [5,6]. To stabilize cementite, it is necessary to introduce alloying elements that prevent the decomposition of cementite, namely: Cr, V, B, Mo and others.

One of the cheapest and most affordable elements is chrome, so it is most widely used in surface alloying of products [10]. The expediency of alloying the welded surfaces with chrome is due to the following circumstances:

- chromium cementite $(Fe, Cr)_3C$ has a higher hardness and therefore wear resistance than unalloyed Fe_3C cementite [1];
- doping with chromium increases the melting temperature of ledeburite, and hence the phenomenon of local melting at the points of high-temperature "flashes" in the "molecular" setting in the zone of friction and wear occurs much less frequently in alloyed cast iron;
- chromium increases chemical resistance and reduces oxidative wear at "setting points".

Studies of the processes of abrasive-corrosion wear of chromium steels [4,7,8,9] have shown that at low and moderate intensity of abrasive particles have sufficient resistance to steels with chromium content up to 14%. Instead of chromium often use V, B, Mo, forming carbides and carborides .

The introduction of boron into the deposited metal helps to change the critical ratios of carbide-forming elements to carbon, intensifies the release of special carbides [11] and carboborides $(Cr, Fe)_7(C, B)_3$ and $(Cr, Fe)_{23}(C, B)_6$), and also contributes to the grinding of the carbide phase, which significantly increases both the hardness and wear resistance of the weld metal [12]. Introduction to the alloy of 0.4 ... 0.6 wt. % boron shifts the eutectic point of alloys to the left, thereby promoting the loss of excess carbides and at the same time to increase the wear resistance of the weld metal, which works well even in conditions of intense abrasive wear without shock loads [2]. Other alloying systems use active carbides: tungsten, molybdenum, vanadium, titanium, niobium, tantalum, zirconium, which form monocarbides in the weld metal, increase its wear resistance, both at normal and at elevated temperatures. Excess alloying elements that are not involved in the formation of carbides, such as vanadium, molybdenum are soluble in solid solution, increase its strength at high temperatures. During heat treatment of welded products, or as a result of the thermal cycle of surfacing, as well as during their operation, supersaturated solid solutions can emit intermetallic compounds, which further increase the hardness of the metal [11]. Chromium-based coatings with the addition of vanadium, molybdenum and boron have shown high wear resistance under abrasive wear. The aim of the work is to create alloying compositions to counteract abrasive wear without shock loads.

Methods of experiments

On the original samples measuring 60x20x8 mm from steel sheet (steel 45) according to GOST 19903-2015 was applied prepared alloying composition (pre-mixed) in the form of a suspension in which the role of liquid dispersion medium was silicate glue (liquid glass according to GOST 13078-81), and the role of the solid dispersed phase is the powder charge (alloying complexes Fe-Cr-Mo-VC and Fe-Cr-B_4C-Mo-C).

In all cases, carbon was added to the composition in the form of graphite powder; alloying elements (chromium, molybdenum, vanadium) - respectively in the form of ferrochrome powders according to GOST 4757-91, ferromolybdenum according to GOST 4759-91, ferrovanadium according to GOST 27130-94; boron carbide. The applied suspension is quite viscous, after some time the samples were dried in an oven for 1 h at a temperature of 300oC. Surfacing of the prepared samples was performed on a surfacing unit UD-209M in carbon dioxide medium with copper-plated wire Sv-08G2S, 1.2 mm in diameter. Surfacing mode: current - 100 A, voltage - 25 V, surfacing speed - 5 m / h. Microstructural studies of the surface layers of the obtained samples were performed using MBS-6 and MIM-8 optical microscopes. Capturing images and converting them into digital form was carried out using a special eyepiece camera and computer. To perform microstructural studies, sections were made according to standard methods. Chemical etching of the sample surface was performed with a 4% solution of HNO3 in alcohol. Microhardness was measured with a microhardness tester PMT-3M.

Characteristics of prototypes

Used alloying compositions of the following composition:

1 - Cr-B4C-Mo-C - 2% chromium, 1% boron carbide, 0.5% molybdenum and 0.4% carbon;
2 - Cr-Mo-V-C - 5% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon;
3 - Cr-Mo-V-C - 10% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon.

