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Developing New Powder Wire for Surfacing Details Which Works in the Wear Resistace Conditions

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Keywords: Surfacing, powder wire, wear, hardness, metallographic analysis, structure, grain, impurity.

Abstract. The paper presents the influence of chemical compositions and structure of the deposited metal on its hardness and wear resistance in abrasive-shock conditions. Metal Was deposited by the arc powder wire automatic welding. The studies have shown that increasing nikel contain to 0.65% in the surfaced steel and cobalt additive while reducing carbon contain to 0.17-0.23%, provides martensite and former austenite grain size disintegration. In consequence of multivariate correlation analysis, it was determined dependence to the hardness of the deposited layer and the wear resistance of the mass fraction of the elements included in the flux-cored wires of the system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co. Obtained dependences could be used in predicting hardness and wear resistance of the deposited metal while changing welding metal chemical composition.

Introduction

Increasing workability of details which works in abrasive-shock conditions by the arc surfacing methods is a major backup for production ramp-up and metal economy, as a result of detail life extension. During working time equipment mechanisms which challenge with abrasive and shock wear quickly lose their geometry. Contacting surface wearout brings the need for their recovery. Developing new materials that could provide high level wear resistance for such details is an important and actual task. One of the way for increasing details wear resistance is developing and manufacturing specialized surfacing powder wires [1-14]. The main question due to developing new surfacing material is to choose the depositing metal impurity system. According to this fact detail's work conditions, surfaced metal price, gathering different materials experimental and industry approbatory results, and also structure and properties of the surfaced metal must be take into account. In response to optimally impurity method selection, surfaced layers obtain high level hardness and abrasive-shock wear resistance.

Materials and Methods

Analyzing surfacing materials (Iron based alloys) C, Cr, Mn and Ni are most widespread for depositing material in our country and abroad. In associate with the following elements there are also added carbide-forming elements like W, V, Ti and Mo. For surfacing abrasive wearout items are widely spread powder wire system Fe-C-Si-Mn-Cr-Ni-Mo tipe A and B according to IIW classification [15]. Currently powder wires of such system are in general use in our country, for example: DRATEC (Germany) brand DT-SG 600 F and ESAB drand OK Tubrodur 15.52, OK Tubrodur 58 O/G M.

Research work was conducted with the use of popular for Russian metallurgical manufactures systems: Fe−C−Si−Mn−Cr− W−V и Fe−C−Si−Mn−Cr−Mo−Ni−V−Co.

Multilayer depositing of metal was conducted with preheat up to 350°C and following slow cooling after the depositing. Surfacing prosses was provided on ASAW-1250 automatic welding machine, with laboratory manufactured powder wires on a metal plates. To some number of powder wire samples was added: nickel, cobalt and tungsten. Amorphous carbon was changed on carbon contain dust with the following component chemical composition %: Al_2O_3 =21-46; F =18-27; Na_2O = 8-15; K_2O=0.4 – 6%; CaO=0.7- 2.3; SiO_2=0.5-2.5; Fe_2O_3=2.1-3.3; $C_{общ}$=12.5-30.2; MnO=0.07-0.9;

MgO=0.06-0.9; S=0.09-0.19; P=0.10-0.18. Practical size of these material afford conducting good mixing with the metal contain in the powder wire's charge. Depositing was conducted on the 09G2S metal plates in 6 layers.

Powder wires we used in researchings, was made on the laboratory machine. Powder wire's shell is covered with the steel band type St3. As a suitable wire charge components was used following powder: : iron powder brand PGV1 by GOST 9849-86, ferrosilicon powder brand FS 75 by GOST 1415-93, powder of high carboned ferrochrome brand FH900A by GOST 4757-91, powder of carboned ferromanganese FMn 78(A) by GOST 4755-91, nickel powder PNK-1L5 by GOST 9722-97, ferromolybdenum powder brand FMo 60 by GOST 4759-91, ferrovanadium powder brand FV50Y 0,6 by GOST 27130-94, cobalt powder brand PK-1Y by GOST 9721-79, tungsten powder brand PVN by TI 48-19-72-92.

Chemical composition of obtained metal samples was defined by XFS method on XRF-1800 spectrometer and LA method on DFS-71 spectrometer (table 1). Hardness measurements was conducted by Rockwell method GOST 9013-59.

