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RESEARCH OF ULTRA-DISPERSED OPAL-QUARTZ-CARBONATE BENTONITE CLAY FOR COATING WELDING ELECTRODES UONI-13/55

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Preliminary Note – Prethodno priopćenje

New single-layer and double-layer coatings of UONI-13/55 welding electrodes for welding low-carbon and low-alloy steels have been proposed. The coatings were applied with superfine ultradispersed opal-quartz-carbonate bentonite clay of the Taganskoye deposit of the East Kazakhstan region. Studies have confirmed that the use of new coatings can improve the welding and technological properties of electrodes and increase the strength and ductile characteristics, as well as the cold resistance of the deposited metal.

Keywords: welding electrode, coating, opal-quartz-carbonate bentonite clay, weld metal, mechanical properties

INTRODUCTION

Low-hydrogen electrodes with the basic type of coating UONI-13/55 are used for the production of critical and especially critical metal structures from low-carbon and low-alloy steels. The main disadvantages of the UONI-13/55 electrodes are: poor ionization of the arc gap, unstable arc burning, poor separability of the slag crust, increased spattering of the electrode metal, a tendency to form porosity during arc elongation, instability of the mechanical properties of the weld metal, mainly impact toughness at low temperatures [1, 2]. The cold brittleness threshold of the metal of welds made with these electrodes is from –30 to –40 ° C. Unstable burning of the welding arc during melting of electrodes with a basic coating is explained by the presence of fluorine ions in the arc gap, which are arc deionizers [3, 4]. However, calcium fluoride also has significant positive properties. It binds free hydrogen and water vapor into thermally stable hydrogen fluoride, and thus ensures the minimum hydrogen content in the deposited metal in welding metallurgy [5]. In the coatings of most brands of low-hydrogen electrodes, the gas and slag-forming system CaF_2–SiO_2–TiO_2 is used, in which the welding-technological properties of theelectrodes and the efficiency of protection of the molten metal are regulated by the $CaCO_3$ / CaF_2 ratio and the coating thickness [6]. With significant positive properties of electrodes with calcium fluoride coating, low technological properties cause technological defects during welding, which significantly reduce the quality and mechanical characteristics of the weld metal.Therefore, finding coatings with improved mechanical and welding-technological characteristics for low-hydrogen welding electrodes is an urgent problem.

To manufacture electrode coatings for manual arc welding, a raw material base is used, such as mineral raw materials, ferroalloys, organic substances and artificial chemical materials [7, 8].Currently, more and more research is being carried out to find cheap local raw materials suitable for the production of welding electrodes [9].

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EXPERIMENTAL PART

In order to improve the complex of technological properties of low-hydrogen electrodes with a calcium fluoride coating, in particular, UONI-13/55 electrodes, while maintaining strength, plasticity and cold resistance properties, it is proposed to additionally introduce opal-quartz-carbonate bentonite clay of the Taganskoye deposit of the East Kazakhstan region into the standard coating formulation.

Electron microscopic studies of the structure and elemental composition of bentonites and deposited metal were conducted using the scanning electron microscope JSM-6390LV.

Mechanical tests of the deposited samples were conducted according to GOST 6996-66 [10].

Tensile and impact tests were conducted using TTM-1000 tensile testing machine (walter+bai, Switzerland) and PH-300-PS impact testing machine, respectively.

Investigation of the welding and engineering properties of the series K1 and K2 electrodes was conducted using direct current of reverse polarity from the VD-301

Table 1 **Base of coatings, dimensional and technological indicators of experimental electrodes**

Test electrode Series	Mass fraction of coating			$D_{coat.}/d_{rod}$/ mm	Coating mass coefficient/%	Slag protection coefficient/%
	$CaCO_3$	CaF_2	$CaCO_3/CaF_2$			
K1	54	15	3 /1	1,50	54,3	25
K2	54	15	3,4/1	1,72	56,2	27

power source, and K2 electrodes additionally using alternating current from the TD-300 welding transformer.

The duration of short circuits was determined with the TX-5000 device when welding in the lower position.

