doi.org/10.15407/tpwj2017.07.08

ARC SURFACING OF LAYERS OF METAL OF VARYING COMPOSITION AND HARDNESS

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In arc surfacing over the layer of alloying charge, the conditions for producing layers with varying composition and structure in the zones of separate beads were determined. On the deposited surface the carbon-containing fibres were preliminarily deposited in bands, the width and distance between which were selected from the conditions of positioning the end of the electrode with displacement relative to the edge of the bands. To fix the fibres, a primer was used, into which the iron powder and aerosol SiO_2 were added. During the experiments a number of deposited layers, the eccentricity in the arrangement of bands relative to the axis of electrode wire, as well as the induction of external magnetic field were varied. The difference in hardness of the metal across the width of the deposited beads (up to *HRC* 9–12) and the successively deposited layers (up to *HRC* 15–25) was established. The hardness reaches its maximum values at the eccentricity c = 4 mm and induction B = 40–80 mT and also at c = 10–12 mm and B up to 40 mT. The increase in hardness is observed with increase in the amount of deposited layers. The metallographic analysis recorded an increase in the fraction of hardening structures (in the form of acicular bainite and martensite) from 15–22 to 25–35 % in the second layer and more than 50 % in the third one 13 Ref., 1 Table, 10 Figures.

Keywords: *arc surfacing over alloying charge, deposited metal, hardness, microstructure of deposited metal, controlling magnetic field, carbon-containing fibre*

It is known that the wear of many parts of machines and mechanisms in the process of operation bears a selective character [1–4]. Nevertheless, as a rule, when such parts are restored applying the methods of surfacing, the selective character of wearing their surfaces is not taken into account [5–7]. The positive

