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# **On the issue of research and development of a slag-forming base for electrode coatings for wear-resistant surfacing**

**J.N. Sadikov, A.S. Saidakhmatov, Z.D. Ermatov**

Researcher, Department of Technological Machines and Equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan

Master of the Department "Technological Machines and Equipment" of Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan

Associate professor, Doctor of Philosophy in Technical Sciences, Department of Technological Machines and Equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan

**ABSTRACT:** This article describes the development of a slag-forming base for electrode coatings for wear-resistant surfacing of the  $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$  system, as well as the study of the influence of the content of  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  in this slag system on the density, viscosity and hiding power of the slag, and the separability of the slag crust.

**KEY WORDS:** Manual arc surfacing, Electrode, Ferroalloys, Marble, Pegmatite, Triple state diagram, Slag, Viscosity, Density, Separability of the slag crust.

## **I. INTRODUCTION**

Metal surfacing on the surface of the part makes it possible to give it the necessary sufficient mechanical and physico-chemical properties and thereby increase the reliability and durability of work and reduce cost.

Surfacing works are used to create surface layers on the parts with the required properties, as well as to restore the original dimensions of worn parts. For example, surfacing is used to manufacture parts from structural, relatively cheap steels, on the working surfaces of which wear-resistant, heat-resistant or other special alloys are deposited.

When surfacing, as a rule, it is necessary to obtain a minimum penetration of the base metal and minimal mixing of the base and deposited metal in order to preserve the mechanical properties of the deposited layer.

At the same time, the deposited metal should be firmly bonded to the base metal and should not contain pores, slag inclusions, crack shells and other defects.

## **II. LITERATURE SURVEY**

The wear of parts is the result of wear - the process of destruction and separation of the material from the surface of a solid and (or) the accumulation of its residual deformation during friction. The process is realized in a pair of friction (conjugation) - a combination of two movably conjugated surfaces in real operating conditions and is manifested in a gradual change in the size and (or) shape of the body. The types of destruction of the surfaces of parts during friction are diverse, which is associated with the combined action of mechanical, physico-chemical, electrochemical and other processes during contact and environmental conditions (temperature, humidity, etc.) [1-2].

The main factors determining surface damage and wear are: plastic deformation, the destruction of microroughness and oxide films as a result of the introduction of certain sections of the surface of one part into the mating surface of another part and their mutual displacement; adhesive setting and transfer of metal from one part to another; hydrogenation and oxidation processes; destruction of the "bridges" of seizure, etc. [3].

Production surfacing is used to obtain new bimetallic (multilayer) products. Such products consist of a base (base metal) providing the necessary structural strength, and a deposited working layer (deposited metal) with special properties (wear resistance, heat resistance, corrosion resistance, etc.) [4].

Recovery surfacing is used to restore the original dimensions of worn or damaged parts. In this case, the deposited metal may be similar in composition and properties to the base metal (reducing dimensional surfacing) or differ from them (reducing wear-resistant surfacing) [5,6].

### III. METHODOLOGY

The electrodes for surfacing in the vast majority have basic coatings. This allows, due to the low hydrogen content in the deposited metal, to provide its better resistance to cracking during surfacing of parts from steels with a high carbon content, hard products. The developed composition of the electrode coating for wear-resistant surfacing contains the following components, wt.%: Marble - 26-28; pegmatite - 14-16, graphite - 9-11, ferrosilicon manganese - 10-12; ferrochrome 25-27; ferrotitanium - 10-12.

The slag system of electrodes for wear-resistant surfacing is composed of oxides of calcium (marble), silicon (pegmatite) and aluminum (pegmatite).

