Influence of Filler Metals in Welding Wires on the Phase and Chemical Composition of Weld Metal

N A Kozyrev[1], I V Osetkovskiy[1], O A Kozyreva[1], E A Zernin[2], D S Kartsev[2]

[1]Federal State Budgetary Educational Institution of Higher Professional Education «Siberian State Industrial University», Russia, Novokuznetsk
[2]Yurga Institute of Technology
National Research Tomsk Polytechnic University Affiliate
ul. Leningradskaya 26, Yurga, Russian Federation, 652055

Abstract: The influence of filler metals used in welding wires on the phase and chemical composition of the metal, which is surfaced to mining equipment exposed to abrasive wear, has been investigated. Under a laboratory environment, samples of Mo-V-B and Cr-Mn-Mo-V wires were made. The performed experiments have revealed that fillers of the Cr-Mn-Mo-V system used in powder wire show better wear resistance of the weld metal than that of the Mn-Mo-V-B system; the absence of boron, which promotes grain refinement in the Mn- Mo-V-B system, significantly reduces wear resistance; the Mn- Mo-V- B weld metal has a finer structure than the Cr-Mn-Mo-V weld metal.

1. Introduction

Reconditioning of hoppers and chutes, used in coal transportation, can provide longer operational life and increase a service life of mining machinery. Most loaded chutes are hard surfaced using welding cored wires of 40H3G2MF and 40GMFR types with a higher content of expensive tungsten and the wire discussed in [1-6]. Operating the reconditioned hoppers and chutes shows that the wear of their surfaces is uneven. Chutes during their operation are often exposed to cyclic thermomechanical stresses, corrosion, and abrasive wear. Wear often occurs as stripes that are caused by the presence of weld metal portions having different structures and hardness. The causes of wear that occurs in gutters surfaced using powder wires 40H3G2MF and 40GMFR have been analyzed to indicate that potential of Mo-V-B and Cr-Mn-Mo-V alloys has not been fully realized and is currently under active study. Therefore, it is of interest to study the influence of changes in a chemical composition of expensive components in the system as well the addition of the various components with the purpose of obtaining new properties of weld metal and reducing the cost of cored wire.

2. Research

The work is aimed at studying the possible use of Mn- Mo-V-B and Cr-Mn-Mo-V alloy systems to hard surface hoppers and chutes designed for coal transportation. Under laboratory conditions, standard samples of flux-cored wire with a 3.6 mm wire in diameter were prepared. The wire was coated with a strip St3, and appropriate powdered materials were used as a filler, wherein amorphous carbon was replaced with carbon-fluorine containing dust, formed after purifying waste gases of aluminum production, with a chemical composition, by weight %: Al_2O_3 = 21-46.23; F = 18-27; Na_2O = 8-15; K_2O = 0.4 – 6; CaO = 0.7-2.3; SiO_2 = 0.5-2.48; Fe_2O_3 = 2.1-3.27; Ctotal = 12.5-30.2; MnO = 0.07-0.9; MgO = 0.06-0.9; S = 0.09-0.19; P = 0.1-0.18. The smallest amount of carbon was added to the wire. Previous studies have proved a positive effect of this material to improve the quality of welds [7-8].

Welds were deposited using the AN-26C flux on a plate made of steel St3. X-ray fluorescence spectrometry using a XRF-1800 spectrometer and atomic emission spectrometry using a DFS-71 spectrometer were conducted to determine a chemical composition of the welded layer. The chemical composition of wire samples and similar steels 40H3G2MF and 40GMFR are shown in Tables 1 and 2. An ASAW-1250 welding machine was used for welding with the following characteristics: I = 390-410 A, U = 226-28 B, V = 20cm/min for all samples.