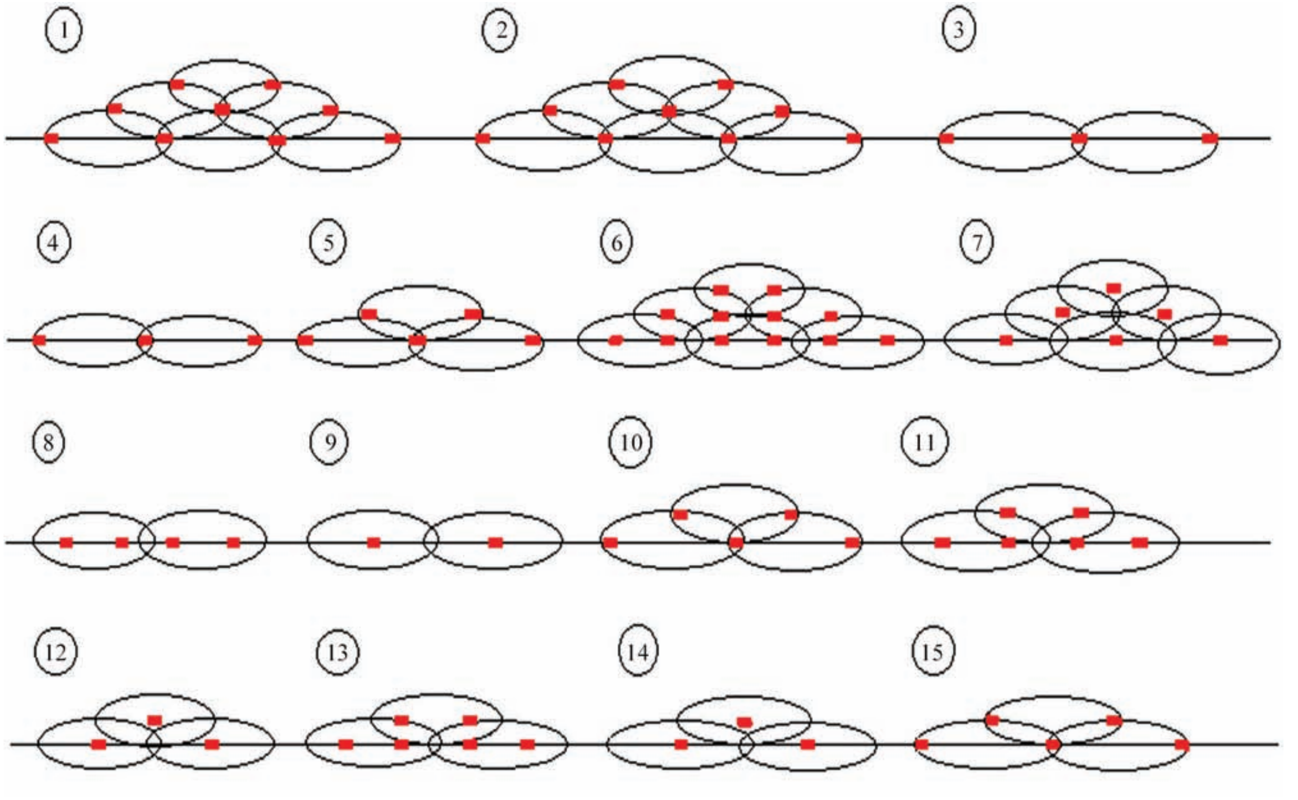

Figure 1. Scheme of arrangement of carbon-containing fibres on all specimens (1–15) with the specified eccentricity (locations of fibres arrangement are indicated by dots)

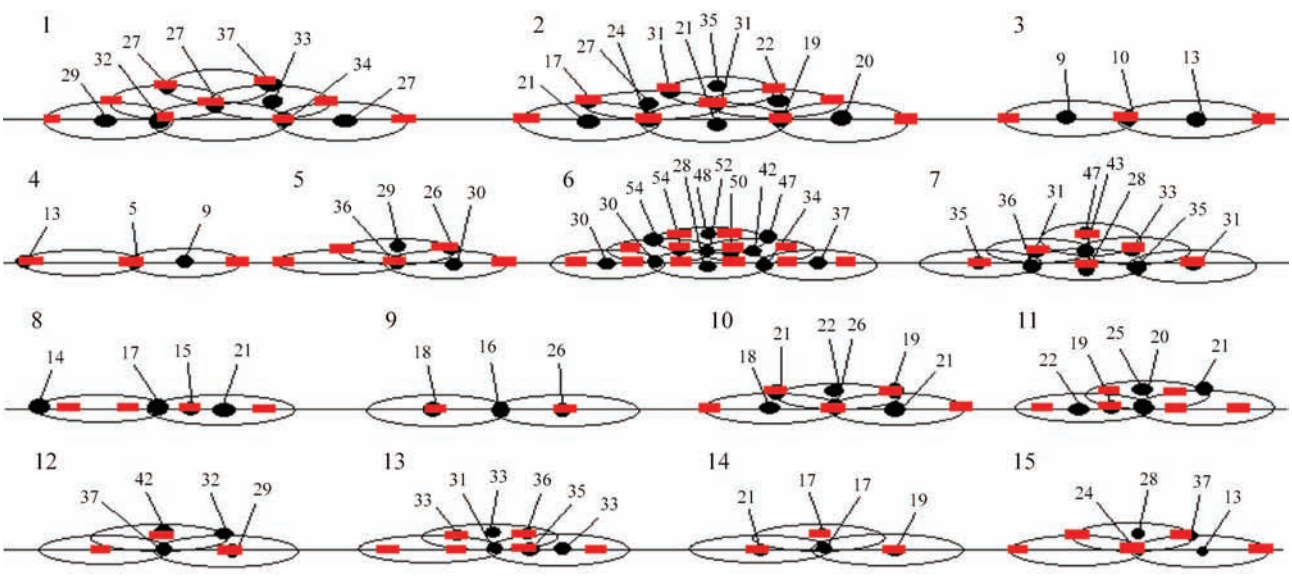

Figure 2. Hardness *HRC* in the zones of deposited beads (measuring places are indicated with dots, description of grey and black dots see in the text)

