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EFFECT OF PRELIMINARY APPLICATION OF ALLOYING POWDERS ON THE STRUCTURE AND HARDNESS OF DEPOSITED METAL

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Considered was efficiency of use of different schemes of preliminary application of alloying powders on structure and hardness of metal deposited by arc method. The optimum parameters of the process and specific consumption of additional (alloying) materials with their preliminary fixing were determined. The highest indices of hardness of deposited metal are reached during local addition of TiC with its fixation by GF-021 primer. 11 Ref., 1 Tables, 4 Figures.

Keywords: *arc surfacing, alloying powders, additional alloying schemes, fixation of additional materials, surfacing modes, structure, hardness*

For parts, especially of considerable sizes, nonuniform wear over the contact area is characteristic. In this regard, it seems logical to carry out restoration surfacing and preliminary strengthening of such surfaces using materials of variable composition, in accordance with the actual changes in linear dimensions.

At different times, the methods were proposed for staggered surfacing of layers and multiarc surfacing using high-carbon wires and alloying fluxes [1, 2]. The disadvantage of such schemes is the need to substitute electrode material in order to achieve variability in composition and properties and the necessity to change wire feed speed, as well as the dubious constancy of specific volume of metal, applied along the length of the bead or across the surface area.

The practice of arc surfacing with preliminary introduction of additional materials allowed solving a number of problems to increase wear resistance of deposited metal. It was proposed several similar schemes, which were implemented in arc surfacing [3–9]. The following schemes based on the obtained data on hardness and wear resistance, can be considered the most effective among them: 1 — deposition of carbon fibers on bodies of revolution; 2 — introduction of nanopowders SiO_2 into the weld pool; 3 — application of the mixture SiO_2 + Fe on the treated surface in the form of a charge. In scheme 1, carbon fibers were deposited along the generatrix, which made it possible to obtain the hardness *HRC* 60–65 and to reduce the mass loss by 2.7 times. Scheme 2 envisaged mixing nanopowders with flux. Applying such a scheme, the hardness of the deposited metal *HRC* 42 was obtained with a 6 times decrease in the mass loss. Surfacing according to the scheme 3 allowed reducing the mass loss by 2.5 times with the hardness *HRC* 20.

From the point of view of a better transition of introduced alloying materials into deposited metal, scheme 3 should be considered as the most effective: the placement of additional powders at the bead periphery contributes to better preservation of the material due to lower temperatures in this zone.

Taking into account the challenge of introducing alloying materials into the weld pool and their role in structural transformations and improving mechanical properties of the metal, it is relevant to reveal the effect of the composition and method of preliminary fixation of such materials in arc welding processes.

The aim of the work is to determine the effectiveness of different schemes of additional introduction of alloying powder materials in arc surfacing on changes in the structure and hardness of deposited metal both in absolute value as well as in the zones of applied beads.

To study the effect of composition of additional materials on the properties of deposited metal, it was decided to choose a paste-like emulsion of TiC and fullerene fiber C_{60}. Such a choice was justified by the influence of the abovementioned materials on the properties of the metal: TiC is the hardest among the existing carbides (20 000 MPa) [10], and C_{60} increases the microhardness of welded joints [11]. The material was introduced in the form of strips, locally, on the periphery of the planned bead. This is predetermined by the fact that there is a risk of burnout of materials if they are located directly under the arc. To fix the emulsion of TiC, two variants were applied: the use of paste in its pure form and its fixation with the primer GF-021. Surfacing was performed with the overlapping of single beads on plates of steel 20 under

Experiment results

Sample number	Input heat q_{inp}, J/mm	Specific consumption of materials n, g/inp, mm	*HB*		
			on the periphery of the bead	in place of overlapping	in the bottom part
1	1848	0.032	192	187	187
2	1848	0	255	293	241
3	1314	0.032	293	302	262
4	1314	0	241	229	277
5	1536	0.032	248	255	277
6	1536	0	241	269	262
7	1848	0.016	293	302	262
8	1314	0.016	241	262	241
9	1536	0.016	192	269	255

flux AN-348A with wire Sv-08 A of 3 mm diameter in the installation of type ADS-1000. The parameters of the mode are the following: welding current is 500 ± ± 10 A, arc voltage is 30 ± 1 V, deposition rate is 25–35 m/h, eccentricity of the application of layers of material is 5–8 mm. To study hardness of the deposited metal, 20 mm thick samples were cut out. For all the schemes, the modes remained unchanged.

