Development of Alloying Fluxes for Wear-Resistant Weld Overlay of the Rolling Stock Parts Using Mineral Raw Materials of the Far Eastern Region

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This work is intended for the development of new materials that ensure required mechanical and operational properties and the quality of the surfaces formed. The paper presents the results of the research in the development of fusion-ceramic welding fluxes for wear-resistant weld overlay of the parts of the rolling stock. We have developed the methodology for obtaining such fluxes and conducted theoretical calculations and experimental research. The latter resulted in obtaining fluxes (granodiorite – 5.8%, fluorite – 3.7%, marble – 4.1%, zirconium concentrate – 4.9%, ferromanganese – 19.6%, titano-magnetite – 3.7%, braunite – 1.2%, scheelite – 2.1%, graphite – 5.5%, ferrochrome – 28.9%, AN22 or AN348A – 20.6%). The required properties are achieved through reduction of alloying elements and formation of chrome carbide (Cr_7C_3), iron carbide (Fe_3C) and other substances in the deposited weld layer.

Introduction. Development of resource saving technologies and new materials using concentrates and waste materials of various production processes is an important factor for fostering the economy of the country. One of the directions of the industrial development is hard-facing welding materials with high physical-mechanical and technological properties. Development of such materials involves
use of raw materials in the form of oxides, fluorides, chlorides and other substances. Within the framework of this work we have conducted the research on the development of fusion-ceramic welding fluxes of ilmenite1-fluorite type ($FeTiO_3$ – CaF_2 – MnO – SiO_2 – Al_2O_3). To achieve this goal we used standard fluxes (AN348A, AN22) and mineral raw materials of the Far Eastern region (Bureya, Sikhote-Alin, Khingan-Badgal, Upper Amgun and others) [1].

Mineral raw materials of the Russian Far East contain oxides of tungsten, zirconium, titanium, boron, chromium, manganese and other elements that perform the function of alloying of the welding deposit aimed at the increase in the mechanical and working properties. In addition to that, multi-component raw materials contain the elements that are capable of protecting molten electrode metal from the environment and facilitating its metallurgical processing. Therefore, they, in an integrated manner, can be used as slag base for fluxes. Use of the local mineral raw materials contributes to the significant decrease in the costs and allows creating new materials ensuring high properties and quality of the surfaces formed. Beyond that, application of these mineral raw materials will contribute to the economic growth of the Far East, will create new jobs and will ensure import substitution.

Research methodology. We have developed a complex methodology for producing fusion-ceramic welding fluxes, that involves the following stages: preliminary calculation of the slag mixture components; determining the basicity index of the slag and its chemical reactivity; thermodynamic analysis of the possible chemical reactions; and experimental research aimed at determining optimum mixture ratio of the components for obtaining coatings with the required mechanical and working properties.

In order to obtain optimum composition of the flux components we conducted experimental research based on calculation models and diagrams for the dependency of the quality and properties of the coatings formed on the composition of the flux-slag system. We determined dependencies between the input (composition of charge material) and the output (quality indexes and properties) parameters. We employed experimental statistical methods to resolve this problem. The scheme of the subject of research (electro thermic process) is presented in Fig.1.

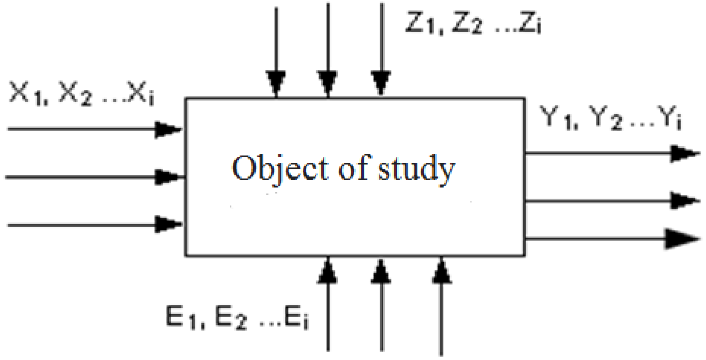


Figure 1 – Subject of research scheme

The input parameters (X1, X2, Xi) are the charge material components, and the output parameters (Y1, Y2, Yi) are the quality-properties indexes. The subject of research can be also influenced by controllable (Z1, Z2, Zi) and uncontrollable (E1, E2, Ei) external factors.

When resolving the problems of creating new materials using mineral raw materials under electro-arch processes, slag systems are described in the most complete and thorough manner by the quartic polynomial below:

y =1x1+2x2+3x3+12x1x2+13x1x3+23x2x3+12x1x2(x1–x2)+
+13x1x3 (x1–x3)+23x2x3 (x2–x3)+12x1x2(x1–x2)2+13x1x3(x1–x3)2+
+23x2x3 (x2–x3)2+1123x21x2x3 + 1223x1x22x3 + 1233x1x2x23,

where x1,x2,x3…xn are the contents of the mixture components (xi=1),
y1,y2,y3,y123 , etc. are the experimentally determined values of the system responses in the simplex lattice nodes. The results obtained were used for constructing mathematical dependencies and plotting diagrams of relationships between the composition of charge material and the properties of the coatings formed.

Discussion of results. This work comprises two stages: development of the slag base; and further production of the welding fluxes for wear-resistant weld overlay. In order to develop the slag base we have conducted the studies to determine the compositions of the fluorite, granodiorite, marble, braunite, scheelite, baddeleyite and datolite concentrates, as well as titano-magnetite schlich. For example, braunite is used as a slag forming substance. The results of research on braunite are presented in Fig. 2 and 3, as well as in Table 1.

Table 1

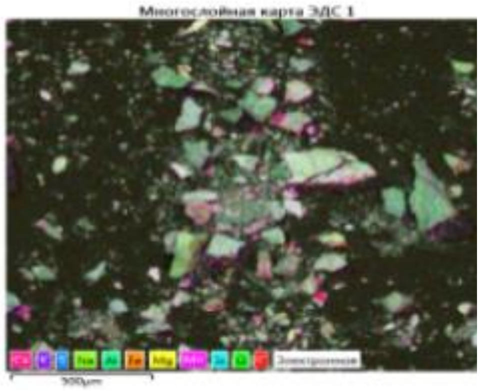
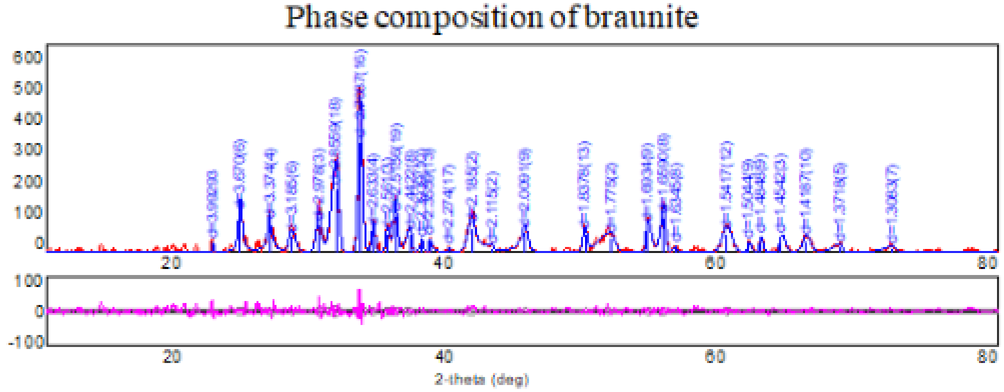


Figure 2. Morphology of braunite



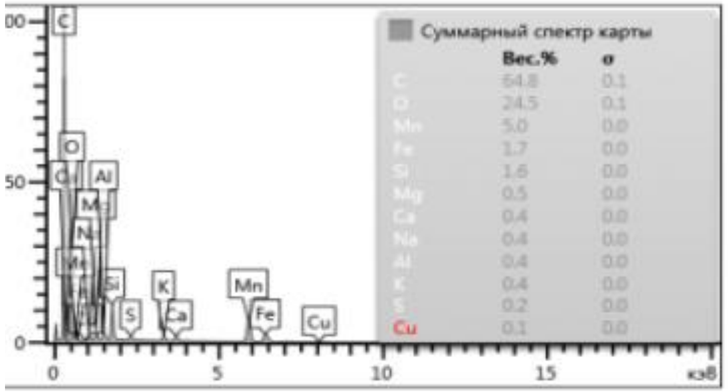


Figure 3. Elemental composition of braunite

No.	2-theta(deg)	Phase name	Chemical formula	DB card number
1	3.99293	Pyroxmangite, syn (1,0,-3)	$MnSiO_3$	00-029-0895
2	3.67042	Rhodochrosite, syn (0,1,2), Pyroxmangite, syn (0,1,3)	$Mn(CO_3)$, $MnSiO_3$	01-086-0172, 00-029-0895
3	3.37426	Pyroxmangite, syn (1,-2,1)	$MnSiO_3$	00-029-0895
4	3.18520	Pyroxmangite, syn (1,2,-2)	$MnSiO_3$	00-029-0895
5	2.97764	Pyroxmangite, syn (2,0,3)	$MnSiO_3$	00-029-0895
6	2.85593	Rhodochrosite, syn (1,0,4), Braunite-1Q, syn, (3,1,2), Pyroxmangite, syn (1,2,1)	$Mn(CO_3)$, $Mn_7O_8(SiO_4)$, $MnSiO_3$	01-086-0172, 01-089-5667, 00-029-0895
7	2.70872	Bixbyite, syn (2,2,2), Braunite-1Q, syn, (2,2,4), Pyroxmangite, syn (0,2,-6)	Mn_2O_3, $Mn_7O_8(SiO_4)$, $MnSiO_3$	00-010-0069, 01-089-5667, 00-029-0895
8	2.63279	Rhodochrosite, syn (0,0,6)	$Mn(CO_3)$	01-086-0172
9	2.56083	Pyroxmangite, syn (2,-2,4)	$MnSiO_3$	00-029-0895

Research into the morphology of the elemental compositions (Fig. 2 and 3) show that braunite is a multicomponent substance containing the elements (manganese, silicon, aluminum, calcium and others) used for production of welding materials. Phase analysis determined that the mineral raw materials contain the elements in the form of oxides, sulfates and other compounds (for example, MnSiO, $Mn_7O_8(SiO_4)$ Mn_2O_3), Table 1.

