Study of the influence of concentration of carbon-fluorine-containing additive in flux-cored wire of 35V9Kh3SF on the properties of deposited metal

A. V. Mazharin, *Junior Researcher* [1], *e-mail: mazharin_av@sibsiu.ru;*
A. R. Mikhno, *Director of the Scientific and Production Center "Welding processes and technologies"* [1], *e-mail: mihno_ar@sibsiu.ru;*
I. A. Panchenko, *Cand. Eng., Associate Prof., Head of the scientific laboratory "Laboratory of electron microscopy and image processing"* [1], *e-mail: panchenko_ia@sibsiu.ru;*
S. V. Konovalov, *Dr. Eng., Prof., Vice-Rector for Research and Innovation* [1], *e-mail: konovalov@sibsiu.ru*

[1] *Siberian State Industrial University (Novokuznetsk, Russia)*

In modern metalworking and mechanical engineering, improving the performance characteristics of component surfaces is a key objective to increase their service life and reliability. This is especially relevant under conditions of high temperatures, intensive mechanical loads, and aggressive environments. One of the promising approaches to addressing this issue is the use of deposited coatings based on special alloys with the addition of modifying components. The aim of this study is to investigate the effect of the concentration of a carbon–fluorine-containing additive (fine dust from aluminum production electrostatic precipitators), added to the core of 35V9Kh3SF flux-cored wire with a steel 08ps sheath, on the properties of the deposited metal. The research methodology included the production of three batches of flux-cored wire with varying contents of the carbon–fluorine-containing additive (1, 3, and 5 wt.% of the total charge mass) and the performance of arc surfacing using a flux derived from ferrosilicomanganese slag on a 09G2S steel plate. To analyze the properties of the deposited layers, the samples were prepared by electro-discharge sawing for determining chemical composition, conducting electron microscopy, energy-dispersion spectral analysis, as well as measuring nanohardness, Young modulus, and microhardness of the deposited layer. The results of the study showed that introduction of the carbon–fluorine-containing additive to the composition of the 35V9Kh3SF flux-cored wire increased the average microhardness of the deposited layer by 64 %, nanohardness by 63 %, and Young modulus by 66 %. These conclusions demonstrate the potential for optimizing the composition of flux-cored wire to produce metallic coatings with enhanced properties. The results can be applied in the development of coatings for mechanical engineering, metallurgy and other industries where high reliability and stability of deposited layers are required.
Key words: arc surfacing, flux-cored wire, multicomponent alloys, carbon-fluorine-containing additive, microstructure, nanohardness, Young modulus, microhardness.
DOI: 10.17580/cisisr.2025.02.12

Introduction

Improvement of operation parameters of the working surfaces for metal products remains one of the main aims in mechanical engineering and metal working [1–3]. The properties of surface layers, such as wear resistance, corrosion resistance, thermal resistance and impact strength are especially important for the components operating in the conditions of high mechanical and thermal loads (e.g. rolls, flat dies, knives and pulleys) [4]. Use of arc welding technology with flux-cored wires is considered as one of the most efficient approaches for surface hardening of such products [5–8].

Flux-cored wires combine the advantages of alloying and possibility of direct management of the structure of deposited metal via modifying of internal filling agent. Unlike solid electrodes, they allow including refractory and active elements in their composition, thus providing improved properties of the obtained coating [9–12].

The wire 35V9Kh3SF, which was developed for surfacing of components operating at the increased impact and temperature loads, presents especial interest among the industrial grades of flux-cored wires. This wire is characterized by high welding and technological parameters, it forms welded seam metal with high hardness, thermal resistance and abrasive wear resistance [13].

The researches aimed on charge modifying for flux-cored wires in order to improve their operating parameters are conducted actively during recent times [14–18]. However, such additives often increased material brittleness, what restricts their application in the conditions of impact loads.

Use of carbon-fluorine-containing additives, which can provide complex effect on the structure of deposited metal, with improvement of distribution of alloying elements as well as wettability and density of a coating, is considered as one of the prospective directions [19, 20].

It is shown in the research [3] that adding of carbon-containing components in composition of nickel-base coatings promotes increase of their adhesion and wear resistance.

Analysis of the up-to-date investigations displays that carbon-fluorine-containing additives can vary essentially microstructure and phase composition of deposited metal. It is shown in the research [5] that adding of carbon-containing components in composition of iron-base coatings promotes increase of their corrosion resistance and mechanical strength. These results demonstrate possibility of use of different grades of additives for improvement of operating parameters of deposited coatings.

Importance of choosing composition of flux-cored wire for development of coatings with improved operating parameters was demonstrated in the research [14]. However, there are questions remaining which require additional investigations, including those aimed on examination of correlation effect of carbon-fluorine-containing additives.