Metallographic researching of obtained samples was conducted on optical microscope OLIMPUS GX-51 in the light field magnification diapason ×100 – 1000 after 4% nitric solution etching. Grain size was defined by GOST 5639-82 under ×100 magnification. Martensite dispersion was coalified by comparing obtained and etalon structures that are shown in GOST 8233-56 (table #6). Martensite needle size was defined with the use of additional program pocket for metallographic analysis Siams Photolab 700. Researching samples surfaced metal for nonmetallic inclusions presence was conducted by GOST 1778-70. Polished samples surface was studied on the LaboMet-1I microscope under ×100 magnification. To provide correctly martensite hardness measurements was used the method of defining structure contain components microhardness in accordance with GOST 9450-76 demanding. Vickers hardness measurements was made on the digital microhardness meter HVS-1000 with automatically turning head and digital data imagine. Every sample was tested 10 times by intruding diamond pyramid into the samples surface under the 1H pressure. After the tests, hardness value was defined according to obtained dent diagonals length. Samples surface wear resistance tests was defined by conducting wear tests on 2070 SMT-1 machine circuit-wise (disk-sample).

Results and Discussion

Metallographic analysis has shown that microstructure of surfaced layers by powder wires system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co is uniform, mentioned thin layers of δ-ferrite. Microstructure consist of martensite, which are forming inside the former austenite grains, and small amount retained austenite as separated islands and thin layers of δ-ferrite located on the former austenite grains borders.

It is found, that increasing nikel contain to 0.65% in the surfaced steel and cobalt additive while reducing carbon contain to 0.17-0.23%, provides martensite and former austenite grain size disintegration.

Nonmetallic inclusions contain results have shown deposited metal surface system Fe-C-Si-Mn-Cr-Ni-Mo-V-Co oxide spots pollution (table 2).

It is found, that changing of powder wire system Fe-C-Si-Mn-Cr-Ni-Mo-V alloy impurity level slightly not effect on surface nonmetallic inclusions pollution.

Most suitable bases for wear resistance alloys while recovering equipment details is martensite and austenite structure. In terms of alloys structure and proeutectoid constituent could be suitable that or another surfaced metal structure base. Combining these two bases (martensite and some amount of austenite) could provide most prosperous surfaced metal properties combination.

Table 1. Surfaced layers chemical composition

Sample №	C	Si	Mn	Cr	Mo	Ni	Al	Co	Cu	W	Ti	V	S	P
G5	0.40	0.72	0.84	5.26	0.52	0.42	0.020	0.100	0.07	0.001	0.003	0.050	0.037	0.025
G6	0.45	0.80	0.77	4.98	0.50	0.56	0.020	0.110	0.07	0.001	0.005	0.040	0.044	0.023
G7	0.27	0.78	0.77	5.50	0.48	0.61	0.020	0.080	0.10	0.001	0.001	0.040	0.042	0.019
G8	0.38	0.62	0.80	4.98	0.47	0.82	0.020	0.090	0.07	0.001	0.020	0.040	0.038	0.020
G9	0.19	0.77	0.61	4.17	0.38	0.34	0.108	0.051	0.07	0.001	0.012	0.020	0.054	0.024
G10	0.19	0.63	0.65	4.06	0.38	0.30	0.066	0.056	0.08	0.001	0.024	0.030	0.056	0.019
G11	0.20	0.59	0.61	4.12	0.38	0.30	0.031	0.121	0.06	0.001	0.007	0.020	0.049	0.019
G12	0.20	0.64	0.60	4.03	0.39	0.30	0.052	0.199	0.08	0.001	0.020	0.030	0.058	0.021
G13	0.20	0.59	0.56	0.01	0.33	0.30	0.019	0.053	0.10	7.740	0.005	-	0.072	0.017
G14	0.20	0.55	0.49	0.01	0.34	0.26	0.025	0.071	0.09	7.420	0.001	0.010	0.048	0.014
G15	0.20	0.58	0.52	0.01	0.34	0.28	0.057	0.071	0.09	7.550	0.003	0.010	0.038	0.014
G16	0.21	0.55	0.52	0.01	0.35	0.27	0.054	0.061	0.08	7.650	0.001	0.020	0.036	0.017
G131	0.26	0.78	1.49	7.10	0.39	0.32	0.082	0.001	0.07	0.001	0.010	0.020	0.033	0.009
G141	0.22	0.73	1.38	5.95	0.32	0.29	0.095	0.001	0.09	0.001	0.033	0.030	0.029	0.014
G151	0.26	0.75	1.23	6.30	0.32	0.30	0.085	0.001	0.09	0.001	0.003	0.020	0.034	0.012
G161	0.26	0.75	1.16	6.06	0.34	0.30	0.077	0.001	0.09	0.001	0.024	0.040	0.033	0.016
G17	0.13	0.56	0.91	3.94	0.25	0.26	0.020	0.003	0.08	0.030	0.001	0.006	0.033	0.170
G18	0.17	0.61	1.20	6	0.37	0.39	0.014	0.002	0.10	0.025	0.002	0.006	0.033	0.150
G19	0.17	0.54	1.19	5.90	0.37	0.38	0.009	0.002	0.01	1.640	0.002	0.002	0.033	0.150
G20	0.10	0.49	0.92	4.15	0.23	0.25	0.009	0.004	0.09	0.025	0.001	0.030	0.033	0.170
G21	0.19	0.54	1.15	6.21	0.38	0.40	0.007	0.002	0.09	0.025	0.002	0.040	0.031	0.150
G22	0.23	0.67	0.94	4.18	0.40	0.27	0.030	0.013	0.07	0.040	0.001	0.005	0.029	0.016
G23	0.28	0.61	0.93	3.57	0.39	0.27	0.020	0.020	0.07	4.660	0.001	0.003	0.032	0.015
G24	0.205	0.78	1.01	4.12	0.37	0.26	0.030	0.190	0.07	0.080	0.001	0.008	0.030	0.015