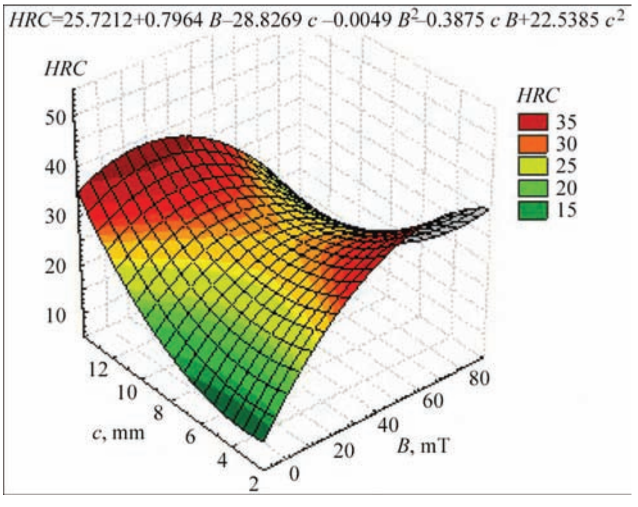

Figure 3. Dependence of hardness *HRC* of the deposited metal on the value of magnetic induction *B* and eccentricity *c*

Experiment matrix

Specimen number	Number of layers *n*	Magnetic induction *B*, mT	Eccentricity *c*, mm
1	3	80	8
2	3	0	8
3	1	80	8
4	1	0	8
5	2	40	8
6	3	40	4
7	3	40	0
8	1	40	4
9	1	40	0
10	2	40	8
11	2	80	4
12	2	80	0
13	2	0	4
14	2	0	0
15	2	40	8

experience of some researchers [8–11] on producing deposited layers with properties varying in depth and in zones of the surface, give grounds to consider this experience as a promising way for improvement of serviceability of contact friction pairs during their restoration.

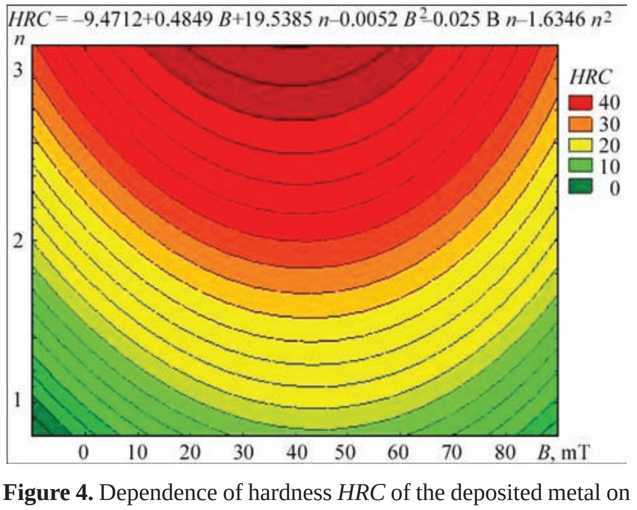

Figure 4. Dependence of hardness *HRC* of the deposited metal on the number *n* of deposited layers and magnetic induction *B*

In this work the task was put to deposit metal with varying composition and structure in the zones of separate beads, separate layers and in the places of overlapping the neighboring beads and layers applying arc surfacing.

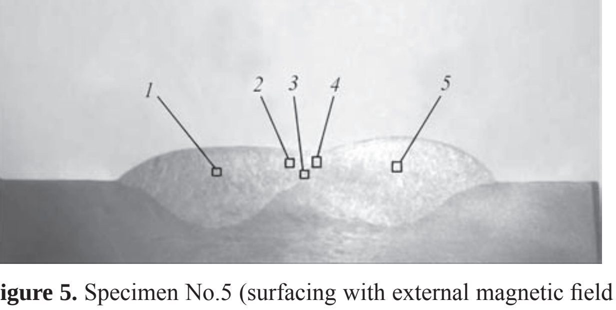

Figure 5. Specimen No.5 (surfacing with external magnetic field $B = 40$ mT, eccentricity $c = 8$ mm); *1–5* — investigated points

