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Preface

Intensive development of engineering contributes to the emergence of new materials and technologies for their processing. This special issue contains research papers on modern technologies for obtaining and processing materials, technologies for obtaining welded joints, additive technologies.

The book is intended for a wide range of specialists engaged in the development and production of heavy-duty metal structures, as well as students, undergraduates, graduate and postgraduate students of technical colleges and universities.

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Studying the Influence of Tungsten and Chromium Additives in Flux Cored Wire System Fe-C-Si-Mn-Mo-Ni-V-Co on Surfaced Metal Properties

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Keywords: flux cored wire, surfacing, microstructure, hardness, wear resistance, grain size, nonmetallic inclusios impurity.

Abstract. In the laboratory conditions were manufactured flux cored wire system Fe-C-Si-Mn-Mo-Ni-V-Co samples, studied the influence of tungsten and chromium appending in surfacing wire charge. Conducted metallographic researches of surfaced metal: microstructure evaluate, grain size, nonmetallic oxides inclusions impurity. Defined hardness and wearout speed of the deposited layers. Conducted evaluation of the chemical composition influence on surfaced metal wearout and hardness.

Introduction

Mechanisms of the mining equipment, which works in abrasive and shock wear conditions, premature brakes down and requires repairmen. That is why developing materials, that increase wear resistance of such mechanisms and details, and developing technologies of their recovering is the main objective. Most perspective for surfacing wearout details is automatic flux cored wire depositing. For these purpose, in Russia and foreign countries using, developing and manufacturing of specialized surfacing flux cored wires is in progress [1-16]. In balanced way of alloying response, deposited metal exhibit high level of hardness, abrasive and abrasive-shock wear resistance. Nowadays in Russia is widely used flux cored wire of the system Fe-C-Si-Mn-Cr-Ni-Mo DRATEC brand (Germany) type DT-SG 600 F and flux cored wires of ESAB brand types OK Tubrodur 15.52, OK Tubrodur 58 O/G M.

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This work continue later researches in developing new flux cored wires chemical compositions for surfacing details of equipment that works in mining industry abrasive wear conditions [17-18], particularly studying the influence of tungsten and chromium appending in system Fe-C-Si-Mn-Mo-Ni- V-Co on wearout and hardness level of deposited layers.

Flux cored wire manufacturing was conducted on laboratory machine. Diameter of powder wire is 5mm, wire shell is made from metal ribbon of St3 grade. As a filler were used corresponding powder materials: iron powder brand PJV 1 by GOST 9849-86, ferrosilicon powder brand FS 75 by GOST 1415-93, powder of high carbon ferrochrome brand FH900A by GOST 4757-91, powder of carbon ferromanganese FMn 78(A) by GOST 4755-91, nickel powder PNK-1L5 by GOST 9722-97, ferromolybdenum powder brand FMo60 by GOST 4759-91, tungsten powder brand PVP-1 by TI 48-19-71-78, ferrovanadium powder brand FV50U 0,6 by GOST 27130-94, cobalt powder brand PK-1U2 by GOST 9721-79, As a carbon-contained component was used carbon-fluorine contain material with the following chemical composition, wt.%: Al_2O_3 = 21-46.23; F = 18-27; Na_2O = 8-15; K_2O = 0.4-6; CaO = 0.7-2.3; Si_2O = 0.5-2.48; Fe_2O_3 = 2.1-3.27; C= 12.5-30.2; MnO = 0.07-0.9; MgO = 0.06-0.9; S = 0.09-0.19; P = 0.1-0.18.

Surfacing under the AN-26S flux was conducted in 6 layers (to prevent mixing deposited metal with plates metal) on plates of the 09G2S grade steel, with the use of automatic welding machine ASAW-1250, under following welding conditions: I_w=450 A; U_a= 30 V; V_w=10 meter per hour.

After the plates were cut on appropriate samples for tests. Chemical composition of the researched samples was defined according to GOST 10543-98 by X-ray fluorescence method on XRF-1800 spectrometer and by atomic emission spectrometer DFS-71. Chemical composition of the surfaced by flux cored wires samples is shown in table 1. Hardness of the researched samples (table 2) was measured with the use of hardness meter MET-DU. Wear resistance (table 2) tests were conducted on machine 2070 SMT – 1. Every test took 6 hours with capacity 30 mA and rotation frequency 20 revolutions per minute. Studying the microstructure of the samples was conducted on optical microscope OLYMPUS GX-51 in the light field in the limits of range ×100-1000 magnification after etching samples by nital to determine the degree of influence changes in chemical composition on parameters of the microstructure. Size of former austenite grain was determined by GOST 5639-56 with ×100 magnification. Martensite needles size was determined by GOST 8233-56 with × 1000 magnification. Studying of longitudinal deposited metal samples on nonmetallic inclusions existence was conducted in according with GOST 1778-70 with ×100 magnification.

