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WELDING-TECHNOLOGICAL PROPERTIES OF FLUX-CORED WIRE WITH BORON-CONTAINING BINDER IN THE CHARGE

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ABSTRACT

In order to improve the performance of metal deposited with PP-Np-50Kh2MNSGF flux-cored wire, boron-containing FKhB-1 binder was added to the wire charge in such a way as to obtain boron content on the level of 0.01 % in the deposited metal. The effect of adding FKhB-1 binder to the flux-cored wire charge on its welding-technological properties was studied experimentally. It was found that application of boron-containing binder in the flux-cored wire charge does not impair its welding-technological properties, boron microalloying leading to refinement of the deposited metal structure and increasing its hardness from *HRC* 53–57 to *HRC* 60–62 at the same content of other alloying elements. Developed PP-Np-50Kh2MNSGF flux-cored wire is proposed for deposition of wear-resistant layers for protection of parts of special machines and mechanisms in mining, metallurgical and other industries, operating under the difficult conditions of abrasive wear in combination with intense shock loads.

KEYWORDS: arc surfacing, flux-cored wire, microalloying, welding-technological properties, deposited metal, deposited metal formation

INTRODUCTION

Analysis shows that boron is quite often used as microalloying element in production of various steels and alloys in order to improve their performance [1–6]. At the same time, boron application as a microalloying or modifying additive at surfacing (welding) is rather limited [7–10], which is related to difficulties of selection of the type and method of adding boron-containing components to the weld pool, boron assimilation processes, determination of its optimal concentrations, etc., as boron is capable of rather significantly influencing the properties of steels and alloys at its concentration in the range of hundredths and thousandths of a percent.

So in work [11] it was shown that microalloying of 25Kh5FMS deposited metal by boron in the range of 0.007–0.010 % leads to a considerable refinement of its microstructure and a certain increase of matrix microhardness, without detracting from the quality of deposited metal formation.

It has a positive effect on the performance of deposited metal microalloyed by boron: its heat- and wear-resistance increases 1.5–2.0 times. Increase of boron concentration in the deposited metal ≥ 0.02 % leads to further increase of microhardness of 25Kh5FMS steel. However, it has a negative influence on the metal crack resistance: it forms a considerable amount of cracks, which propagate through all the deposited metal layers.

The objective of the work consists in determination of the influence of boron microalloying on welding-technological properties of surfacing PP-Np-50Kh2MNSGF flux-cored wire designed for improvement of wear resistance of special machines and mechanisms in mining, metallurgical and other industries, working under the difficult conditions of abrasive wear in combination with intense high dynamic shock loads.

INVESTIGATION MATERIALS AND PROCEDURES

In order to protect the working surfaces of the above-mentioned parts, which include lining elements of screens, bins, dump truck bodies, blades and covering discs of draft blowers and similar parts, in this work it is proposed to deposit wear-resistant metal layers by submerged-arc surfacing with flux-cored wire of PP-Np-50Kh2MNSGF grade.

Total thickness of the deposited wear-resistant metal depends on the service conditions of a particular part, and it can be from 3 to 10 mm. Considering the high coefficient of deposited metal dilution by base metal (up to 50 %) in flux-cored wire arc surfacing, it is usually necessary to deposit 3 to 4 layers to achieve the specified chemical composition of the deposited metal. Proceeding from the need to ensure the specified chemical composition and properties already in the 1^{st}–2^{nd} layer of deposited metal in some cases, the charge composition of PP-Np-50Kh2MNSGF flux-cored wire was optimized, and FKhB-1 binder, containing 12 % boron, was further added to the charge.

The quantity of FKhB-1 binder, added directly to the charge of experimental flux-cored wire in the form

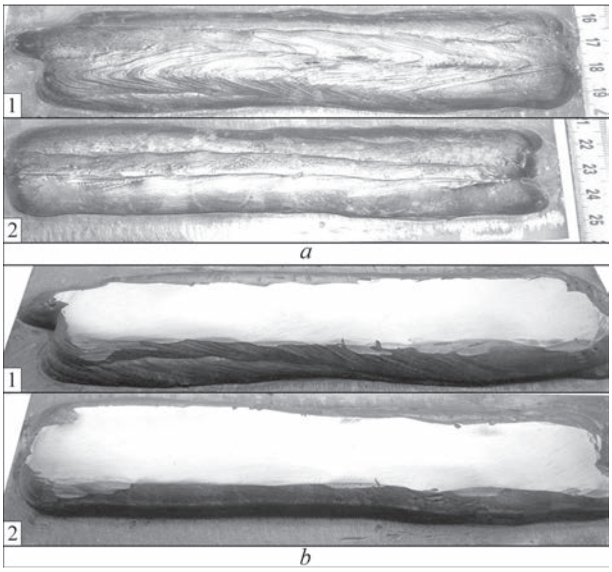

Figure 1. Appearance of beads deposited with PP-Np-50Kh2MNSGF wires of standard (1) and experimental (2) compositions immediately after deposition (*a*) and after mechanical scraping of the surface (*b*)

of powder during its manufacture, was calculated so as to obtain boron content on the level of 0.01 % in the deposited metal, taking into account the coefficients of wire filling and alloying element transition into the deposited metal. Such a concentration of boron in the deposited metal was selected in order to prevent cracking [11]. The flux-cored wire design is tubular with edge overlapping, 1.8 mm diameter and filling coefficient of 24 %.