To provide comprehensive evaluation of the properties of deposited coatings, the following parameters were chosen: microstructure, chemical composition, microhardness and Young modulus. Examination of microstructure allows revealing variations in distribution of phases and carbide inclusions when adding a modifier. Varying the chemical composition provides information about heterogeneity of distribution of the alloying elements. Evaluation of hardness and Young modulus is required for determination of mechanical properties of the material at micro- and nano-levels, what is especially important for the coating operating under intensive loads.

The aim of this study is to analyze the effect of carbon–fluorine-containing additive in charge of 35V9Kh3SF flux-cored wire on structure chemical composition, nanohardness, Young modulus and microhardness of deposited coatings.

To achieve the formulated goal, the following studies were carried out.

1. Three batches of flux-cored wire with various content of carbon-fluorine-containing additive were manufactured and three batches of samples for examination were deposited.
2. Chemical composition, microstructure and mechanical properties (nanohardness, Young modulus and microhardness) of deposited coatings were conducted.
3. It was concluded which percent relationship of carbon-fluorine-containing additive in charge of the flux-cored wire is characterized by the best mechanical properties.
4. Variation of mechanical properties of the deposited layer by 35V9Kh3SF flux-cored wire, with introduction of carbon–fluorine-containing additive, was analyzed.

The technique of the research

Surfacing and manufacture of flux-cored wire was carried out on the base of the scientific and production center “Welding processes and technologies” at the Siberian state industrial university (SibSIU).

Three batches of flux-cored wire with diameter 4.2 mm and length 10 m, made of 08ps steel band sheath with thickness 0.6 mm were manufactured for this research.

The process of preparing of flux-cored wire for surfacing included the following stages.

1. Charge components of 35V9Kh3SF flux-cored wire (“Polema” JSC) and carbon–fluorine-containing additive were weighed using laboratorial analytical scales AUX 120. This additive contains fine-dispersed dust from electric filters of aluminium production (25.3 % F; 13.5 % Na_2O; 4.27 % K_2O; 1.8 % CaO; 1.54 % SiO_2; 2.3 % Fe_2O_3; 18.5 % C_{tot}; 0.64 % MnO; 0.41 % MgO; 0.11 % S; 0.13 % P; 31.5 % Al_2O_3). Weighing of these components and additive were directed on achievement of the following mass percent relations:
   – batch *1* – 95 % of charge of 35V9Kh3SF flux-cored wire and 5 % of carbon–fluorine-containing additive;
   – batch *2* – 97 % of charge of 35V9Kh3SF flux-cored wire and 3 % of carbon–fluorine-containing additive;
   – batch *3* – 99 % of charge of 35V9Kh3SF flux-cored wire and 1 % of carbon–fluorine-containing additive.
2. The obtained mixtures were processed during 30 min in laboratorial rotating mixers.
3. Powder was packed at the laboratorial machine tool in metallic 08ps steel band sheath (it is swinging via die drawing) and afterwards obtained flux-cored wire was coiled on a coiling drum (**Fig. 1**).

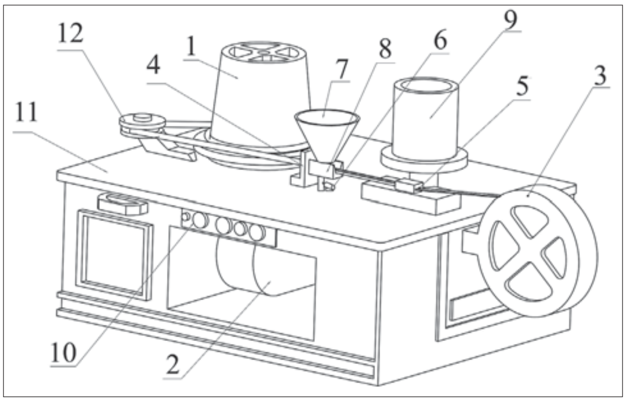

Fig. 1. Laboratorial machine tool: *1* – drawing drum; *2* – asynchronous motor; *3* – coiler with band; *4* – mandrel with die; *5* – band cleaning unit; *6* – pressure unit; *7* – bunker; *8* – hopper with gate; *9* – reel; *10* – button pulpit; *11* – housing; *12* – block

Surfacing process

Surfacing was carried out on the plate made of 09G2S steel with the following chemical composition: 0.1 % C; 0.64 % Si; 1.51 % Mn; 0.02 % S; 0.021 % P; 0.2 % Ni; 0.005 % N; 0.24 % Cr; 0.19 % Cu; 0.06 % As; 97.01 % Fe. The welding device ASAW-1250 with flux welding was used, this flux was produced of silicomanganese production slag containing 0.5 % FeO; 15.16 % MnO; 29.13 % CaO; 42.4 % SiO_2; 6.8 % Al_2O_3; 1.39 % MgO; 0.18 % Na_2O; 0.59 % K_2O; 0.28 % S; 0.022 % P; 0.004 % ZnO; 0.024 % C; 0.32 % F; 0.17 % TiO_2; 0.033 % Cr_2O_3. The process was conducted in four layers for all samples with the same parameters; these parameters were revealed experimentally based on the results of testing for different surfacing methods providing qualitative forming of deposited bead, lack of defects in the form of pores, cracks and blisters. Evaluation was carried out via the method of visual and measuring control:

- electric current — 422 A;
- voltage — 38.0 V;
- feed — 18 cm/min.

