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On the issue of research and development of a slag-forming base for coatings of cellulose-type electrodes

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ABSTRACT: This article describes the development of the slag-forming base of the CaO-SiO_2-TiO_2 system of cellulose-type electrode coatings, as well as the study of the influence of the Al_2O_3 content in the CaO-SiO_2-TiO_2 system on the density, viscosity and hiding power of the slag, and the separability of the slag crust.

KEY WORDS: Manual arc welding, Electrode, Cellulose coating, Triple state diagram, Slag, Viscosity, Density, Slag peel separability

I.INTRODUCTION

Electrode coatings are mixtures of gas-forming and slag-forming substances, which during the welding process protect the metal from exposure to air and produce the desired metallurgical processing of the metal. For this purpose, various metallic additives are often added to the coatings.

However, gas-forming (for air displacement) and slag-forming substances (partially insulating the surface of the molten metal) introduced into the coating, as a rule, are not neutral with respect to metal during welding.

Usually, organic additives (starch, dextrin, cellulose, etc.) or carbonic salts - carbonates (marble, magnesite, etc.) are used as gas-forming substances in coatings. The former, decomposing, form hydrogen and various complex gases CO, CO_2, H_2O in the presence of a certain amount of free oxygen.

The second ones give CO, CO_2, as well as oxygen and a certain amount of water vapor, the presence of which is determined by the technology of coating production.

Slag-forming substances are systems of oxides of various elements and halide compounds (most often fluorides). Under welding conditions, some of them also interact with the metal, in particular, oxidizing it.

Thus, in fusion welding, it is necessary to take into account the interaction of the metal, its impurities or alloying additives with the surrounding gas, slag or gas-slag environment. The main gases in this case are O_2, N_2, H_2, CO, CO_2, H_2O, some of their derivatives and halogens.

II. LITERATURE SURVEY

In arc welding with a consumable electrode, metal from the electrode is transferred to the weld pool in the form of droplets heated to temperatures well above the melting point and in the form of vapors. When welding with coated electrodes under the action of an arc, not only the electrode metal, but also the coating melts and partially passes into a gaseous state. The slag resulting from the melting of the coating is transferred in the arc partly in the form of droplets, and partly in the form of slag coat on the metal droplets and inside them [1].

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Slags are the melts of non-metallic compounds - oxides, halogens, sulfides, etc. - both free and complex compounds. Most slag is insoluble in metals. In the molten state, metals and slags are immiscible liquids, separated by specific gravity (density) [2].

The properties of slag and the nature of the effect on the metal are determined by their chemical composition. The composition of slags affects their basic physical properties: melting point, viscosity and its changes in temperature, interfacial tension at the slag-metal interface, density, etc.

The chemical effect of molten slag on the metal is largely determined by the ratio in its composition of basic, acidic and amphoteric oxides. Acid oxides, often found in welding slags, are SiO_2, TiO_2 and, less commonly, P_2O_5. The main oxides in welding slags are Na_2O, K_2O, CaO, MgO, MnO, FeO, NiO, etc. Of the amphoteric oxides, Al_2O_3 and B_2O_3 are most often used in welding slags. [1-3].

Formally, the predominance of acidic or basic slag characteristics is estimated by the basicity coefficient adopted by the International Institute of Welding [3]:

$$B = \frac{CaO + MgO + BaO + Na_2O + K_2O + Li_2O + CaF_2 + 0{,}5(MnO + FeO)}{SiO_2 + 0{,}5(Al_2O_3 + TiO_2 + ZrO_2)} \qquad (1)$$

Under various conditions, amphoteric oxides can act either as basic oxides, forming complex compounds with acidic ones when the amount of basic oxides is insufficient, or acidic with an excess of basic ones.

The chemical effect of the slag on the metal can be oxidizing or deoxidizing (by transferring the oxides dissolved in the metal into slag), as well as changing the content of sulfur and phosphorus in the metal [5-7].