Table 2. Nonmetallic inclusions, structure, wear speed and hardness characteristics of the deposited metal

Sample №	Structure	Rating	Needle size, mcm.	Austenite grain size	HRC	Wearout speed, gram per. revolution
G5	Martensite	5	2-8;	7	49	0.0000140
G6	Martensite	5	3-8;	6, 7	52	0.0000056
G7	Martensite	5	3-8;	6	50	0.0000710
G8	Martensite	5	2-8;	6, 7	52	0.0000140
G9	Martensite	7	3-14;	6, 7	44.5	0.0000710
G10	Martensite	4-5;	3-6;	6, 7	42.5	0.0000390
G11	Martensite	7	8-12;	6, 7	42.5	0.0000440
G12	Martensite	7	3-11;	6, 7	37	0.0000730
G13	Hypopearlitic	-	-	5, 6	22.5	0.0002060
G14	Hypopearlitic	-	-	6	25.5	0.0000480
G15	Hypopearlitic	-	-	5	22	0.0000360
G16	Hypopearlitic	-	-	6	26	0.0000390
G131	Martensite	3-4;	2-6;	7	55	0.0000280
G141	Martensite	3-4;	2-6;	7	41	0.0000550
G151	Martensite	3-4;	2-6;	7	45	0.0000074
G161	Martensite	3-4;	2-6;	7	45	0.0000340
G17	Martensite	5	3-8;	6, 7	40	0.0000280
G18	Martensite	5-6;	4-9;	6	45	0.0000540
G19	Martensite	6	5-10;	6	49	0.0000430
G20	Martensite	5	4-8;	6, 7	38	0.0001420
G21	Martensite	5-6;	3-10;	6	48	0.0000550
G22	Martensite	6-7;	6-10;	6	43	0.0000330
G23	Martensite	5	4-8;	6, 7	49	0.0000650
G24	Martensite	5-6;	3-9;	6, 7	42	0.0000300

Metallographic analysis has shown, that microstructure of surfaced layers is uniform, thin layers of δ-ferrite presents. Microstructure consist of martensite, which are forming inside the former austenite grains, and small amount retained austenite as separated islands and thin layers of δ-ferrite located on the former austenite grains borders.