Results and Discussion

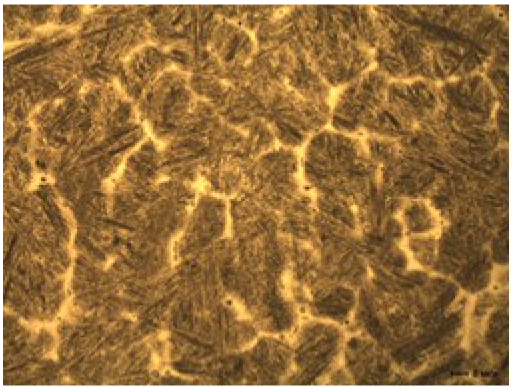
Table 1. Chemical composition of surfaced samples.

Sample number	Components weight content %													
	C	Si	Mn	Cr	Ni	Mo	V	Co	W	Al	Cu	Ti	S	P
1G9	0.19	0.77	0.61	4.17	0.34	0.38	0.02	0.05	0.002	0.01	0.07	0.02	0.054	0.024
2G10	0.19	0.63	0.65	4.06	0.3	0.38	0.03	0.06	0.001	0.01	0.08	0.03	0.056	0.019
3G11	0.2	0.59	0.61	4.12	0.3	0.38	0.02	0.12	0.001	0.02	0.06	0.04	0.049	0.019
4G12	0.2	0.64	0.6	4.03	0.3	0.39	0.03	0.2	0.002	0.01	0.08	0.03	0.058	0.021
5G13	0.2	0.59	0.56	0.01	0.3	0.33	0.01	0.05	7.74	0.01	0.1	0.02	0.072	0.017
6G14	0.2	0.55	0.49	0.01	0.26	0.34	0.01	0.07	7.42	0.02	0.09	0.02	0.048	0.014
7G15	0.2	0.58	0.52	0.01	0.28	0.34	0.01	0.07	7.55	0.05	0.09	0.03	0.038	0.014
8G16	0.21	0.55	0.52	0.01	0.27	0.35	0.02	0.06	7.65	0.05	0.08	0.02	0.036	0.017

Table 2. Hardness and wear intensity of surfaced samples.

Sample number	Hardness, HRC	Wear intensity, grams per revolution
1G9	44.5	0.000071
2G10	43	0.000039
3G11	46	0.000044
4G12	30	0.000073
5G13	22	0.000206
6G14	25	0.000048
7G15	21	0.000039
8G16	25	0.000036

a



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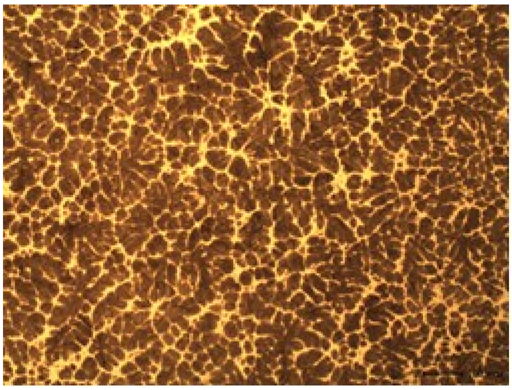

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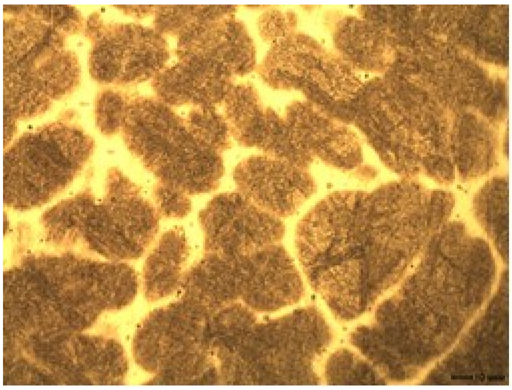