Table 1 - Chemical composition of Cr-Mn-Mo-V wire metal

Types of Wire	C	Mn	Si	Cr	Ni	V	Mo
40H3G2MF	0.35-0.45	1.3-1.8	0.4-0.7	3.3-3.8	< 0.4	0.1-0.2	0.3-0.5
21	0.06	0.48	0.3	1.98	0.15	0.06	0.3
21.1	0.19	0.52	0.74	2.79	0.17	0.14	0.26
71	0.14	0.5	0.57	3.49	0.11	0.05	0.33
72	0.07	0.54	0.57	2.63	0.24	0.08	0.4

Table 2 - Chemical composition of Mn- Mo-V-B wire metal

Types of Wire	C	Mn	Si	Cr	V	Mo	B
40GMFR	0.36-0.44	0.9-1.2	0.17-0.37	0.2-0.5	0.06-0.1	0.08-0.16	0.001-0.003
22	0.06	0.43	0.26	0.36	0.01	0.07	0.003
22.1	0.16	0.32	0.62	0.25	0.19	0.11	0.003
73	0.06	0.4	0.49	0.39	0.04	0.13	-
74	0.04	0.43	0.49	0.3	0.04	0.11	0.002

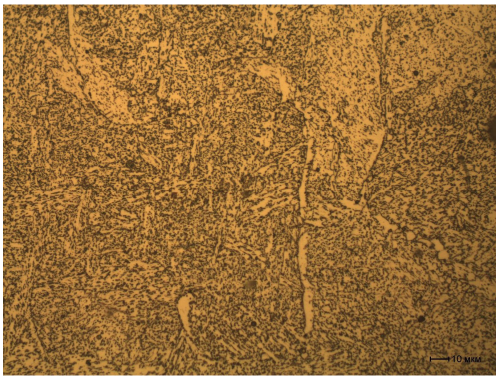
Note: Boron is not added to sample No.73

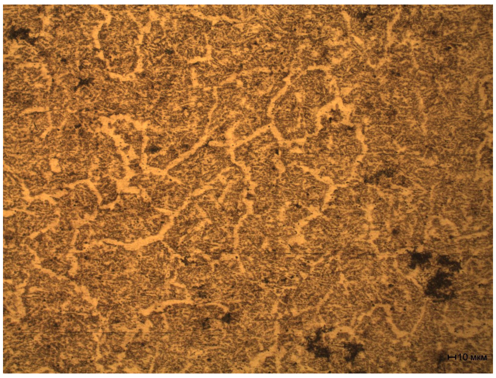
Metallographic studies are performed on polished surfaces using an optical microscope OLYMPUS GX-51 in bright field at various magnifications × 100 - 1000 after etching with a solution of alcohol and nitric acid. Longitudinal specimens of the welded layer were analyzed at 100X magnification using a standard technique relating to the presence of non-metallic inclusions. The grain size was evaluated according to the standard test method at 100X magnification. Test specimen No.21 has a ferrite-perlite structure tending to the Widmannstaetten type (Figure 1a). The examined test specimen showed the following non-metallic inclusions: non-deformable silicates (grain size number 2b) and spots of oxides (number 2a) (Figure 2a). The grain size corresponds to numbers 3 and 4 according to the comparison grain size rating chart.

