INCREASING THE MELTING STABILITY OF SELF-SHIELDED FLUX-CORED WIRE

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The stability of the electrode melting process, in particular self-shielded flux-cored wire, is characterized by the relative losses of the electrode metal, measured by the coefficients of total losses φ and spatter losses $φ_p$ [1]. In [1, 2], the influence of the composition of gas-slag-forming components of a complex-alloyed self-shielded flux-cored wire on these coefficients was studied. An analysis of the experimental results made it possible to classify the studied minerals in descending order of the impact on the loss factors φ and $φ_p$: carbonates, zirconium, rutile concentrates, vermiculite, wollastonite, nepheline, perovskite concentrate and fluorspar [2].
To establish the reasons for the increased spattering of the electrode metal during surfacing with flux-cored wires with a high content of carbonates, zirconium or rutile concentrate, self-shielded wires with gas-slag-forming charge components of various compositions were made (Table 1). The content of alloying elements in the wire was, %: C 2.1-2.3. Mп 3.4-3.7, Si 0.7-0.8, Cr 8.2-8.8, V 1.3-1.4, Mo 1.1-1.2, W 1.3- 1.5.
The experiments were carried out according to the method of works [1, 2]. Surfacing was carried out by direct current of reverse polarity with a wire with a diameter of 3 mm in the mode: $I_{св}$=280÷320 A, $U_д$=26÷28 V, $ϑ_н$=18 m/s, $L_э$=25÷30 mm. In this case, a power supply with a rigid external characteristic was used. The results of the experiments are presented in table. 2
The increased spattering of the electrode metal during surfacing with a flux-cored wire, in the composition of the gas-slag-forming part of the core of which there is a large amount of zirconium or rutile concentrate (more than 50-60 % in wires №. 4, 10, 11), can be explained as follows.

Table 1

Wire number	Content of elements, %					
	Fluorspar	Marble (magnesite)	Rutile concentrate	Zirconium concentrate	Nepheline concentrate	wollastronite
1	15	40	45	-	-	-
2	15	(40)	-	45	-	-
3	15	40	-	-	45	-
4	10	-	45	45	-	-
5	10	-	45	-	45	-
6	10	-	-	45	45	-
7	10	-	-	45	-	45
8	43,3	(26,7)	-	-	30	-
9	43,3	26,7	-	-	-	30
10	10	-	30	30	30	-
11	10	-	30	30	-	30
12	30	16	18	9	9	18

13	39	(16)	9	9	18	9

Note. The total amount of gas and slag forming materials is 10-11% of the mass of the wire

Table 2

Wire number	H_c , %	*K*	$\Psi_{p,}$ %	Ψ, %
1	60,5	11,8	10,8	15,2
2	59,6	10,4	11,5	15,5
3	62,8	16,5	8,6	12,4
4	55,7	5,2	13,3	17,6
5	58,1	8,4	10,0	13,7
6	59,5	5,0	13,0	16,2
7	61,3	4,8	12,4	15,4
8	73,1	13,8	6,5	9,6
9	74,0	14,5	6,4	9,2
10	62,5	6,6	11,3	15,4
11	63,6	6,2	13,4	16,8
12	67,2	15,8	6,8	10,4
13	68,9	15,2	6,1	9,5

These minerals, forming acidic slags as a result of the melting of the components of the filler of the flux-cored wire [2, 3], promote intensive metallurgical reactions, in particular, enhanced oxidation of carbon at the metal-slag interface, as evidenced by a decrease in the transition coefficient η_c (см, Table 2). Since the drop is covered with slag, the resulting carbon monoxide does not have a free exit into the surrounding space and is collected in gas bubbles [4]. Local explosive release of gases as a result of bubble rupture leads to the release of gases as a result of bubble rupture leads to the ejection of droplet metal particles [4, 5], which contributes to increased spattering of the electrode metal. The effect of carbon oxidation on the spattering of the electrode metal is evidenced by an increase in the coefficient φ_p with an increase in its concentration in the flux-cored wire. So, with an increase in the carbon content in the wire from 0.5 to 3.0% (№. 4), the coefficient φ_p increased from 8.2 to 14.8%.