The processes of interaction of slag and metal are greatly influenced by the physical properties of the slag. In this regard, a very important characteristic is the melting point. The melting point of slag is a much less defined characteristic than the melting point of metals.

Slags change their viscosity over a fairly wide temperature range, and therefore their melting point is conditional. Depending on the nature of the change in viscosity with temperature, the slags are “long” and “short”. Short slags are mainly basic. They harden in a small temperature range; when cooling, they quickly enough pass from a state of significant fluid mobility to the formation of a slag crust. Acidic slags, as a rule, gradually change their viscosity, gradually thicken and go over the glassy structure [8-9]

III. METHODOLOGY

Consider, for example, the development of cellulose type electrodes that meet the following technical requirements: the electrode is designed for welding carbon and low alloy steels with alternating current for any spatial location of the welds and should provide the properties of the deposited metal corresponding to the E46 type according to GOST 9467-70.

Since the electrode under development has a general purpose, it is advisable to use Sv-08A grade wire as rods according to GOST 2246–70. From the experience of existing electrodes of type E46 it is known that the mechanical properties of the deposited metal can be ensured with the following chemical composition: C $\approx$ 0.12%; Mn$\approx$0.5-1.1%; Si $\approx$0.08-0.16%; S$\leq$0.04%; P $\leq$0.04%, and with restrictions on nitrogen, oxygen, and hydrogen. With the selected composition of the electrode rod, the alloying of the deposited metal with silicon and manganese should be done through the coating.

Slag system for electrodes with a cellulose coating containing the following components, wt.%: cellulose - 50-54, ferrosilicon manganese - 18-20; marble - 6-8; rutile - 16-18; kaolin - 4-6, are oxides of calcium (marble), silicon (kaolin) and titanium (rutile).

From the presented state diagrams of CaO-SiO_2-TiO_2 (Fig. 1) it follows that this ternary system has a range of melting temperatures of slags of about 1300 ° C, which satisfies the requirements for welding slags when welding steels. The range of such melting temperatures is close to ~ 30-40% CaO, 20-35% SiO_2 and 35-55% TiO_2 in the composition of slags

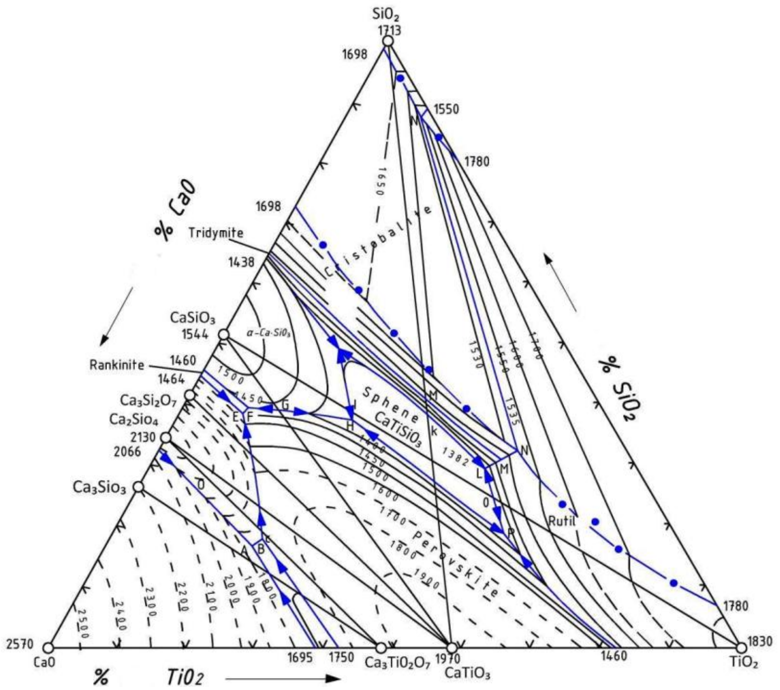

Fig. 1. Triple diagram of $CaO-SiO_2-TiO_2$

The mineralogical composition of the slag and its structure also affect its physical and technological properties. We studied the effect of Al_2O_3 oxide additives (26.7% in kaolin) on the properties of slag (density, viscosity, surface tension) related to the $CaO-SiO_2-TiO_2$ system. At the same time, the influence of the physical state of slag on the welding and technological properties, such as: the covering power of the slag and its separability, was investigated.