During the experiments, a central composite rotatable second-order design was applied for two factors: input energy q_{inp}, J/mm, and specific material consumption n, g/inp.mm. Hardness measurements were performed in the hardness tester TK-2. The emphasis was placed on hardness values at the periphery and at the bottom part of the bead. Measurement was carried out roughly in those areas to reveal localization of zones of increased hardness. Processing of the experimental data was carried out using the mathematical package STATISTICA 7.0. The results of experiments are shown in Table.

Based on the processed data, regression dependencies were obtained:

$$HB_{overlapping} = 282.1948 - 0.007q - 489.5833n \qquad (1)$$

$$HB_{periphery} = 270.2357 - 0.016q - 41.6667n \qquad (2)$$

$$HB_{bottom\ part} = 354.1273 - 0.0598q + 562.5n \qquad (3)$$

These equations allow predicting by calculation the values of hardness in different areas of the deposited bead based on the heat input and the expected specific consumption.

When analyzing the constructed dependency diagrams (Figure 1), it was found that:

● a significant increase in hardness on the periphery of the bead is facilitated by an increase in heat input up to 1800–1900 J/mm and specific consumption up to $0.8 \cdot 10^{-2}$–$1.6 \cdot 10^{-2}$ g/inp.mm. This may be connected with a high coefficient of transition of additional material to the deposited metal while providing its moderate consumption and high heat input. Such conclusion is based on the fact that an increase in specific consumption within $1.6 \cdot 10^{-2}$–$3.2 \cdot 10^{-2}$ g/inp.mm at the same values of current, voltage and welding speed led to a decrease in hardness;

● at the bottom part of the bead a significant increase in hardness is observed at the heat input within the range of 1200–1300 J/mm and the specific consumption of $1.6 \cdot 10^{-2}$–$3.2 \cdot 10^{-2}$ g/inp.mm. These values confirm the conclusion formulated above that to provide a better preservation of additional materials in order to achieve the maximum effect from local fixation, it is necessary to provide specific consumption reversely proportional to heat input.