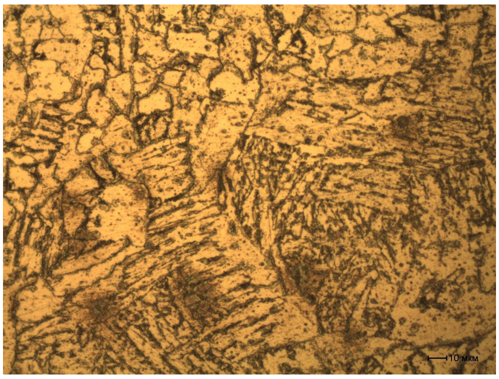
Table 3 – Wear resistance test results

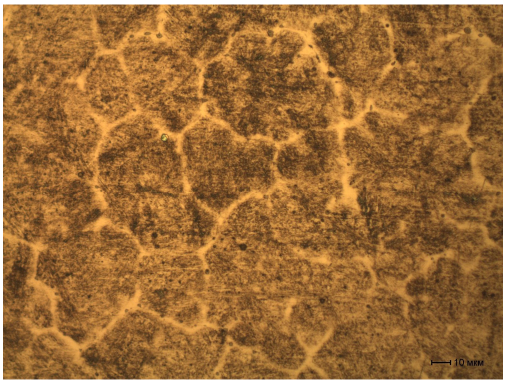
Number of test specimen	Mass of test specimen before testing, g	Mass of test specimen after testing, g	Loss in mass, (g/ %)	Number of revolutions	Wear rate, g/rev
21	197.059	194.386	2.673/ 1.36	5843	0.00046
21.1	132.768	132.573	0.195/ 0.26	6214	0.00003
71	168.509	168.222	0.287/ 0.17	7685	0.000037
72	134.85	133.548	1.302/ 0.97	7965	0.00016
22	185.317	183.220	2.092/ 1.13	6304	0.00033
22.1	130.281	129.398	0.883/ 1.15	5760	0.00015
73	145.977	143.8537	2.123/ 1.45	7112	0.0003
74	133.4405	131.4593	1.981/ 1.48	7370	0.00027

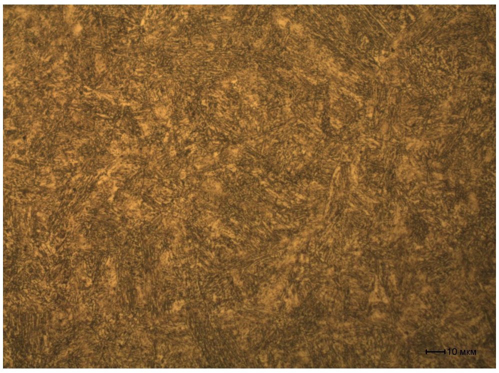
Note: 21, 21.1, 71, 72 – the test specimens where 40H3G2MF wire was used; 22, 22.1, 73, 74 – the test specimens where 40GMFR wire was used. Test specimens Nos. 21.1 and 71 show the best results in terms of wear resistance.