Preparing for the research

1. The sample for research was cut from the obtained deposited batches using jet-type electro-discharge sawing machine tool DK7732 M11 for wire cutting.

2. Cutting surface was polished using grinding and polishing machine FORCIPOL for obtaining plane and smooth surface.

3. Chemical pickling of the examined sample surface was carried out during 15 min using the solution containing H_2O (8 %), HF (42 %) and HCl (50 %) in order to increase contrast features of microstructure.

The scheme of the deposited sample is presented in the **Fig. 2**.

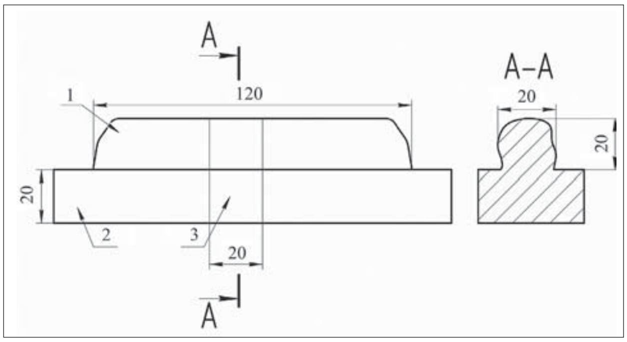

Fig. 2. The scheme of the deposited sample: *1* – deposited layer; *2* – substrate; *3* – cutting sample for research

Analytical methods

1. Microstructure analysis

Microstructure images and summarized chart spectra were obtained at the distance of 2 μm from the top of deposited layer in order to exclude mixing between deposited metal and substrate metal. The pictures were made using an electron microscope KYKY EM6900, the obtained results were analyzed for revealing structure defects and features. Length of martensite needles and size of pores were calculated via the software program Siams Photolab 700.

2. Chemical analysis of the composition

Scanning electron microscope KYKY EM6900 with thermal emitting tungsten cathode was used fro determination of elemental composition. Its operating parameters were as follows: accelerating voltage 20 kV, emission current 150 μA, filament current 2.4 A.

3. Measuring of nanohardness and Young modulus

Nanohardness and Young modulus were measured using "Nanoscan 4D" sensor in correspondence with GOST R 8.748-2011 and ISO 14577. A diamond triangular Berkovich pyramid with a load on indentor 100 mN was applied. The measurements were carried out in several points (**Fig. 3**) along the straight line at the distance 150 μm from each other, in order to evaluate variation of the properties of deposited layer for its separation from basic material.

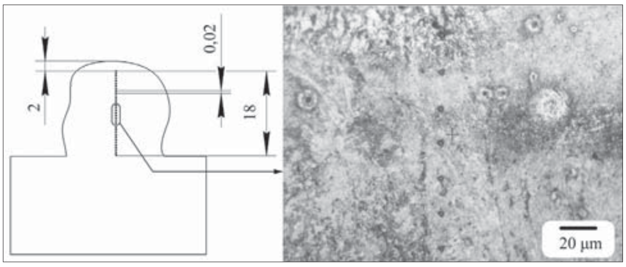

Fig. 3. The scheme of nanohardness measuring

4. Measuring of microhardness

Measuring of microhardness was conducted using Vickers microhardness meter HVS-1000 according to the GOST 9450-76 via diamond pyramid indentation. Indentor load achieved 500 g.

Results and discussion

The energy-dispersion X-ray spectrogram for the powders of the batches 1–3 as well as wire of 35V9Kh3SF grade is presented in the **Fig. 4**.