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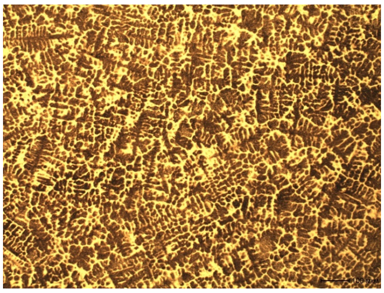
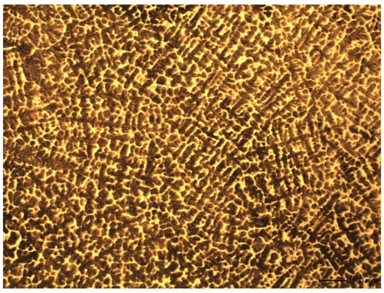
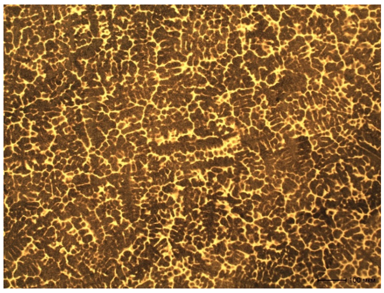
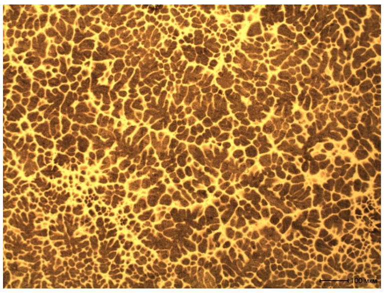
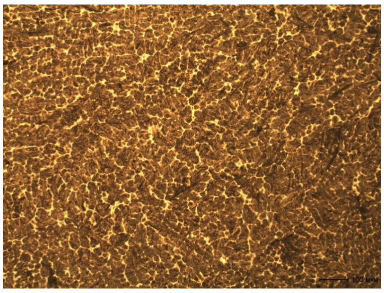
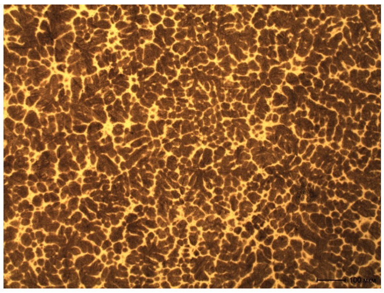
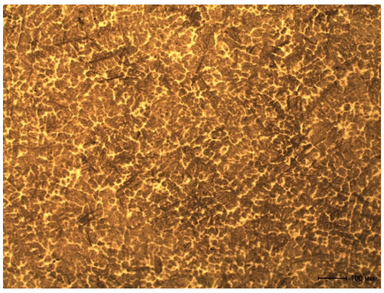
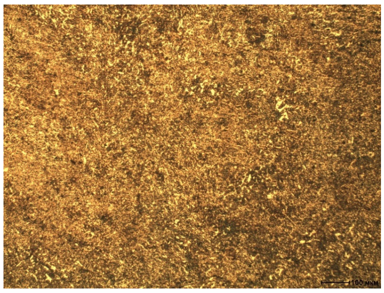




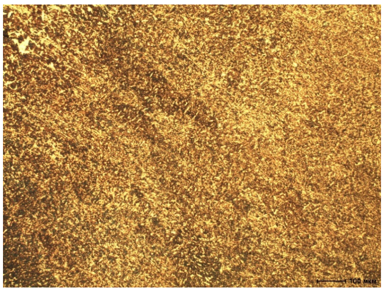
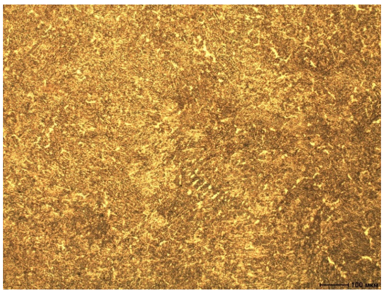
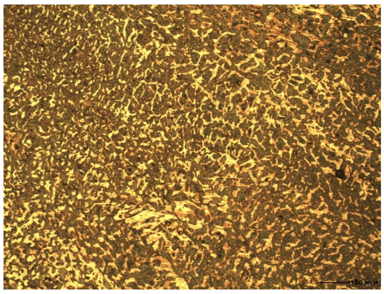
G5 G6 G7

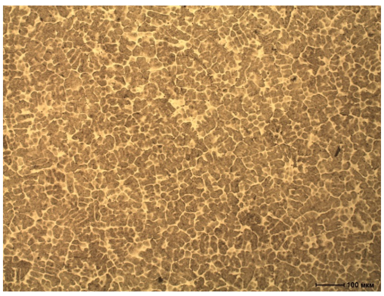
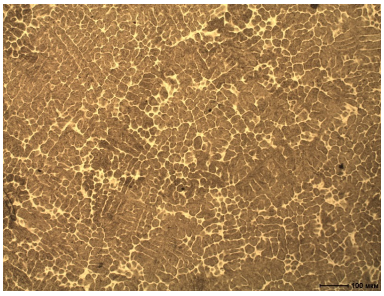
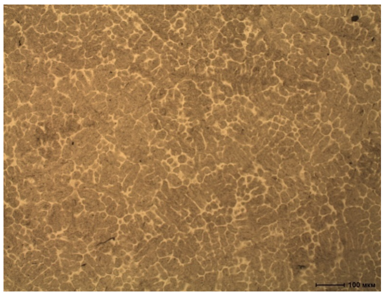
G8 G9 G10