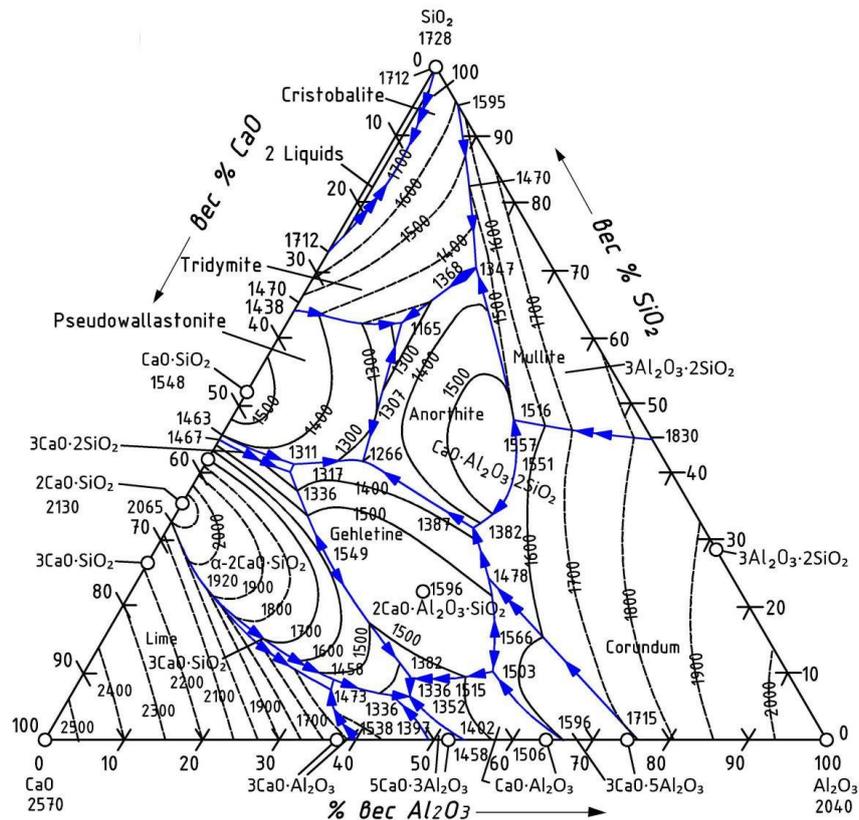


Fig. 1. Triple diagram of CaO-SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub>

In the CaO-SiO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> system, a melting point of 1300 °C occurs at compositions of ~ 50% SiO<sub>2</sub>, ~ 30% CaO, and ~ 20% Al<sub>2</sub>O<sub>3</sub>. Several chemical compounds are formed in this system, including two ternary ones: CaO · Al<sub>2</sub>O<sub>3</sub> · SiO<sub>2</sub> containing 20% CaO, 37% Al<sub>2</sub>O<sub>3</sub> and 43% SiO<sub>2</sub> and melting at 1550 °C, as well as 2CaO·Al<sub>2</sub>O<sub>3</sub>·SiO<sub>2</sub> containing 41% CaO, 37% Al<sub>2</sub>O<sub>3</sub> and 22% SiO<sub>2</sub> and melting at 1590°C. The system under consideration has a large region of melts with a melting point not exceeding 1600°C, which ensures widespread use of slags based on SiO<sub>2</sub>-CaO-Al<sub>2</sub>O<sub>3</sub>. The slags of this system, if they contain 48–54% CaO, are scattered into powder upon cooling.

The mineralogical composition of the slag and its structure also affect its physical and technological properties.

We studied the effect of additives of oxides  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  (content of 7.08% and 4.15% in pegmatite, respectively) on the properties of slag (density, viscosity, surface tension) related to the  $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$  system. In parallel, the influence of the physical state of the slag on the welding and technological properties, such as: the covering power of the slag and its separability, was investigated.

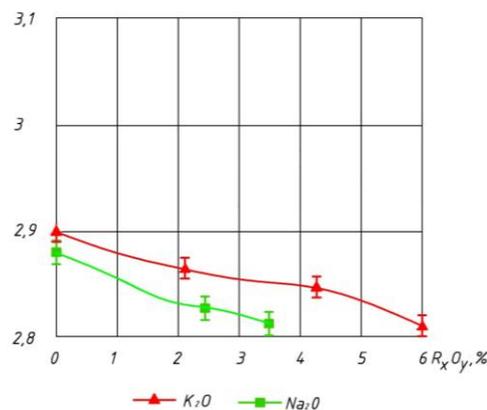


Fig. 2. Dependence of the density of surfacing slag of the  $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$  system on the  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  content

As can be seen from fig. 2 oxides of sodium and potassium significantly reduce the density of slag.

To measure the viscosity of the slag used methods of viscometry. The method is based on the law of fluid flow, which is 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 content of  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  in the initial slag at  $T = 1700 \text{ K}$  is shown in Fig. 3.

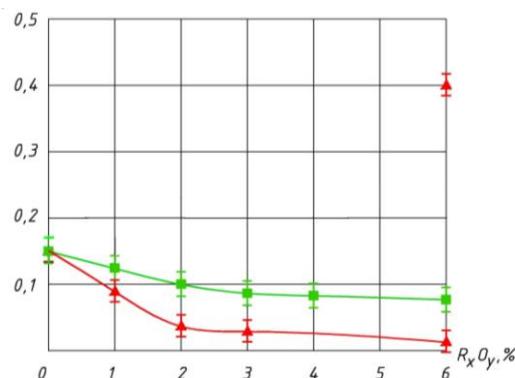


Fig. 3. Dependence of the slag viscosity of the  $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$  system on the  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  content

Potassium and sodium oxides reduce the viscosity of molten slag, and with an increase in the amount of  $\text{K}_2\text{O}$ , the viscosity of the slag decreases more than with the same amount of  $\text{Na}_2\text{O}$ . All this is explained by the properties of anions and cations, which are formed during the dissociation of these oxides.