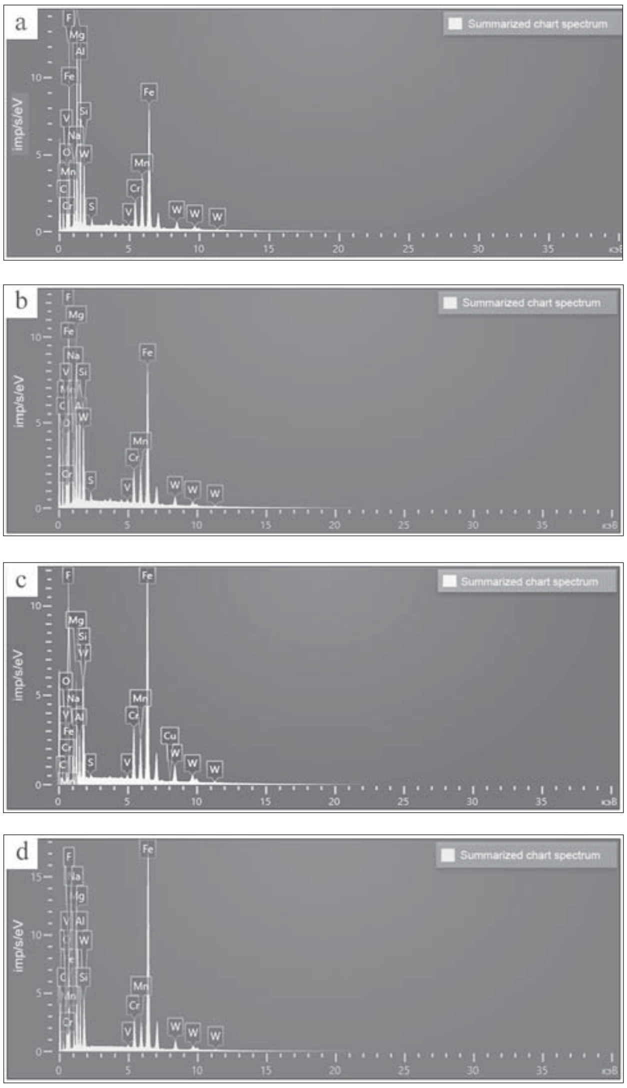

Fig. 4. The energy-dispersion X-ray spectrogram for the powders: *a–c* — batches 1–3; *d* — wire of 35V9Kh3SF grade

Table 1. Summarized chart spectra for the obtained powders

Element	Content of the element in the batch, %			Content of the element in 35V9Kh3SF flux-cored wire
	1	2	3	
C	29.03	33.83	14.52	12.64
O	8.94	9.30	6.80	7.73
F	22.67	24.20	25.80	12.64
Na	4.21	4.29	5.99	3.40
Mg	9.40	6.93	6.71	14.59
Al	7.78	4.09	2.47	5.67
Si	2.12	1.90	2.80	2.15
S	0.21	0.21	0.11	–
V	0.08	0.13	0.24	0.18
Cr	1.34	1.53	3.47	2.82
Mn	3.18	1.93	3.19	2.88
Fe	8.60	8.96	20.17	29.08
Cu	–	–	0.07	–
W	2.44	2.70	7.66	6.23

The results of summarized chart spectra for the obtained powders are shown in the **Table 1**. It can be noticed that introduction of carbon–fluorine-containing additive in charge of the 35V9Kh3SF flux-cored wire leads to rise of fluorine, carbon, sodium amount in chemical composition.

Microstructure of deposited layers, which were obtained using three different batches of flux-cored wire with carbon–fluorine-containing additive and 35V9Kh3SF flux-cored wire without additives is presented in the **Fig. 5**.

The batches 1–3 are characterized by martensite structure. It is typical for coatings obtained via surfacing by 35V9Kh3SF flux-cored wire. The average length of martensite needles in the batch 1 (5 % additive) makes 3.71 μm, presence of pores with average square 0.29 μm² is