Test electrodes series were manufactured and tested, the base of coatings of which were marble, fluorspar, quartz sand. The total content of the main gas-slag-forming ($CaCO_3$ and CaF_2), as well as the ratio between them are shown in Table 1.

- K1 - electrodes with a single-layer coating, containing a standard formulation of electrodes UONI-13/55, which was additionally injected with opal-quartz-carbonate bentonite clay of the 11th horizon of the Taganskoye deposit. Its elemental composition / wt%: SiO_2 – 51,98; Al_2O_3 – 0,96; Fe_2O_3 – 1,27; CaO – 0,22; MgO – 0,13; K_2O – 0,9; Na_2O – 0,10; TiO_2 – 0,10 [11].

- K2 - electrodes with a two-layer coating, where the standard formulation of the UONI- 13/55 electrodes was used as the first layer. For the second outer layer, opal-quartz-carbonate bentonite clay of the 11th horizon of the Taganskoye deposit was also used [12].

Ferroalloys of industrial production were used as deoxidizers: electric furnace medium-carbon ferromanganese (84-85 /wt% Mn), lump ferrosilicon with 44-45 / wt. % Si), as well as ferrotitanium (35/wt% Ti/ 5 wt% Si, and 8/ wt% Al).

RESULTS AND DISCUSSION

As follows from Table 1, in the K1 and K2 series coatings, the gas-slag-forming base, dimensional and engineering parameters of the coating of the UONI-13/55 electrodes are reproduced. In them, the $CaCO_3/CaF_2$ ratio is 3/1; therefore, there is a high oxidation potential, rather effective protection of molten metal from air, and fine-droplet transfer of electrode metal. In the coating of K2 series electrodes, the $CaCO_3/CaF_2$ ratio is 3,5/1, and therefore its oxidation potential increases significantly.

To make the K1 series electrodes additional introduction of dried opal-quartz-carbonate clay ground to an ultradispersed state into the standard mixture of the coating components of the UONI 13/55 electrodes is required. The high ductility of bentonite leads to a significant increase in the ductile properties and quality of the coating.

All components were mixed with liquid glass and applied by pressing onto metal rods made of Sv08A wire. The test coating is characterized by good ductile properties, uniformity over the entire surface of the electrode, retains its quality after calcination at T 300 ... 35 °C and meets the requirements of GOST 9466-75 [13], GOST 9467-75 [14].

To make the K2 series electrodes bentonite clay was preliminarily subjected to super-grin-ding in a vibrating mill [15] and mixed with water glass, and then applied to the first dried layer by pressing onto a standard electrodelayer by pressing onto a standard electrode coating UONI-13/55.

When the tip of the electrode burns, the activating properties of superfine bentonite at the level of nanoparticles increase and the electronegative ions formed in the vapor, mixing with the positive ions of the slag-forming and gas-forming components, contract (compress) the column of the welding arc due to electrodynamic forces. In this case, the active section of the arc column decreases, and the current density in the arc increases. This allows to increase the penetration depth of the welded metal and increase the productivity of the welding process. As a result, arc constriction and penetration and hence the productivity of the welding process will increase.

The test results indicate that the experimental series of electrodes are characterized by fine-droplet transfer of electrode metal, negligible spatter, and good protection of the welding zone from the surrounding atmosphere (Table 2).

Electron-microscopic studies of the deposited metal show that in the deposited metal of the test electrodes K1, K2, in comparison with UONI-13/55, a higher content of deoxidizing elements Mn, Si, Ti with an additional presence of Al, which has passed from the bentonite of the coating of the test electrodes (Figures 1, 2,

Table 2 **Welding and engineering properties of electrodes**

Electrode series	Current type and polarity	Slag crust separability	Bead formation and surface	Short circuit duration $\tau_{s.c}$/ms	Penetration depth/ mm	Splashing	Pore tendency in arc lengthening
UONI- 13/55	Direct, reverse	Satisfactory	Satisfactory	3,7	2,5..2,8	Excessive	Excessive (ΔL_{arc}>3,5 mm)
K1	Direct, reverse	Excellent	Excellent, fine-scaled	2,7	3…3,5	Negligible	None ($\Delta L_{arc}\leq$6 mm)
K2	Alternating, direct reverse	Excellent	Excellent, fine-scaled	2,2	4...4,5	Small	None ($\Delta L_{arc}\leq$7 mm)