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.:

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

The influence of the content of  $Na_2O$  and  $K_2O$  in the slag on the opacity of the slag is shown in Fig. 4.

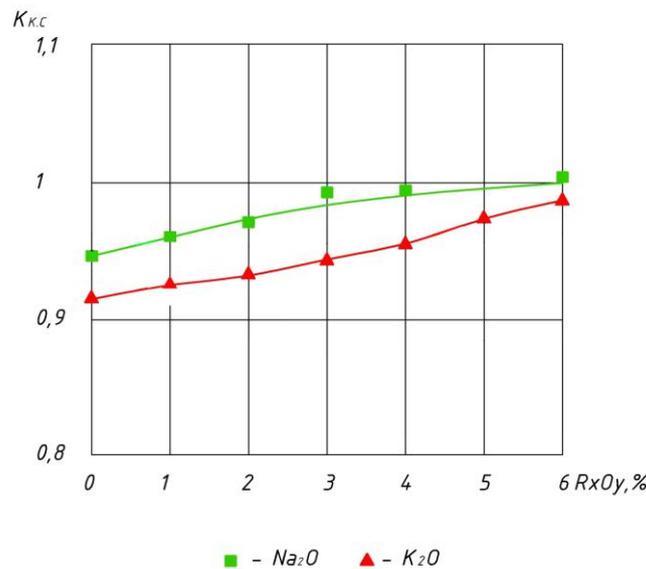


Fig. 4. Dependence of the covering power of the  $CaO-SiO_2-Al_2O_3$  system on  $Na_2O$  and  $K_2O$  content

As can be seen from fig. 4, with an increase in the content of  $Na_2O$  and  $K_2O$ , the covering power of slag increases.

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 above  $450^\circ C$ , 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  $60^\circ$ . 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  $Na_2O$  and  $K_2O$  oxides in it is presented in Fig. 5.

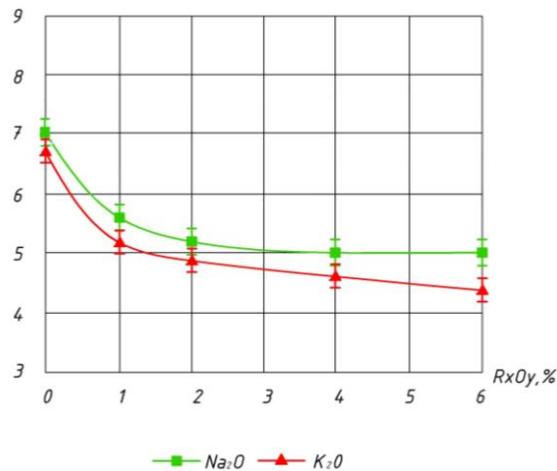


Fig. 5. Dependence of the slag crust separability  $m^2/MJ$  on the  $Na_2O$  and  $K_2O$  content in the slag of the  $CaO-SiO_2-Al_2O_3$  system

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. As can be seen from fig. 5, with an increase in the content of  $Na_2O$  and  $K_2O$ , the separability of the slag crust decreases.

#### IV. CONCLUSION AND FUTURE WORK

Electrodes for wear-resistant surfacing were developed, containing the following components, wt.%: Marble - 26-28; pegmatite - 14-16, graphite - 9-11, ferrosilicon manganese - 10-12; ferrochrome 25-27; ferrotitanium - 10-12. The introduction of  $Na_2O$  and  $K_2O$  into the  $CaO-SiO_2-Al_2O_3$  system reduces the density, viscosity of the slag, worsens the separability of the slag crust, but increases the hiding power of the slag.

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**AUTHOR'S BIOGRAPHY**

	<p style="text-align: center;"><b>Sadikov Jaxongir Nasidjanovich ,</b></p> <p>Has more than 10 published scientific works in the form of articles, journals, theses and tutorials. Currently works as researcher at the department of “Technological machines and equipment” in Tashkent State Technical University.</p>
	<p style="text-align: center;"><b>Saidakhmatov Asrorhon Saidakbar ugli,</b></p> <p>Currently studying in the magistrate of the department of “Technological machines and equipment” in Tashkent State Technical University.</p>
	<p style="text-align: center;"><b>Ermatorov Ziyadulla Dosmatovich ,</b></p> <p>Doctor of Philosophy in Technical science, Associate professor Has more than 70 published scientific works in the form of articles, journals, theses and tutorials. Currently works at the department of “Technological machines and equipment” in Tashkent State Technical University.</p>