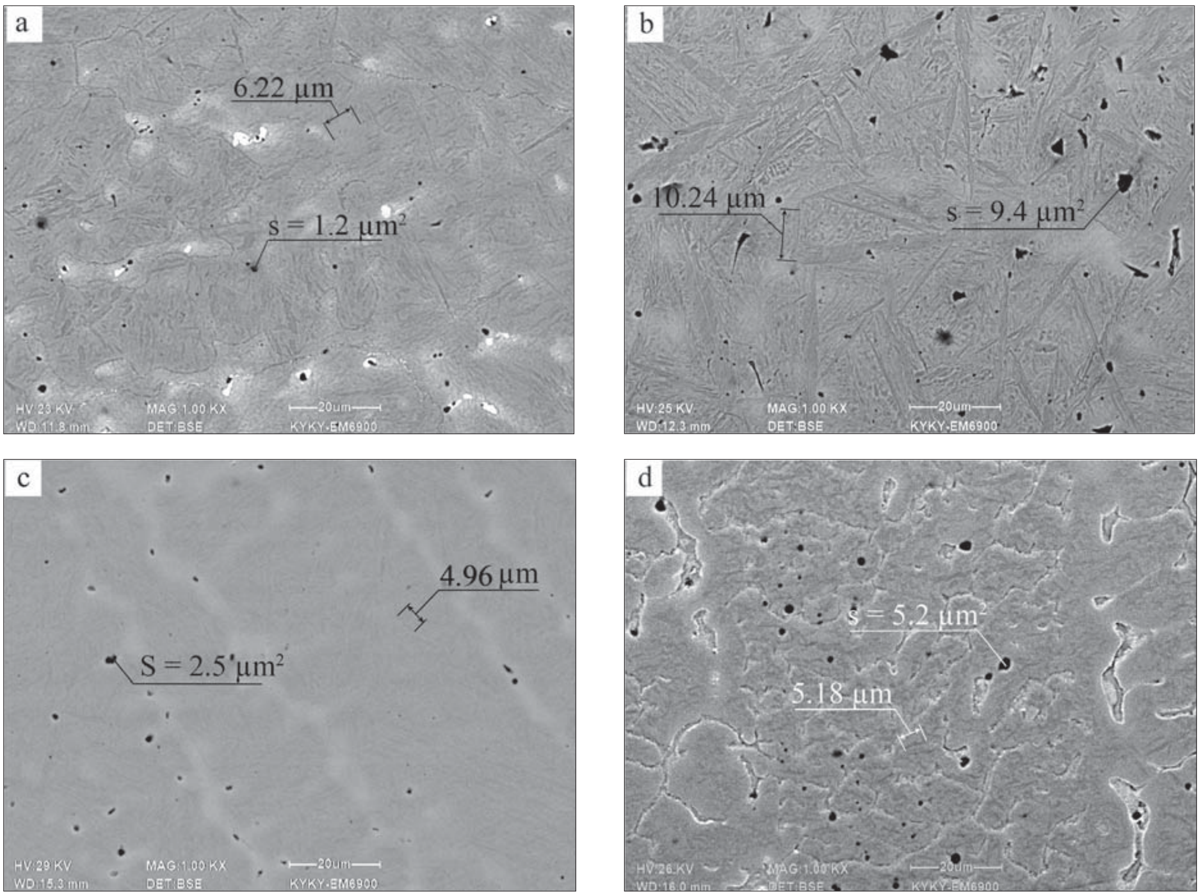

Fig. 5. Microstructure of deposited layer: *a–c* — batches 1–3; *d* — 35V9Kh3SF flux-cored wire

Table 2. Summarized chart spectrum for deposited layer of the obtained samples

Sample	Amount of the elements in the sample, % (mass.)										
	Fe	W	Cr	C	Mn	Si	O	Cu	V	Sr	Al
1	79.97	7.11	2.44	6.63	1.02	0.63	1.62	0.58	–	–	–
2	81.83	6.11	2.17	6.28	1.03	0.57	1.70	–	0.14	–	0.17
3	86.25	4.86	1.81	5.58	0.85	0.55	–	–	0.10	–	–
35V9Kh3SF	82.48	9.16	3.33	–	1.96	1.14	–	–	0.08	1.85	–

noted (they are presented by black dots). Pores in the batch 2 (3 % additive) is larger (10.36 μm) in comparison with the batch 1. Pores in the batch 3 (1 % additive) have average square 0.42 μm² and the average length of martensite needles 3.02 μm. As for the sample deposited by 35V9Kh3SF flux-cored wire, average square of pores was 0.35 μm² and the average length of martensite needles — 5.41 μm.

Energy-dispersion X-ray spectrogram of the examined areas is presented in the **Fig. 6.**

The **Table 2** displays the summarized chart spectrum for deposited layer of the obtained samples. Fe is the main element both for surfacing by 35V9Kh3SF flux-cored wire and for the batches 1—3.It means that the main mass remains constant. The main alloying elements (tungsten, manganese, silicon, chromium) were absorbed and their content varies depending on concentration of carbon—fluorine-containing additive, what reflects its influence on chemical composition of deposited layer. Carbon content in the batches 1—3 increases substantially, what confirms significant increase of its concentration with introduction of carbon—fluorine-containing additive. Content of chromium and tungsten is lower, it can be connected with possible losses during surfacing. Content of manganese and silicon in deposited layers is stable due to their content in welding flux.