Slag base was developed on the base of standard fluxes AN22, AN348A and mineral raw materials of the Far Eastern Region. For this purpose, the following constituents have been selected: slag-forming (fluorite, granodiorite, marble); stabilizing (titano-magnetite); alloying (scheelite, braunite); and binding (sodium silicate). Oxide composition of the selected raw materials is presented in Table 2.

Table 2

Composition of the mineral raw materials of the Far Eastern region

Name	Oxide composition, mass. %
Fluorite	92-CaF_2; 2,5-SiO_2; 2,5-CaO
Granodiorite	63-SiO_2; 16-Al_2O_3; 5,49-Fe_2O_3; 5,1-CaO; 4,28-K_2O; 3,3-Na_2O
Marble	98-$CaCO_3$
Titanomagnetite	22,57-$FeTiO_3$; 18,27-SiO_2; 1,41-Al_2O_3; 13,97-Fe_2O_3; 0,94-MnO; 1,81-CaO
Scheelite	59,5-WO_3; 2,9-SiO_2; 26,8 -CaO; 3,8-Fe_2O_3; 1,6-MgO
Braunite	21,55-MnO; 25,45-SiO_2; 5,62-Al_2O_3; 9,02-FeO; 15,47-$CaCO_3$; 4,34-MgO

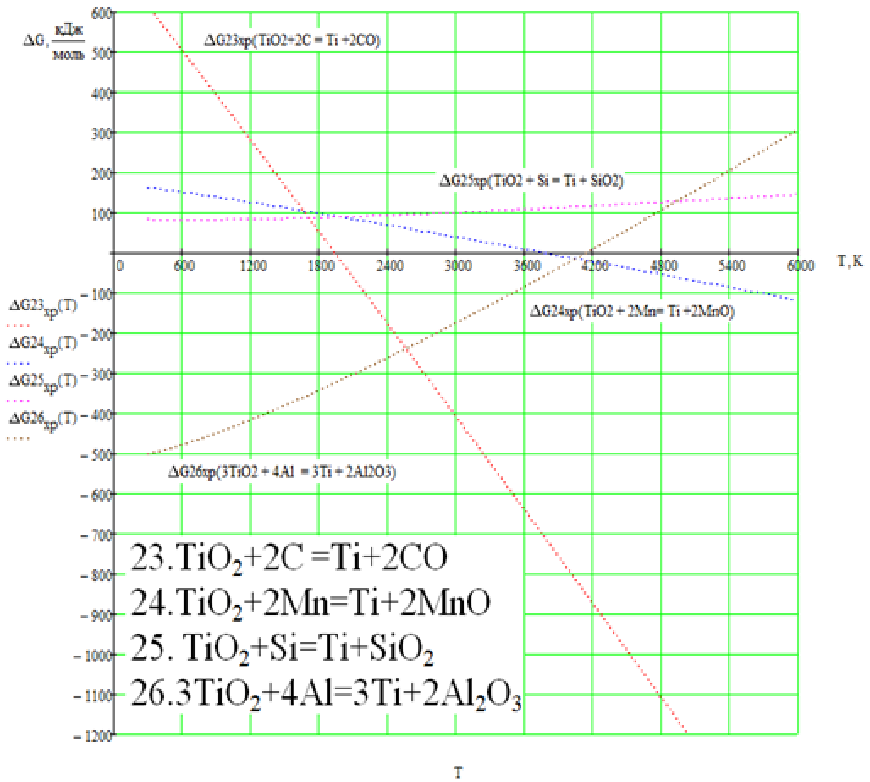


Figure 4 – Change of Gibbs free energy ($\Delta G^0_{x.p}$) with the temperature for reduction reactions

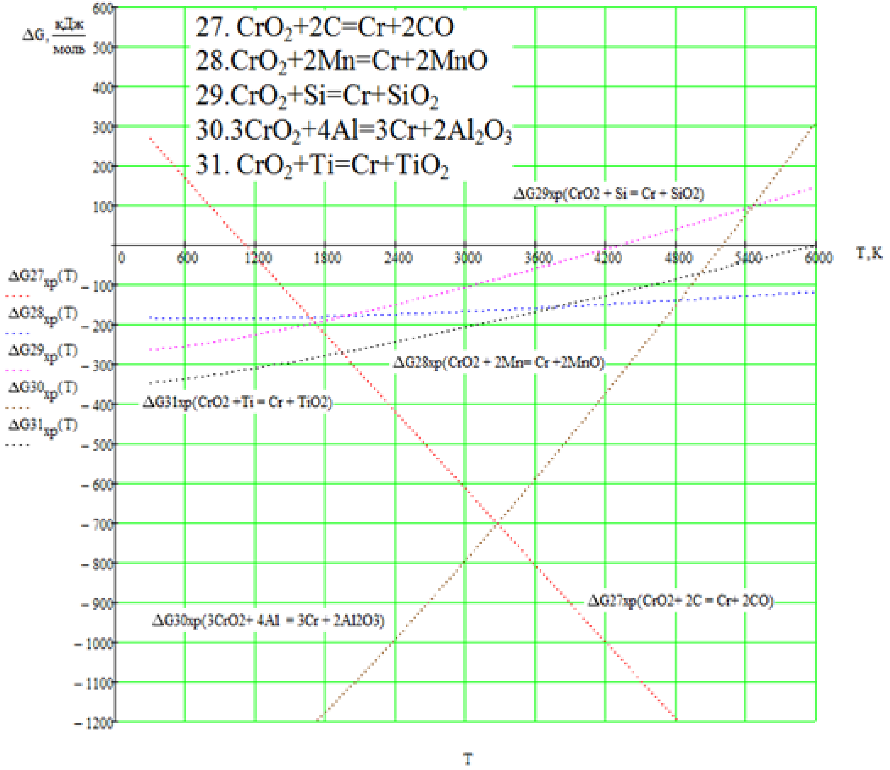


Figure 5 – Change of Gibbs free energy ($\Delta G^0_{x.p}$)with the temperature for reduction reactions

In order to determine possible chemical reactions behavior, we have performed a thermodynamic calculation for the selected multicomponent mineral raw materials [5]. Fig. 4 and 5 present the results of some of these calculations.

The next stage comprised the calculation of the percentage mixture ratio for the charge material, basicity and chemical reactivity of the slag, consisting of 50% of the mineral raw materials components and 50% of standard flux AN22.

The calculations show that the flux with the 50% content of the Far Eastern mineral raw materials components and 50% content of the standard flux AN22 is basic (B=1.46) and low-active (A = 0.22). This flux does not oxidize metal, decreases the slag melting point and improves the welding seam formation quality. In addition, we have established that the slag under study possesses high technological properties and will be used as the base for selection of the optimum flux composition that will ensure required quality of the surfaces formed. For these purposes we have conducted research in accordance with the scheme above (Fig. 1), in which input (variable) parameters were: slag-forming (fluorite, granodiorite, marble, braunite), X1; stabilizing (titano-magnetite), X2; alloying and deoxidizing (scheelite), X3. Flux AN22 was the permanent input (excipient) parameter. General porosity (P) and grain structure (G) were accepted as output criteria.

Experimental research resulted in mathematical functions and diagrams for the dependence of the flux performance in the electro-arc process on the charge material components. Analysis of the diagrams allows us to establish the optimum composition of the mineral raw materials components with rational values for porosity and grain structure: X1 (40 % slag-forming – fluorite 27.35%; granodiorite 42.38%; marble 30.27%); X2 (44 % stabilizing – titano-magnetite 100%); X3 (16 % alloying – scheelite 62.50; braunite 37.50).

At the next stage, this composition was used to perform sample welding for further research into the structure and properties of the coatings formed, Fig. 6.

