Structure and characteristics of chromium steel coatings alloyed with boron carbide

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Abstract. This study explores the problems arising from the increase of wear resistance on the coatings of details of a wide range of applications, obtained by surfacing the Fe - Cr system with flux-cored wires. It has shown that insignificant wear resistance of such steel under conditions of metal friction against another metal is due to their relatively low hardness and the absence of strengthening phases. It also shows the effect of boron carbide on the structure and the characteristics of chromium steel obtained by the surfacing process. It was established that the use of high-chromium flux-cored wires alloyed with boron carbide aids the production of a deposited metal of a composite type, with a dispersed hardening based on chromium carboboride. The deposited metal with such structure has a high wear resistance and the hardness of 55 ... 58 HRC and can be used for surfacing cladding the hardening, corrosion-resistant coatings.

1. Introduction

A significant range of parts used in various industries is made from chromium steel, which combines sufficiently high strength with corrosion resistance [1]. Prospectively these can be used as surfacing materials in order to obtain wear-resistance on a wide range of details (parts), thus increasing their service life and providing a significant economic effect. Therefore, the development of these wear-resistant compounds is an urgent task.

2. Statement of a problem

The majority of chromium steel compounds are based on the Fe-Cr system. It serves as a base for the development of solid steel and flux-cored surfacing wires containing 13–17 % chromium [2–4]. At the same time, its wear resistance becomes negligible if friction is present. This happens due to the relatively low steel hardness and the absence of the strengthening phase.

Therefore, the task ahead consists of obtaining the coatings made from chromium steel with a high-hardness strengthening phases.

3. Theory

One of the ways to imrpove the properties of the deposited metal is by adding boride compounds into the dispersion hardening process [5–10]. Alloying the deposited metal with boron carbide opens extra prospects [7, 8, 11, 12]. At the same time, the use of boron carbide in surfacing chromium steel with flux-cored wires has not been sufficiently studied.

Therefore, this study explores the influence of boron carbide on the structure and properties of chromium steel obtained by the surfacing process.

4. Results of the experiments and discussion

As our research object, we chose chromium steel 10X15, obtained by surfacing with a flux-cored wire that contains an additional 2 % of boron carbide.

The surfacing was carried out on St3 steel plates, 200 × 50 × 10 mm in size with experimental flux-cored wires 2,4 mm in diameter in argon in three layers. Surfacing mode: current strength is 230 A; the voltage is 24 V; the speed of surfacing is 20 m/h. The metal was analyzed upon the completion of the surfacing process.

We carried out the metallographic research of the deposited metal on an optical microscope AXIO Observer A1m (Carl Zeiss). The microstructure was detected by chemical etching in a reagent of the composition: $CuSO_4$ – 4 g; HCl – 20 ml; H_2O – 20 ml.

Electron microscopy examination was carried out with a raster-type electron microscope JEOL JSM-6610-LV with add-on device Inca-350 of energy-dispersive analysis (EDA).

Durometric research WAS carried out on the metal samples after surfacing using TK-2 hardness testers by the Rockwell method and Shimadzu HMV-2 using the Vickers method.

The effectiveness of alloying chromium steel with boron carbide is convincingly manifested when comparing the hardness of the deposited metals. The results of the distribution of hardness along the height of the surfaced bead are shown in figure 1.

