ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 12 , December 2022

Study of metal refining in electric arc welding

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ABSTRACT: This article provides a study of the refining process in arc welding and surfacing of low-carbon and low-alloy steels.

KEY WORDS: arc welding, flux, low alloy steel, mild steel, slag.

I. INTRODUCTION

The refining of the weld metal consists in its purification from harmful impurities, for steel, mainly sulfur and phosphorus. The negative effect of sulfur impurities is the formation of hot cracks in the weld metal. Their appearance is associated with the formation of iron sulfide with a melting point below the melting point of steel. In addition, with molten iron, iron sulfide forms an even more fusible eutectic. Thus, during the crystallization of the weld metal, eutectic inclusions are in a liquid state for a long time, preventing the formation of bonds between metal grains.

II. LITERATURE SURVEY

To obtain a quality weld, the sulfur content must be reduced to a minimum. To this end, the sulfur content in all components of the welding electrodes, as well as in the base metal, is limited. Directly in the process of welding, a special refining treatment of the melt is carried out, which consists in the transfer of sulfur in the form of compounds insoluble in the base metal into slag [1].
The degree of harmful effect of segregating impurities of sulfur and phosphorus on the low-temperature brittleness of the weld metal mainly depends not on their total content, but on the degree of phosphorus segregation in the grain structure of the weld metal, size, shape and distribution of sulfide inclusions [2].
Based on thermodynamic calculations, various methods for removing sulfur from liquid iron are analyzed [3]. It has been determined that this is most effectively carried out using slags with a high sulfide capacity. Studies of the kinetics of the transition of sulfur from metal to slag have shown that during welding it is possible to create such conditions under which deep desulfurization of the metal is possible even for a short period of time comparable to the duration of the existence of the weld pool. The presence of phosphorus impurities in the composition of the electrode coatings has an effect similar to the effect of sulfur, that is, it increases the tendency of the deposited metal to develop hot cracks. Phosphorus, unlike sulfur, not only forms low-melting iron phosphides Fe_2P, Fe_3P and phosphide eutectics, but also dissolves in iron and can be dissolved in the weld metal [4].

ISSN: 2350-0328
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The appearance of such inclusions leads to the formation of hot cracks. The possibility of their formation is the higher, the higher the concentration of phosphorus and the lower its solubility in the metal. Thus, the solubility of phosphorus in the crystal lattice of austenite is less than in the crystal lattice of ferrite, which leads to an increase in the possibility of hot cracking when welding high-alloy steels [5].
Reducing the concentration of phosphorus is achieved by stringent technical conditions for the content of this element in the components of welding consumables, as well as by binding it during welding into slagging complex compounds. It should also be noted that when welding carbon and low alloy steels, the specifications for phosphorus content are not as stringent, since normal concentrations of phosphorus in this case do not cause hot cracks [6].

III. METODOLOGY

An important metallurgical operation is metal refining, that is, purification from harmful impurities; in particular for iron-based alloys - from sulfur and phosphorus.
The sources of sulfur and phosphorus entering the metal during welding are:
a) melting base and additional metals;
b) slags (fluxes, coatings).
Sulfur is a harmful impurity that causes red brittleness of steels and significantly increases their tendency to form hot cracks during casting and welding.
Such an effect of sulfur on the properties of the metal at high temperatures is determined by the fact that it forms compounds with iron and low-melting eutectics, which weaken the bonds between individual crystallites and grains in a wide temperature range.
So, iron sulfide FeS has a melting point of 1195° C. The eutectic of this sulfide with iron melts at 985° C. The eutectic 2FeO • SiO2 + FeS also has a low temperature.
The more sulfur in the metal, the more fusible eutectics appear, the stronger the red brittleness of steel. Therefore, the sulfur content is usually limited to a certain amount that is acceptable in steel in general and in weld metal in particular.
The presence of sulfur in alloyed steels is very harmful, especially at elevated concentrations - nickel in them, as even more fusible ones can be formed - based on NiS sulfide with a melting point of 644° C. Other elements, in particular in unalloyed steels - carbon.
In this regard, in order to improve the properties of steels and weld metal, the sulfur content is sought to be reduced to an acceptable minimum. To do this, when welding, the upper limit of the sulfur content is limited mainly in filler metals, as well as in coatings. In addition, various methods are used to transfer sulfur from metal to slag or bind it into compounds that do not give low-melting components in the metal.
To do this, when welding steels, they use:
a) binding of sulfur to manganese sulfide MnS (T_{melt} = 1610° C);
b) removal of sulfur into the slag by the action of MnO and CaO. The binding of sulfur in MnS occurs according to the reaction

$$[FeS]+[Mn]\longleftrightarrow[MnS]+[Fe] \quad (1)$$

with equilibrium constant

$$K=\frac{[MnS]\cdot[Fe]}{[FeS]\cdot[Mn]} \quad (2)$$

The concentration of FeS in the metal decreases with an increase in the concentration of Mn in it. However, the reaction in the direction of sulfur binding to MnS develops only with a decrease in the temperature of the metal, when the reactions proceed more sluggishly. In this regard, even with a sufficiently large amount of Mn in the metal, a significant part of the sulfur can remain bound in the form of FeS sulfide. The decrease in FeS in liquid metal is achieved by the action of slags containing MnO and CaO:

$$[FeS]+(MnO)\longleftrightarrow(MnS)+[FeO]$$
$$[FeS]+(Caa)\longleftrightarrow(CaS)+[FeO] \quad (3)$$

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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The decrease in the concentration of FeS in the metal is facilitated by the better deoxidation of the metal (decrease in [FeO]) in an increase in MnO and CaO in slags. In this regard, the main slags are more favorable in terms of their effect on reducing the sulfur concentration in the metal.