a

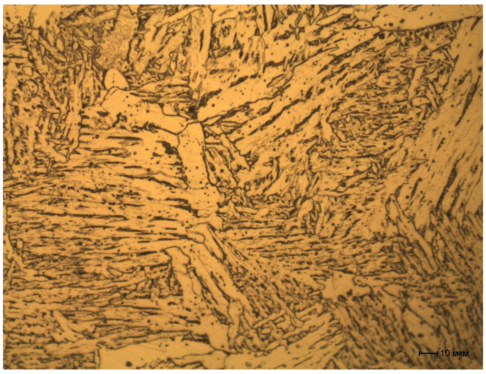

b


c

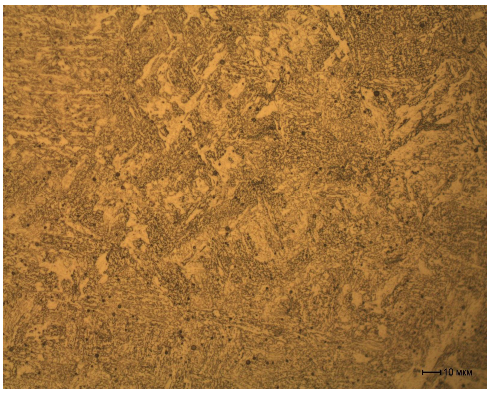

d



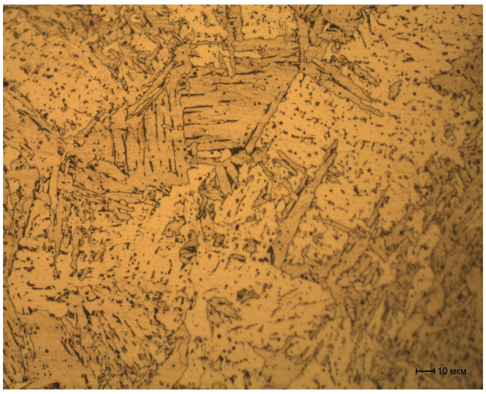
e



f



g

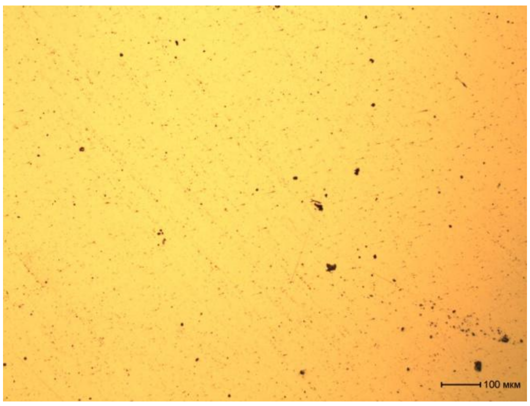


h

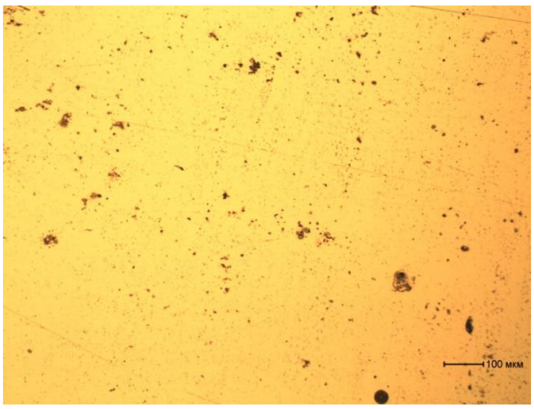
a – test specimen No.21; b – test specimen No.21.1; c – test specimen No.22; d – test specimen No.22.1;
e – test specimen No.71; f – test specimen No.72; g – test specimen No.73; h – test specimen No.74

Figure 1. Weld metal microstructure, × 500

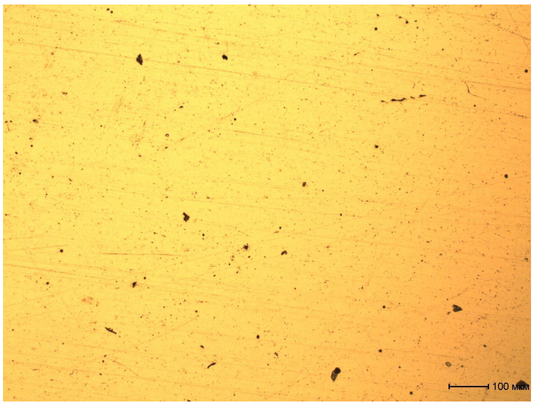
The structure of test specimen No. 21.1 comprises ferrite and pearlite; and ferrite is identified not in the form of a separate structural constituent but a grid (Figure 1b). In this case, there is a high level of content of nonmetallic inclusions. Non-deformable silicates (number 5b and 4b) and spots of oxides (number 2a and 3a) are present as well (Figure 2b). The grain size corresponds to numbers 5 and 4.



