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INFLUENCE OF DIFFERENT TYPES OF MODIFIERS ON THE STRUCTURE AND PROPERTIES OF DEPOSITED METAL OF THE TYPE OF 25Kh5MFS TOOL STEEL

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ABSTRACT

Comparative analysis of the influence of modifying additives of boron or titanium carbides on the structure and properties of the metal deposited with PP-Np-25Kh5FMS flux-cored electrode wire was performed in this study. It is shown that addition of some modifier in the amount of 0.01 % does not have any significant influence on the deposited metal structure. Their influence on the structure differs to a certain extent. Boron modifying leads to an essential reduction of the crystallite dimensions, redistribution of nonmetallic inclusions and increase of metal microhardness. Unlike that, introducing titanium carbide microadditives into the weld pool influences the kinetics of metal solidification, which results in elimination of crystallite columnarity and metal structure transformation into the cellular one. It is shown that owing to the mentioned changes in the structure, the wear and heat resistance of the metal, deposited with application of both the types of modifiers, is increased. Obtained results can be used at selection of promising methods to improve the service properties of the surfaced parts, which operate under the conditions of thermal force loading and wear at metal friction against metal.

KEYWORDS: arc surfacing, modifying, microalloying, deposited metal, flux-cored wire, wear resistance, heat resistance, microstructure

INTRODUCTION

It is known from technical literature that modifying or microalloying of steels and alloys, at which grain refinement, redistribution of nonmetallic inclusions, cleaning of the grain boundaries, etc., take place, allows significantly influencing the structure and service properties of these metals. Materials with microadditives of boron, tungsten, titanium, etc. are used for modifying [1–3]. Doping the steels and alloys with microadditives of these elements, usually leads to formation of a large number of crystallization centers and influences the ratio of crystal initiation and growth rates, which in its turn, has an impact on the metal mechanical properties. At the same time, control of the metal structure and properties by its modifying or microalloying has a rather limited use at surfacing [3].

Some works, aimed mainly at solving practical tasks, give examples of application of various types of modifiers, in order to improve the performance of parts, differing by service conditions, chemical composition, etc., so that it is difficult to compare such data even for one type of modifier [4–8]. Known are the good prospects of deposited metal modifying by microadditives of boron [9] and titanium carbides [10], which were added to the deposited metal through the flux-cored wire charge.

The objective of this work is conducting comparative experimental evaluation of the effectiveness of application of modifying additives with boron or titanium carbides, added in equal quantities to the flux-cored wire charge, on the structure and service properties of the deposited metal of the type of heat-resistant tool steel 25Kh5FMS.

EXPERIMENTAL MATERIALS AND PROCEDURES

Flux-cored wire for investigations was selected proceeding from that the flux-cored wire PP-Np-25Kh5FMS is rather widely used in manufacture and restoration of rolls of hot rolling mills, hot stamping dies, CCM rolls and similar parts, operating under the conditions of thermal cycling, in combination with wear at metal friction against metal, so that heat resistance and wear resistance are important for them. It is exactly deposited metal 25Kh5FMS, which is characterized by a high fatigue life under the conditions of thermal force loading and wear [11].

Deposited metal modifying was performed by using powders with the respective additives in the charge of flux-cored electrode wires. This method

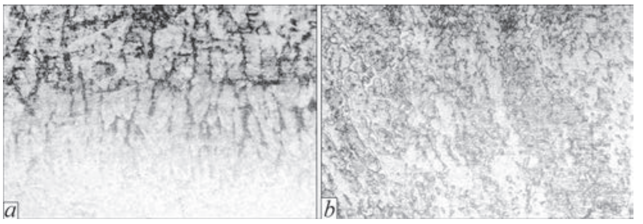

Figure 1. Microstructure (×320) of 25Kh5FMS deposited metal without modifying additives near the fusion line (*a*) and in the deposited metal upper part (*b*)

is quite simple in terms of technology, and it can be applied with success in practice [9]. The flux-cored wire charge was calculated so as to obtain the same composition of modifying additives in the deposited metal at the level of 0.01 %. The initial charge materials used were FKhB-1 master alloy which contains 12 % boron, as well as powder of Ti–TiC system with ≥ 23 % carbide content, produced by titanium powder treatment by a high-voltage electric discharge in the hydrocarbon liquid [10]. The quantity and type of modifiers, added to the deposited metal, were selected proceeding from the earlier obtained data, in order to improve the deposited metal service properties and prevent crack initiation in it [9, 10].

Test samples were surfaced by flux-cored wires of 1.8 mm diameter using AN-26P flux. Plates from 40Kh steel were used as the base metal. Surfacing modes were as follows: I = 220 A; U = 36 V; v = = 25 m/h. Each sample was surfaced in five layers to avoid the impact of deposited and base metal mixing. Used for comparison were samples, surfaced by flux-cored wire PP-Np-25Kh5FMS of a standard composition without modifying additives.