In a number of cases, for desulfurization, the binding of sulfur into volatile compounds (for example, $A1_2S_3$ and with boiling points of 1550 and 940° C, respectively) turns out to be useful.

Phosphorus in iron alloys is also a very harmful impurity. It degrades the mechanical properties of steels, causing cold brittleness in low alloy and carbon steels and an increased tendency to hot cracking in austenitic grade steels.

Reducing the amount of phosphorus in the weld metal is achieved by limiting its content in the main and additional metals, as well as in coatings, flux-slags and the gas phase interacting with the metal.

The removal of phosphorus from a metal is based on its oxidation and the binding of phosphorus anhydride into slagging complex compounds. The oxidation of phosphorus, which forms Fe_2P and Fe_3P phosphides with iron, is carried out according to the reactions [7]:

$$2Fe_2P + 5FeO = P_2O_5 + 9Fe$$
$$2Fe_3P + 5FeO = P_2O_5 + 11Fe \quad (4)$$

The acidic oxide P_2O_5 forms complex compounds with basic oxides. According to the increasing strength of affinity to it, the basic oxides can be arranged in the following row: FeO, MnO, MgO, CaO.

The binding of phosphoric anhydride occurs most actively through the reactions:

$$3CaO + P_2O_5 \longleftrightarrow (CaO)_3 \cdot P_2O_5 \quad (5)$$

P_2O_5 binding via MnO occurs less actively. A decrease in the phosphorus content in the metal is facilitated by an increase in the content of free FeO and CaO in the slag and a decrease in the amount of CaO associated with P_2O_5.

In acidic slags, FeO and CaO will be combined into complex compounds with SiO_2 and TiO_2, so their free concentrations will be lower and the removal of phosphorus from the metal into the slag is difficult. Basic slags are more favorable for dephosphorization processes. In basic slags, the concentration of $Ca_3P_2O_8$ is reduced by diluting the slag with appropriate neutral additives, usually fluorspar. Such an additive is often used to improve a number of physical properties of slags, increasing their liquid mobility, and hence the possibility of participating in a larger relative volume of it in reactions with metal.

The process of dephosphorization of the metal during its treatment with slag will occur more actively with a decrease in temperature.

Similar, but affecting to a lesser extent the dephosphorization process, are the reactions of P_2O_5 with MnO. In this case, it should be taken into account that phosphorus is an accompanying impurity of manganese and an increase in manganese compounds in coatings and fluxes will be accompanied by an increase in the phosphorus content in the slag, and therefore in the metal.

The presence of a significant amount of non-metallic inclusions in the composition of the weld metal adversely affects the mechanical and technological parameters of welded joints, especially the cold resistance and tendency to brittle fracture of the weld metal. Stress concentration occurs near non-metallic inclusions, resulting in the formation of areas of concentrated plastic deformation. With an increase in the total number of such inclusions, the number of simultaneously occurring cracks increases and their coalescence is facilitated.

The degree of participation of non-metallic inclusions in the processes of ductile and brittle fracture is different. The influence of inclusions on the ductile fracture of the weld metal is manifested in the mechanism of formation and coalescence of micropores. The stress state around the inclusions is exacerbated by the thermal stresses existing in the metal. Brittle fractures are associated with the presence of internal defects of critical size. Contamination with non-metallic inclusions is a determining factor for the resistance of a metal to brittle fracture.

The cold resistance of the weld metal is ensured if, at the operating temperature of the welded structures, the destruction occurs according to the viscous mechanism, that is, through the growth and merging of voids that originate on non-metallic inclusions. The higher the distance between non-metallic inclusions, the more energy-consuming the process of crack formation in the weld metal becomes.

IV.CONCLUSION

The influence of sulfur and phosphorus on the formation of hot cracks is mutually enhanced, since the places of segregation of the compounds of these elements in the weld metal coincide. It is easier to achieve a low sulfur content in the flux and weld metal than a low phosphorus content, since during the smelting and welding process, sulfur is oxidized and its content decreases. It is practically impossible to reduce the phosphorus content in the flux itself and in the deposited metal; therefore, the use of a pure flux is a necessary condition for obtaining welds with high technological characteristics.
The fracture resistance of the weld metal is significantly affected by the morphology of non-metallic inclusions. Thus, plastic, well-deformable rounded inclusions, in contrast to brittle acute-angled inclusions, have a temperature coefficient of linear expansion and a modulus of normal elasticity that do not differ significantly from the metal, which leads to a decrease in thermal stresses inside the weld metal.

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 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».

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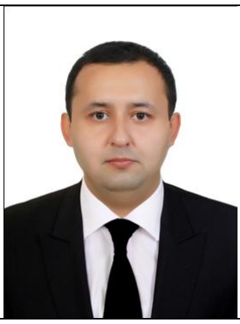

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ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 12 , December 2022

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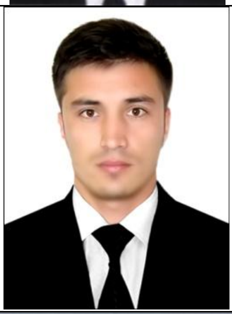	**Saidakhmatov Asrorhon Saidakbar ugli**, Assistant, was born November 16, 1993 year in Tashkent city, Republic of Uzbekistan. Has more than 15 published scientific works in the form of articles, journals, theses and tutorials. Currently works at the department of "Technological machines and equipment" in Tashkent State Technical University.
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