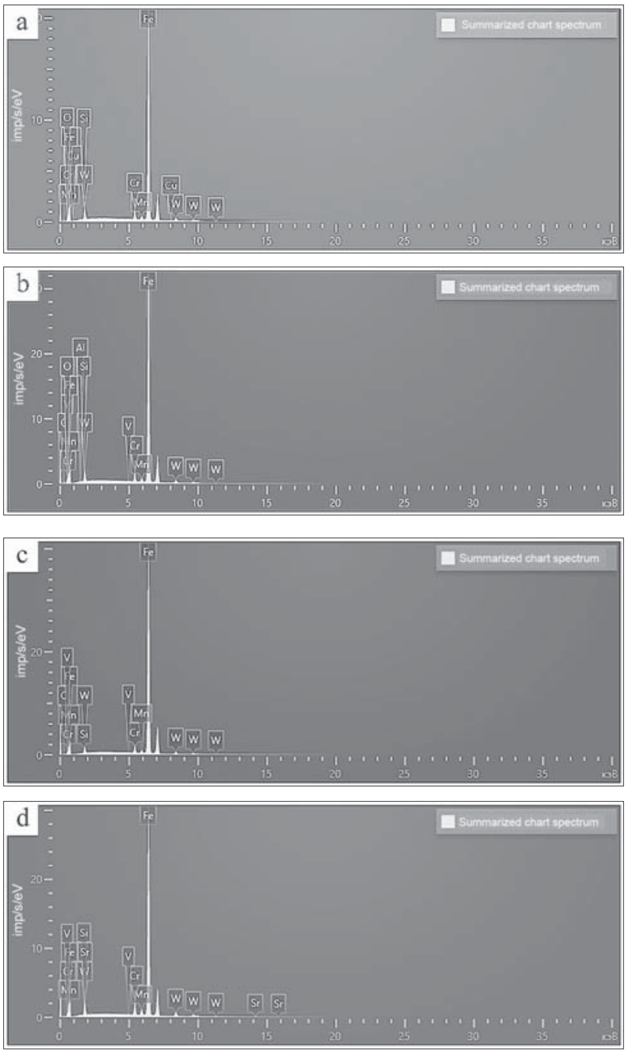

Fig. 6. Energy-dispersion X-ray spectrogram of the deposited layer: *a–c* — batches 1–3; *d* — 35V9Kh3SF flux-cored wire

The results of examination of deposited layers for nanohardness, Young modulus and microhardness are presented in the **Fig. 7–9** and in the **Table 3**. The value of Young modulus is calculated automatically by a sensor:

$$E_r = \frac{1}{\beta} \cdot \frac{\sqrt{\pi}}{2} \cdot \frac{s}{\sqrt{A_c}}$$

where β — is a constant depending on indentor form;

$S = \left(\frac{dP}{dh}\right)_{P=P_{max}}$ — contact rigidity, which is determined via inclination angle of a tangent line to unloading curve in the point $P_{\max}$;

$A_c = f(h_c)$ — contact square for maximal load, which is determined by the contact depth h_c.

Deposited metal with carbon—fluorine-containing additive are characterized by high values of nanohardness, Young modulus and microhardness in comparison with surfacing by 35V9Kh3SF flux-cored wire without any additions. In this case the batch 3 has maximal nanohardness and microhardness among presented samples.

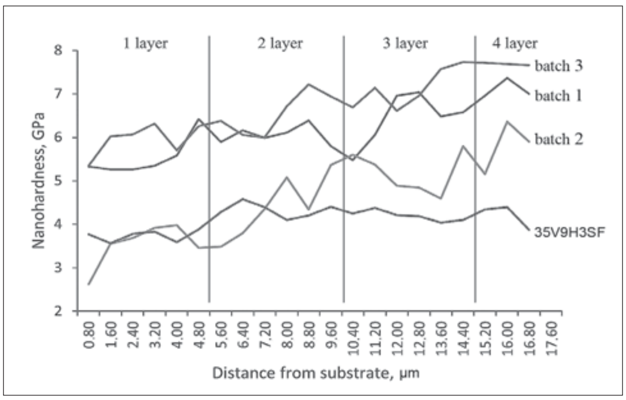

Fig. 7. Varying nanohardness depending on the distance from substrate

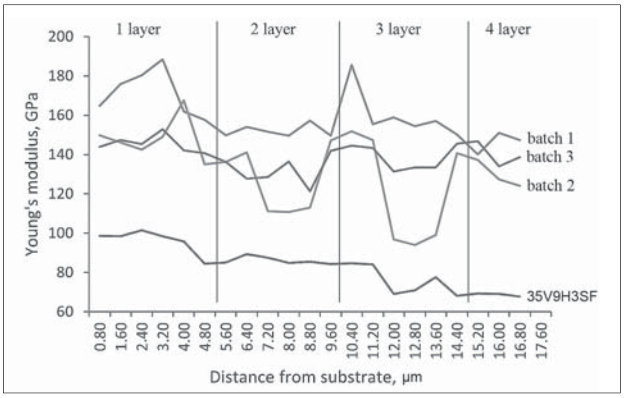

Fig. 8. Varying the Young modulus depending on the distance from substrate

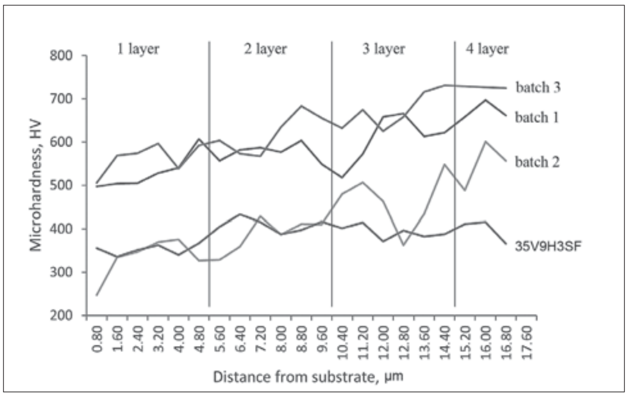

Fig. 9. Varying microhardness depending on the distance from substrate

Table 3. Values of nanohardness, Young modulus and microhardness for deposited layer