Visible defects, micro- and macrocracks are absent for the deposited layers.

From the above data on the chemical composition of the components it is clear that the main alloying elements are chromium with the addition of vanadium, molybdenum or boron carbide in the presence of carbon.

Results of research and discussion

Figure 1 shows the structure of the base metal of steel 45, which is ferritic-pearlitic.

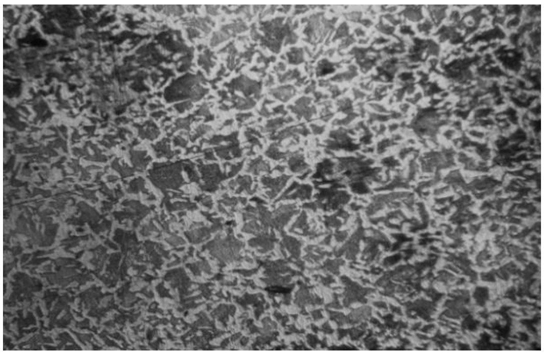

Fig.1. The structure of the base metal of steel 45 (x150)

The results of studies of the microstructures of the deposited coating system Fe-Cr-B4C-Mo-C are shown in Fig.2. In the transition zone (Fig. 2.a) a carbide grid was detected, which stood out along the grain boundaries. In the deposited layer (Fig. 2.b) this composition was ground grain due to the presence of carboborides with a limited amount of carbon.

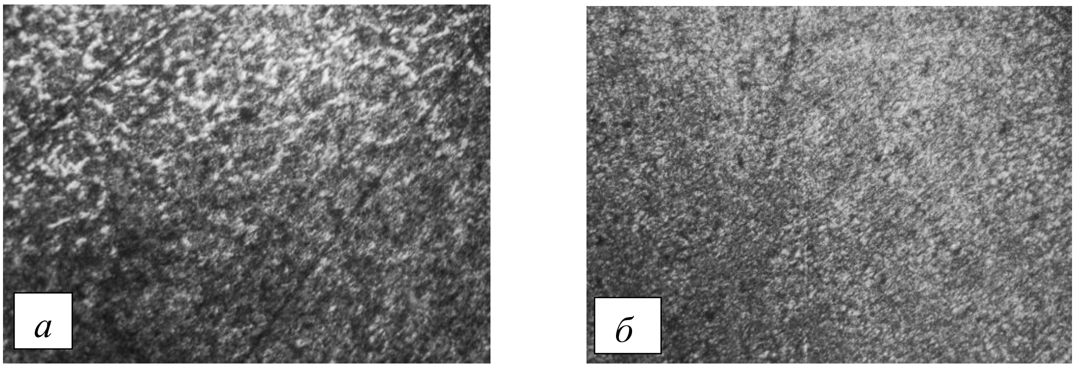

Fig.2. Microstructures of the deposited coating system Fe-Cr-B4C-Mo-C - 2% chromium, 1% boron carbide, 0.5% molybdenum and 0.4% carbon, thickness up to 0.5 mm (x150)

In fig. 3 shows the results of studies of the microhardness of the sample coated with the composition Fe-Cr-B4C-Mo-C, which is made on a microhardness tester PMT-3 with a step of 0.125 mm, starting from the coating surface to the base. The highest hardness is found on the surface of the coating and reaches ≈ 9500 MPa. Measurement of microhardness with a constant step leads to the fact that the indenter falls on different structural components. Carbides and carboborides show high hardness, and the matrix shows the hardness of hardened steel.