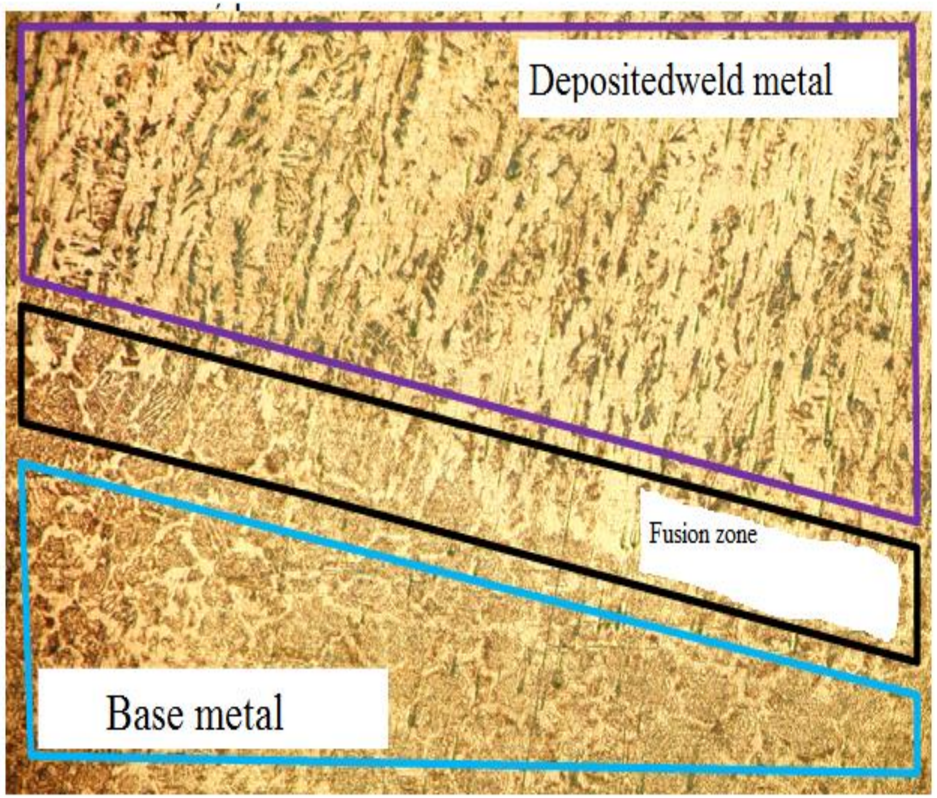


Figure 6 – Photograph of the deposited weld metal microstructure

Figure 6 shows that the structure of the deposited weld metal is ferrite-pearlite and that the crystals have dendritic structure corresponding to the structure of metal under thermal processes. Fusion zone and deposited weld metal have no defects.

The composition of the slag base developed ensures high quality of the deposited weld metal and required welding-technological properties (slag separability, arc stability, deposited weld layer formation, tendency to flawing and others).

Based on the slag base obtained, we developed fusion-ceramic fluxes to restore worn-out surfaces of the rolling stock parts. These fluxes are capable of ensuring wide range hardness of the weld deposit metal (250-500HB), its impact strength of no less than 30 J/cm2 and high wear resistance. The problem was resolved in accordance with the scheme presented above (Fig. 1). Slag base, graphite, ferromanganese, ferrochrome, zirconium concentrate were accepted as the input parameters; while hardness and wear resistance index were accepted as the output parameters. Results of the experiment were used to calculate the indexes and to construct the equations for output parameters of the system under study.

Based on the system responses we obtained in the course of the experiment, polynomial coefficients were calculated and the regression equations were set up:

– for hardness (HRC):

$$y(\text{Тв}) = 46{,}9x1+25{,}8x2+29{,}9x3+27{,}8x1x2+22{,}4x1x3+31{,}8x2x3-163{,}46x1x2\,(x1-x2)+1062{,}93x1x3(x1-x3)-1354{,}93x2x3(x2-x3)+30{,}13x1x2(x1-x2)2-45{,}33x1x3\,(x1-x3)2+19{,}46x2x3(x2-x3)2-12x12x2x3-29{,}86x1x22x3-47{,}2x1x2x32;$$

– for wear resistance index (Кi):

$$y(\text{Кi}) = 9{,}91x1+3{,}06x2+3{,}54x3-7{,}66x1x2+19{,}62x1x3+13{,}35x2x3+65{,}29x1x2(x1-x2)-26{,}17x1x3(x1-x3)+27{,}68x2x3(x2-x3)+8{,}36x1x2(x1-x2)2-7{,}2x1x3(x1-x3)2-7{,}55x2x3(x2-x3)2+21{,}72x12x2x3+27{,}23x1x22x3-16{,}05x2x32.$$

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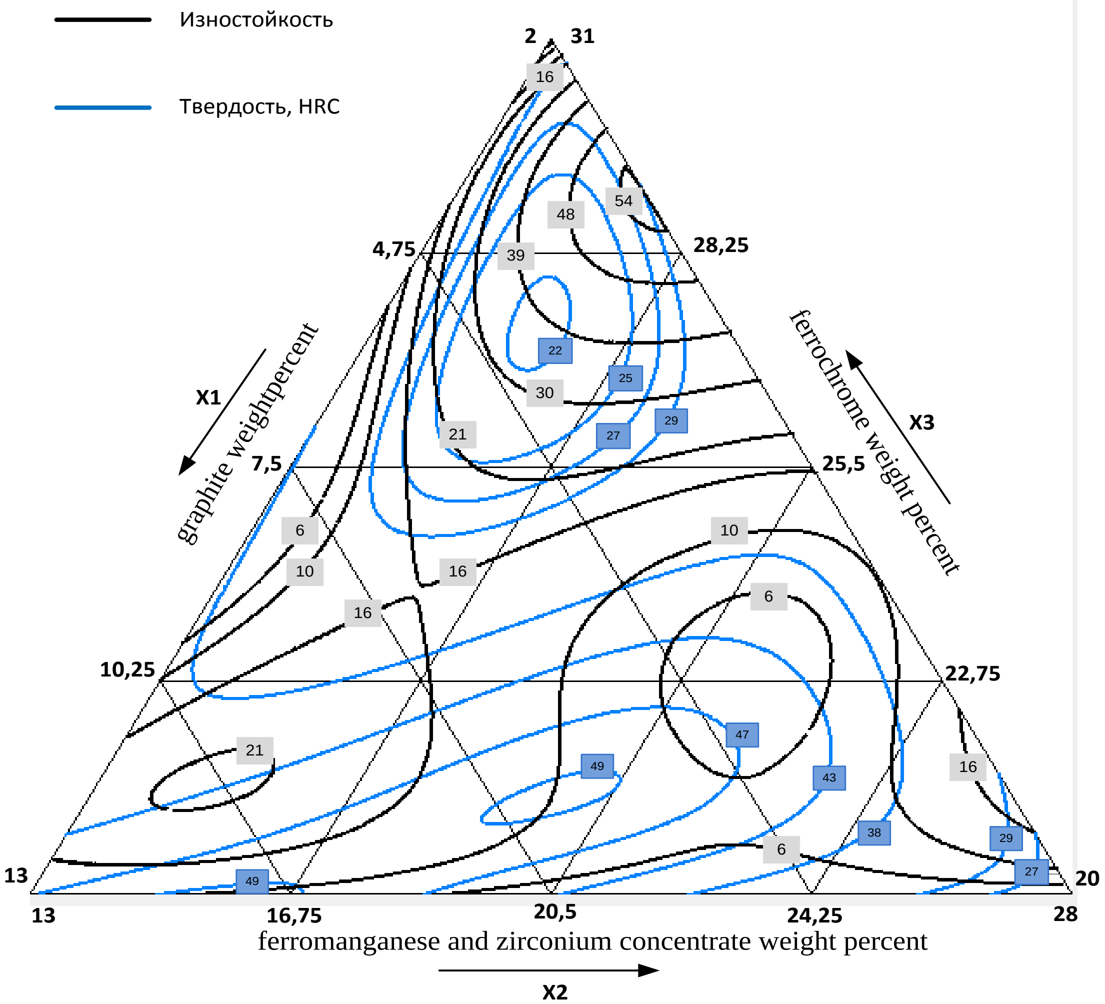


Figure 7 – Reconciled diagram for the influence of flux components mixture ratio on the performance criteria (HRC, Ki).

Based on the calculation data the reconciled diagram of the influence of the mass fractions of the input parameters on the properties of weld deposited metal was plotted (Fig. 7).

In accordance with the reconciled diagram we chose the optimum composition of the flux depending on the required properties of the weld deposited metal and assigned it type marking (AN22PK-DMS). The composition of the fusion-ceramic flux to ensure the hardness of the deposited weld metal 47HRC, (mass. %) is as follows: AN-22 – 20.6; granodiorite – 5.8; flu

4.1; titano-magnetite – 3.7; braunite – 1.2; scheelite – 2.1; zirconium concentrate – 4.9; ferromanganese – 19.6; graphite – 5.5; ferrochrome – 28.9

Sample welding was performed using the composition of the mineral raw material (chosen in accordance with the diagram above) and standard fluxes AN22 and AN348A. Sample welding was followed by examining of the compositions, structures and properties of the weld deposited layers obtained. Welding materials used were: commercial quality steel (St3)4 as a back support; and the electrode wire Sv-085 3 mm in diameter. Tables 4 and 5, as well as Fig. 8 and 9, present the research data.

Table 4

Elemental composition of the metal welded up with experimental fluxes

AN22PK-DMS								
Element concentration, %								
C	Al	Si	Ni	Ti	Cr	Mn	Zr	W
1.4-1.7	0.894	2.129	1.282	0.251	9.374	8.326	0.390	0.087
AN348APK-DMS								
Element concentration, %								
C	Al	Si	Ni	Ti	Cr	Mn	Zr	W
1.4-1.7	0.026	0.248	1.288	0.025	7.992	4.488	0.090	1.746

Chemical composition of the deposited weld metal obtained with the use of AN22PK-DMS and AN348APK-DMS fluxes corresponds to the hypereutectoid steel, alloyed with chromium, manganese, tungsten and other elements. Carbon content in the weld deposit layer exceeded 1.4 %; chromium content varies from 7.992 % to 9.374 %; manganese content - from 4.488 % to 8.326 %; and tungsten - from 0.087 % to 1.746 %, which testifies to possible formation of carbides, alloyed cementite and other substances in the weld-up layer.