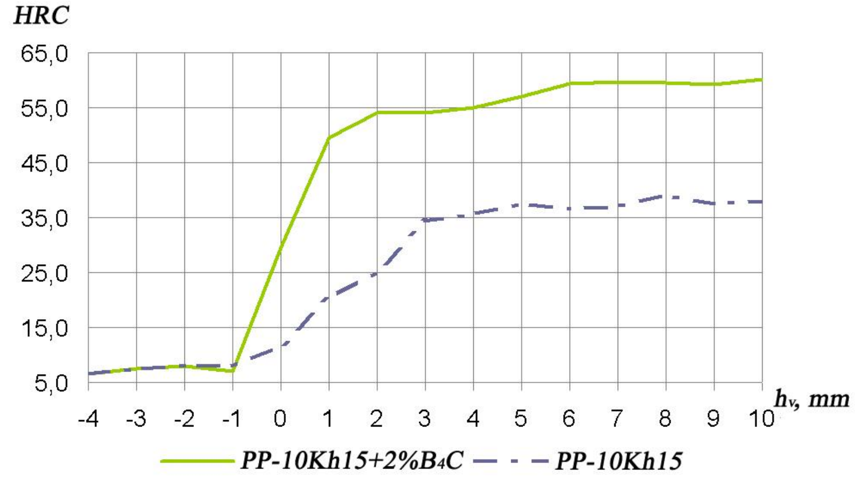
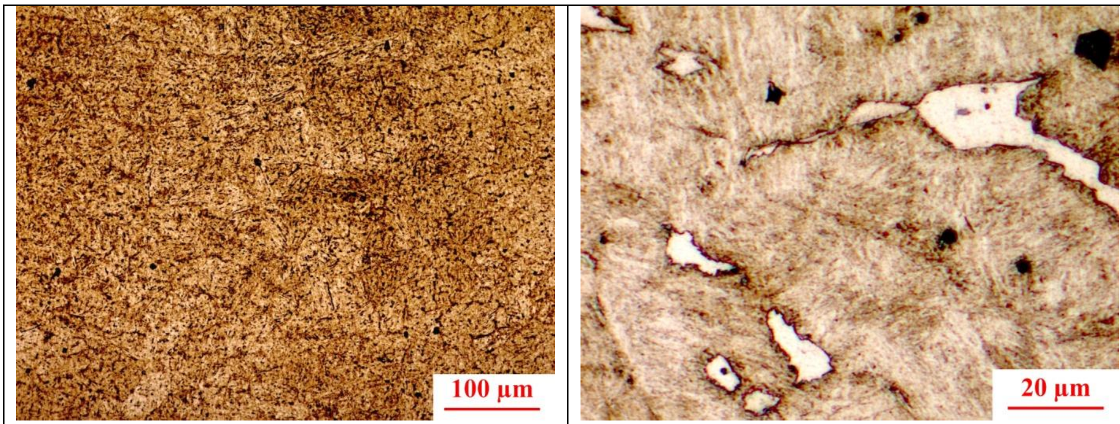


Figure 1. Relationship between the hardness value and the distance from the fusion line (0) during the surfacing process using the compounds in question.

Through the analysis of the collected data, it can be noted that the hardness of the deposited metal is almost equally distributed over the height of the coating. Evidentally, this is due to the invariance of its obtained structure, resulting, in small part, from the main metal. The hardness values of the metal with boron remain stable in the range of 55 ... 58 HRC and significantly exceed the hardness of the metal without boron, which remains in the range of 35 ... 38 HRC.

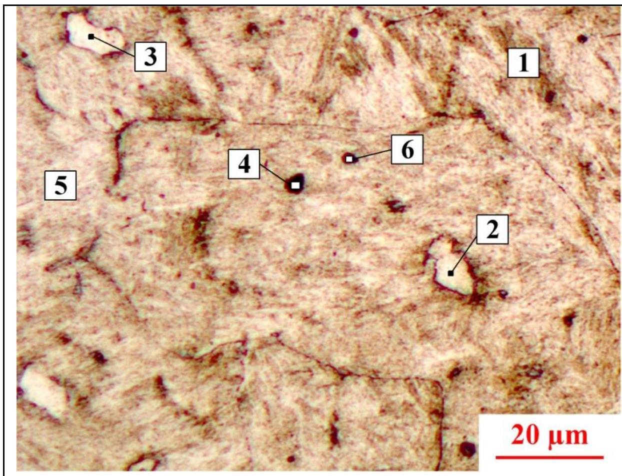
Metallography research carried out to identify these differences has shown that the deposited metal without boron has a ferritic-martensitic structure (fig. 2, a). In addition, a large amount of δ-ferrite precipitate was observed on the grain boundaries (fig. 2, b).



a) b)

Figure 2. The microstructure of the metal surfaced with flux-cored wires type PP-10Kh15.