Wires with a high content of zirconium and rutile concentrates are characterized by unstable arc burning. The stability of the welding arc during surfacing with flux-cored wires of various compositions was evaluated by the following method[1]. The wire was fixed in a tripod, and the distance between the end of the wire and the plate was set equal to 2 mm. Welding voltage was applied to the electrode and plate from a source with a rigid external characteristic (VKSM-1000) and an arc discharge was excited by a sharpened carbon electrode. After the arc burned out to a natural break, the distance L_p (mm) between the ends of the electrode and the surfacing on the plate (arc breaking length) was measured, as well as the current I_{min} (A) at the moment of time preceding the arc break, and the cross-sectional area of the current-carrying part of the wire Sэ (mm^2). The process of changing the arc current was recorded with and Н338-6П self-recording device. According to the recording results

I_{min} and the criterion $K = 10L_p / (I_{min} / S_э)$ were determined

The use of a source with a rigid external characteristic is caused by the need to reduce the influence of the energy stability of the arc-power source system on the evaluation criterion and highlight only the physical stability associated with the electrode materials used. A source with a rigid external characteristic provides a constant voltage supply to the electrode, which depends little on the parameters of the welding arc, which increases the reliability of the results when evaluating welding materials that differ in physical properties.

Measuring the current at the moment of time preceding the arc break makes it possible to evaluate the influence of a particular electrode on the stability of the arc discharge, since the properties of materials depend not only on the breaking length of the arc, but also on the minimum allowable current.
The values of the welding arc stability criterion for the investigated powder arcs are given in Table. 2. Table data analysis.1 and 2 shows that for wires with a high content of rutile and zirconium concentrates in the gas-slag-forming part of the charge (№. 4-7. 10.11), the stability of the welding arc is much lower than wires of other compositions. The decrease in the stabilizing properties of wires or zirconium concentrate in the presence of CaF_2 can be associated with the formation of gaseous fluorine compounds in the inter electrode gap.
The resulting negative ions in the form lead to the creation of an uncompensated negative space charge at the cathode surface. The presence of this charge prevents the exit of electrons from the cathode and their entry into the arc gap, which causes a deterioration in the conditions for ignition and arc burning [6].
The unstable arcing causes significant fluctuations in the welding current, which leads to a change in the electromagnetic force, which is proportional to the square of the current. A sharp increase in the electromagnetic force leads to explosive destruction of the neck of the drop with its ejection outside the weld pool [4], which causes a large spatter of the electrode metal.
Increased metal losses during surfacing with flux-cored wires (№. 1-3) with higher values of the K criterion (10.4-16.5) are explained by a high content of carbonates (40%) in gas-slag-forming components. Intense dissociation of carbonates in a narrow temperature range [4] at such a content in the gas-slag-forming part of the charge leads to explosive release of gases from the wire core and the formation of a powerful gas flow, which contributes to increased spattering of the electrode metal away from the bath [1]. In addition, at a high content of carbonates in the charge, the flow of the gas phase oxidizer increases. An excess of oxygen leads to the fact that the reaction zone passes from the phase interface into the depth of the metal [4, 5], and the carbon monoxide formed during oxidation is partially collected inside the liquid metal droplets into bubbles that explode and scatter part of the electrode metal away from the weld pool [5,7].
With the introduction of calcium or magnesium carbonates into the gas-slag-forming part of the charge up to 15-27%, especially together with fluorspar, nephew line concentrate and Wollastonite, φ decreases to 8-10% (wires №. 8, 9, 12, 13). This is probably due to the fact that such a content of carbonates and these minerals in the composition of gas-slag-forming components leads to the early formation of a slag melt, uniform dissociation of $CaCO_3$ and $MgCO_3$ over a wide temperature range without explosive gas evolution, less carbon oxidation and an increase in the stability of the welding arc (см Table .2). The latter is explained by the significant content in the slag base of stabilizing elements, oxides of alkali and alkaline earth metals, which, evaporating in the inter electrode gap, reduce the effective ionization potential of the arc gas.
Thus, the use of a complex of gas and slag-forming components in optimal ratios can significantly improve the melting stability of self-shielded flux-cored wire for surfacing complex-alloyed alloys.

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