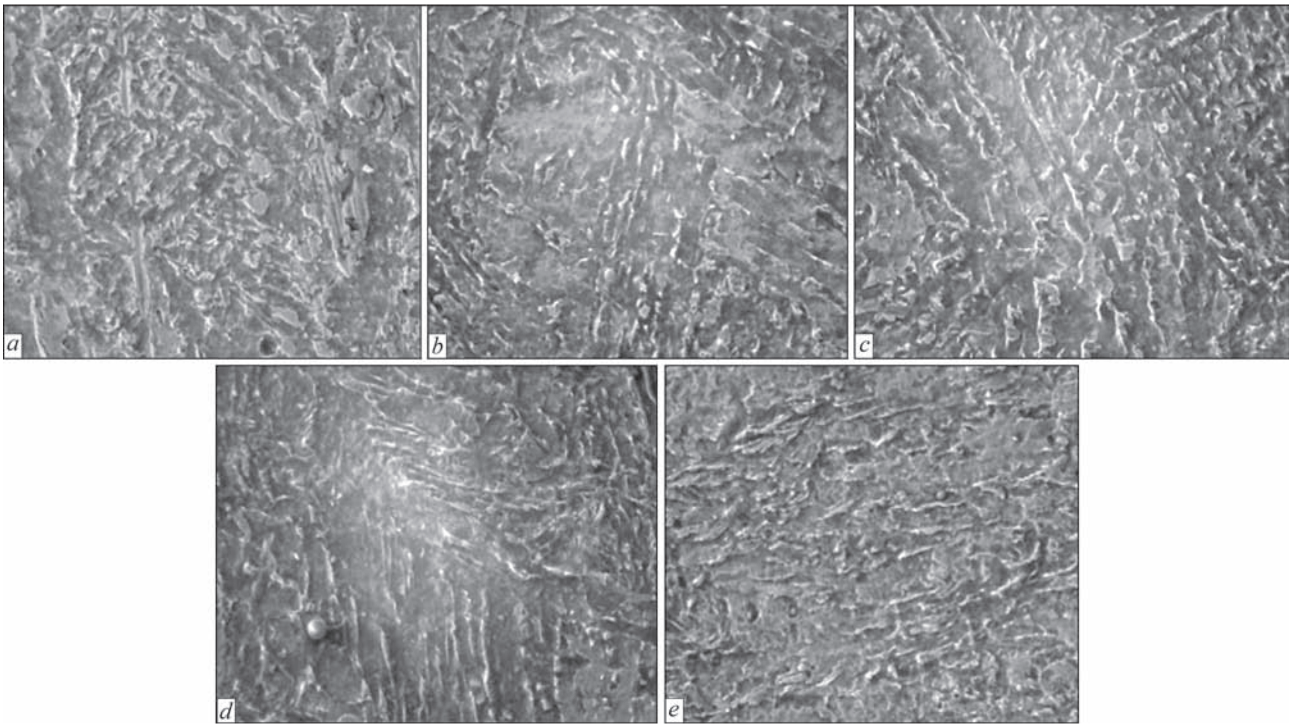

Figure 6. Microstructure (×400) of the deposited metal of specimen No.5: *a*–*e* — points *1*–*5* according to Figure 5, respectively

In the experiments the method of arc surfacing over the layer of alloying charge was used, which, under certain conditions, provides an effective preservation of materials, additionally introduced into the surfacing pool, from their complete dissolution [12, 13].

The carbon-containing fibres (T 700SC Torey) were preliminarily applied on the deposited surface in bands, the width *a* and the distance *b* between which were selected from the condition of positioning the electrode wire end with displacement *c* relatively to the edge of the mentioned bands (Figure 1). As a material fixing the arrangement of carbon-containing fibres, a primer was used, to which iron powder (15–25 wt.%) and aerosil (0.3–0.6 wt.%) were added. The values of the parameters *a*, *b* and *c* were also selected from the condition of formation of beads with overlapping.

In the experiments, the automatic welding machine of the type ADS-1000 and the universal rectifier VDU-506, as a power source, were used.