Submerged-arc surfacing of test samples was performed by single beads with AN-26P flux in U-653 unit with VDU-506 power source in the following modes: 24 V voltage, 220 A current, 20 m/h deposition rate, 4 mm surfacing step, direct current, reverse polarity. Plates from 40Kh steel were used as base metal.

Two series of test samples were made. The first series was surfaced with wires of standard and experimental composition in four layers, which was followed by visual inspection of the processed surface before and after its mechanical cleaning. The second series of samples were surfaced stepwise in one, two and three layers. After that X-ray spectral method was used to determine the chemical composition of the deposited metal in the upper layer.

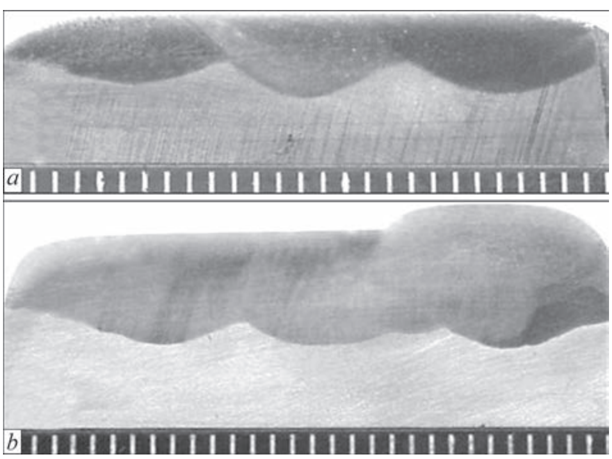

Figure 2. Macrosections of metal deposited by PP-Np-50Kh2MNSGF wire of experimental composition in one (*a*), two and three layers (*b*)

Welding-technological properties of experimental PP-Np-50Kh2MNSGF wire microalloyed by boron, compared to wire of the same grade of standard composition, were assessed by the following parameters:

- arc excitation mode (light, medium, complicated);
- melting characteristics (coefficients of melting, deposition, losses);
- arc burning stability (stable, satisfactory, unstable);
- quality of deposited bead formation (sound, satisfactory, poor);
- type and availability of defects in the deposited metal (absent, isolated, considerable number);
- quality of slag crust detachment (easy, satisfactory, complicated);
- compliance of deposited metal chemical composition and hardness with the specification (compliant, not compliant).

For calculation of the coefficients of melting (α_m), deposition (α_d) and losses (ψ) the plate and wire weight was determined before and after surfacing and deposition time was recorded. The respective coefficients were determined using common expressions:

$$\alpha_m = G_m/(I \cdot t), \quad (1)$$

$$\alpha_d = G_d/(I \cdot t), \quad (2)$$

$$\psi = ((\alpha_m - \alpha_d)/\alpha_m) \cdot 100\ \%, \quad (3)$$

where G_m is the molten metal weight, g; G_d is the deposited metal weight, g; I is the welding current, A; t is the deposition time, h.

EXPERIMENTAL RESULTS AND THEIR DISCUSSION

Appearance of the first series of samples immediately after surfacing and after mechanical scraping of the processed surface is given in Figure 1. Templates were cut out of samples of the second series (Figure 2), microsections were prepared and structural studies of the samples were conducted at magnifications of ×240 (Figure 3, 4). Chemical composition and hardness of the metal deposited with standard and experimental PP-Np-50Kh2MNSGF flux-cored wires, as well as composition of 50Kh2MNSGF deposited metal according to the specification, is given in Table 1.

As one can see from Figure 1, boron microalloying at its concentration of 0.01 % in 50Kh2MNSGF

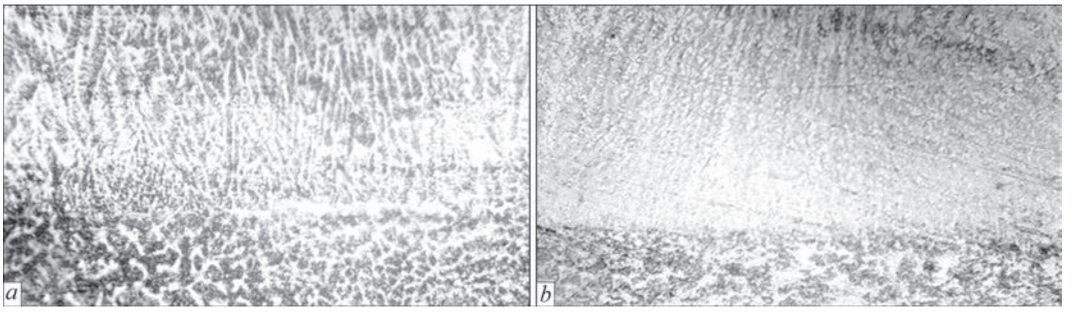

Figure 3. Microstructure (×240) of metal near the fusion line in samples surfaced with PP-Np-50Kh2MNSGF wire of standard (*a*) and experimental composition (*b*)

