Materials and Processing Technology

Edited by
Dmitry A. Chinakhov

Materials and Processing Technology

Special topic volume with invited peer reviewed papers only

Edited by

Dmitry A. Chinakhov

Trans Tech Publications Ltd
Reinhardstrasse 18
8008 Zurich
Switzerland
http://www.scientific.net

Volume 906 of
Materials Science Forum
ISSN print 0255-5476
ISSN cd 1662-9760
ISSN web 1662-9752

Full text available online at *http://www.scientific.net*

***Distributed** worldwide by*

Trans Tech Publications Ltd
Reinhardstrasse 18
8008 Zurich
Switzerland

Phone: +41 (44) 922 10 22
Fax: +41 (44) 922 10 33
e-mail: sales@scientific.net

and in the Americas by

Trans Tech Publications Inc.
PO Box 699, May Street
Enfield, NH 03748
USA

Phone: +1 (603) 632-7377
Fax: +1 (603) 632-5611
e-mail: sales-usa@scientific.net

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.

Dmitry A. Chinakhov, PhD,
Vice-Chancellor, Yurga Institute of Technology
of National Research Tomsk Polytechnic University

Table of Contents

Materials Science Forum
ISSN: 1662-9760, Vol. 906, pp 1-7
doi:10.4028/www.scientific.net/MSF.906.1

Submitted: 2017-06-01
Accepted: 2017-06-06

Abrasive Wear Resistance Comparative Analysis of the Metal Surfaced by Flux Cored Wires Systems Fe-C-Si-Mn-Ni-Mo-W-V and Fe-C-Si-Mn-Cr-Ni-Mo-V

I.V. Osetkovskiy[a], N.A. Kozyrev[b], R.E. Kryukov[c]

Siberian Industrial State University,
654007, Russia, Kemerovo region, Novokuznetsk, Kirova street, 42

[a]dadlic@mail.ru, [b]Kozyrev_na@mtsp.sibsiu.ru, [c]rek_nzrmk@mail.ru

Keywords: flux cored wire, abrasive-shock wear, surfacing, recovering, wear resistance, hardness, nonmetalic incusions, structure.

Abstract. In the article is shown the comparative analysis between structures of surfaced by the flux coded wire metal systems Fe-C-Si-Mn-Cr-Ni-Mo-V and Fe-C-Si-Mn-Ni-Mo-W-V. These powder wires are supposed to be used in recovering details and equipment components and machines, that works in conditions of intensive abrasive – shock wear. Manufacturing and surfacing of flux cored wires samples were made in laboratory conditions. Defined chemical composition of the surfaced metal. Deposited metal samples hardness and wear resistance were researched. In the course of deposited meta surface metallographic analysis were made following metallographic researches: defined nature and level of nonmetallic oxides impurity, type and morphology of the microstructure, grain size of surfaced samples. Estimation of the chemical composition components influence on the hardness and wear resistance were obtained.

Introduction

Developing new materials and innovation recovering technologies, that extremely increase items wear resistance property, is the current problem in engineering. For these purpose development and manufacturing of specialized methods and materials of surfacing is in progress [1-16]. Most popular for surfacing detail which works in abrasive wear conditions is flux cored wire for surfacing of low-carbon and low-allow type, austenitic and high-manganese type C, and rapid steels type F per IIC classification [17]. Also, surfacing carbide allows type P have a widespread use, that constitute composite materials, and comprise reinforcing tungsten carbide elements and matrix. They are notable for high wear resistance in abrasive-shock wear conditions [17]. The characteristic feature in the wearout prosses for such allows is stepwise separate elements wearout of composition. In that case appears what is known as shading affect, when most wear resistance reinforcing elements took all major pressure from destructive force on itself, protecting allow matrix from wearout. Then, while matrix wear resistance is in balance its components working capacity could be defined by its chemical composition, concentration, wear resistance and durability of the reinforce elements [1]. However, matrix wear resistance could be the key factor of detail working capacity in abrasive wear conditions.

Materials and Technology

In these work is shown the hardness and wear resistance research results of the metal which is surfaced whit the use of flux coder wire systems Fe-C-Si-Mn-Cr-Ni-Mo-V and Fe-C-Si-Mn-Ni-Mo-W-V.

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 (CFCM) that was previously used in works [18-21] 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_{obsh} = 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 on samples of the 09G2S grade steel with its 16mm thickness. Prosses was conducted with the use of automatic welding machine ASAW-1250 under following welding conditions: I_w=500 A; U_a= 30 V; V_w=9 meter per hour.