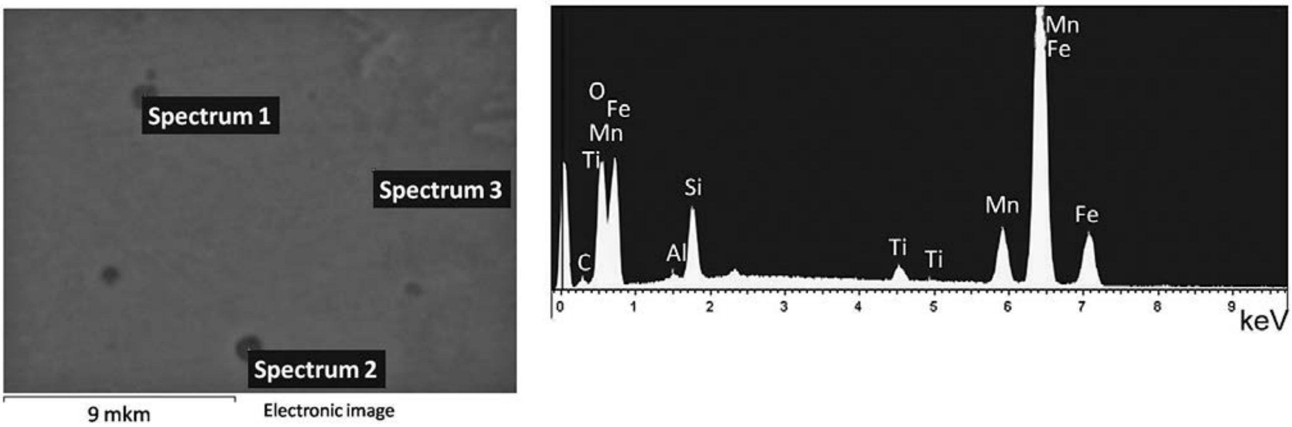

Figure 1 Point scanning of the elemental composition of the deposited metal of the K1 electrodes

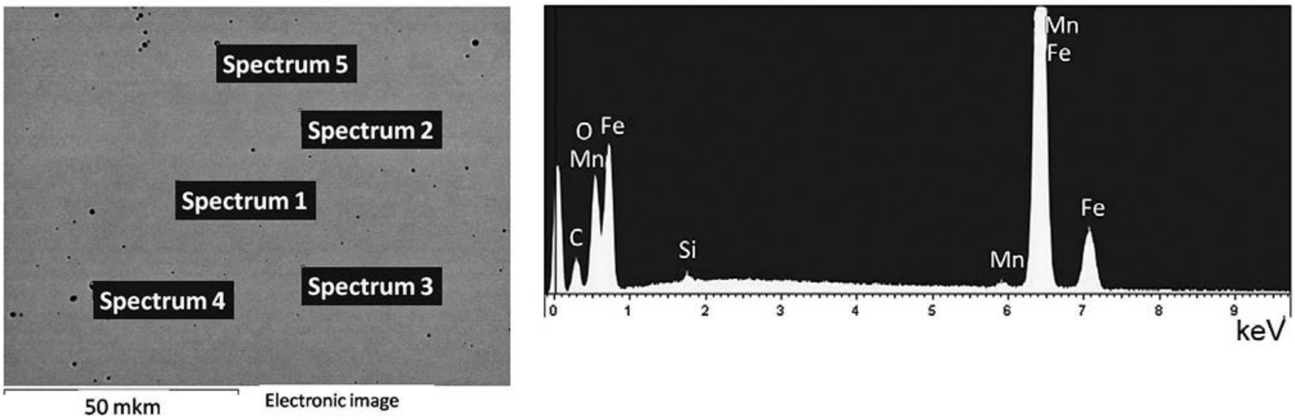

Figure 2 Point scanning of the elemental composition of the deposited metal of the K2 electrodes