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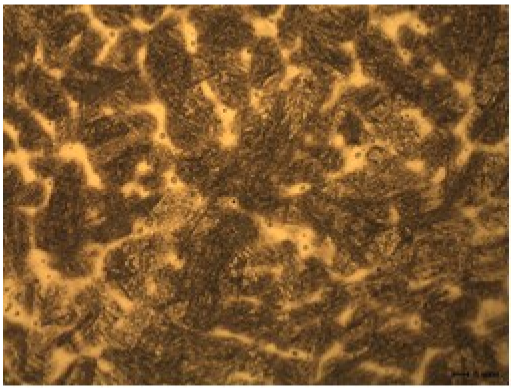

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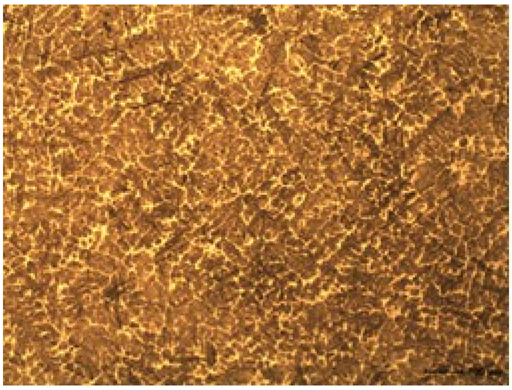

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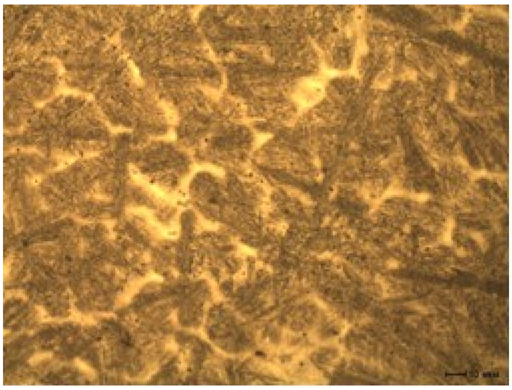

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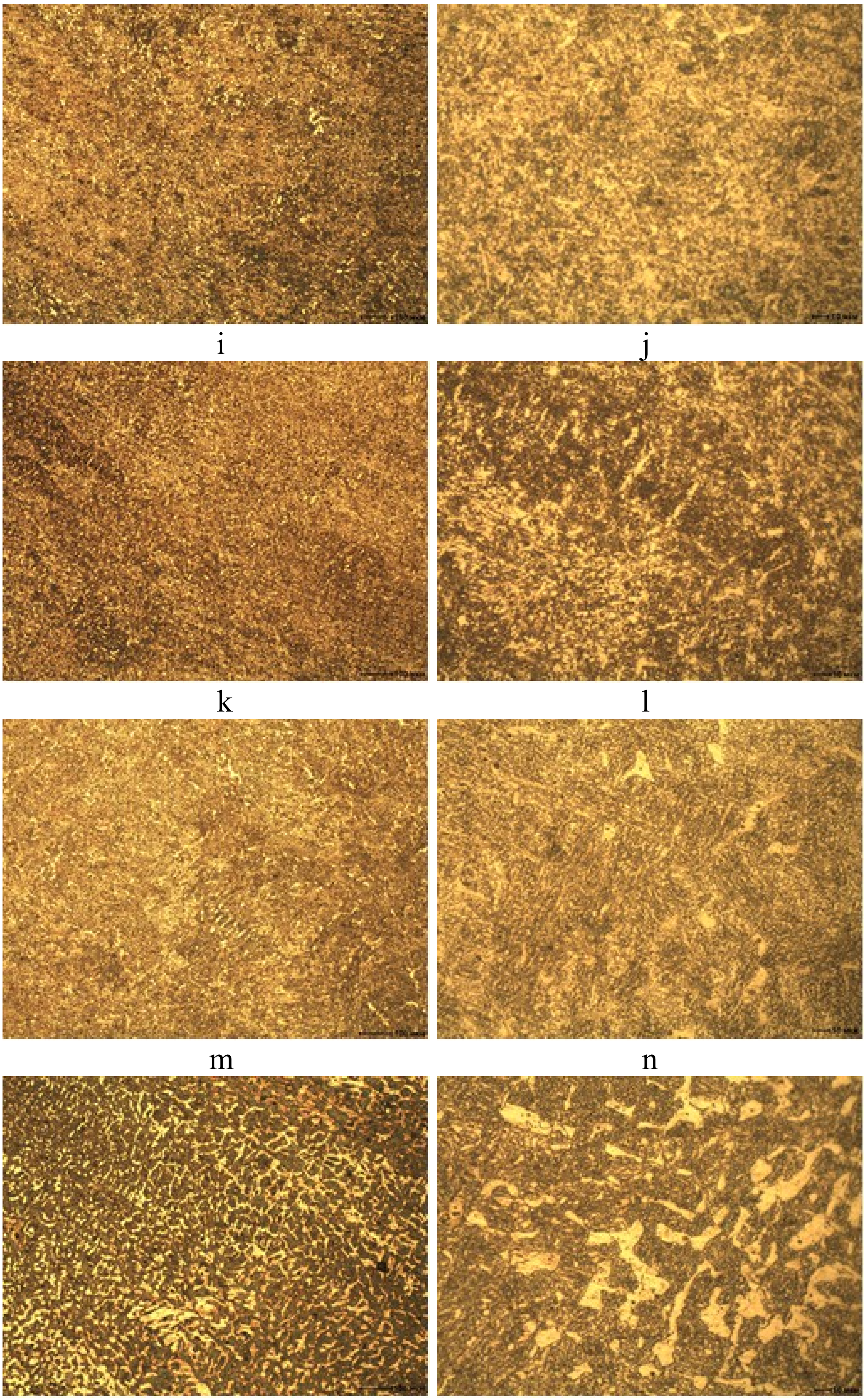