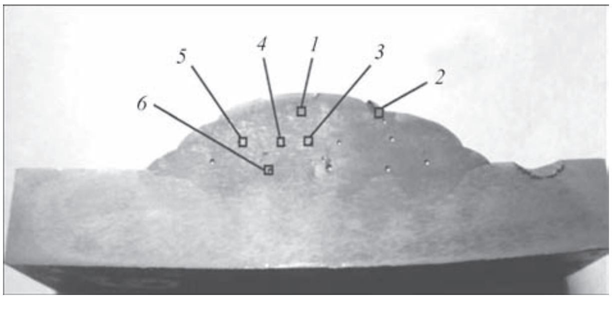

Figure 7. Specimen No.6 (surfacing with external magnetic field *B* = 40 mT, eccentricity *c* = 4 mm); *1*–*6* — investigated points

The surfacing was performed on the specimens of flat shape of steel 20 under the flux AN-348A using the wire Sv-08A of 3 mm diameter. The surfacing mode was the following: current — 400–420 A, voltage — 32–36 V, wire feed speed — 160 m/h, surfacing speed — 12–16 m/h, surfacing pitch — 6–8 mm, the current is direct of reverse polarity.

To control the crystallization of bead metal, the longitudinal magnetic field was used [12]. The coil, which provided axial magnetic field, was attached to the torch nozzle through the layer of electrical insulation. To measure the hardness, the specimens of 15 mm thickness were cut from the deposited semi-products in the meter TK-2.

To reduce the number of experiments, a central non-compositional planning of the second order was performed for three factors: eccentricity in arrangement of the electrode wire relative to the edge of the bands of previously applied additional components (from 0 to half of the bead width, about 6 mm); number of layers of deposited metal (up to three); induction of external magnetic field (from 0 to 80 mT) (Table).

Figure 2 shows the results of measurements of hardness in the places of preliminary fixation of additional components (grey), as well as in the places of additional measurements (black dots).

The difference in the metal hardness across the width of deposited layers should contribute to increasing the wear resistance due to formation of periodic waviness of the contacting surfaces and, as a result, to reducing their slipping, for example, in case of rotational working travel of the parts.