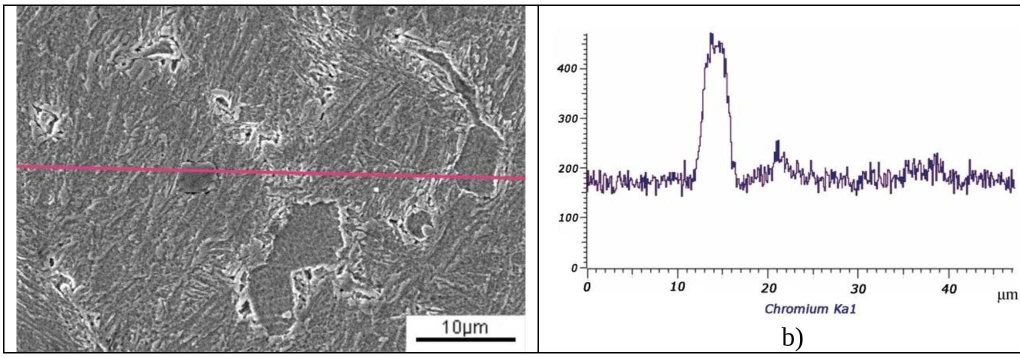
The analysis of the microhardness structure of the metal without boron is shown in figure 3 and confirms the presence of a ferritic-martensitic matrix, δ-ferrite and carbides. The hardness of the matrix is low and amounts to 408 ... 429 HV. The hardness of δ-ferrite is even less – 358 ... 376 HV, and carbides are 551 ... 609 HV.



Puncture №	Hardness, $HV_{0,01}^{*}$ and $HV_{0,05}$
1	408
2*	376
3*	358
4*	551
5	429
6*	609

Figure 3. The measurement field and the values of the microhardness of the structural constituents of the metal surfaced with a flux-cored wire type PP-10Kh15.

The results of the qualitative energy dispersive analysis (EDA) of this metal, carried out through the raster-type electron microscopy method, are shown in figure 4.



b)

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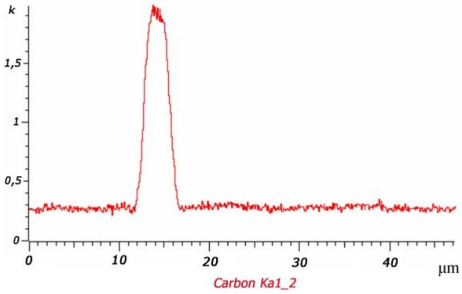
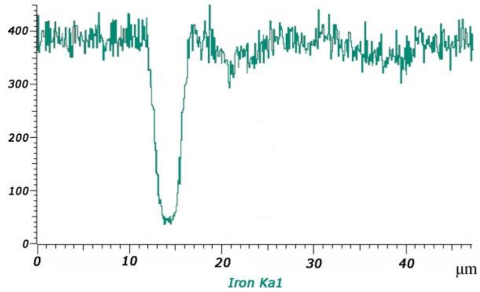
a)



c)



d)

Figure 4. The results of scanning the structure of the deposited coating obtained by the flux-cored wire type PP-10Kh15: a) image of a scanned microstructure; b)-d) concentration spectrograms of the distribution of elements along the scanning line.

The obtained data shows that chromium carbides serve as a base for the hardening of this metal.

Adding boron carbide into the deposited metal leads to the formation of a composite structure (fig. 5). It has significant dendritic characteristics. A coarse eutectic is located along the boundary of the dendritic cells, while a large amount of strengthening phases is observed in the martensitic matrix.