Hardness of the researched samples was measured with the use of hardness meter MET-DU. Hardness measurements were performed 5 times on the surface of each sample. In table 1 is shown average value of surfaced metal hardness measurements. Wear resistance tests were conducted no the laboratory machine 2070 SMT – 1. Wear tests were conducted as per flowchart rotating disk – sample. The disk has tungsten allow hard surface. Every test took 6 hours with rotation frequency 20 revolutions per minute. Before and after wear tests the samples were weighted to define the difference between initial and final weight, and the disk revolution amount of each test was noted. The wearout intensity was calculated in terms of weight reducing in one revolution of the disk.

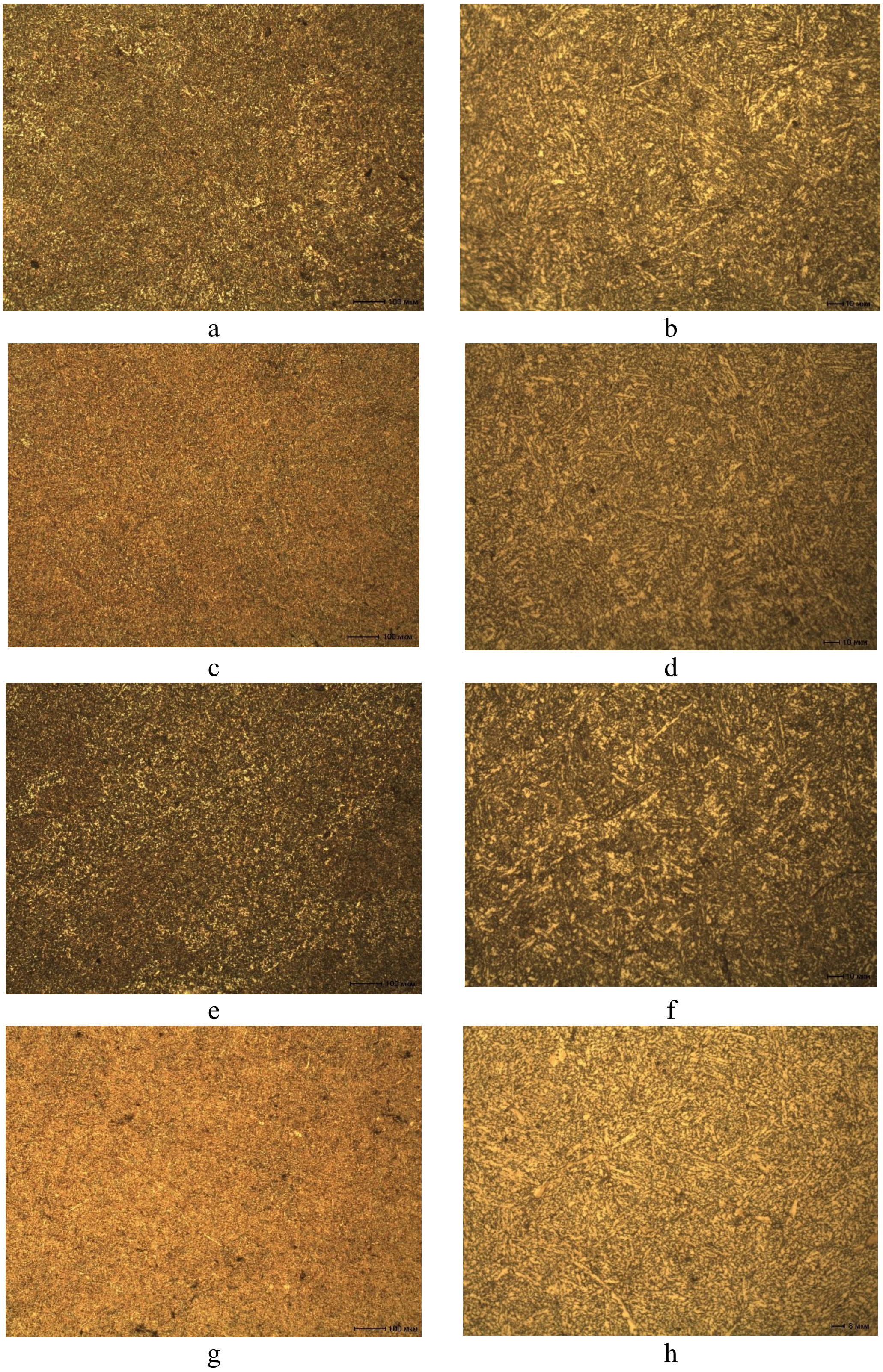
Metallographic analysis was conducted on optical microscope OLYMPUS GX-51 in the light field in the limits of range ×100-1000 magnification after etching samples by nital to determine the degree of influence changes in chemical composition on parameters of the microstructure. Studying of longitudinal deposited metal samples on nonmetallic inclusions existence was conducted in according with GOST 1778-70 with ×100 magnification. 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.