Table 5

Mechanical and working properties of the deposited weld meta

Flux	Property	Value
AN22PK-DMS	Hardness, HRC	47
	Wear Resistance Index relative to steel 20, (Кi)	8,5
	Impact stregnth KCU, ^{2} (at 20^{o}C)	39
AN348APK-DMS	Hardness, HRC	50
	Wear Resistance Index relative to steel 20, (Кi)	10
	Impact stregnth KCU, J/cm^{2} (at 20^{o}C)	36

Deposited weld metal has hardness of 47-50 HRC and high wear resistance relative to steel 20 Кi 8.5-10. The value of impact strength is KCU 36-39 J/cm2, which complies with the requirements of the technical specifications for rolling stock operation. High hardness of the weld-up layer is determined by the formation of carbides, alloyed cementite and other compounds. The latter is confirmed by the metallographic examination.

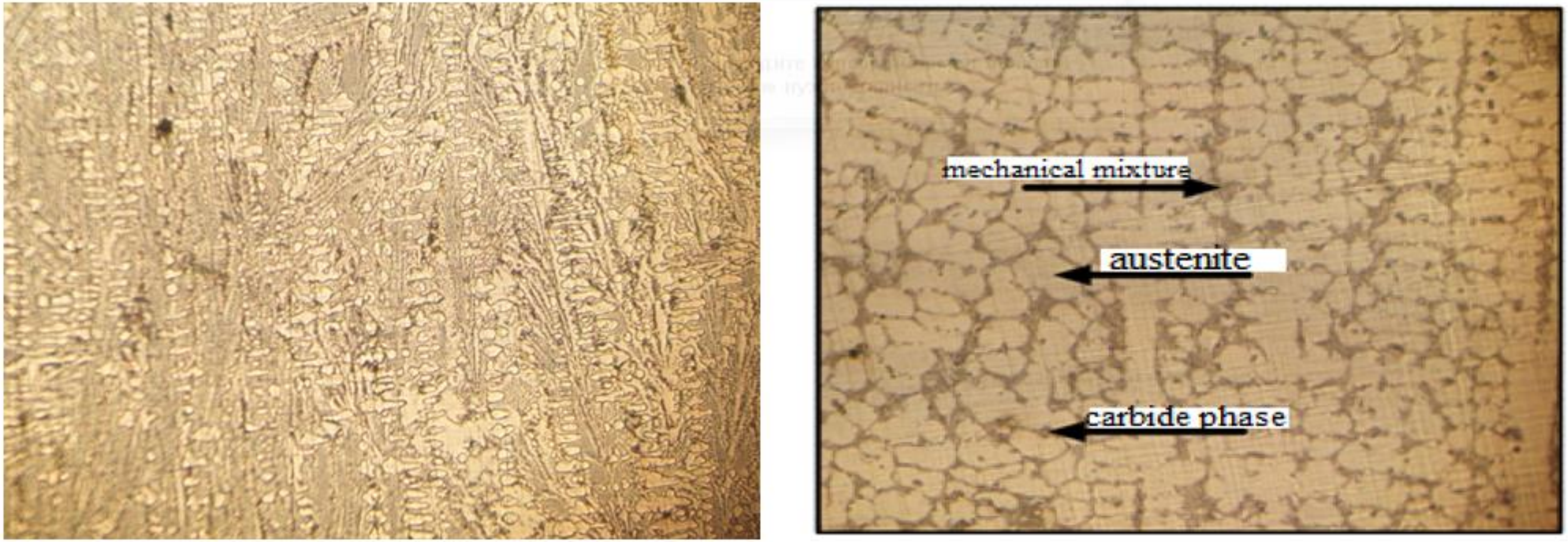
Fig. 8 and 9 displays microstructure of the metal deposited under AN22PK-DMS and AN348APK-DMS fluxes. Base metal is of ferrite-pearlite structure (the content of the pearlite constituent is 20…25%). Fusion zone (55 µm wide) is of sorbate structure with the microhardness of 230 HV. Dendritic crystals, consisting of sorbite penetrate 15-20 µm deep from the fusion zone into the deposited weld metal.

Deposited weld layer is of cellular dendritic structure, characteristic of the intracrystalline structures of the surfaces of eutectoid alloys (Fig. 8-a and 9-a). The figures show that the cells appear at a certain distance from the weld adjacent zone. Dendritic crystals form at a later stage of hardening.

The structure of the layer welded up with the AN22PK-DMS flux consists of three phases. One of the phases forms rounded areas (grains) aligned towards the growth of the dendritic crystals (Fig. 8-b). The structure of this phase consists of austenite (Atlas of Microstructures of Metals and Alloys), with the micro hardness of 250-300 HV. The other phase corresponds to the mechanical mixture (eutectoid) consisting of alloyed cementite and austenite (400-450 HV). The intergranular space contains carbide phase (alloyed cementite, 550-620 HV). The research

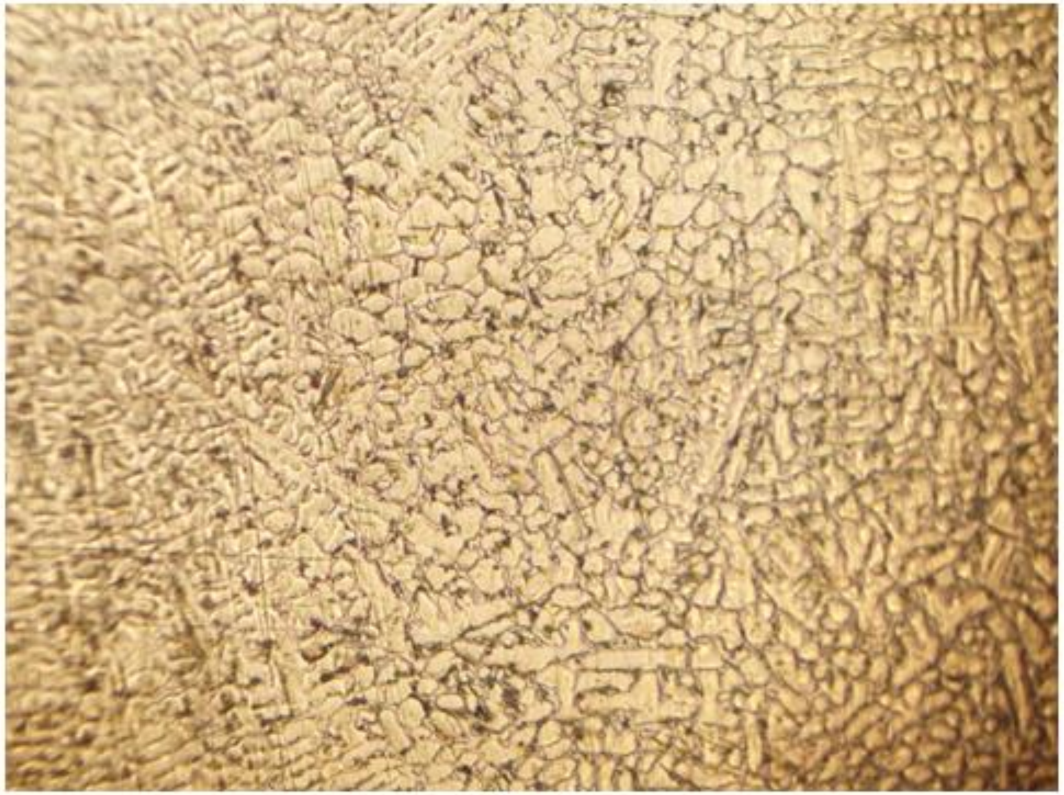
results allow us to conclude that the microstructure of the layer welded up with the AN22PK-DMS flux consists of austenite, eutectoida and carbide phase.

The structure of the layer welded up with the AN348APK-DMS flux also consists of three phrases. One of the phases forms rounded areas (grains) aligned towards the growth of the dendritic crystals (Fig. 9-b). The structure of this phase consists of austenite with the microhardness of 250-300 HV. The second phase corresponds to the mechanical mixture (eutectoid) – alloyed cementite and bainite (400-450 HV). The intergranular space contains carbide phase (alloyed cementite, 550-650 HV). The research results allow us to conclude that the microstructure of the layer welded up with the AN348APK-DMS flux consists of austenite, eutectoid and carbide phase.