G11 G12 G13

G14 G15 G16

G131 G141 G151

Figure 1. Microstructure of the deposited metal surface× 100

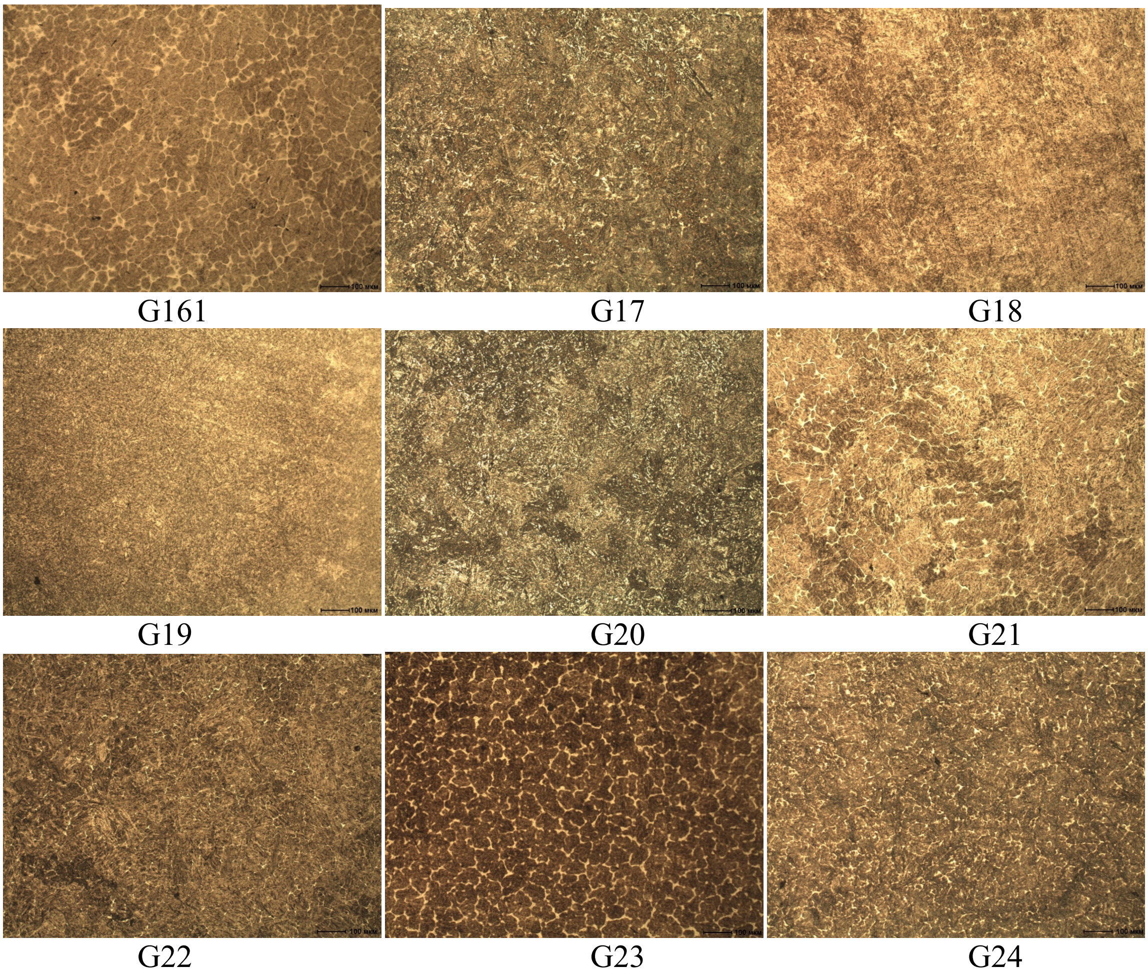


Figure 2. Microstructure of the deposited metal surface× 100

It is found, that microstructure of the samples with 0.22-0.55% carbon contain are martensite with ne needle size 6mcm (rating №4).