Results and Discussion

Hardness, wear intensity tests results and chemical composition analysis of the samples is shown in table 1.

Table 1 – Chemical composition, hardness, and wear intensity of the deposited metal.

Sample number	Components weight content %								Sample hardness, HRC	Sample wear intensity, grams per revolution * 10^{-4}
	C	Si	Mn	Cr	Ni	Mo	V	W		
1	0.23	0.12	0.85	1.45	0.53	0.51	0.68	0.08	25	1.65
2	0.21	0.23	0.89	1.45	0.54	0.55	0.54	0.03	21	1.15
3	0.17	0.18	0.85	1.40	0.52	0.54	0.63	0.05	21	1.11
4	0.17	0.28	0.91	1.32	0.45	0.46	0.59	0.06	21	1.12
5	0.15	0.20	0.79	0.08	0.56	0.25	0.51	3.38	17	1.15
6	0.14	0.17	0.75	0.07	0.5	0.13	0.47	2.57	16	4.08
7	0.14	0.26	0.78	0.09	0.55	0.68	0.56	2.88	16	1.70
8	0.12	0.21	0.71	0.07	0.52	0.5	0.44	2.43	15	1.79



a, b – sample №1; c, d – sample №2; e, f – sample №3; g, h – sample №4

Fig. 1 – Microstructure of the metal deposited by the flux cored wire system Fe-C-Si-Mn-Cr-Ni-Mo-V, (a, c, e, g × 100), (b, d, f, h × 500).

Metallographic analysis of the samples which were surfaced by flux cored wire system Fe-C-Si-Mn-Cr-Ni-Mo-V shown, that when carbon contain is 0.17-0.23% and chromium contain is within the limits 1.30-1.50% (samples №1-4) it provides uniform structure with fine-needled martensite (rating №3) which is formed inside the borders of the former austenite grain, retained austenite, which is presented in small amounts in the form of separate islands, and thin layers of δ-ferrite, which is located on the borders of the former grain austenite (Fig. 1). Martensite needle size in the structure of the researched samples is in ranges 2-5 mcm (table 2). Size of former austenite grain conforms №6.

Use of CFCM as a carbon contain component provided high metallurgical quality of the surfaced metal. Nonmetallic inclusions impurity of all researched samples is inconspicuous: low amount of tiny nonmetallic inclusions was established, particularly non-deformable silicates and oxide spots (table 2).

Table 2 – Nonmetallic inclusions and structure characteristics of researched samples.