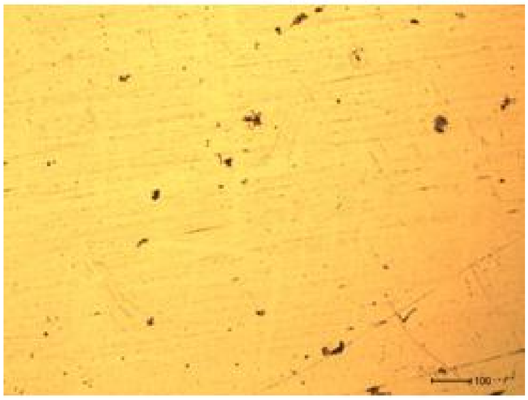
a



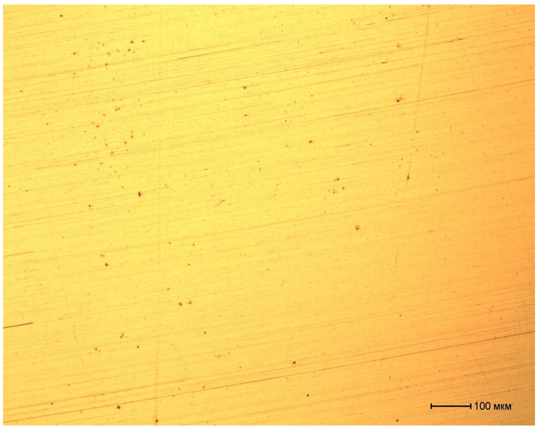
b



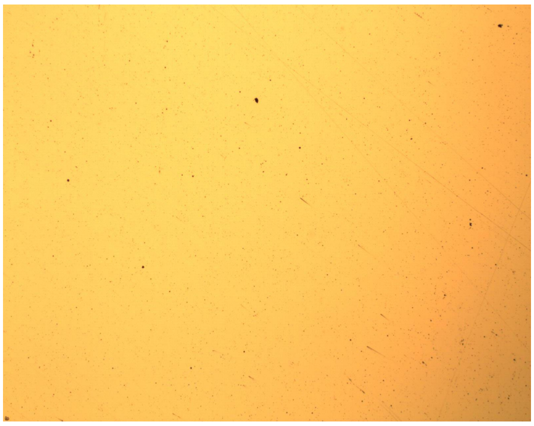
c



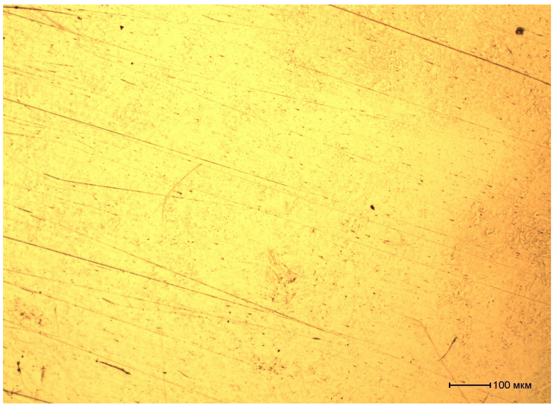
d



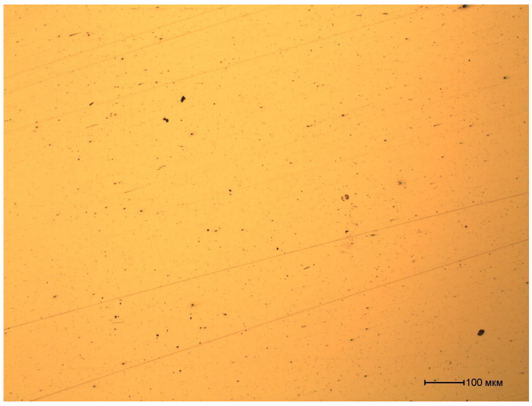
e



f



g



h

a – test specimen No.21, b – test specimen No.21.1, c – test specimen No.22, d – test specimen No.22.1, e – test specimen No.71, f – test specimen No.72, g – test specimen No.73, h – test specimen No.74

Figure 2. Nonmetallic inclusions in the test specimens

Test specimen No.22 has a ferrite-pearlite structure of the Widmannstaetten type (Figure 1c). This test specimen shows non-deformable silicates (number 2b), spots of oxides (number 1a and 2a) (Figure 2c). The grain size corresponds to numbers 4 and 5 according to the comparison chart used to rate grain sizes.

Test specimen No 22.1 is of a ferrite and pearlite structure, but the ferrite constituent is observed in the grid-like form (Figure 1d). The content of nonmetallic inclusions is higher when compared to the previous specimen: non-deformable silicates (number 3b and 5b), spots of oxides (point 1a) (Figure 2d). The grain size corresponds to number 5 and 6. Thus, 40GMFR steel has a finer grain.

The structure in test specimen No. 71 contains medium acicular martensite (number 5) (Figure 1d) and a little residual austenite. This test specimen shows non-deformable silicates (number2a and 2b) and spots of oxides (number 1a and 2a) (Figure 2e). The grain sizes are 6 and 7 according to the comparison grain size chart.