Sample		Nanohardness H, GPa	Young modulus E, GPa	Microhardness H, HV
Batch1	Average	6.17	159.13	585.86
	Standard deviation	0.66	12.96	59.78
Batch 2	Average	4.68	130.94	426.05
	Standard deviation	0.98	20.45	88.73
Batch 3	Average	6.70	138.84	633.95
	Standard deviation	0.72	7.77	68.11
35V9Kh3SF flux-cored wire	Average	4.10	83.56	386.39
	Standard deviation	0.29	11.20	27.73

Conclusions

Based on the conducted investigation of influence of carbon-fluorine-containing additive in 35V9Kh3SF flux-cored wire on the properties of deposited layers, the following conclusions were made.

1. *Nanohardness.*

The results of analysis displayed that introduction of carbon–fluorine-containing additive in 35V9Kh3SF flux-cored wire leads to substantial increase of nanohardness of deposited layer. Maximal average value of nanohardness (6.70 GPa) was achieved for the batch 3, while the batch 2 demonstrates minimal average value of nanohardness (4.68 GPa); it is connected with structural defects.

2. *Young modulus.*

Maximal Young modulus (159,13 GPa) was observed for the batch 1 (5 % additive); its value for the batch 3 makes 138.84 GPa, what is lower. However, standard deviation is minimal in this case, it testifies on stability of properties. Introduction of carbon–fluorine-containing additive provides rise of the values of Young modulus for all batches.

3. *Microhardness.*

The layers deposited by the flux-cored wire with carbon–fluorine-containing additive show larger amounts in comparison with the layers deposited by 35V9Kh3SF flux-cored wire without any additives. The batch 3 demonstrates maximal microhardness (633.95 HV), what correlates with its high nanohardness, while the batch 2 has minimal microhardness (426.05 HV).

4. *Microstructure.*

When introducing carbon–fluorine-containing additive in 35V9Kh3SF flux-cored wire, decrease of martensite needles is observed in the structure of deposited layer. Based on the obtained testing results, the batch 1 displays the largest Young modulus and the smallest size of pores (in comparison with other batches). The batch 2 is characterized by the smallest Young modulus, nanohardness and microhardness and the largest pores. The batch 3 demonstrates maximal parameters of nanohardness and microhardness, with average size of pores smaller than in the batch 2 but larger than in the batch 1.

Thus, the most balanced mechanical parameters (high nanohardness and microhardness with minimal size of pores) among the tested samples were obtained for the batch 1 (1 % additive). The research displayed that introduction of carbon–fluorine-containing additive in 35V9Kh3SF flux-cored wire (in mass correlation 99 to 1 %) allowed increasing average microhardness of deposited layer by 64 %, nanohardness by 63 % and Young modulus by 66 %. It confirms efficiency of such modification for improvement of mechanical properties of deposited layer.

Acknowledgement

The research was carried out within the framework of the State Assignment of the Ministry of Higher Education of Russian Federation No. 075-00087-2401.