a, b - №1G9; c, d - №2G10; e, f - №3G11; g, h - №4G12; i, j - №5G13; k, l – 6G14; n, m – 7G15; o, p – 8G16.

Fig. 1. Microstructure of the researched samples, (a, c, e, g, i, k, m, o × 100), (b, d, f, h, j, l, n, p × 500).

The structure of №1G9 sample (Fig. 1 a, b) contain big-needled martensite (rating №7) in former austenite grains, in which borders is presented unlocked thin layers of something what is proposed to be comprise of δ-ferrite. Martensite needles size is in ranges of 3-14 mcm. Deposited layer could be characterized by surely dendritic structure signified. Austenite grain size conforms №6 and 7 in grain fineness scale compliance. All round the body and in borders of grains, dispersive inclusions are located.

The structure of №2G10 sample (Fig. 1 c, d) contain fine- and middle-needled martensite (rating №4, 5) in former austenite grains, in which borders is presented unlocked thin layers of something what is proposed to be comprise of δ-ferrite. Martensite needles size is in ranges of 3-6 mcm. Deposited layer could be characterized by surely dendritic structure signified. Austenite grain size conforms №6 and 7 in grain fineness scale compliance. All round the body and in borders of grains, dispersive inclusions are located.

The structure of №3G11 sample (Fig. 1 e, f) contain big-needled martensite (rating №7), which is formed inside clearly seen borders of former austenite grains. On the borders of former austenite, unlocked thin layers of something what is proposed to be comprise of δ-ferrite are located. Martensite needles size is in ranges of 8-12 mcm. Deposited layer could be characterized by surely dendritic structure signified. Austenite grain size conforms №6 and 7 in grain fineness scale compliance. All round the body and in borders of grains, dispersive inclusions are located.

The structure of №4G12 sample (Fig. 1 g, h) contain big-needled martensite (rating №7), in former austenite grains, in which borders is presented unlocked thin layers of something what is proposed to be comprise of δ-ferrite. Martensite needles size is in ranges of 3-11 mcm. Deposited layer could be characterized by surely dendritic structure signified. Austenite grain size conforms №6 and 7 in grain fineness scale compliance. All round the body and in borders of grains, dispersive inclusions are located.

The structure of №5G13 sample (Fig. 1 i, j) contain ferrite and perlite. Former austenite grain size conforms №5 and 6 in grain fineness scale compliance. All round grain body and ferrite, spot inclusions are located.

№6G14 sample (Fig. 1 k, l) have hypopearlitic structure. Former austenite grain size conforms №6 in grain fineness scale compliance. All round grain body and ferrite, spot inclusions are located.

№7G15 sample (Fig. 1 m, n) have hypopearlitic structure. Former austenite grain size conforms №5 in grain fineness scale compliance. All round grain body and ferrite, spot inclusions are located.

№8G16 sample (Fig. 1 o, p) have hypopearlitic structure. Former austenite grain size conforms №6 in grain fineness scale compliance. All round grain body and ferrite, spot inclusions are located.

Chromium and tungsten concentration influence on samples hardness is shown on Figure 2 and 3. Despite appending tungsten in 5G13-8G16 samples chemical composition, their wear resistance is predetermined by the structure of deposited metal. Wear resistance of samples 1G9-4G12 is higher because they have martensite structure, and 5G13-8G16 samples have hypopearlitic.