Sample surface was prepared for metallographic studies by standard methods, which include stage-by-stage grinding of the sample surface, using diamond pastes of different dispersity and subsequent electrolytic etching in 20 % solution of chromic acid. Microstructural studies were performed in metallographic optical microscope MIM-7 with digital video oculator Sigeta MCMOS-3100 at ×320 magnification.

Service properties of the deposited metal were evaluated experimentally by two indices — heat resistance and wear resistance at higher temperature. Two parameters were compared to assess the deposited metal heat resistance: number of heating-cooling cycles up to appearance of a network of thermal cracks on the test sample surface and their propagation depth after all the samples reached 200 heating-cooling cycles. The temperature of the sample surface is equal to 650 °C at heating and to 60 °C at cooling.

Wear resistance at higher temperatures was assessed at metal friction against friction by the "shaft-plane" schematic. During testing the deposited surface of the test sample wears against the surface of a ring counter-body heated up to the temperature of 950 °C The temperature of the sample surface in the zone of contact of the sample and the ring is equal to approximately 600 °C. Wear resistance was evaluated by the test sample weight loss before and after testing.

Samples from steel 45, hardened to *HRC* 48–52 were used as the reference samples at optimization of the testing modes. Derived values of heat and wear resistance for the reference samples were taken as the conventional unity. The procedures of investigation of the deposited metal service properties are described in greater detail in work [9].

INVESTIGATION RESULTS AND THEIR DISCUSSION

Metallographic investigations of the surfaced samples (Figures 1–3) showed that application of both the types of modifiers leads to refinement of the deposited metal structure. So, the average size of unmodified metal crystallites in its central part is equal to 30–60 μm, in the majority of them it is 40–45 μm. In the metal modified by boron, the crystallite size in a similar area of the metal is equal from 20 to 40 μm, and in the majority of them it is 20–25 μm. In the metal modified by titanium carbides, the average crystallite size is equal to 20–50 μm, in the majority of them it is 30–35 μm.

Alongside the crystallite size, the structure of the deposited metal sample, containing microadditives of boron (Figure 2), differs little from that of an unmodified metal sample (Figure 1), and it consists of columnar crystallites, growing in the heat removal direction. An acicular martensitic structure is observed in the crystallite body, and light precipitates of residual austenite are found beyond their boundaries. Individual

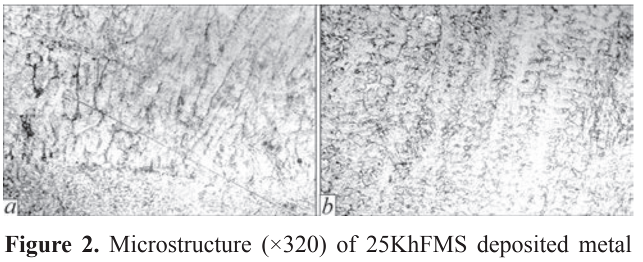

Figure 2. Microstructure (×320) of 25KhFMS deposited metal with boron microadditives near the fusion line (*a*) and in the deposited metal upper part (*b*)

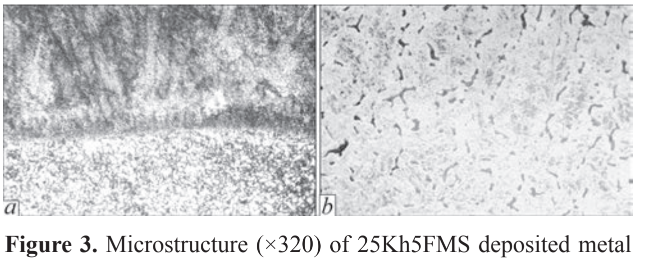

Figure 3. Microstructure (×320) of 25Kh5FMS deposited metal with titanium carbide microadditives near the fusion line (*a*) and in the deposited metal upper part (*b*)

round-shaped precipitates are present in the crystallite body, which, obviously, are complex carboborides. Microhardness in this zone in a sample with boron microadditives is equal to *HV*1–6130–6420 MPa, which is higher than that of a similar area of a sample without modifying additives (*HV*1–5720–6060 MPa).

In a sample deposited by wire, containing a modifier of Ti–TiC system, the structure of the deposited metal upper layer consists of rather equilibrium cells, within which dark etching precipitates are observed (Figure 3). The microhardness of this area of the deposited metal is equal to *HV*1–5720–5850 MPa. Influence of modifying TiC particles, compared to boron, is manifested not so much in crystallite refinement, but in transformation of the deposited metal structure from the columnar into the cellular one, and precipitation of complex compounds beyond the cast crystallites in the form of individual inclusions. Microhardness of the deposited metal, compared to an unmodified sample, practically does not change.

Investigations of the level of the surfaced sample contamination by nonmetallic inclusions in keeping with the procedure of GOST 1778–70 on polished unetched microsections showed that the highest contamination of the deposited metal, mainly by oxides, is observed in the sample without modifying additives: it corresponds to point No. 3a of "Point oxides" Table. Deposited metal samples, which were modified by boron additives, are cleaner compared to a sample without additives and their contamination corresponds to point No. 1a of the same Table. The lowest level of contamination by nonmetallic inclusions which is lower than point No. 1a, is observed in a sample, surfaced with application of a modifier of Ti–TiC system.