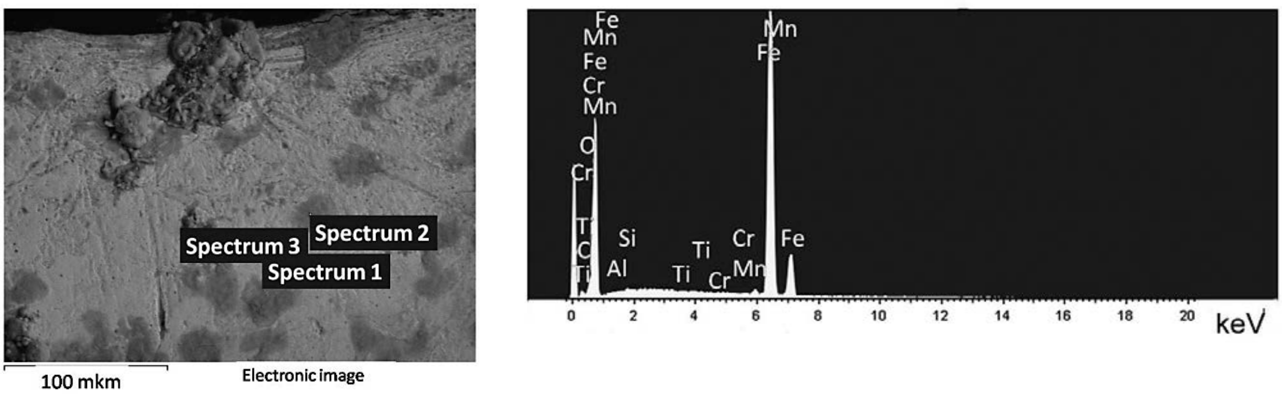

Figure 3 Point scanning of the elemental composition of the deposited metal of the UONI-13/55 electrodes

3). At the same time, the oxygen content in the deposited metal in the K1 and K2 electrodes is noticeably reduced relative to the UONI-13/55 electrodes. In this case, the main source of oxygen is non-metallic inclusions that did not have time to escape into the slag, which are formed at the stage of crystallization of the weld pool (Figure 3).

Chemical composition of the deposited metal corresponds to standard electrodes (Table 3).

In the study of the macrostructure of welded samples, it was found that the melting depth of metal welded by standard electrodes without an external layer of activating components was 2,5...2,8 mm, and the smelting of samples welded by an experimental electrode with a layer of activating components applied to the surface of the smear, the layer of slag-forming and gas-forming components was 4...4,5 mm. This indicates an increase in the smelting capacity of welding arc of the recommended electrode by 60%, which improves the performance of manual arc welding and energy savings at the expense of counter-reaction of the welding arc.

Table 3 **Chemical composition of the deposited metal/wt%**

Type of electrode	Chemical composition				
	C	K	Si	S	P
UONI- 13/55	0,08 – 0,13	0,8 – 1,2	0,20-0,45	0,030	0,035
K1	0,062	1,25	0,35	0,020	0,023
K2	0,062	1,27	0,32	0,020	0,026

Table 4 **Comparative mechanical properties of the melted metal obtained using experimental and standard UONI-13/55 electrodes**

Test and standard electrodes series	Yield strength R_n/MPa	Ultimate tensile strength R_m/MPa	Elongationδ A/ %	Reduction of area Z/ %	Impact strength KCV at E = 300 J (J/cm²) at temperature/°C			
					+20	–20	–40	–60
K1- d_e 3mm	415	545	32	77,6	262,6	225,6	129,6	42
K2- d_e 4mm	415	540	32,5	78	250,6	220,6	130	37
UONI 13/55 d_e 4mm	395	520	28,5	72	200	140	115	28

Comparative mechanical properties of the cladded metal of experimental and manufactured according to the standard formulation of UONI- 13/55 electrodes show a slight increase in their strength and ductile properties. However, the values of impact strength of the melted metal of the experimental electrodes significantly exceed these indicators of UONI-13/55 electrodes at both positive and negative temperatures (Table 4).

CONCLUSION

When welding with UONI-13/55 electrodes, the welding zone, due to its low technological properties, is insufficiently protected from the ambient air, and the deposited metal has a low impact strength at T – 60 °C. Under welding conditions, the main deoxidizers of Mn, Si and Ti, such as a deoxidizer and a nitride former, do not fully provide an increase in toughness.