Reducing carbon contain while changing chromium, nickel, molybdenum and other impurity components which are in chemical compositions, provides martensite needles and former austenite grain growth.

Nonmetallic analysis has shown surface layers oxide spots and non-deformable silicates pollution (table 2).

With increase of carbon contain in alloy increases former austenite amount and also carbide amount and carbide discontinuity. With the high-level chromium contain in alloy, besides forming special carbides, hardening martensite and austenite take place. Chromium as a carbon, increase carbide discontinuity and in general provides wear resistance improving, however as an increasing metal fraility.

Adding different amount of manganese and nickel into the surfacing material afford changing retained austenite amount, that could influence on material wear resistance in different ways. Manganese and nickel are similar in that facts that they're both deliquesce in austenite, increases austenite stability and provides increasing amount of former austenite. Nickel is not a carbide forming element and basically alloys solid solution (metal base). Manganese both contain in the solid solution and partly in the carbides. Increasing manganese in surfacing materials provides deposited metal power for the grain growth while heating, that negatively causes on properties (increasing metal fraility). Alloying surfacing materials with tungsten and vanadium provides forming their carbides, that increases wear resistance. Moreover, tungsten while being in the solid solution, some way induces austenite stability.

Assessing the influence of the flux-cored wires with chemical composition system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co on wear and hardness of the deposited layers was carried out by means of multivariate

correlation analysis, which allows to study the patterns of change in the resulting index, which depends on the behavior of various factors, the procedures set forth in the works [19, 20, 21].
To conduct the analysis were determined factors, that influence on resulting index, and then were selected most essential of them (table 1, 2). After this initial check was made for the accuracy of the information, it's uniformity and conformity to the law of normal distribution. Further the model of factorial system was built. Deterministic factor analysis is used, because of presence of independent factorial signatures in the reduced system.
Per the results of calculations obtained dependencies, the adequacy of which was checked by actual values in index of the average approximation error:

$$\bar{\varepsilon} = \frac{1}{m}\sum_{i=1}^{m}\left|\frac{Y_i - \widetilde{Y}_i}{Y_i}\right| \cdot 100 \quad , \tag{1}$$

m - the number of observations; $\widetilde{Y}_i$ – calculated value of resulted index; Y_i – real value of resulted index.
Hardness and wear resistance dependencies of deposited metal from its mass fraction of the elements included in the cored wire system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co obtained in consequence of the analysis:
Surfaced metal hardness:
HRC = 2.3377 + 5.6546 * C + 7.6699 * Si – 9.1156 * Mn + 3.60734 * Cr + 11.82667 * Mo + 12.7042 * Ni – 36.6614 * Al – 34.5273 * Co – 50.5506 * Cu + 0.423266 * W – 58.9559 * V – 18.3934 * S + 40.03811 * P + 1.24721 * Rating – 0.36977 * Needle size + 3.530554*Grain size. (approximation error 2.1%);
Surfaced metal wear resistance:
Wear = 0.00031532 – 0.00006259 * C + 0.00019988 * Si + 0.00013612 * Mn – 0.00003317 * Cr – 0.00098075 * Mo – 0.00010513 * Ni 0.00064361 * Al + 0.00018912 * Co + 0.000792237 + 0.00001736 * W + 0.00220178 * V + 0.00021693 * S – 0.00086627 * P + 0.0000098398 *Rating + 0.0000133582 * HRC – 0.0001064174 * grain size. (approximation error 8.14%).
Calculated values of average approximation error argue that obtained dependencies are adequate and they can be used to define the resulted indexes.

In consequence of multivariate correlation analysis, it was determined dependence to the hardness of the deposited layer and the wear resistance of the mass fraction of the elements included in the flux-cored wires of the system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co. Obtained dependences could be used in predicting hardness and wear resistance of the deposited metal while changing welding metal chemical composition.

Conclusions

1. It is found that, by reducing carbon contained in the surfaced metal down to 0.19-0.2% while changing contain of chromium, nickel, molybdenum and other present components in its composition, promotes increasing in the size of martensite needles and former grain austenite.

2. In consequence of multivariate correlation analysis, it was determined dependence to the hardness of the deposited layer and the wear resistance of the mass fraction of the elements included in the flux-cored wires of the system Fe-C-Si-Mn-Cr-Mo-Ni-V-Co. Obtained dependences could be used in predicting hardness and wear resistance of the deposited metal while changing welding metal chemical composition.

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