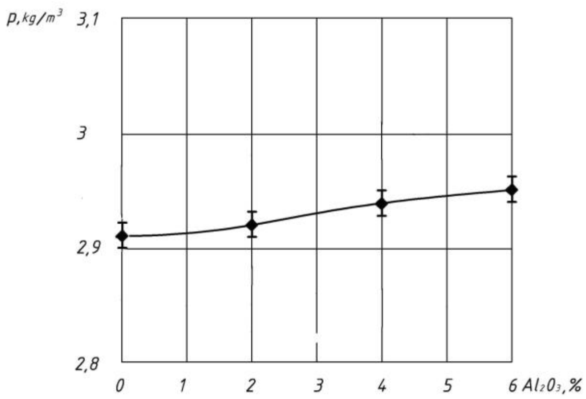

Fig. 2. Dependence of the density of surfacing slag of the $CaO-SiO_2-TiO_2$ system on the Al_2O_3 content

As can be seen from fig. 2 alumina does not significantly affect the density of slag. To measure the viscosity of the slag, viscometric methods were used. The method is based on the law of fluid flow in the gap between two coaxial bodies, one of the bodies rotating and the other stationary. The viscosity is determined by the measured torque at a given angular velocity. Slag viscosity was measured on a rotational viscometer with a rotating working fluid. The dependence of slag viscosity on the Al_2O_3 content in the initial slag at T = 1700 K is shown in Fig. 3.

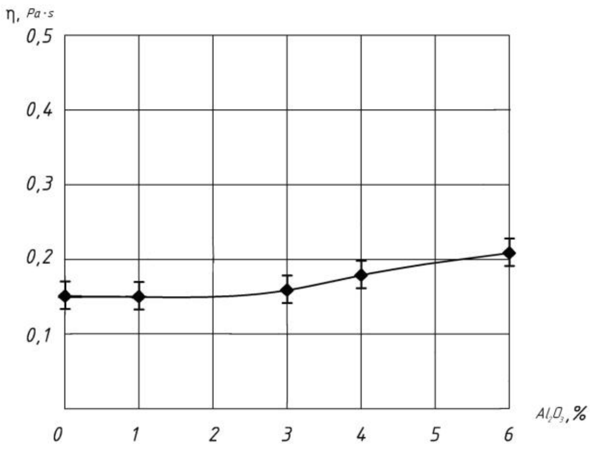

Fig. 3. Dependence of the slag viscosity of the CaO-SiO_2-TiO_2 system on the Al_2O_3 content

Al_2O_3 has little effect on the value of viscosity.

The covering power of slag during surfacing with coated electrodes was determined by the product of the quotient of dividing the thickness of the slag crust at the top of the deposited bead to the thickness of the slag crust at the base of the deposited bead and the surface area of the deposited bead coated with slag, S_1, to the total surface area of the bead S_2, i.e.:

$$K_{K.C.} = \frac{\Delta_1}{\Delta_2} \cdot \frac{S_1}{S_2}$$

The influence of the Al_2O_3 content in the slag on the opacity of the slag is shown in Fig. 4.