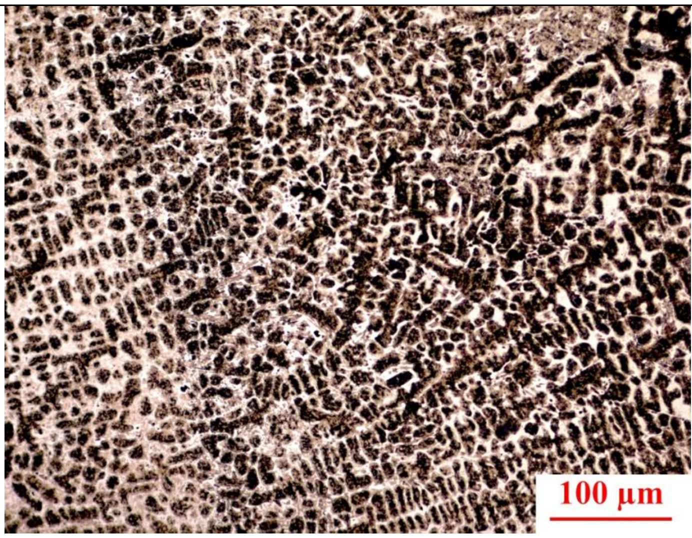
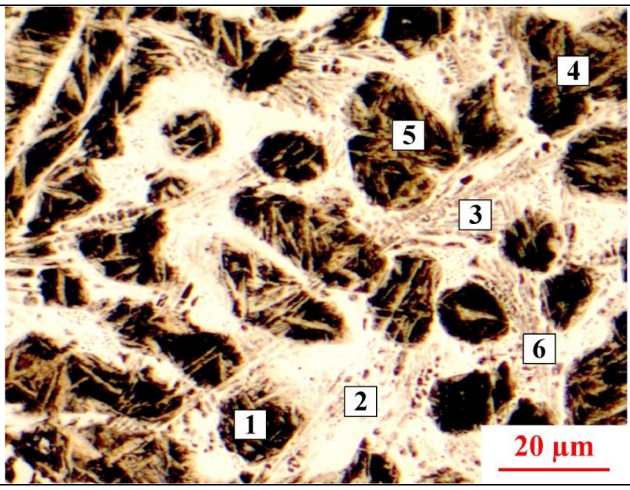


Figure 5. The microstructure of the metal surfaced with flux-cored wire type PP-10Kh15+2%B_4C.

The results of the microhardness research carried out on the structural components of the deposited metal are shown in figure 6.