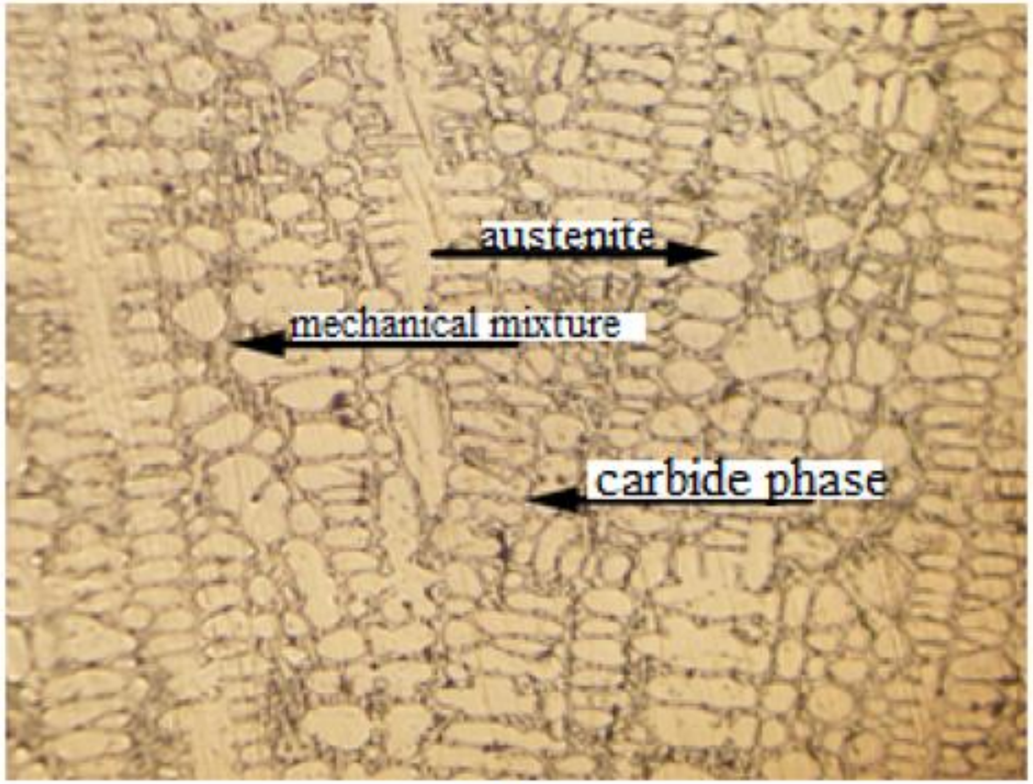


(a) (b)

Fig. 8. The microstructure of the layer welded up under the AN22PK-DMS flux (a – deposited weld metal; magnitude (a)-x200, b–(a)-x400)



(a)



(b)

Fig. 9. The microstructure of the layer welded up under the AN348APK-DMS flux (a – deposited weld metal; magnitude (a)-x200, b –(a)-x400)

The microhardness of the metal, that was welded using the fluxes developed, is 600-650 HV, which testifies to possible formation of hard structure constituents (Fig. 10 and 11). The microhardness of the base metal (St3 steel) is 140-170 HV.

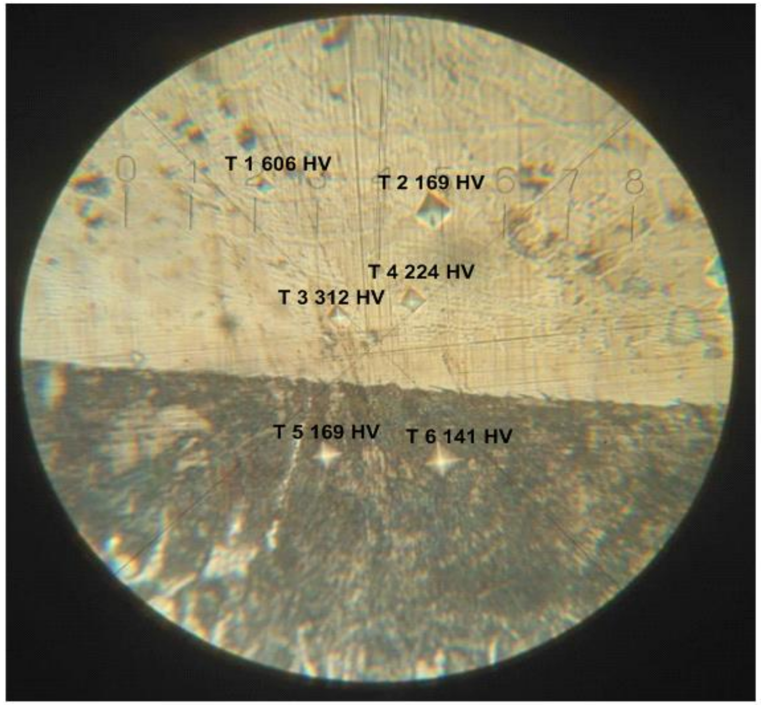


Fig. 10. Micro-hardness of the deposited weld metal under AN22PK-DMS flux

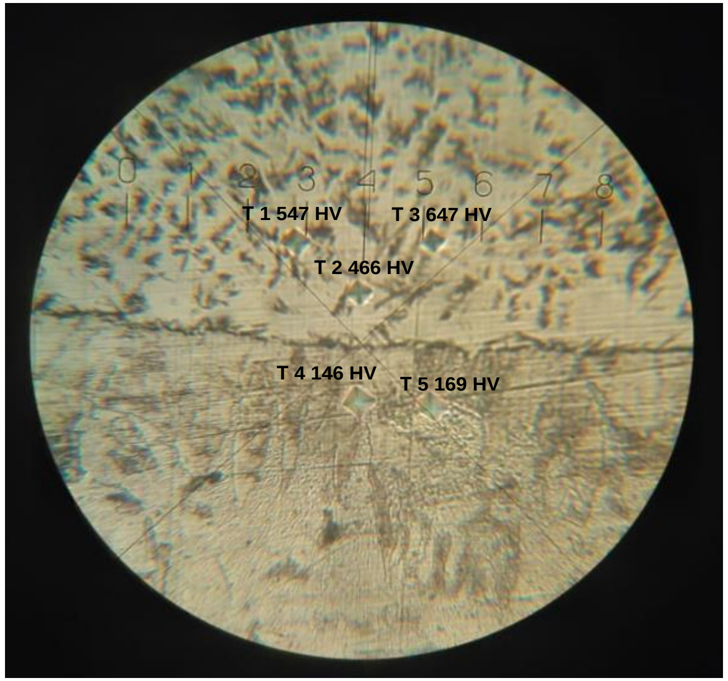


Fig. 11. Micro-hardness of the deposited weld metal under AN348APK-DMS flux

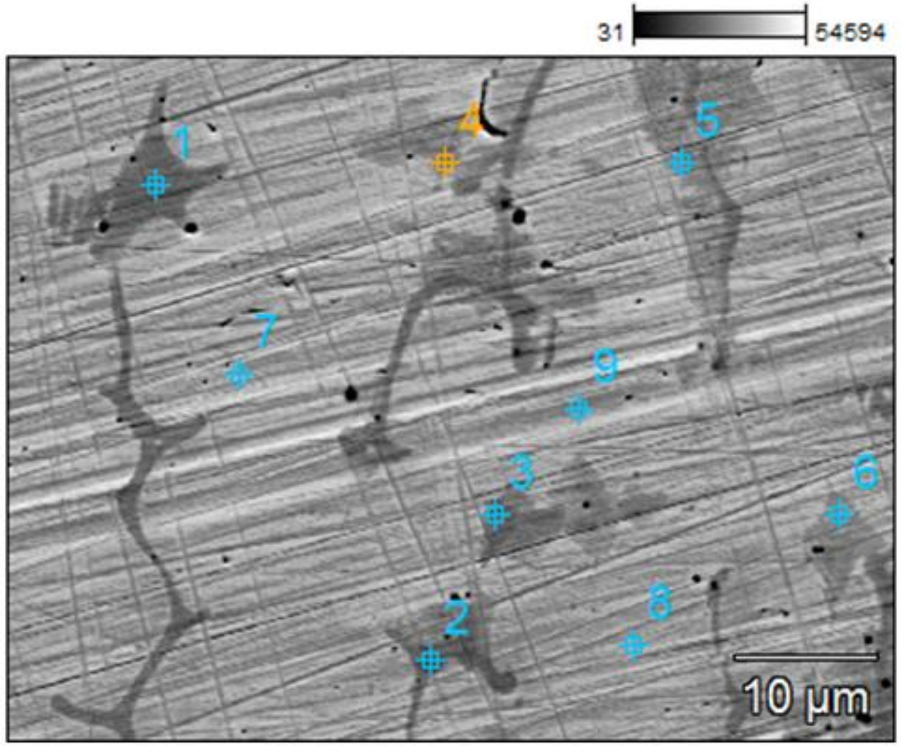


Figure 12.Macrostructure of the weld-up layer

Table6

Elemental composition ofdeposited weld metal, atom %

Точка	C	Si	Cr	Mn	Fe
1	17.42	0.52	15.56	6.27	60.14
2	16.65	0.67	12.30	6.31	64.06
3	19.02	0.55	14.83	6.06	59.54
4	16.08	1.65	6.03	5.19	71.05
5	12.66	1.47	4.16	3.95	77.76
6	10.13	1.36	3.90	3.53	81.08
7	6.29	1.18	4.09	4.05	84.39
8	7.46	1.31	3.89	3.59	83.76
9	14.23	1.40	3.76	3.92	76.70

X-ray spectroscopic microanalysis conducted was aimed at establishing the laws governing the distribution of the alloying elements within the deposited weld metal.

Results of the X-ray spectroscopic microanalysis for the metal welded under AN22PK-DMS flux are presented in Fig. 12 and Table 6.