Investigations of service properties of surfaced samples showed that modifying of the deposited metal by boron allows improvement of its hardness from *HRC* 48–50 to *HRC* 52–54. Hardness of the deposited metal, modified by Ti–TiC, practically did not change and is equal to *HRC* 48–52.

Results of experimental investigations of the deposited metal service properties are given in Figure 4, where the values of wear resistance at a higher temperature (ε_{600}), heat resistance by the number of cycles to crack initiation (N_q) and their average length (N_d) are given in relation to the respective characteristics of reference-samples made from steel 45, the values of which are taken as a unity.

As one can see from Figure 4, heat and wear resistance of samples of metal deposited by flux-cored wires with microadditives of both types, became higher. Thermal fatigue cracks in the modified metal of the surfaced samples initiate later, their average length and quantity is smaller than in the samples without

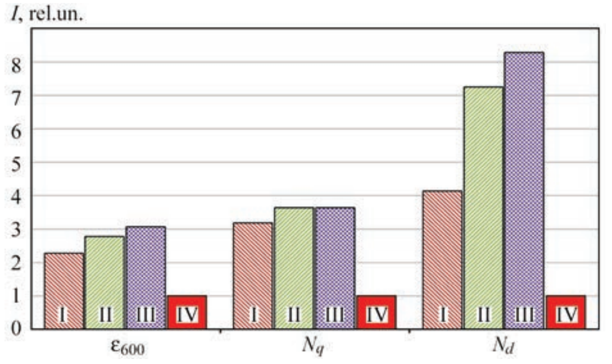

Figure 4. Relative wear resistance of 25Kh5FMS deposited metal at a higher temperature (ε_{600}), relative heat resistance by the number of cycles to crack initiation (N_q) and their average length (N_d): without modifying additives (I), with modifying additives of boron (II) and titanium carbides (III) relative to a reference-sample from steel 45 (IV), the values of which are taken to be a unity

the modifying additives. It should be noted that evaluation of heat resistance, made by the average depth of crack propagation, turned out to be more accurate than evaluation by the number of cycles to formation of a ramified crack network. This is attributable to the fact that 25Kh5FMS steel is characterized by rather high heat resistance, and visual determination of the exact moment of appearance of a ramified network of cracks may be inaccurate. Positive impact of microadditives of both types on the deposited metal was found not only in a smaller loss of the surfaced sample weight, but also in reduction of the extent of wear of ring counter-bodies, contacting the studied samples, which means more favourable service conditions, which were in place in the friction pairs.

In general, increase of wear resistance of the deposited metal with modifying additives of both types is on approximately the same level, and it is equal from 22 to 34 %, compared to unmodified metal. Increase of heat resistance, assessed by the number of cycles to crack initiation, is equal to 20 % for both types of modifiers, and in the case of evaluation by the average crack depth, it is from 75 % at boron application and up to 200 % at titanium carbide application. As we can see, deposited metal modifying by microadditives of powder of Ti–TiC system has a more positive influence on its service properties.

In our opinion, a positive influence of modifying by boron microadditives on the deposited metal properties is attributable to several factors. First, boron is a more active deoxidizer, compared to silicon and manganese, and it has high surface activity. Due to that, boron is predominantly located on the crystal boundaries, which leads to redistribution of nonmetallic inclusions and their driving from the boundaries into the crystallite volume [6]. Secondly, deposited metal modifying by boron leads to increase of the crystallite microhardness, while the matrix microhardness remains practically unchanged, which can be accounted for by increase in the density and ramification of boron-hardened crystallite boundaries.

Positive influence of microadditives of powder with titanium carbides on the properties of the deposited metal is obviously related, primarily, to the high melting temperature of these compounds (3260 ± 150 °C). Deposited metal modifying by these compounds leads to their effective transition from the flux-cored wire charge into the weld pool, due to their low dissolution in the weld pool, thus influencing the kinetics of the deposited metal solidification. It results in elimination of columnar crystallites and their refinement, which has a positive influence on the deposited metal performance.

CONCLUSIONS

1. Introducing microadditives of boron or titanium carbides in equal quantity (0.01 %) into the deposited metal of the type of 25Kh5FMS tool steel has a different influence on its structure and leads to significant refinement of the crystallite sizes and a certain increase in the microhardness of its matrix in the first case, and to an essential change of its structure with transformation of the columnar structure into the cellular one without any major change in the crystallite sizes or microhardness in the second case.

2. Modifying by both the types of the studied additives has a positive effect on the deposited metal service properties. Here, application of powder, containing titanium carbides as a modifier, looks more promising, allowing increase of the deposited metal wear and heat resistance by 1.34 and 2.0 times, respectively.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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