The addition of opal-quartz-carbonate bentonite clay of the Taganskoye deposit of the East Kazakhstan region with a single-layer and two-layer coating into the composition of new electrode coatings UONI-13/55 additionally makes it possible to improve the welding and engineering properties of the gas-slag base of the coating, which helps to increase the protective functions of the welding zone from the surrounding atmosphere and an increase in the impact strength of the weld metal at temperatures of +20 °C and at negative temperatures, including –60 °C due to additional deoxidation of Al.

REFERENCES

[1] S.″V. Mikhailitsyn, M. A. Sheksheev, S. I. Platov, A. N. Emelyushin, S.V. Naumov, Investigation of viscosity of liquid welding slags and melts of electrode coatings. Izvestiya Vysshikh Uchebnykh Zavedenij. Chernaya Metallurgiya 61 (2018) 4, 280-287

[2] D. P. Ii'yashchenko, S. B. Sapozhkov, Splashing in manual arc coated electrode welding and methods of reducing splashing. Welding International 22 (2008) 12, 874-877. https://doi:10.1080/09507110802650677

[3] K. D. Basiev, G. V. Rukhlin, A.M. Baimatov, Plasticising and stabilising components in coatings of basic electrodes. Welding International 17 (2003) 9, 739-740. http://doi:10.1533/wint.2003.3191

[4] K. C. Mills, B. J. Keene, Physicochemical properties of molten CaF2 - based slags. International Metals Reviews, 26 (1981) 1, 21-69. http: doi:10.1179/imtr.1981.26.1.2

[5] A. E. Marchenko, N. V. Skorina Influence of technological factors in manufacture of low-hydrogen electrodes on hydrogen content in the deposited metal. The Paton Welding Journal (2013) 8, 13-24

[6] V. D. Makarenko, C. P. Shatilo Stability of arcing in welding with calcium fluoride electrodes. Welding International 4 (1990) 12, 988-989. http://doi:10.1080/0950711900 9453038

[7] K. Z. Kosimov, B. D. Yusupov Learning Chemical Characteristics of Low Toxic Surfacing Electrodes For Welding, Improving The Plastic Properties And Effects To Welding Ability of The Electrode Coating Using Different Raw-Mineral Materials, International Journal of Advanced Research in Science, Engineering and Technology 6 (2019) 12, 12024-12029

[8] N. I. Urbanovich, T. I. Bendik, K. E. Baranovsky, E. V. Rozenberg Assessment of influence of input method of modifying additive in the coating of electrode on their welding-technological properties and mechanical properties of the weld metal. Litiyoi Metallurgiya (2019) 1, 119-123. (In Russ.) http://doi.org/10.21122/1683-6065-2019-1-119-123

[9] K. D. Basiev, A. A. Bigulaev, E. A. Chadzaragova, O.E. Kapustin Economic and technological aspects of sustainable development of mountain areas in the production of high-performance welding materials. Sustainable development of mountainous areas. 10 (2018) 2, 260-269

[10] GOST 6996-66 Welded joints. Methods of mechanical properties determination.

[11] Yu. I. Lopukhov, A. K. Adryshev, A. A. Khairullina, G. K. Daumova, D. T. Baigazinov, M. B. Syzdykov, Electrode coating composition, Patent of the Republic of Kazakhstan for the invention No 33142 (24.09.2018.)

[12] E. Yu. Van, Yu. I. Lopukhov, G. K. Daumova, M. B. Syzdykov, Electrode for arc welding, Patent of the Russian Federation for the invention No 2717429 (23.03.2020.)

[13] GOST 9466-75 Covered metal electrodes for manual arc welding of steels and deposition. Classification and general specifications.

[14] GOST 9467-75 Metal covered electrodes for manual arc welding of structural and heat-resistant steels. Types.

[15] G. K. Daumova, S. A. Abdulina, G. A. Kokayeva, M. A. Adilkanova Experimental studies on wastewater sorption treatment with subsequent disposal of used sorbents, Chemical engineering transactions (2018) 70, 2125-2130. https://doi:10.3303/CET1870355

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