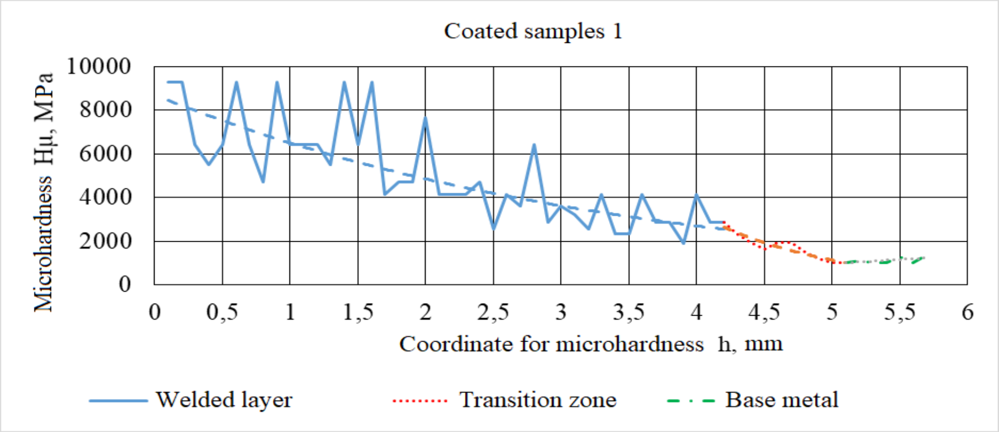

Fig. 3. Microhardness of the sample coated with the composition Fe-Cr-B4C-Mo-C - 2% chromium, 1% boron carbide, 0.5% molybdenum and 0.4% carbon

Figure 4 shows the microstructures of the transition zone (Figure 4, a) and the deposited coating of the Fe-Cr-Mo-V-C system (Figure 4, b). In the transition zone there are small inclusions and signs of stratification of structural components.

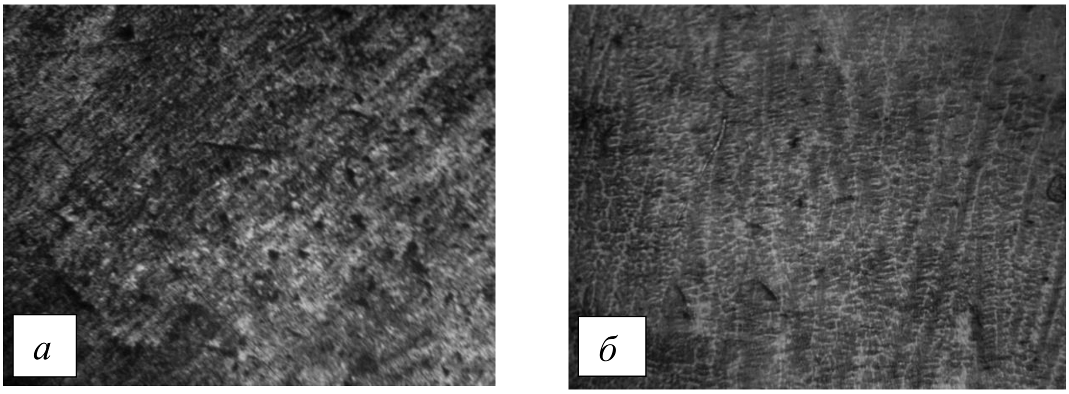

Fig.4. Microstructures of the deposited coating system Fe-Cr-Mo-V-C - 5% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon, thickness up to 0.5 mm (x150)

In the deposited layer, a similar pain is also observed. The hardness of the surface layer (Fig. 5) was also measured with a hardness tester PMT-3 with a step of 0.125 mm from the surface to the depth of the coating. The maximum microhardness reaches ≈ 14000 MPa, and the microhardness of the matrix, as in the previous case for the Fe-Cr-B4C-Mo-C system, is ≈ 4500 MPa.

