



ISSN: 2350-0328

**International Journal of Advanced Research in Science,
Engineering and Technology**

Vol. 9, Issue 9 , September 2022

Study interaction of molten metal and slag in arc welding

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ABSTRACT: This article provides a study of the interaction of molten metal and slag during arc welding and surfacing of low-carbon and low-alloy steels

KEY WORDS: arc welding, flux, low alloy steel, slag, oxide

I. INTRODUCTION

Slags are melts of nonmetallic compounds—oxides, halides, sulfides, etc.—both free and complex compounds. Most slags are insoluble in metals. In the molten state, metals and slags are immiscible liquids, separated by specific gravity (density) [1].

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

II. LITERATURE SURVEY

At present, there are two theories describing the structure of liquid slags, molecular and ionic [2].

According to the molecular theory, slags are systems of free and chemically bound non-metallic compounds (oxides, etc.), between which there is a mobile chemical equilibrium. In this case, only free compounds, in particular oxides, interact with the metal. The presence of ions in slags is not denied by molecular theory, but their influence in the general scheme of interaction between slags and metal is neglected [3].

According to the later ionic theory of slags, slags have an ionic structure, i.e., each cation is surrounded by anions, and an anion by cations. The forces that determine the structure of slags are of electrostatic origin. Cations are positively charged metal particles (K^+ , Na^+ , Ca^{+2} , Mg^{+2} , Fe^{+2} , Mn^{+2} , Mn^{+3}). Anions are negatively charged particles (F^- , O^{2-} , SiO_4^{4-} , AlO_4^{5-} , etc.) [4]. The ionic structure of molten slags is confirmed by their electrical conductivity, as well as an improvement in electrical conductivity with increasing temperature [5].

The ionic theory of slags makes it possible to explain a number of important phenomena that are difficult or impossible to explain from the point of view of molecular theory. However, its insufficient development, in particular in relation to welding slags, determines the leading position of molecular theory for explaining the interaction of metal and slag [6].



III. METODOLOGY

The chemical effect of molten slag on the metal is largely determined by the ratio of basic, acidic and amphoteric oxides in its composition.

Acid oxides, often found in welding slags, are SiO₂, TiO₂ and, less commonly, P₂O₅.

The main oxides in welding slags are Na₂O, K₂O, CaO, MgO, MnO, FeO, NiO, etc.

Of the amphoteric oxides, Al₂O₃ and B₂O₃ are most often used in welding slags.

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

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

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

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

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

Slags change their viscosity in a fairly wide range of temperatures, and therefore their melting point is, as it were, conditional. Depending on the nature of the change in viscosity with temperature, slags are "long" and "short". Short slags are mainly basic. They harden in a small temperature range; upon cooling, they quickly pass from a state of significant liquid mobility to the formation of a slag crust. Acid slags, as a rule, gradually change their viscosity, gradually thicken and have a glassy structure.

During the welding process, the slags must have a melting (solidification) temperature not too different from the melting temperature of the metal. If the melting temperature of the slag is much lower than the melting temperature of the metal, then it will spread strongly along the heated edges, weakly protecting the weld pool. At very high melting temperatures, slag collects only in the hottest zone. The edges of the tub are bare. Usually, such a ratio of the melting points of metal and slag is favorable when the slag melts at a temperature somewhat lower than the melting point of the metal. For example, when welding steels, this difference can be 200 + 350 ° C.

The viscosity of slags at the melting temperature of the metal, as a rule, is much higher than the viscosity of the metal, but it should not be very high. Experimental studies show that when welding steels (metal viscosity coefficient 0,01-0,02 poise), slags with a viscosity of 0.8+3.0 poise at a temperature of ~1500°C have satisfactory characteristics.

Slags with a viscosity of 10 poise or more are unsuitable for welding purposes. Due to the fact that the high viscosity of slags is undesirable, various additives are added to them, in particular fluorspar, titanium dioxide. Such additives can impart other properties to the slag.

A very important characteristic of welding slags is the interfacial tension at the slag-metal interface. It determines the effect of slag on the formation of the outer surface of welds, and also affects the separation of slag and metal mixed in the bath.

An important characteristic of slags is also their density and gas permeability. At a lower density (more precisely, at a greater difference in the densities of liquid metal and slag), slag is more easily removed from the weld pool, floating to its surface.

The gas permeability of basic slags, as a rule, is greater than that of acidic ones. This is a negative characteristic in relation to the protection of the metal from the gaseous atmosphere, but it contributes to a better removal through the slag of gases that have floated to the surface of the crystallizing bath when the temperature of the metal is lowered.

In general, slags, in particular welding slags, are subject to such a set of requirements that makes it necessary to make a rather complicated choice of their compositions, which provide the necessary for welding various metals and alloys.

Welding slags are obtained by:

- 1) melting (in some cases after a preliminary decomposition) of mechanical mixtures of various slag-forming materials interconnected by binders;
- 2) melting of slags previously obtained by melting from various materials;
- 3) melting powder mixtures.