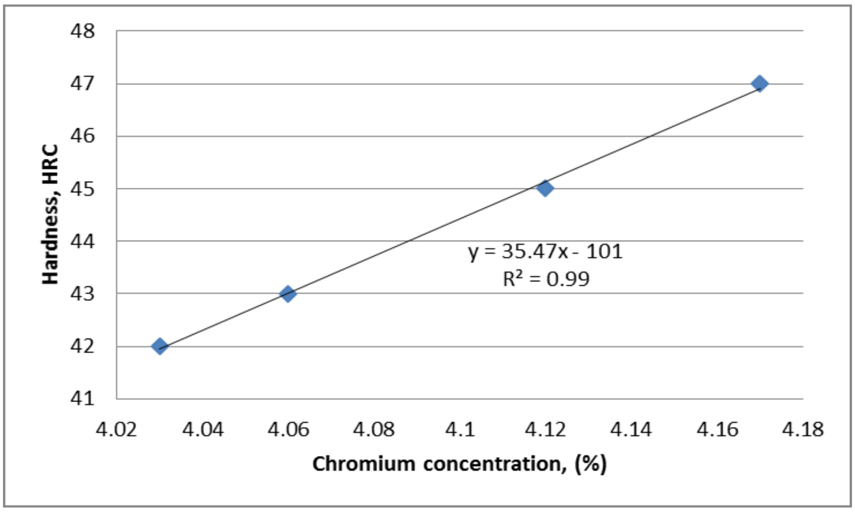

Fig. 2. 1G9-4G12 samples hardness.

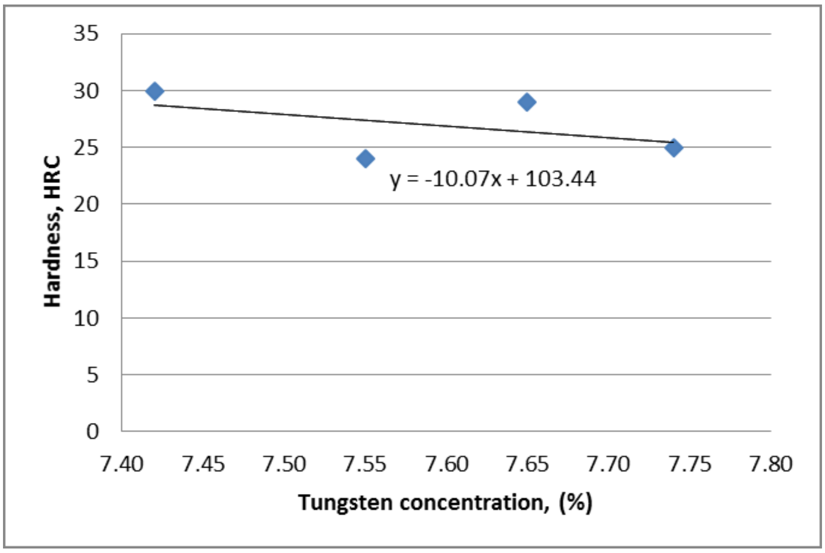

Fig. 3. 5G13-8G16 samples hardness.

According to the results of samples nonmetallic inclusions impurity research could be established the presence of nonmetallic inclusions, particularly nondeformable silicates an oxide spots (table 3).

Table 3. Nonmetallic inclusions and structure characteristics of the researched samples.

Sapmle number	The contamination of nonmetallic inclusions, rating		Size of austenite grain, rating	Size of martensite needles, mcm
	Non-deformable silicates (fragile)	Oxide spots		
1G9	1b, 2b, 3a	1a	6, 5	2-5
2G10	1b, 2b, 3a	1a, 2a	6	2-4
3G11	1b, 2b, 3a	1a	6	2-5
4G12	1b, 2b, 3a	1a	6	2-4
5G13	2b, 1b, 2a	1a	4, 5	-
6G14	2b, 1b, 2a	1a	4, 5	-
7G15	1b, 2b, 2a	1a	4	-
8G16	2b, 3b	1a	4	-

Conclusions

1. Appending chromium in the system Fe-C-Si-Mn-Mo-Ni-V-Co provides forming martensite structure in the deposited layer, with thin layers of δ-ferrite, supplies requiring hardness and wear resistance for the details which works in abrasive wear conditions.
2. Appending tungsten in the system Fe-C-Si-Mn-Mo-Ni-V-Co and almost absence of chromium in its charge, provides forming hypopearlitic structure in deposited layer with the tungsten carbide elements, while didn't supplying requiring hardness and wear resistance level.