X-ray spectroscopic micro analysis of the deposited weld metal was performed layer by layer (upper and middle layers and fusion zone). The upper layer (Fig. 12 and Table 6) display maximum content of chromium 12-15 atom% and manganese 6 atom% distributed in the points 1, 2 and 3, which testifies to the possible formation of the carbides of these elements. Points 4-9 display the content of chromium and manganese within the range of 3-6 atom %. The results of examination with X-ray spectroscopic analysis testify to the fact that AN22PK-DMS flux facilitates reducing chromium and manganese in the deposited weld metal.

Further X-ray spectroscopic analysis was focused on determining the elemental concentration within the deposited weld layer. The examination was performed along the line of the distribution of elements in the cross-section. Figures 13-15 present the examination results.

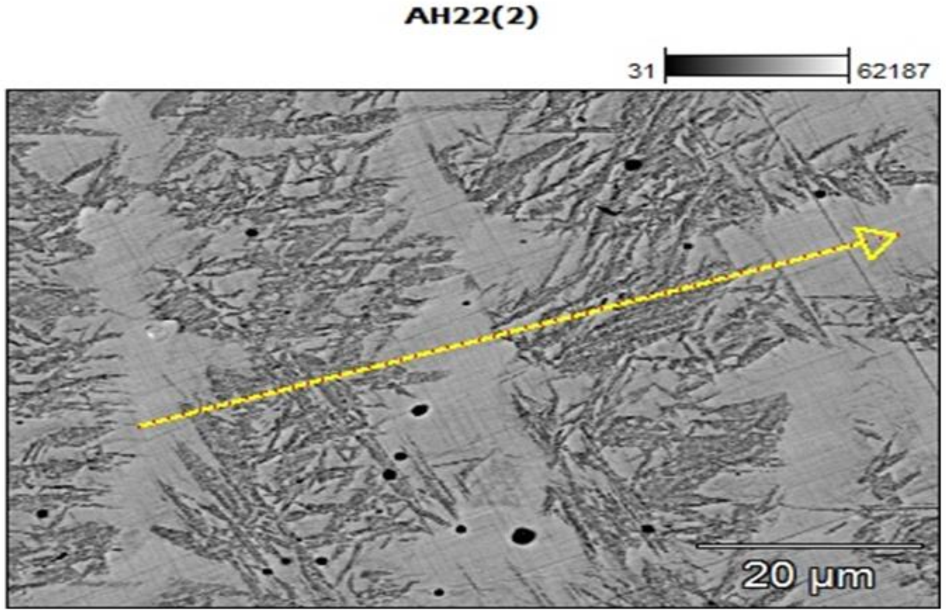


Fig. 13. Distribution of the elements along the line

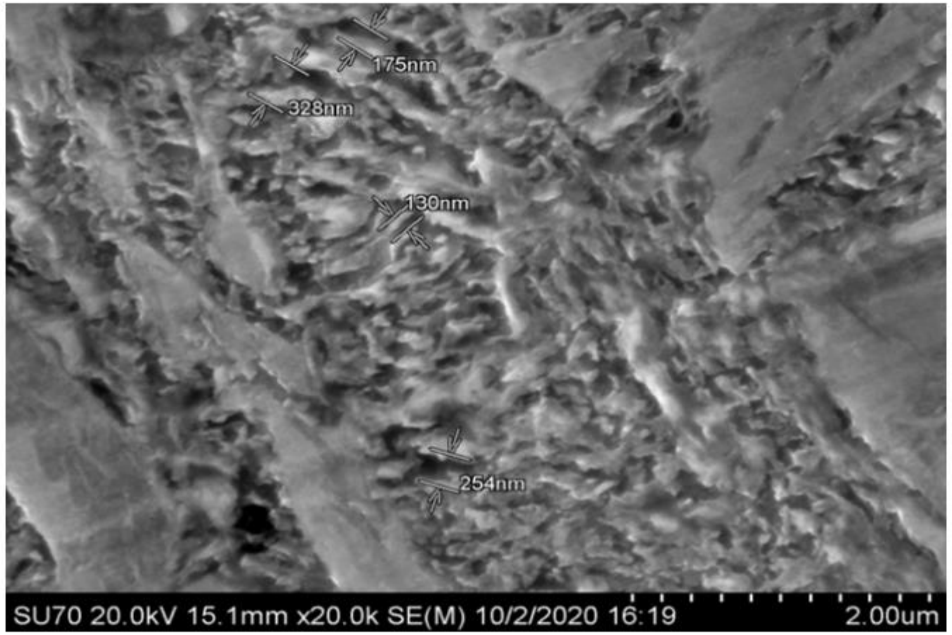


Fig. 14. Microstructure of deposited layer with the interplane distances denoted

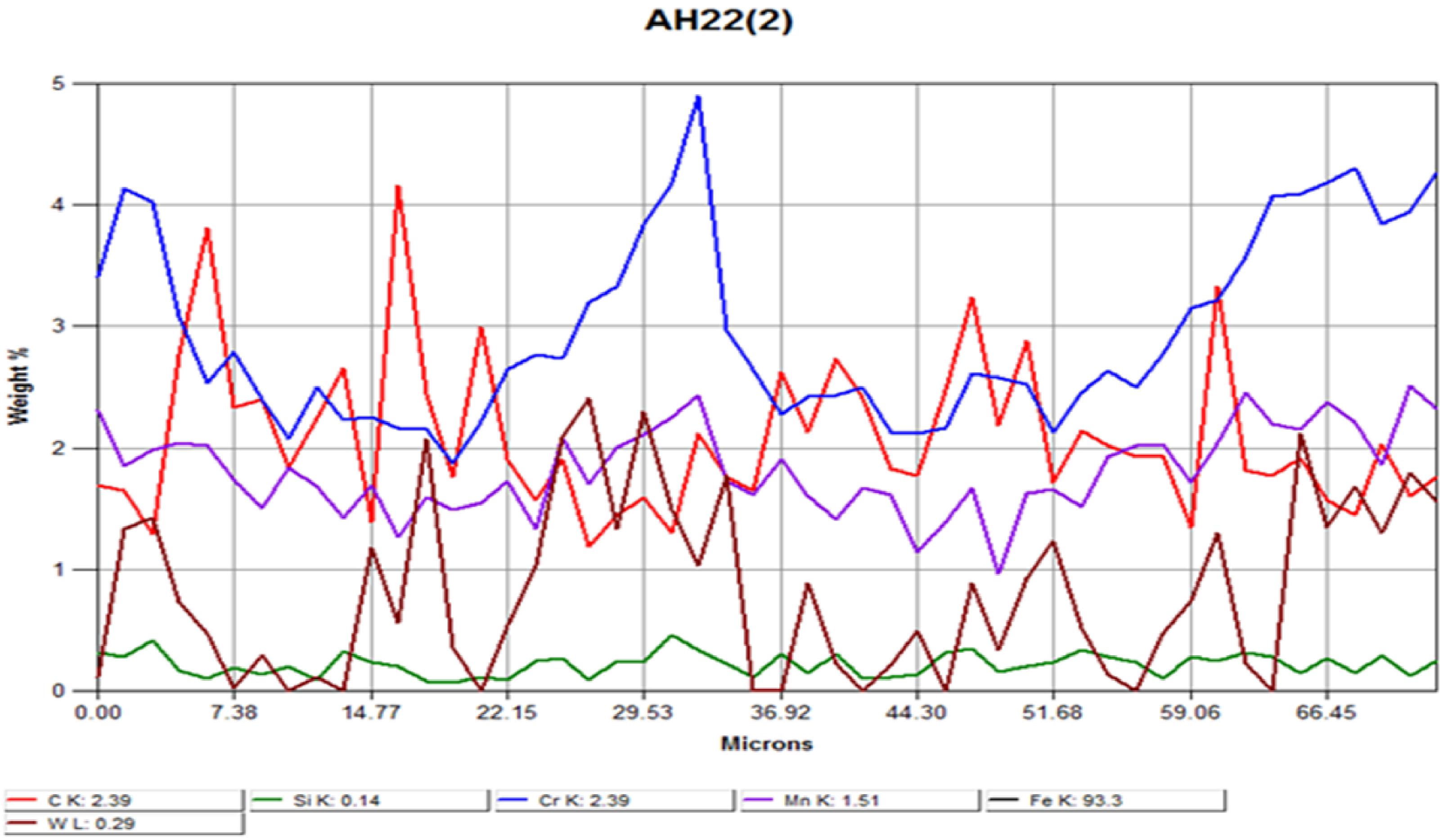


Fig. 15. Concentration of the elements along the distribution line

The research has shown that the alloying elements (Cr, Mn, and W) are distributed throughout the whole volume of the deposited weld metal. Some locations display peak contents of carbon, chromium, manganese, which testifies to the possible formation of carbides (Fig. 14).

Results of the X-ray spectroscopic analysis of the metal, deposited under AN348APK-DMS flux, are presented in Fig. 16 and Table 7.