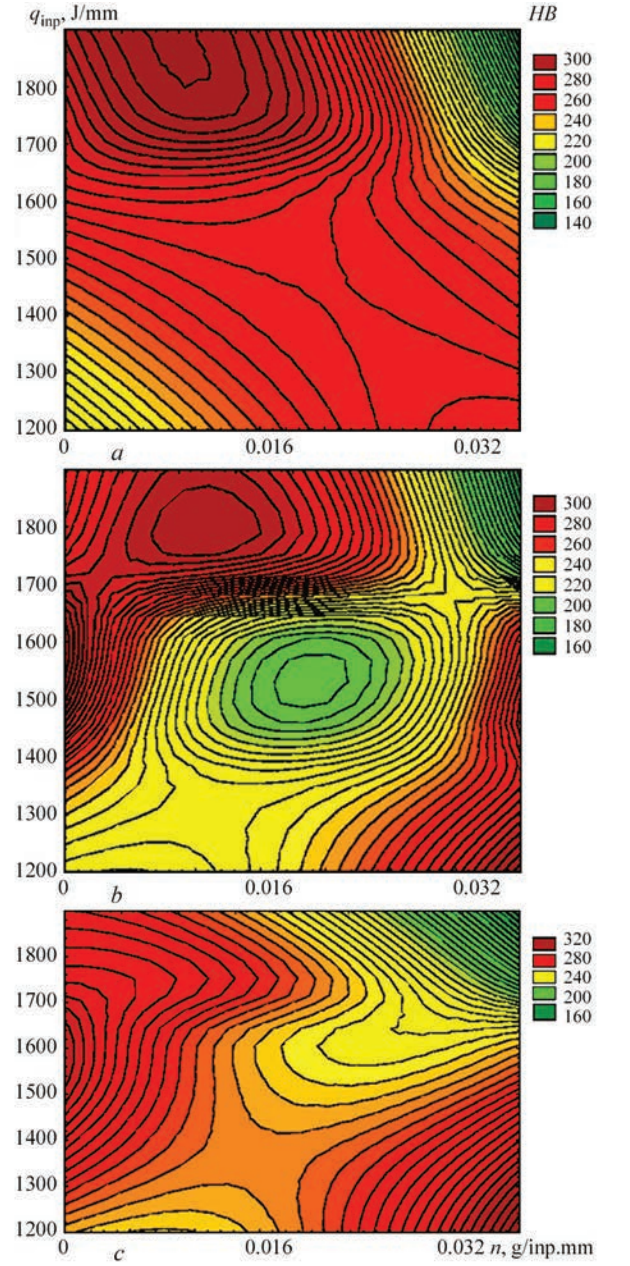

Figure 1. Dependence of hardness on heat input and specific consumption: *a* — in the overlapping zone; *b* — on the periphery of the bead; *c* — in the bottom part of the bead

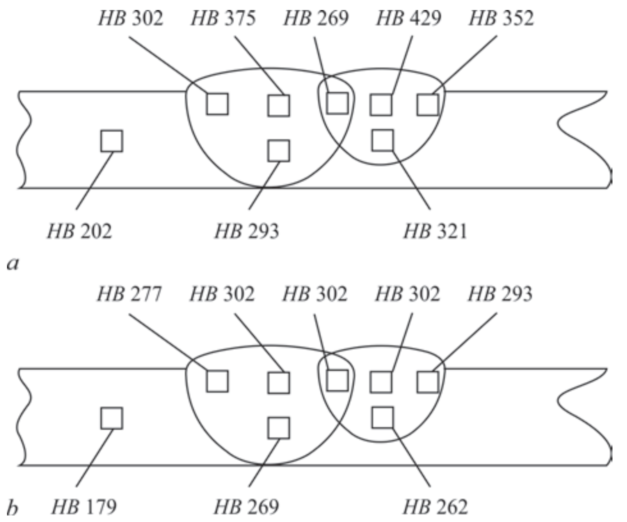

Figure 2. Results of measuring hardness of metal deposited using different methods of fixation of additional materials: *a* — at the fixation of TiC using a primer; *b* — at the fixation of TiC in a pure form

The maximum values of hardness were obtained at the introduction of TiC: at the periphery — *HB* 293, in the overlapping zone — *HB* 302 and in the bottom part of the bead — *HB* 277 at the hardness of base metal being *HB* 197.

Thus, optimal parameters and specific consumption of materials were established for the maximum surfacing effect with their preliminary fixation. However, under these conditions there is no localization of zones of increased hardness. Taking this into account, a comparison of schemes of fixation the emulsion of TiC with the primer GF-021 and in a pure form was made. For adequate comparison, a specific consumption of the material was $1.6 \cdot 10^{-2}$ g/mm.

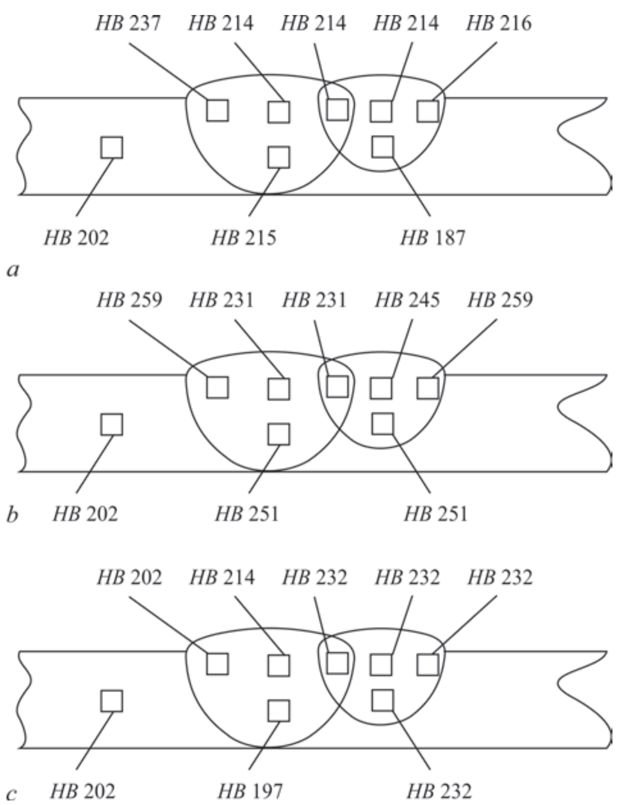

Figure 3. Results of measuring hardness of metal deposited using different methods of fixation of additional materials: *a* — local introduction of fullerene; *b* — local introduction of the mixture TiC + GF-021; *c* — continuous introduction of TiC + GF-021

The difference in the effects of the fixation method on the distribution of hardness in the section of deposited metal at the heat input of 1800 J/mm and at specific consumption of $1.6 \cdot 10^{-2}$ g/inp.mm is shown in Figure 2.