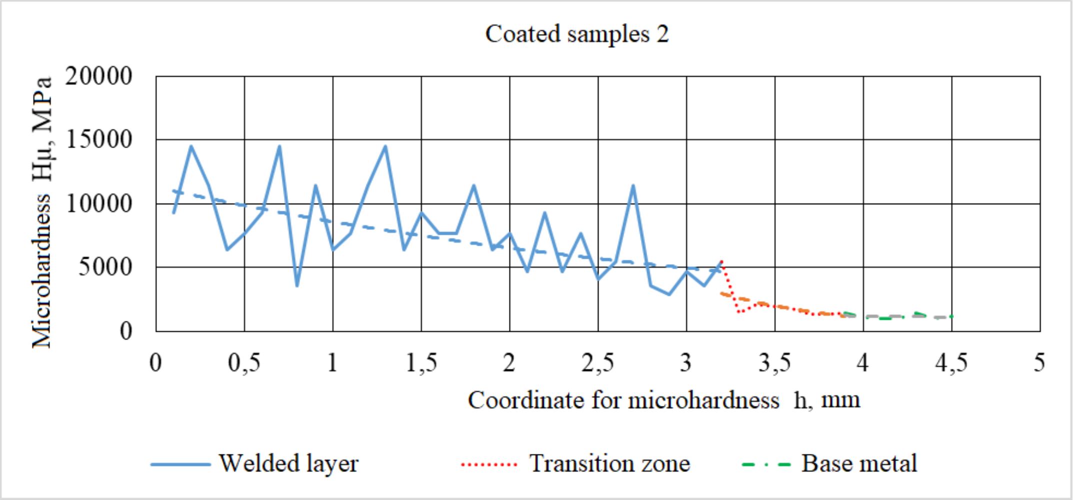

Fig. 5. Microhardness of the sample coated with the composition Fe-Cr-Mo-V-C - 5% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon

Figure 6 shows the transition zone (Figure 6, a) and the deposited layer (Figure 6.b) of the Fe-Cr-Mo-V-C composition with high chromium content. In the transition zone, the inclusion of chromium defunted by various mechanisms is observed. Carbide mesh of the cementite type was formed in the deposited coating along the boundaries of small grains.

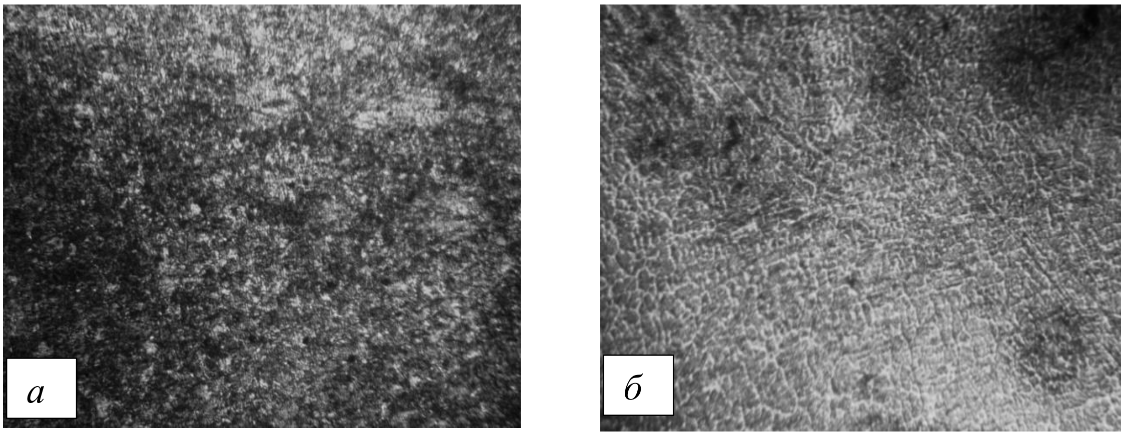

Fig.6. Microstructures of the deposited coating system Fe-Cr-Mo-V-C - 10% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon, thickness up to 0.5 mm (x150)

The microhardness of the surface layer (Fig. 7) was measured by a similar method. The maximum microhardness reaches ≈ 15000 MPa, and the microhardness of the matrix, as in the previous case for the Fe-Cr-B4C-Mo-C system, is ≈ 8000 MPa due to doping.