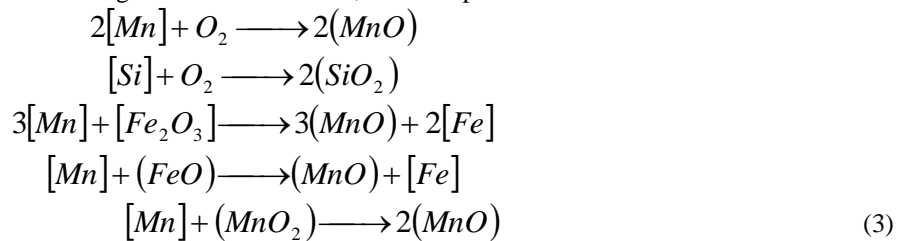
In the process of welding, the interaction of these slag melts with the metal to some extent changes their composition and the final slag may differ from the initial one.

In connection with the heating of the welding wire and flux in the part approaching the end of the electrode, a number of reactions begin to occur even before it melts in the fluxes. Such reactions include, for example, the decomposition of organic constituents. At temperatures above 350-500°C, a number of thermally unstable higher oxides dissociate:



At higher temperatures (usually above 600°C), carbonates also dissociate.

In this case, both direct oxidation of various elements present in the coating in an unoxidized state (usually in the composition of ferroalloys) and various exchange reactions can occur, for example:



Near the end of the welding wire, the molten metal, flux and the resulting gas phase interact intensively with each other. In this case, the liquid metal can be oxidized by oxygen and carbon dioxide released from the flux, and also as a result of direct interaction with slag oxides formed during the melting of the coating. At the same time, the dissolution of unoxidized elements from the flux in the metal (iron, manganese, silicon from ferroalloys, products of easily reduced coating oxides, for example, NiO, Cu₂O, etc.) occurs.

As a result, the composition of the metal droplets changes with respect to the initial composition of the welding wire. These interaction reactions continue during the transition of the metal through the arc gap into the weld pool located on the workpiece being welded.

In the weld pool, the molten base metal and the metal coming from the electrode in the form of drops are mixed. Due to the fact that the drops enter the pool at a sufficiently high speed, some of them sink in the weld pool. In this regard, not only on the surface, but also in the internal volumes of the bath, molten slag and gases enter in the form of bubbles present in the drops of the deposited metal.

As the melt moves from the hottest “head” part of the bath to the colder “tail” part, the metal and the slag insoluble in it are separated in the bath and gas bubbles emerge. In this case, complex compounds of various slag components are formed, coarsening and coagulation of slag precipitates and their removal to the surface of the bath due to floating and “pushing out” of growing crystals by the front. Such washing of metal with slag in some cases is useful for its purification from harmful impurities.

A number of reactions also take place in the tail section of the bath, mainly between ferrous oxide and elements with a greater affinity for oxygen than iron. In this case, various oxides can be formed, for example, MnO and SiO₂, etc. Due to the very essence of the reaction between iron oxide dissolved in the metal and deoxidizing elements, the resulting new oxides are dispersed and are poorly removed from the bath if they do not enlarge.

IV. CONCLUSION

Scientifically based selection of the composition of slag and deoxidizers in arc welding allows to deoxidize the liquid metal to the required extent and obtain deoxidized weld metal, despite the short duration of metal processing under welding conditions and the unattainability of equilibrium in the interaction of metal with the environment during temperature decrease and weld pool crystallization

ACKNOWLEDGMENT:

This work was carried out within the framework of a business agreement with the Tashkent Pipe Plant named after V.L. Galperin No. 1/2022 on the topic: "Research and development of the composition of ceramic fluxes for automatic arc



ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology




Vol. 9, Issue 9 , September 2022

welding of low-carbon and low-alloy steels", No. 3/21 on the topic: "Development of the coating composition and technology for the production of electrodes for surfacing a layer of low-alloy steel".

REFERENCES

- [1] Dunyashin N.S. Development of a multicomponent coating of electrodes for manual arc welding of low-carbon and low-alloy steels. - T.: Fan va texnologiya, 2019 - 160 p.
- [2] Pokhodnya I.K. Metallurgy of arc welding of structural steels and welding materials // Welding production. - 2009. - No. 4. - P. 3-15.
- [3] Ermatov Z.D. Development of scientific bases for creating multicomponent electrode coatings for manual arc surfacing. Monograph. T: Fan va texnologiyalar nashriyot-matbaa uyi, 2021 – 140p.
- [4] Kuznetsov M.A. Nanotechnologies and nanomaterials in welding production (Review) / M.A. Kuznetsov, E.A. Zernin // Welding production. - 2010. - No. 12. - P.23-26.
- [5] Khudoyov S.S., Dunyashin N.S. Mineral resources of the Republic of Uzbekistan for the production of fused fluxes for automatic arc welding // International Journal of Advanced Research in Science, Engineering and Technology - India, 2020. - No. Vol.7, Issue 5, - P. 13598-13601 .
- [6] Verkhoturov A.D. Methodology for the creation of welding consumables: monograph - Khabarovsk: Publishing House of the Far Eastern State University of Railway Engineering, 2009. - 128 p.

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ISSN: 2350-0328

**International Journal of Advanced Research in Science,
Engineering and Technology**

Vol. 9, Issue 9 , September 2022

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