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Investigation of the metal deoxidation process in the development of the composition of ceramic fluxes for automatic arc welding of low-carbon and low-alloy steels

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ABSTRACT: The article presents a study of the metal deoxidation process in the development of the composition of ceramic fluxes for automatic arc welding of low-carbon and low-alloy steels.

KEY WORDS: automatic arc welding, flux, low alloy steel, oxygen, oxidation, deoxidation

I. INTRODUCTION

Metal oxidation is one of the characteristic processes occurring in automatic arc welding. Sources of metal oxidation are: oxides present on the molten edges of the base and filler metal, oxides present in the slag and dissolving in the metal, chemically active slags that release oxygen to the metal as a result of exchange redox reactions, gaseous free oxygen - the presence of complex oxygen-containing gases (carbon dioxide and water vapor) capable of releasing oxygen during decomposition. In automatic arc welding of alloys, oxidation of the base of the alloy and impurities occurs, the degree and probability of oxidation of which depends on the temperature conditions and the concentration of impurities in the solution and is determined by their affinity for oxygen.

II. LITERATURE SURVEY

The content of deoxidizing elements in the liquid metal determines the oxidation of the metal in the welding zone. Elements with a high affinity for oxygen at their sufficient concentration in the metal solvent are deoxidizers [1].

Mn already at concentrations of 0.1% at 1540° C has a lower dissociation elasticity of the oxide than oxygen-saturated iron and can act as a deoxidizer that takes oxygen from the iron base. Cr especially at high temperatures acts weaker than Mn. Nickel, when it is an alloying impurity, cannot be a deoxidizer for iron, and its burnout (oxidation) during welding of iron-based alloys should be insignificant [2].

Si, Ti, Al are stronger iron deoxidizers. As the temperature rises, carbon becomes the most powerful deoxidizer [3].

Based on the known temperature dependences of the equilibrium constants of various reactions, the equilibrium oxygen concentrations can be calculated in the presence of various concentrations of deoxidizers in the molten iron. Carbon monoxide deoxidation products are carbon monoxide gases. In this case, the tail of the weld pool is bubbling. In this case, the bubbles, which did not have time to leave the solidifying metal, form spherical or round pores in the metal filled with gas, which reduce the strength properties of the metal [4].

With an increase in the oxygen content, the properties of the metal deteriorate. Since welding usually creates a favorable environment for increasing the oxygen concentration in the molten metal, one of the most important processes is metal deoxidation [5].

Deoxidation is the process of removing oxygen from the liquid metal dispersed in the form of chemical compounds with other elements and dissolved in the base of the alloy [6].

The oxygen content in the metal can be reduced by the action of slags or deoxidizers. Deoxidizing elements are elements that, at the process temperature and their corresponding concentration, have a greater affinity for oxygen than the base of the alloy and its alloying components. As a result of interaction with the oxidized metal, deoxidizers are able to form gaseous, as well as liquid and solid condensed reaction products [1, 2].

III. METODOLOGY

When welding, the oxidation process of various metals is different. Some metals (Fe, Cu, Ni, Ti) have the ability to dissolve a certain amount of oxygen. Moreover, the solubility of oxygen increases with increasing temperature, and is much higher in the liquid phase than in the solid.

Metal oxidation with gaseous free oxygen occurs according to the following reaction:

$$nMe + O_2 = mMe_{n/m}O_{2/m} \qquad (1).$$

If the metal and oxide are condensed solid or liquid phases, the constant of this oxidation reaction is determined by the partial oxygen pressure P_{O_2}, corresponding at a given temperature and pressure of the oxide dissociation elasticity.

Under specific external conditions under welding conditions at different temperatures, the possibility of oxidation or reduction of any oxide as a result of its interaction with the gas phase containing free oxygen is determined by comparing P_{O_2} and the partial pressure of free oxygen in the gas phase, which we denote $\{P_{O_2}\}$. If the pressure $\{P_{O_2}\}$ is greater than the dissociation elasticity of the oxide P_{O_2}, then oxidation will proceed; for $\{P_{O_2}\} < P_{O_2}$ - recovery.