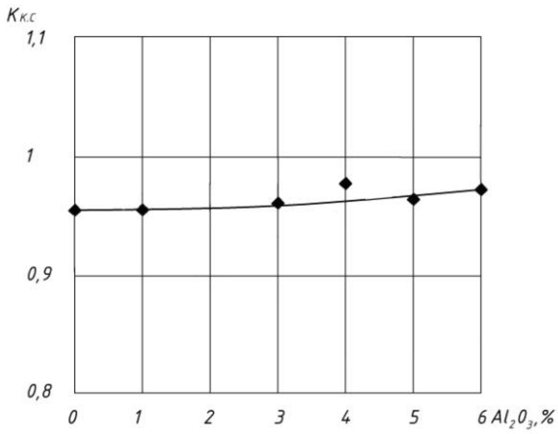

Fig. 4. Dependence of the covering power of the CaO-SiO_2-TiO_2 system on the Al_2O_3 content

The introduction of Al_2O_3 oxide into the slag has practically no effect on the slope opacity.

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The determination of the separability of the slag crust is based on the determination of the impact force applied to the sample. The essence of this method lies in the fact that on the surface of the plate is surfacing the first roller. After surfacing, it is freed from slag and the second roller is surfaced with the first half overlapping by half its width. The surfaced plate is placed in the quick-acting clamps of the pendulum head, at a temperature of the deposited metal it was higher than 450 ° C, and a striking stroke was performed on the back side of the deposited layer of the plate.

The angle of rise of the pendulum is maintained in all experiments constant and equal to 60 °. The magnitude of the shock load is chosen such that no plastic deformation of the sample occurs. The assessment of the separability of the slag coating is carried out by the area of the separated slag crust.

The dependence of slag separability on the content of Al_2O_3 oxides in it is presented in Fig. 5.

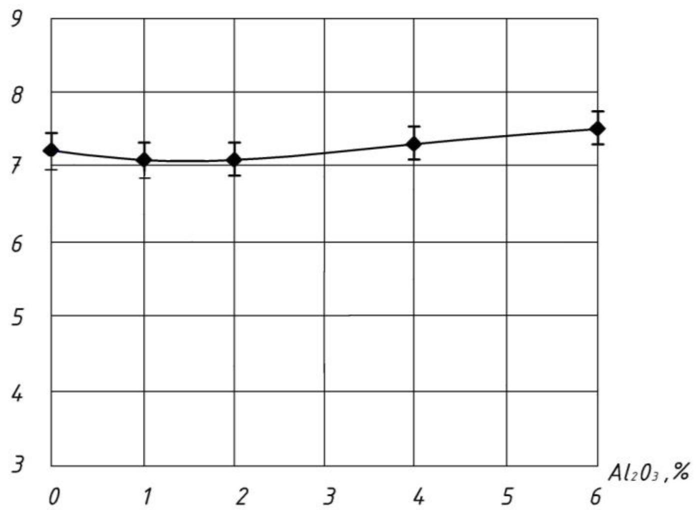

Fig. 5. Dependence of the slag crust separability m^2/MJ on the Al_2O_3 content in the slag of the CaO-SiO_2-TiO_2 system

The separability of the slag crust is one of the most important indicators of the processability of surfacing materials. The separability of slag depends mainly on the epitaxial intergrowth of slag and weld metal, which is possible if they have a similar structure at the phase boundary. A factor contributing to the separability of slag is the restructuring of the structure of individual components, for example, the transition γ - Al_2O_3 to α- Al_2O_3. This rearrangement is manifested in a change in the phase volume of the components of the slag, which causes the destruction of the slag-metal boundary and improves the separability of the slag. This explains the improvement in the separability of slag with an increase in the amount of Al_2O_3 oxide formed as a result of the exothermic reaction.

IV. CONCLUSION AND FUTURE WORK

Electrodes with a cellulose type coating containing the following components were developed, wt.%: Cellulose - 50-54, ferrosilicon manganese - 18-20; marble - 6-8; rutile - 16-18; kaolin - 4-6. The introduction of Al_2O_3 into the CaO-SiO2-TiO2 system has practically no effect on the density, viscosity and hiding power of the slag, but it improves the separability of the slag crust

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