REFERENCES

1. Zhang L., Li S., Zhang C., Zhang S., Ai X., Xie Z. Optimizing Wear Resistance and Tensile Strength of Nickel-Based Coatings through Tungsten Carbide Reinforcement. *Metals*. 2024. Vol. 14. No. 10. Art. 1097. DOI: 10.3390/met14101097.
2. Zirari T., Trabadelo V. A review on wear, corrosion, and wear-corrosion synergy of high entropy alloys. *Heliyon*. 2024. Vol. 10. Iss. 4. Art. e25867. DOI: 10.1016/j.heliyon.2024.e25867.
3. Akhter R., Zhou Z., Xie Z., Munroe P. Enhancing the adhesion strength and wear resistance of nanostructured NiCrN coatings. *Applied Surface Science*. 2021. Vol. 541. Art. 148533. DOI: 10.1016/j.apsusc.2020.148533.
4. Elhefnawey M., Shuai G. L., Li Z., Zhang D. T., Tawfik M. M., Li L. On achieving ultra-high strength and improved wear resistance in Al–Zn–Mg alloy via ECAP. *Tribology International*. 2021. Vol. 163. Art. 107188. DOI: 10.1016/j.triboint.2021.107188.
5. Wu H., Zhang S., Wang Z. Y., Zhang C. H., Chen H. T., Chen J. New studies on wear and corrosion behavior of laser cladding FeNiCoCrMox high entropy alloy coating: The role of Mo. *International Journal of Refractory Metals and Hard Materials*. 2022. Vol. 102. Art. 105721. DOI: 10.1016/j.ijrmhm.2021.105721.
6. Zhai W., Bai L., Zhou R., Fan X., Kang G., Liu Y., Zhou K. Recent Progress on Wear-Resistant Materials: Designs, Properties, and Applications. *Advanced Science*. 2021. Vol. 8. Iss. 11. Art. 2003739. – DOI: 10.1002/advs.202003739.
7. Konovalov S. V., Aryshenskiy E. V., Lapshov M. A., Drits A. M. (AlSi)3ScZr nanoparticles formed during cooling down of Al–Mg–Si alloy ingots and their effect on mechanical properties. *Tsvetnye Metally*. 2023. Vol. 11. pp. 68–75.
8. Li Y., Shi Y. Microhardness, wear resistance, and corrosion resistance of AlxCrFeCoNiCu high-entropy alloy coatings on aluminum by laser cladding. *Optics & Laser Technology*. 2021. Vol. 134. Art. 106632. DOI: 10.1016/j.optlastec.2020.106632.
9. Kuzmenko A. G., Mazurov E. F., Krupennikov S. A. Basic technolohical and engineering parameters of flux-cored wire for universal use. *Elektrometallurgiya*. 2008. No. 5. pp. 12–17.
10. Liao M., Chen W. A Comparison of Gas Metal Arc Welding with Flux-Cored Wires and Solid Wires Using Shielding Gas. *International Journal of Advanced Manufacturing Technology*. 1999. Vol. 15. pp. 49–53. DOI: 10.1007/s001700050038.
11. Im H.-D., Choi C.-H., Jung J.-H., Kil W. The Latest Technology Development Trends of Flux Cored Wire. *Journal of Welding and Joining*. 2016. Vol. 34. pp. 1–10. DOI: 10.5781/JWJ.2016.34.6.1.
12. Świerczyńska A., Varbai B., Pandey C. et al. Exploring the trends in flux-cored arc welding: scientometric analysis approach. *International Journal of Advanced Manufacturing Technology*. 2024. Vol. 130. pp. 87–110. DOI: 10.1007/s00170-023-12682-6.
13. Kryukov R. E., Kozyrev N. A., Kibko N. V. et al. Study of the quality of deposited metal for the system Fe–C–Si–Mn–Cr–W–V. *Problemy chernoy metallurgii i materialovedeniya*. 2023. No. 2. pp. 86–94. DOI: 10.54826/19979258_2023_2_86.
14. Panchenko I. A., Drobyshev V. K., Konovalov S. V., Bessonov D. A. Structural Change in Co–Cr–Fe–Mn–Ni Alloys upon Variation in Mn and Fe Concentrations. *Technical Physics Letters*. 2024. DOI: 10.1134/s1063785024700391.
15. Xue H., Zhao J., Peng H., Guo W., Li T., Ding Z. Modifying of mechanical properties in the deposited metal prepared by welding wire containing nanosized oxide particles. *Materials Research Express*. 2021. Vol. 8. No. 10. Art. ac2bd5. DOI: 10.1088/2053-1591/ac2bd5.
16. Boyko I. A., Grin A. G. Influence of the surface state of flux-cored wire on stability of an arc process. *Svarochnoe proizvodstvo*. 2014. No. 7. pp. 8–13.
17. Osintsev K. A., Konovalov S. V., Kormyshev V., Ivanov Yu. F., Panchenko I. A. Microstructure and mechanical properties of non-equiatomic Co25.4Cr15Fe37.9Mn3.5Ni16.8Si1.4 high-entropy alloy produced by wire-arc additive manufacturing. *Materials Letters*. 2022. Vol. 312. p. 131675. DOI: 10.1016/j.matlet.2022.131675
18. Tian W., Li J., Liu Y., et al. Atomic-Scale Layer-by-Layer Deposition of FeSiAl–ZnO–Al_2O_3 Hybrid with Threshold Anti-Corrosion and Ultra-High Microwave Absorption Properties in Low-Frequency Bands. *Nano-Micro Letters*. 2021. Vol. 13. Art. 161. DOI: 10.1007/s40820-021-00678-4.
19. Agrawal P., Haridas R.S., Yadav S., et al. Processing-structure-property correlation in additive friction stir deposited Ti–6Al–4V alloy from recycled metal chips. *Additive Manufacturing*. 2021. Vol. 47. Art. 102259. DOI: 10.1016/j.addma.2021.102259.
20. Kryukov R.E., Kozyrev N.A., Kozyreva O.A. The Carbon-Fluorine Additives For Welding Fluxes. *Mechanics, Materials Science & Engineering Journal*. 2016. DOI: 10.13140/RG.2.1.1002.3443.