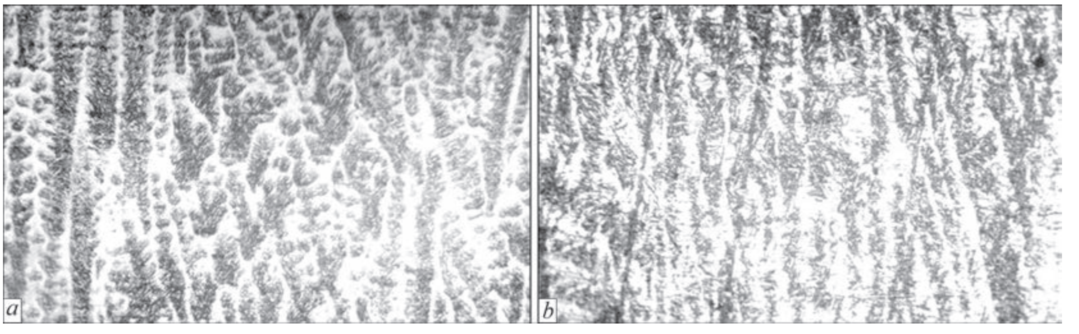

Figure 4. Microstructure (×240) of the central part of metal in samples surfaced with PP-Np-50Kh2MNSGF wire of standard (*a*) and experimental composition (*b*)

Table 1. Chemical composition and hardness of metal deposited with PP-Np-50Kh2MNSGF flux-cored wires of standard and experimental compositions

Deposited metal type	Number of deposited layers	Weight fraction of elements, %								Hardness, *HRC*
		C	Si	Mn	Cr	Ni	Mo	V	B	
50Kh2MNSGF (to specification)	3–5	0.3–0.5	0.4–1.0	0.4–1.0	1.5–2.5	0.8–1.6	0.3–0.6	0.3–0.6	–	55–60
50Kh2MNSGF (standard)	4	0.42	0.89	0.75	1.88	1.52	0.48	0.37	–	53–57
50Kh2MNSGF (experimental)	1	0.39	0.75	0.65	1.41	1.24	0.37	0.28	0.004	55–57
	2	0.43	0.83	0.72	1.86	1.47	0.43	0.35	0.005	57–60
	3	0.46	0.97	0.83	1.94	1.54	0.54	0.43	0.006	60–62

Table 2. Welding-technological properties of PP-Np-50Kh2MNSGF flux-cored wires of standard and experimental compositions

Parameter	Wire type	
	Standard	Experimental
Mode of arc excitation	Light	Light
Coefficients of: • melting — α_m, g/A·h • deposition — α_d, g/A·h • losses — ψ, %	 17.56 17.04 2.96	 17.52 16.98 3.08
Arc burning stability	Stable	Stable
Quality of deposited bead formation	Sound	Sound
Presence of defects in the deposited metal	Absent	Absent
Quality of slag crust detachment	Satisfactory	Satisfactory
Compliance of deposited metal chemical composition and hardness with the specification	Compliant (standard)	Compliant

deposited metal does not impair its formation quality. Detachability of the slag crust remains on the same satisfactory level in all the samples, spinels on the sample surface are absent. Pores, cracks or other defects on the deposited metal surface are also absent.

Hardness of the metal deposited with experimental wire with microalloying additives of boron, is equal to *HRC* 57–60 already in the second layer, compared to hardness of metal deposited with wire of standard composition in the fourth layer — *HRC* 53–57 at the same concentration of other alloying elements.

As one can see from Figure 3, in samples deposited by wires of both types, the line of fusion of the deposited (above) and base metal (below) is clear, internal defects in the form of pores, cracks, and lacks of fusion are absent. Metal structure is quite homogeneous, here it is finer in the case of boron microalloying (Figure 4, *b*). Table 2 gives the generalized data on comparative assessment of welding-technological properties of the developed PP-Np-50Kh2MNSGF flux-cored wire of standard and experimental compositions.

It follows from the data given in Table 2 that welding-technological properties of experimental PP-Np-50Kh2MNSGF flux-cored wire with boron microalloying additives are at a high level by all the parameters and correspond to the characteristics of wire of standard composition of the same grade.

CONCLUSIONS

It was found that application of FKhB-1 binder with boron in the charge of PP-Np-50Kh2MNSGF flux-cored wire does not impair its welding-technological properties. Here, microalloying by boron in the quantity of 0.006–0.012 % leads to refinement of the deposited metal structure and allows its hardness to be increased from *HRC* 53–57 to *HRC* 60–62 at the same content of other alloying elements.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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