Test specimen No. 72 has a ferrite-pearlite structure of the Widmannstaetten type orientation (Figure 1f), containing the following non-metallic inclusions: non-deformable silicates (number 2b) and spots of oxides (number 1a) (Figure 2f). The grain size corresponds to numbers 4 and 5.

Test specimen No.73 is of a ferrite-pearlite structure (the Widmannstaetten type) (Figure 1 g) with the non-metallic elements including non-deformable silicates (number 1b and 4b) and spots of oxides (number 1a) (Figure 2g). The grain size corresponds to numbers 5 and 4.

Test specimen No. 74 has a ferrite-pearlite structure tending to the Widmannstaetten type (Figure 1h). This specimen shows a significant amount of non-metallic inclusions: non-deformable silicates (number 2b) and oxides (number 1a) (Figure 2h). The grain size corresponds to numbers 6 and 5 according to the comparison grain size chart.

Conclusions

1. The powder wire of the Cr-Mn-Mo-V system shows higher wear resistance than the powder wire of the Mn- Mo-V-B system.
2. The weld metal of the Mn- Mo-V-B system and 40GMFR steel has a finer grain structure than the weld metal of the Cr-Mn-Mo-V system and 40H3G2MF steel.

1 – This work has been done at Siberian State Industrial University in the framework of government contract No. 11.1531/2014/k with the Ministry of Education and Science RF. The equipment of the Common Use Centre "Material Science" at SibSIU was used in tests, researches and measurement.

References

[1] Lukashov A S, Zernin E A, Kuznetsov M. A. Application of inorganic nanopowders in welding, surfacing and spraying (review) // Applied Mechanics and Materials. - 2015 - Vol. 770. - pp. 299-303
[2] Kuznetsov M A, Kolmogorov D E, Zernin E A Upravlenie strukturoj i svojstvami metallov metodom modificirovanija (obzor) [Controlling a structure and behavior of metals by the process of modification (Summary)] // Journal "Tekhnologiya Mashinostroeniya". - 2012 – No.2 - pp. 5-8
[3] Malushin N N, Valuev D V Measuring stress condition in hard faced work rolls for cold rolling // Applied Mechanics and Materials. - 2013 - Vol. 379. - pp. 71-76
[4] New carbon-fluorine additives for welding fluxes/ N.A. Kozyrev, N.E. Krukov, R. Ev. Krukov, A.V. Roor, L.P. Bashchenko, U.I. Lipatova/ Steel in Translation.-2015. -T. 45. –No. 4. - pp. 251-253.
[5] Kuznetsov M A, Kolmogorov D E, Zernin E A, Lukashov A S Sposoby modificirovanija metalla nanostrukturirovannymi poroshkami dlja uvelichenija dolgovechnosti i jekspluatacionnoj nadezhnosti detalej gornoshahtnogo oborudovanija [Methods of modifying nanostructured metal powders to increase durability and operational reliability of mining equipment]// Journal "Gornoe mashinostroenie". – 2012 – No. OVZ - 552 p., pp. 306 – 309.
[6] Reinhard Rosert, M V Karasev POROShKOVYE PROVOLOKI - TENDENCII, RAZVITIE I IH PRIMENENIE V PROMYShLENNOSTI [Powder wires – tendencies, development, their application in industries] // Int. Sc. Tech. Conf. - St. Petersburg: SPbSPU Publ. 2012. pp. 220-230.

[7] N A Kozyrev, G V Galevsky, D V Valuev, V M Shurupov, O E Kozyreva 2015 IOP Conference Series: Materials Science and Engineering Surfacing with tungsten-containing ores 91 doi:10.1088/1757-899X/91/1/01/012009.
[8] N A Kozyrev, R E Kryukov, G V Galevsky, D A Titov, V M Shurupov 2015 IOP Conference Series: Materials Science and Engineering Development of new materials and technologies for welding and surfacing at research and production center “Welding processes and technologies” 91 doi:10.1088/1757-899X/91/1/01/012013.