The results of measuring hardness in the section of the deposited bead indicate that localization of hardening zone is facilitated by the fixation of the material using GF-021. The addition of TiC suspension in its pure form leads to a greater burnout of the material. Here, only a slight increase in hardness at the places of fixation is observed as compared to other zones.

To compare the effect of adding fullerene C_{60} and TiC, the samples were surfaced using the parameters of the mode, described above, at $n = 0.8 \cdot 10^{-2}$ g/inp.mm. Hardness measurements revealed the following its distribution (Figure 3).

As is seen from Figure 3, TiC has the most significant effect on the hardness of the deposited metal. Its local application with fixation of a primer provides a maximum growth of hardness in the places of addition. With the continuous introduction of TiC and with the introduction of fibers of fullerene C_{60}, lower values of hardness are observed. Such a result is obviously associated with the burnout of materials. Thus, a better preservation of material is contributed by the preliminary fixation of materials at the periphery. A more effective material to increase the hardness of the metal is titanium carbide.

From deposited workpieces the samples were made for the study of microstructure. The analysis of the microstructure was carried out in scanning electron microscope Zeiss EVO50. Comparing the structures of beads (Figure 4) deposited with preliminary fixation of fullerene with primer (*a*), TiC in a pure form (*b*) and with a mixture of TiC + GF-021 (*c*), it can be concluded that the most significant structural

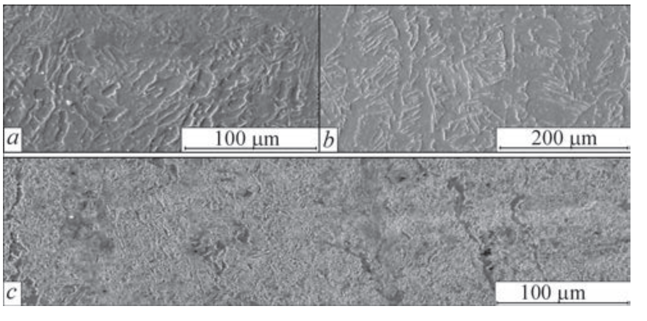

Figure 4. Structure of metal deposited with local introduction: *a* — C_{60} + GF-021; *b* — TiC; *c* —TiC + GF-021

transformations are affected precisely by the last variant of preliminary introduction. For metal deposited with this combination, a martensitic structure is characteristic (*c*). At the places of introducing mixture of titanium carbide with the primer, coarser particles of carbides are observed than in the cases of the introduction of C_{60} + GF-021 (*a*) and TiC (*b*).

Carbide inclusions of maximum size are observed at the edge of the bead (Figure 4, *c*).

Thus, the abovementioned indicates the fact that different methods of preliminary fixation have a different effect on the structure and properties of deposited metal.

The range of problems that can be solved by preliminary application of additional materials is not limited to the problems of wear-resistant surfacing. In the future, it seems possible to test such a scheme during welding of dissimilar steels.

Conclusions

1. It was established that preliminary fixation of additional materials is an effective method of differentiating chemical composition and properties of deposited metal within the single beads.

2. Taking into account the indices of achieved hardness and pronounced structural and mechanical heterogeneity, the most effective is the preliminary local introduction of TiC with its fixation by a primer GF-021. This is connected with the protective effect of a primer and localization of the strengthening zone.

3. The effectiveness of applying TiC + GF-021 as an additional reinforcing material is confirmed by the obtained indices of hardness: at the place of introduction, the hardness of base metal being *HB* 202, TiC allows increasing the hardness by 57 units at a specific consumption of carbide being $0.8\cdot10^{-2}$ g/inp.mm and by 100–150 units at $1.6\cdot10^{-2}$ g/inp.mm. This is by 22 units higher than during fixation of fullerene C_{60} by a primer.

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