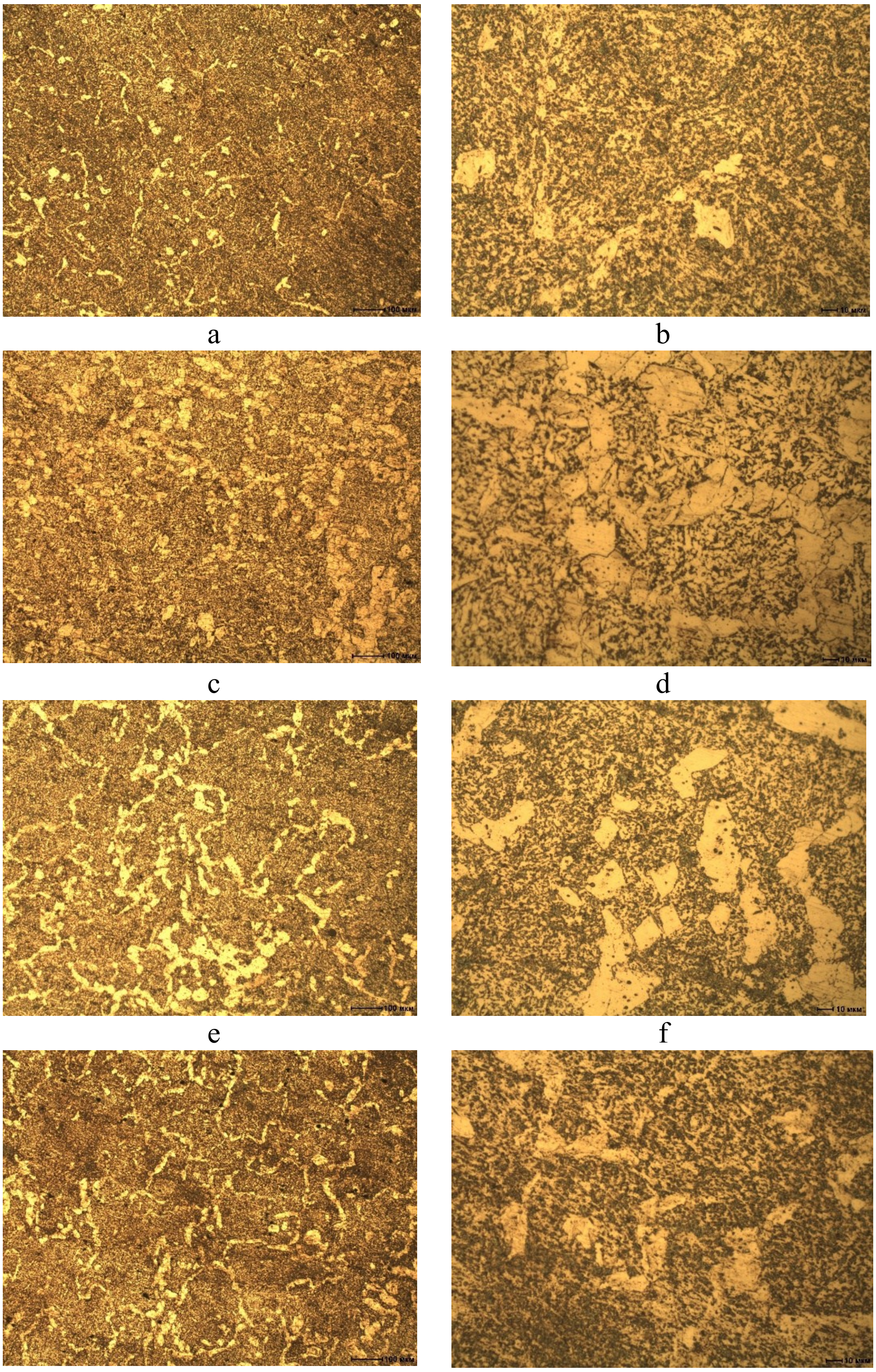
Sapmle number	The contamination of nonmetallic inclusions, rating		Size of austenite grain, rating	Size of martensite needles, mcm
	Non-deformable silicates (fragile)	Oxide spots		
1	1b, 2b, 3a	1a	6, 5	2-5
2	1b, 2b, 3a	1a, 2a	6	2-4
3	1b, 2b, 3a	1a	6	2-5
4	1b, 2b, 3a	1a	6	2-4
5	2b, 1b, 2a	1a	4, 5	-
6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

It is established, that chromium contains in the deposited layer in 1.32-1.45% amount, bars from growing austenite grain during surfacing prosses and, consequently, promotes forming fine-needled martensite structure during metal cooling, that is confirmed by better rating of hardness and wear resistance in comparison with samples which are surfaced by the wire with higher tungsten contain (table 1).

Metallographic analysis of metal surfaced by flux cored wire system Fe-C-Si-Mn-Ni-Mo-W-V shown, that appending tungsten in amount 2.43-3.38% while reducing carbon and chromium contain down to 0.12-0.15% and 0.07-0.09%, consequently produce forming hypopearlitic structure in the deposited layer (Fig. 2).

Samples №4-8 has hypopearlitic structure with former austenite grain size №4, №5. What is more, there is big amount of retained austenite in the structure, that is located on boundaries of pearlite grain colonies. Also, is noticed presence of fine black inclusions in the boundaries of pearlite grain colonies, what is characteristically for tungsten carbides. Assigned structure changes determine reducing of deposited metal hardness and wear resistance (table 2).