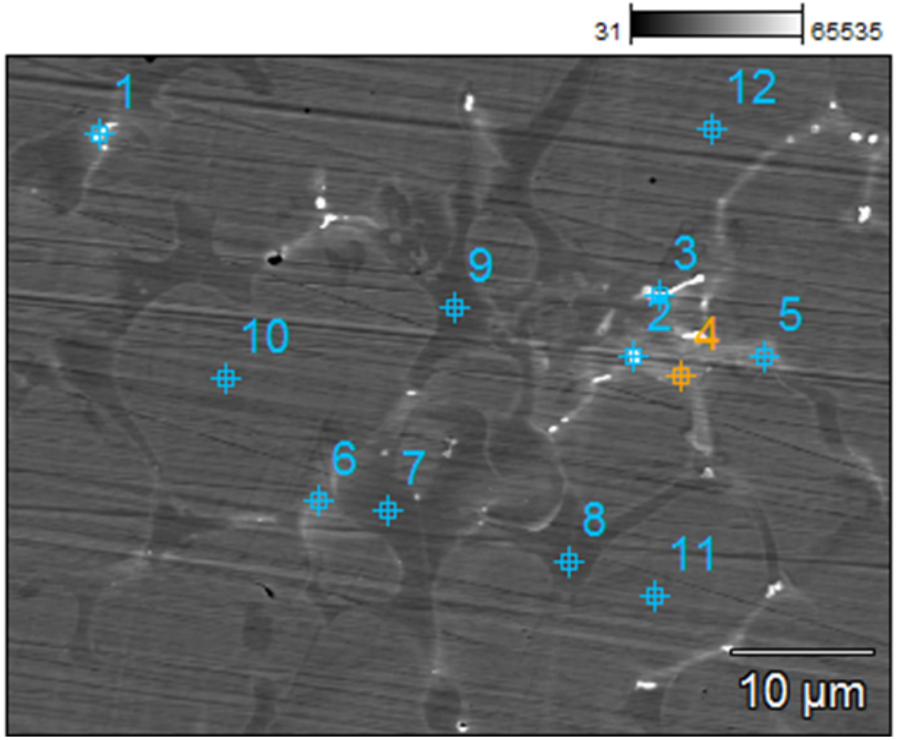


Figure16. Macrostructure of deposited layer

Table7

Elemental composition of deposited weld metal, atom %

Точка	C	W	Cr	Mn	Fe
1	12.61	10.27	8.50	4.74	63.87
2	26.71	16.30	6.38	3.49	47.11
3	20.74	21.34	7.29	3.98	46.65
4	16.10	2.50	6.69	4.97	65.03
5	9.22	1.35	3.09	3.78	81.73
6	13.87	2.30	10.99	5.87	66.43
7	17.27	1.32	15.23	5.39	60.78
8	17.58	1.15	14.69	5.34	61.24
9	17.31	1.25	15.51	5.40	60.54
10	5.70	0.36	4.24	3.15	86.55
11	5.87	0.21	4.31	3.67	85.94
12	6.15	0.35	4.09	3.44	85.97

X-ray spectroscopic microanalysis of the metal welded under theAN348APK-DMS flux shows that the maximum contents of alloying elements were reduced in the upper layer, (Fig.15 and Table 7). Thus, point 3 displays the following contents of the elements: tungsten- 21.34 atom.%, chromium - 7.29 atom. %, and manganese - 3.98 atom. %. X-ray spectroscopic micro analysis of the deposited weld layer testifies to the fact that this composition of the flux facilitates the reduction of tungsten, chromium and manganese, which testifies to the possible formation of carbides and alloyed cementite.

Further X-ray spectroscopic analysis was focused on determining the elemental concentration within the deposited weld layer. The examination was performed along the line of the distribution of elements in the cross-section. Figures17-19 present the results of examination.