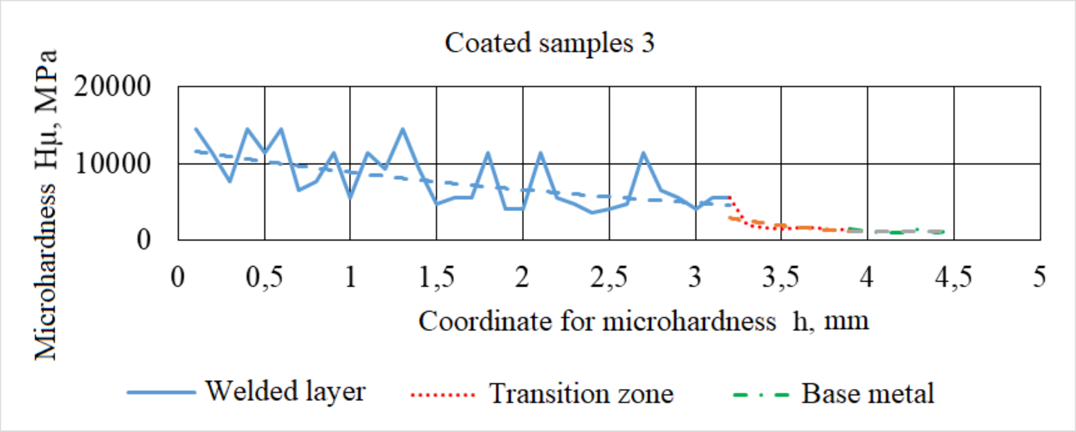

Fig. 7. Microhardness of the sample coated with the composition Fe-Cr-Mo-V-C - 10% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon

The integrated hardness of the deposited layers is shown in Figure 8.

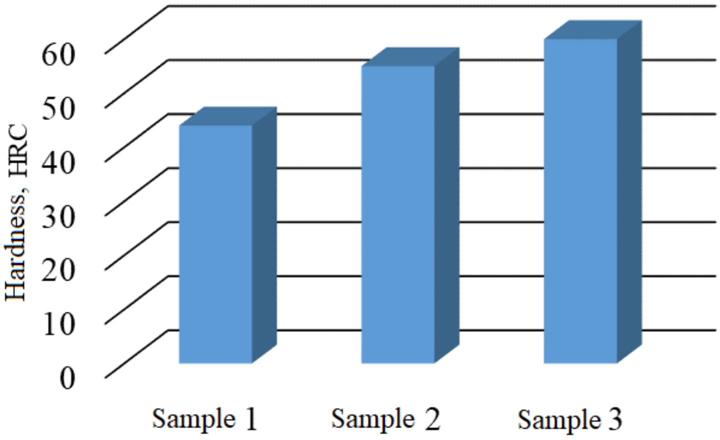

Fig.8 . Chart of hardness of prototypes

Coatings with hardness were obtained by the number of alloying elements: for the first sample (Cr-B_4C-Mo-C - 2% chromium, 1% boron carbide, 0.5% molybdenum and 0.4% carbon) - the hardness of the deposited surface was 44 HRC; for the second sample (Cr-Mo-V-C - 5% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon) - 55 HRC; for the third sample (Cr-Mo-VC - 10% chromium, 1% molybdenum, 1% vanadium, 0.8% carbon) the surface hardness of the scale is 60 HRC, which is 5 units of HRC higher than the second sample due to different contents chromium (with the same content of other elements). Visible defects, micro- and macrocracks are absent for the deposited layers.

Conclusions

1. High wear resistance in abrasive wear showed chromium-based coatings with the addition of vanadium, molybdenum and boron.
2. With an increase in the amount of chromium in alloying compositions from 2% to 10%, the hardness and wear resistance of coatings increases due to the formation of a significant amount of complex alloyed carbides. The microhardness of the structural components of the deposited coatings correlates with the percentage of carbide-forming elements.
3. The introduction of boron carbides in the alloying composition promotes the grinding of grains.

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Савуляк В.І., Шенфельд В.Й., Шиліна О.П., Осадчук А.А. Структуроутворення нанесених абразивностійких покриттів.

В роботі показані результати дослідження абразивностійких покриттів, отриманих шляхом наплавлення на легувальні композиції Fe-Cr-Mo-V-C та Fe-Cr-B4C-Mo-C. Встановлено, що зі збільшенням кількості хрому в легувальних композиціях від 2% до 10%, підвищується твердість та зносостійкість покриттів за рахунок утворення значної кількості складнолегованих карбідів. Мікротвердість структурних складових наплавлених покриттів корелює з відсотком карбідотворних елементів. Високу зносостійкість в умовах абразивного зношування показали покриття на основі хрому з додаванням ванадію, молібдену та бору.

Ключові слова: електродугове наплавлення, легувальні композиції, карбідні включення, леговані структури, мікротвердість.