With that said, established, that, despite tungsten carbides presence in hypopearlitic structure of the samples, which was surfaced by low-carbon flux cored wire system Fe-C-Si-Mn-Ni-Mo-W-V, more suitable and preferable for surfacing equipment details and mechanisms, that works in abrasive wear conditions, is flux cored wire system Fe-C-Si-Mn-Cr-Ni-Mo-V. Apparently, hypopearlitic matrix could not provide enough good counterstand against abrasive wear because of lower hardness, so formed tungsten carbides could not fully provide wear resistance, because they require more hard matrix for rigid adherence. Consequently, the conclusion is that hypopearlitic structure is not preferable to incorporate it with tungsten carbides to increase wear resistance.



a b c d e f g h

a, b – sample №5; c, d – sample №6; e, f – sample №7; g, h – sample №8

Fig. 2 – Microstructure of the metal deposited by the flux cored wire system Fe-C-Si-Mn-Ni-Mo-W-V, (a, c, e, g × 100), (b, d, f, h × 500).

Conclusions

1. Established, that using lean alloyed flux cored wires of the systems Fe-C-Si-Mn-Cr-Ni-Mo-V and Fe-C-Si-Mn-Ni-Mo-W-V with the use as a carbon contain component CFCM provides forming deposited layers with low nonmetallic impurity level.

2. Using flux cored wire of the system Fe-C-Si-Mn-Cr-Ni-Mo-V for surfacing provides forming in the deposited layer uniform fine-needled martensite structure with thin layers of δ-ferrite and

former austenite, that supply enough hardness and wear resistance for miner equipment details exploitation.

3. Using flux cored wire of the system Fe-C-Si-Mn-Cr-Ni-Mo-V provides obtaining deposited layers with lower carbon and chromium contain, but higher tungsten contain, that leads forming not martensite, but hypopearlitic structure with tungsten carbides, which could not supply requiring hardness and wear resistance level.

References

[1] A.I. Belih. Wear resistance and durability of tungsten carbides WC–W_2C, obtained by different ways, Automatic welding, 12 (2010) 20-23.

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

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

[4] 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.

[5] 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.

[6] 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.

[7] Z. Rao, B. H. O'Connor, D. K. Sood & J. S. Williams, Wear behaviour of carbon implanted hard chromium coatings, Surface Engineering. 13 (1997) 61-65.

[8] D. S. Liu, R. P. Liu & Y. H. Wei. Influence of tungsten on microstructure and wear resistance of iron base hardfacing alloy / Material Science and Technology. 2014. 30. P. 316-322.

[9] 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.

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

[11] 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.

[12] 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, 125 (2016) 012028.

[13] Y F Jiang, F Z Yang, Z Q Tian & S M Zhou, Effects of iron ion contents on composition, morphology, structure and properties of chromium coatings electrodeposited from novel trivalent chromium sulphate electrolyte, Transaction Of The IMF, 12 (2012) 86-91.

[14] 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.

[15] Alejandro Basso, Sebastian Laino & Ricardo C. Dumarce, Wear Behavior of Carbidic Ductile Iron with Different Matrices and Carbide Distribution, Tribology Transactions. 56 (2013) 33-40.

[16] X. D. Du, Y. F. Wang, K. Wang & D. R.. Xu, Microstructure and wear behaviour of WC-steel composite cladding, Materials Technology. 26 (2011) 90-95.

[17] B.E. Paton, Technology of electro-fusion welding steels and alloys, M.: Metallurgy, 1974

[18] A. A. Umanskiy, N. A. Kozyrev, D. A. Titov, Experimental researches of the flux cored wire alloying system C-Si-Mn-Cr-V-Mo and C-Si-Mn-Cr-W-V composition influence, bulletin «Black metallurgy» 4 (2016) 74-78.

[19] A. A. Umanskiy, N. A. Kozyrev, D. A. Titov, Researching and developing new flux cored wire compositions for surfacing mill rolls, providing high working performance characteristics of the deposited metal, Manufacturing mill products, 5 (2016) 43-47.

[20] N. A. Kozyrev, N. V. Kibko, A. A. Umanskiy, D. A. Titov, A. G. Nikitin / Research and development new compositions of flux cored wires system C–Si–Mn–Cr–V–Mo for surfacing mill rolls, News of Higher Educational Institutes. Black metallurgy, 10 (2016) 727-733.

[21] N. A. Kozyrev, N. V. Kibko, A. A. Umanskiy, D. A. Titov, L. P. Bashenko Flux cored wire system C–Si–Mn–Cr–W–V composition improvement to increase quality and working performance characteristics of the deposited layer, News of Higher Educational Institutes. Black metallurgy, 11 (2016) 806-813.