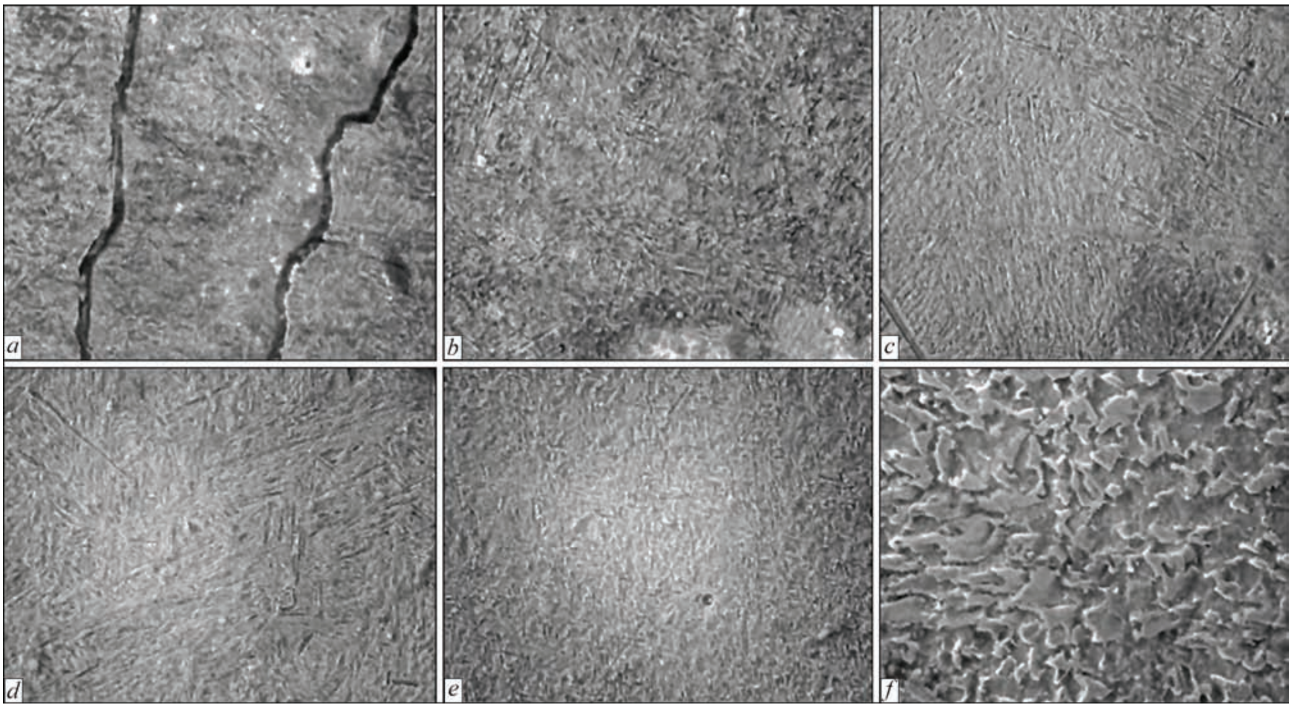

Figure 8. Microstructure (×400) of the deposited metal of specimen No.6: *a–f* — points *1–6* according to Figure 7 respectively

The processing of experimental data was carried out with the help of the program StatSoftStatistica 6.0. The obtained dependencies between the surfacing parameters are shown in Figures 3, 4.

As is seen from Figure 3, the hardness reaches the maximum values at arrangement of carbon-containing fibre with the eccentricity of 4 mm and the magnetic induction of 40–80 mT, as well as with the eccentricity of 10–12 mm and magnetic induction of up to 40 mT.

The maximum hardness is observed in the case of three-layer surfacing at the induction values of external magnetic field of 40 mT (Figure 4).

The microstructure of deposited metal was examined in the scanning electron microscope REM-106I-Selmi.

Illustrative are the results of metallographic examination of the specimen No.5 (Table; Figures 5, 6), which was deposited with the fixation of carbon-containing material and application of external magnetic field.

The analysis of microstructure of the specimen No.5 shows that throughout the entire cross-section of deposited beads the grain refinement is observed, which is the result of the effect of external magnetic field. In the places of overlapping the beads (correspond to the places of location of carbon-containing material), a significant increase in the fraction of hardened phases is recorded, a number of which is 25–40 %. The hardness drop for these zones reaches *HRC* 20.

On the specimen No.6 (Table; Figures 7, 8), produced according to the scheme of three-layer surfacing, the appearance of cracks was noted, which are a consequence of increasing the residual stresses and growth of carbon content not only in the zones of separate beads, but also across the layers of deposited metal.

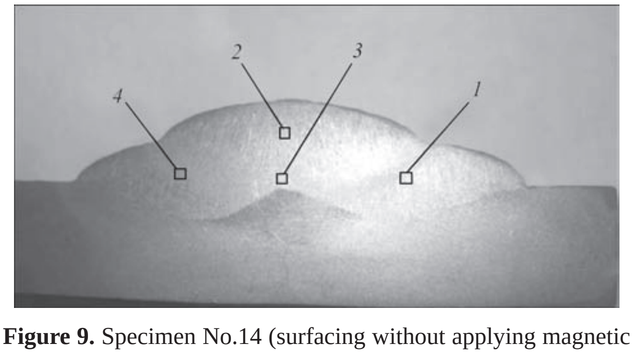

Figure 9. Specimen No.14 (surfacing without applying magnetic field, eccentricity c = 0 mm)

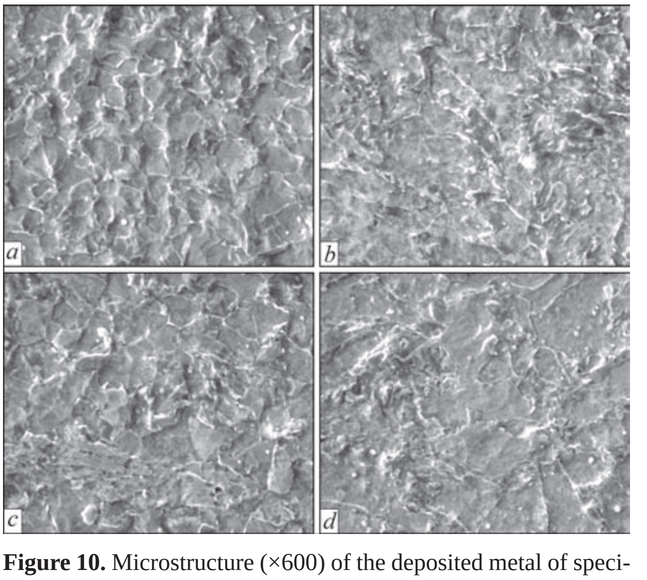

Figure 10. Microstructure (×600) of the deposited metal of specimen No.14: *a–d* — points *1–4* according to Figure 9