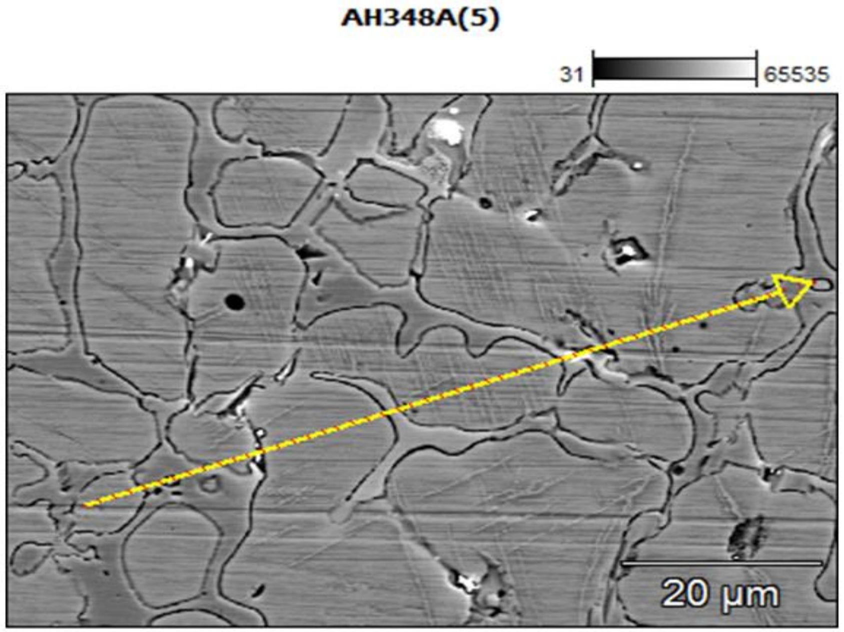


Fig. 17. Distribution of the elements along the line

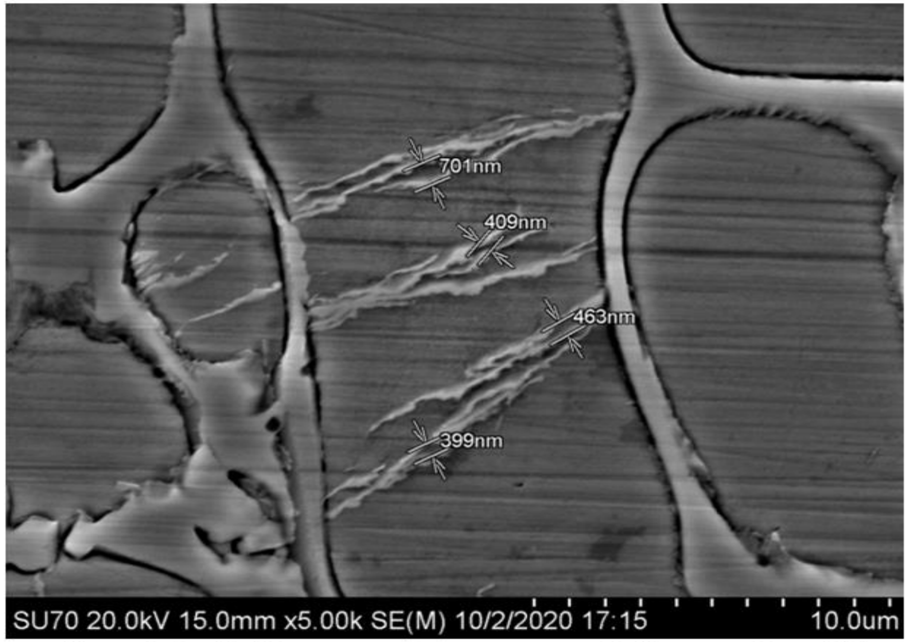


Fig. 18. Microstructure of deposited layer with the interplane distance denoted

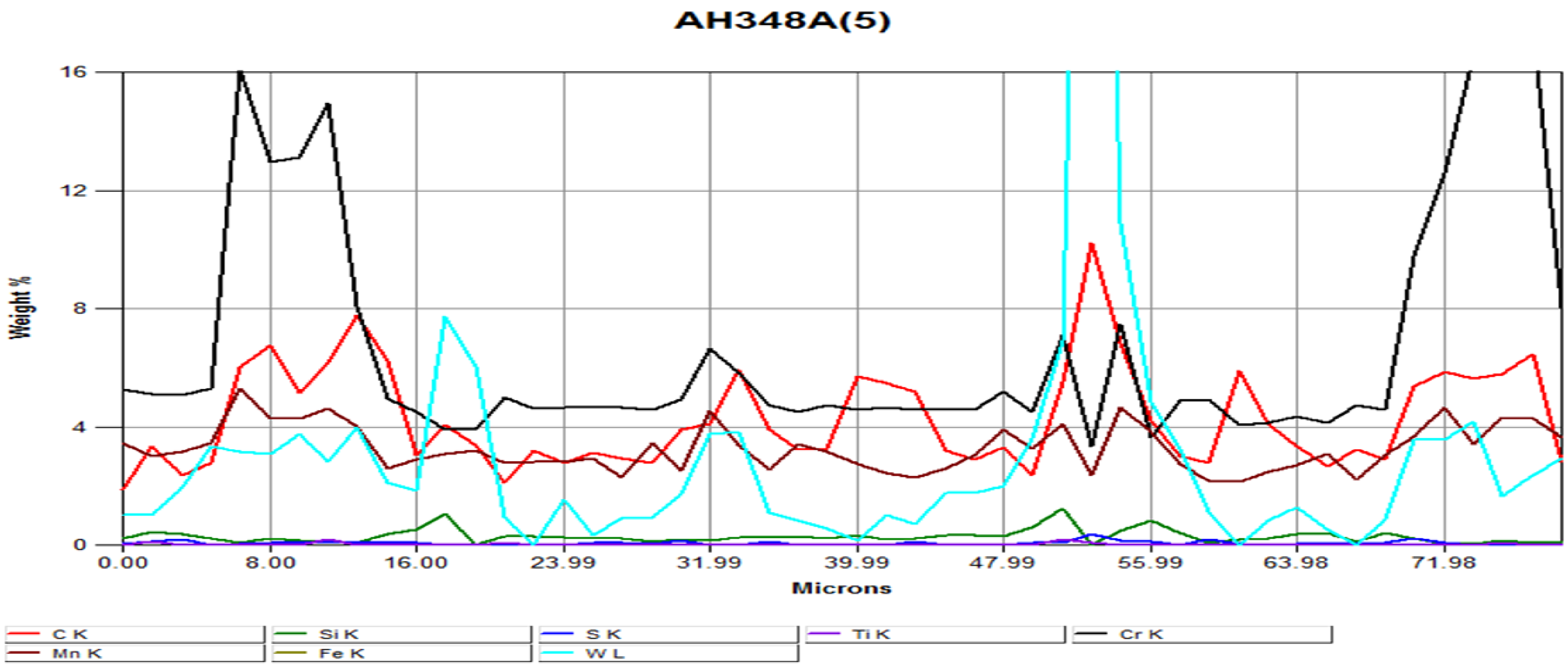


Figure 19.Concentration of the elements along the distribution line

The research shows that the alloying elements (Cr, Mn, and W) are distributed throughout the whole volume of the deposited weld metal. Some locations display peak contents of carbon, chromium, manganese and tungsten which testifies to possible formation of carbides (Fig. 19)

The research results for the phase composition of the deposited weld metal are presented in Fig. 20 and 21.

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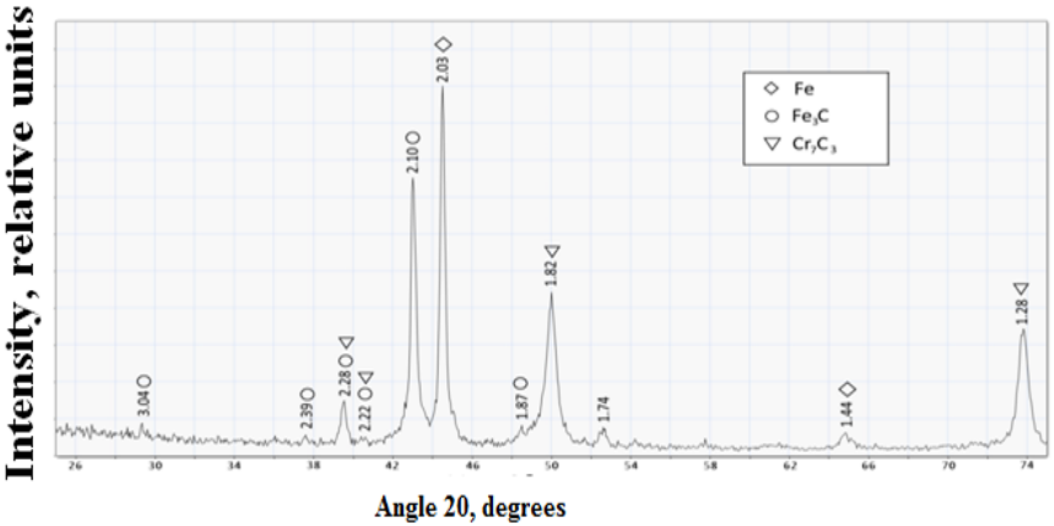

Figure20. X-ray diffraction pattern of the weld deposit layer (AN22PK-DMS)

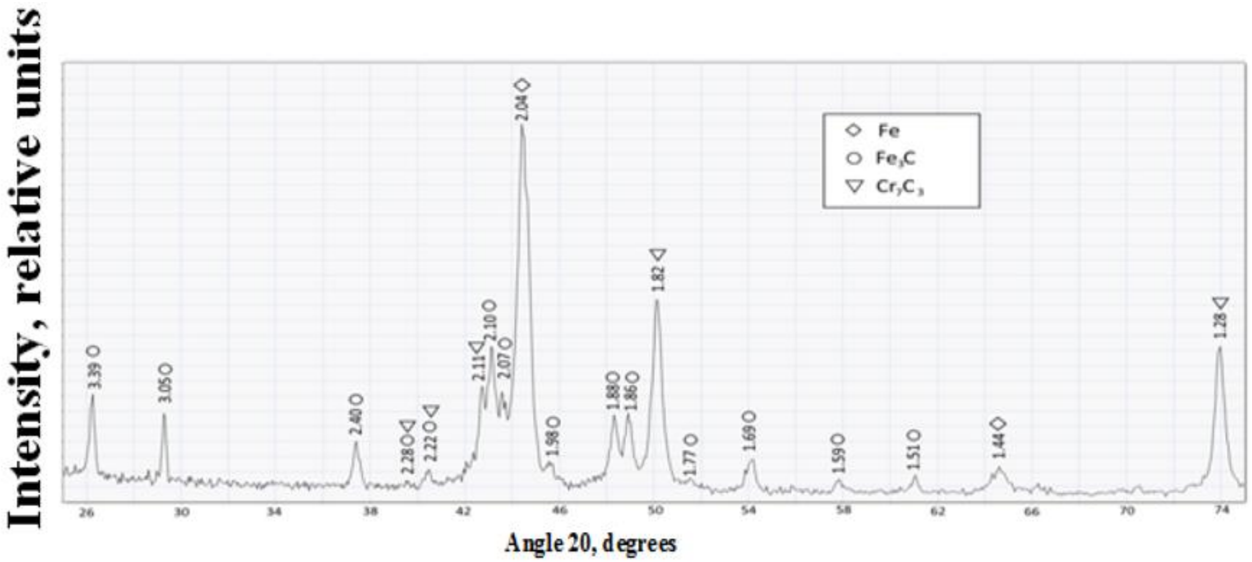

Figure 21.X-ray diffraction pattern of the weld deposit layer (AN348APK-DMS)

The results of the research confirm the possibility of formation of the carbides of chromium Cr_7C_3 and iron Fe_3C (Fig.20 and 21) in the weld deposit layer. This ensures high hardness and wear resistance of the coatings formed.

The research results for the phase composition of the deposited weld metal are presented in Fig. 20 and 21.

Conclusions

1. Analysis of the mineral resources base of the Russian Far East shows that the region possesses considerable deposits of mineral raw materials (scheelite, zirconium concentrate, titanomagnetite, braunite) good for creating fluxes and other materials. For example, braunite is a multicomponent substance containing oxides of manganese, silicon, aluminum, calcium and other elements used to produce materials (21.55-MnO; 25.45-SiO_2; 0.5- TiO_2; 5.62-Al_2O_3; 9.0_2-FeO; 15.47-$CaCO_3$; 4.34-MgO; 0.85-K_2O; 0.05-SO_3; 0.06 – P_2O_5).

2. We have developed the methodology for production of fluxes. This methodology involves preliminary calculations of the components for the slag base of the ilmenite-fluorite type; determining the basicity and the chemical reactivity of the slag; thermodynamic analysis of possible chemical reactions; and experimental research focused on determining the optimum composition of the slag components.

3. Based on the equations and diagrams developed we have chosen the optimum composition of the slag base - 40% of slag-forming substances (fluorite 27.35%, granodiorite 42.38%, marble 30.27%), 44 % of stabilizing substances (titano-magnetite 100%), and 16% of alloying substances (scheelite 62.50%, braunite 37.50%) – for high quality and required working properties of the coatings formed.

4. Based on the slag base fusion-ceramic fluxes (AN22PK-DMS, AN348APK-DMS) were developed. These fluxes ensure the required technological, mechanical and working properties of the coatings formed due to the reduction of the alloying elements and formation of carbides and other substances. Flux compositions are as follows:

– granodiorite – 5.8%, fluorite – 3.7%, marble – 4.1%, zirconium concentrate – 4.9%, ferromanganese – 19.6%, titanomagnetite – 3.7%, braunite – 1.2%, scheelite – 2.1%, graphite – 5.5%, ferrochrome – 28.9%, AN22 or AN348A – 20.6%.

5. Metallographic examination of the metal deposited under AN22PK-DMS and AN348APK-DMS fluxes established that:

–the chemical composition of the deposited layer corresponds to the hypereutectoid steel, alloyed with chromium, manganese, tungsten and other elements. Carbon content in the metal is from 1.4% to 1.7%; chromium content - from 7.992% to 9.374%; manganese content - from 4,488% до 8,326%; and tungsten content- from 0.087 to1.746;

• – the deposited metal has the hardness of 47-50 HRC, and a high wear resistance relative to steel 20 Ki 8.5-10. The impact strength value is KCU 36-39 J/cm^2, which complies with the requirements of the rolling stock operating specifications;

– base metal is of ferrite-pearlite structure. The deposited weld layer is of cellular dendritic structure which is characteristic of the intracry stalline structures of the surfaces of alloys of eutectoid type. Microstructure of the layer welded up with the AN22PK-DMS and AN348APK-DMS fluxes consists of austenite, eutectoid and carbide phases;

Research into the phase composition has confirmed the possibility of formation of carbides in the deposited weld metal: chromium carbide Cr_7C_3 andiron carbide Fe_3C when using AN22PK-DMS flux; and chromium carbide Cr7C_3 and iron carbide Fe_3C when using AN348APK-DMS flux. This ensures high hardness and wear resistance of the coatings formed.

Thank you!

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