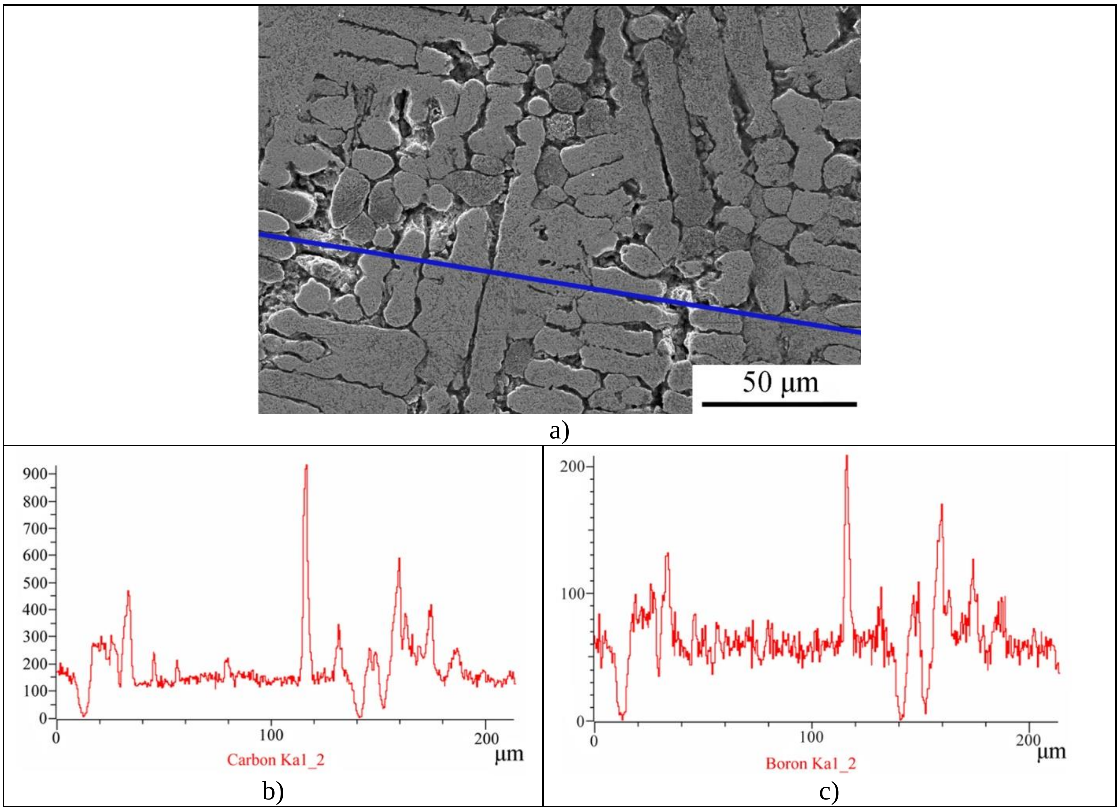


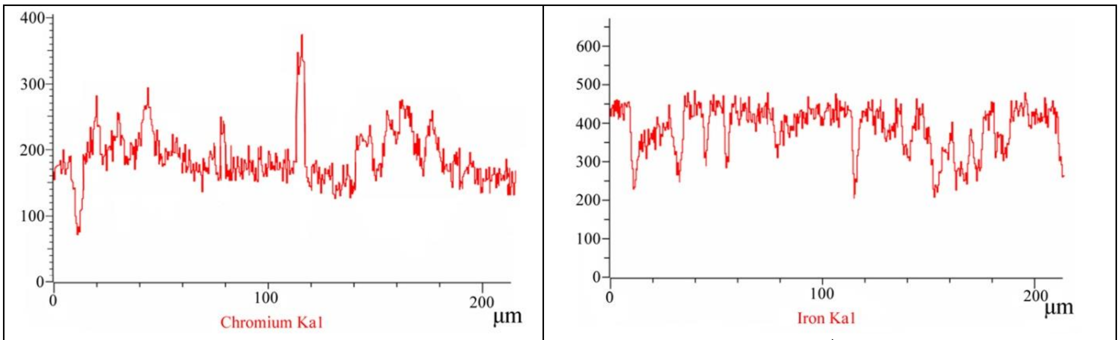
Puncture №	Hardness, $HV_{0,05}$
1	499
2	859
3	924
4	532
5	603
6	891

Figure 6. The measurement and the values of the structural constituents microhardness of the metal surfaced with a flux-cored wire type PP-10Kh15+2%B_4C.

It is established that the hardness of the matrix is in the range of 499…603 HV. A large amount of eutectic is observed. The hardness of the precipitated strengthening phases is significantly increased and is in the range of 859 ... 924 HV. Thus, the microhardness of the deposited metal structure significantly exceeds the microhardness of the constituent metal without borides.

The chemical composition of the areas coated through surfacing with flux-cored wires PP-10Kh15+2%B4C obtained by the EDA method are shown in figure 7.





d) e)

Figure 7. The results of scanning the deposited coating structure obtained by the flux-cored wire type PP-10Kh15+2%B_4C: a) image of a scanned microstructure; b)-e) concentration spectrograms of the elements distribution along the scanning line.

As the scanning results show, chromium carboboride acts as the main strengthening phase of this metal. The formation of the hardening phase with high hardness provides the deposited metal with an increased wear resistance.

5. Conclusion

The use of high-chromium flux-cored wires alloyed with boron carbide aids in the production of a composite type deposited metal, with high-hardness chromium carboboride serving as a base for its dispersed hardening. The deposited metal with this structure has a high wearing resistance and can be used to surface strengthening, corrosion-resistant coatings.

Acknowledgments

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