In particular, in the microstructure of the third layer of the deposited metal (Figure 7, point *1*), the fraction of martensite is maximal and exceeds 50 %. In the microstructure of the deposited metal in the place of overlapping the second and the third layers (Figure 7, point *2*), an increased content of hardening structure in the form of acicular martensite is also observed. In the deposited metal of the second layer (points *3* and *4*), the structure is also hardening and consists of bainite and martensite.

Figure 9 shows macrosection of the specimen No. 14, indicating the places in which the microstructure of deposited metal was investigated (Figure 10). The surfacing of this specimen was performed without using of magnetic field and with zero eccentricity.

In this case, the difference in the grain number in the selected points is almost absent. The values of hardness differ insignificantly. Obviously, a uniform distribution of introduced materials over the volume of beads with equalization of carbon content occurs.

Conclusions

1. The possibility of producing layers of deposited metal with varying structure and properties in arc surfacing along the charge preliminary applied to the deposited surface and the action of external magnetic field was experimentally confirmed.

2. In case of preliminary application of carbon-containing material on the deposited surface, an increase in the concentration of carbon from layer to layer was revealed. This is confirmed by increase in the fraction of hardening structures in the deposited metal, which increases from 15–22 to 25–35 % in the second layer and to more than 50 % in the third one. The hardening structures are represented by acicular bainite and martensite.

3. The dependences for predicting hardness of the metal deposited during preliminary application on the surface were obtained applying separate bands of carbon-containing and modified materials.

1. Garkunov, D.N. (1989) *Tribo-engineering*. Moscow: Mashinostroenie.
2. Kostetsky, B.I. (1975) *Reliability and service life of machines*. Kiev: Tekhnika.
3. Kragelsky, I.V., Dobychin, M.N., Kombalov, V.S. (1977) *Calculation principles on friction and wear*. Moscow: Mashinostroenie.
4. Vlasov, V.M. (1987) *Working capacity of strengthened rubbing surfaces*. Moscow: Mashinostroenie.
5. Frumin, I.I. (1961) *Automatic electric arc surfacing*. Kharkov: Metallurgizdat.
6. Tylkin, M.A. (1971) *Improvement of life of metallurgical equipment parts*. Moscow: Metallurgiya.
7. Ryabtsev, I.A., Kondratiev, I.A. (1999) *Mechanized electric arc surfacing of metallurgical equipment parts*. Kiev: Ekotekhnologiya.
8. Leshchinsky, L.K., Gulakov, S.V., Stepnov, K.K. et al. (1985) New design rolls with deposited layer increase operating efficiency of mills. In: *Surfacing. Experience and efficiency of application*. Kiev: PWI, 17–20.
9. Gulakov, S.V., Golovachev, M.V., Alengos, N.N. (1990) Automated equipment for arc surfacing of working layer with regulated distribution of properties. In: *Equipment and materials for surfacing*. Kiev: PWI, 14–17.
10. Sokolov, G.N., Lysak, V.I. (2005) *Surfacing of wear-resistant alloys on press dies and tool for hot deforming of steels*. Volgograd: RPK Politekhnik.
11. Savulyak, V.I., Zabolotny, S.A., Shenfeld, V.I. (2010) Surfacing of high-carbon coatings using the carbon fibers. *Problemy Trybologii*, **1**, 66–70.
12. Peremitko, V.V. (2014) Wear-resistant arc surfacing over the layer of alloying charge. *The Paton Welding J*., **8**, 54–57.
13. Peremitko, V.V., Nosov, D.G. (2015) Optimization of modes of submerged arc surfacing over the layer of alloying charge of caterpillar machine running gear parts. *Ibid*., **5/6**, 44–46.

Received 16.04.2017