References

[1] Kirchgaßner M, Badisch E, Franek F, Behaviour of iron-based hardfacing alloys under abrasion and impact, Wear Journal, 264 (2008) 772–779.

[2] Azzoni M, Directions and developments in the types of hard phases to be applied in abrase deposits against abrasion, Weld International, 23 (2009) 706–716.

[3] Klimpel A, Dobrzanski LA, Janicki D, Lisiecki A, Abrasion resistance of GMA metal cored wires surfaced deposits, Materials Processing Technology, 164 (2005) 1056–1061.

[4] Wang Q, Li X, Effects of Nb, V, and W on microstructure and abrasion resistance of Fe–Cr–C hardfacing alloys, Welding. 89 (2010) 133–139.

[5] Metlitskii V.A, Flux-cored wires for arc welding and surfacing of cast iron, Welding International, 22 (2008) 796-800.

[6] R. Kejžar & J. Grum, Hardfacing of Wear-Resistant Deposits by MAG Welding with a Flux-Cored Wire Having Graphite in Its Filling, Welding International, 20 (2005) 961-976.

[7] Y. V. Poletaev & A. S. Zubchenko, Structure and properties of welded joints in chromium-manganese steels, Welding International, 2 (1988) 452-455.

[8] K.C. Barker & A. Ball, Synergistic abrasive—corrosive wear of chromium containing steels / British Corrosion Journal, 24 (1989) 222-228.

[9] I. El-Mahallawi, R. Abdel-karim & A. Naguib, Evaluation of effect of chromium on wear performance of high manganese steel, Materials Science and Technology, 17 (2001) 1385-1390.

[10] S. Mizoguchi, T. Tanigaki, M. Tokura, H. Koike & H. Nishimura, Multilayer Submerged Arc Surfacing With High Chromium Iron Alloy, Surfaced Engineering, 3 (1987) 313-320.

[11] A. Molinari, G. Straffelini & P. Campestrini, Influence of microstructure on impact and wear behaviour of sintered Cr and Mo steel, Powder metallurgy, 42 (1999) 235-241.

[12] L. C. Casteletti, Rafael Nucci, Lombardi A. Neto, E. A. B. Arnoni & G. E. Totten, Hard chromium substitution using HVOF coatings, International Heat Treatment And Surface Engineering, 2 (2008) 27-31.

[13] N. A. Kozyrev, G. V. Galevsky, R. E. Kryukov, D. A. Titov, V. M. Shurupov, New materials for welding and surfacing, IOP Conf. Series: Materials Science and Engineering 150 (2016) 012031.

[14] N.A. Kozyrev, R.E. Kryukov, G.V. Galevsky, D.A. Titov, V.M. Shurupov, Development of new materials and technologies for welding and surfacing at research and production center "Welding processes and technologies", IOP Conf. Series: Materials Science and Engineering 91(2015) 012013.

[15] N. A. Kozyrev, I. V. Osetkovskiy, O. A. Kozyreva, E. A. Zernin, D. S. Kartsev, Influence of Filler Metals in Welding Wires on the Phase and Chemical Composition of Weld Metal, IOP Conference Series: Materials Science and Engineering, 125 (2016) 012027.

[16] N. A. Kozyrev, G. V. Galevskiy, D. A. Titov, D. E. Kolmogorov, D. E. Gusarov, On Quality of a Weld Bead Using Power Wire 35v9h3sf, IOP Conference Series: Materials Science and Engineering, Volume 125 (2016) 012028.

[17] A. I. Gusev, N. V. Kibko, N. A. Kozyrev, M. V. Popova, I. V. Osetkovsky, A study on the properties of the deposited metal by flux cored wires 40GMFR and 40H3G2MF, IOP Conf. Series: Materials Science and Engineering 150 (2016) 012033.

[18] Gusev A.I., Kibko N.V., Popova M.V., Kozyrev N.A., Osetkovskiy I.V, Structure and properties of deposited layers, surfaced by using powder wires 40GMFR and 40H3G2MF, Bulletin of mining-metallurgy section in Russian Academy of Natural Science. Metallurgy department: Collection of Scientific works - Vol. 36.- Novokuznetsk: Publishing. SibSIU, 2016 P. 174-181.