When $\{P_{O_2}\} = P_{O_2}$, neither oxidation nor reduction occurs, which meets the equilibrium conditions. This case is not typical for welding as a final state. The elasticity of dissociation of oxides in solution p'_{O_2} differs from the elasticity of dissociation of free oxides P_{O_2}. In this case, $p'_{O_2} = p_{O_2} a^m_{ок}$, where $a^m_{ок}$ is the degree of saturation of the metal solution with oxide.

In air containing over 20% oxygen, the latter is a strong oxidizing agent for iron in welding conditions $\{P_{O_2}\} > P_{O_2}$).

The equilibrium pressure P_{O_2} decreases with a decrease in oxygen in the solution and it is held by the metal more strongly.

If any metal is diluted with another metallic solvent (Mn is dissolved in Fe), that is, its concentration is less than unity, and the oxide is also in solution, then the dissociation elasticity P_{O_2} of such an oxide is:

$$p''_{O_2} = p_{O_2} \frac{a^m_{ок}}{a^n_{Me}} \left(\frac{M_{Me}}{M_{solvent}} \right)^n \qquad (2)$$

where a_{Me} is the degree of saturation of the solvent with the metal;

M_{Me} and $M_{solvent}$ are the molecular weights of the metal and solvent.

With a decrease in a_{Me}, the dissociation elasticity of the p''_{O_2} oxide increases significantly; therefore, it is almost impossible to completely oxidize such a metal additive in a solvent.

In the melting zone, metal oxidation by surface oxides is carried out by remelting the oxides on the filler metal surface and on the edges of the welded products. The oxidation state of the metal with surface oxides increases the long-term storage of ceramic fluxes, the absence of preliminary cleaning of the welded metal and welding wire.
It occurs in connection with the redistribution of oxides between the slag and the metal, the oxidation of the metal by oxides that dissolve in the metal and are in the slag. Such a free oxide, under certain conditions, will tend to a distribution between the metal and slag phases, determined by the distribution constant $L_{MeO} = \frac{(MeO)}{[MeO]}$ changing with temperature, where (MeO) and $[MeO]$ are, respectively, the concentration of these oxides in the slag and metal. For FeO, this distribution constant depends on the temperature $\lg\frac{1}{L_{MeO}} = \lg\frac{[MeO]}{(MeO)} = -\frac{6300}{T} + 1{,}386$; from T_{pl} to 2500° C increases from 0,011 to 0,125.

Oxidation with oxygen-reactive slags in connection with exchange reactions is described by the equation:

$$Me^{''}_xO_y + yMe^{'} = yMe^{'}O + xMe^{''} \tag{3}$$

Silicon and manganese reduction processes in the presence of significant amounts of SiO_2 and MnO in the slag during welding of carbon steels proceed according to this scheme. Oxidation of slag by silica and manganese oxide can be very intense if the metal contains elements with a stronger affinity for oxygen. With a sufficiently high content of SiO_2 and MnO in the slag, when welding steels containing elements with a high affinity for oxygen (aluminum, titanium), their burnout can occur almost completely.

The deoxidation reaction in general and the constant of this reaction:

$$[Me_xO_y] + z[Ra] = x[Me] + Ra_zO_y\,, \tag{4}$$

where $[Me_xO_y]$ is the concentration of the oxide of the base of the alloy [Me];

Ra — designation of the deoxidizer element;

$$K = \frac{[Me_xO_y][Ra]^z}{[Me]^x[Ra_zO_y]} \tag{5}$$

It is necessary to increase the amount of deoxidizing agent to reduce the content of oxygen dissolved in the metal.

Metal deoxidation by the action of slags is a process in which oxides are transferred from metal to slag by physical dissolution of oxides in the slag or chemical action of the components of the slag on oxides, the content of which should be reduced in the metal.

The liquid metal contains an oxide such as Me_nO_m. If this oxide is contained in a free state in the slag, the distribution constant, which depends on temperature and pressure, determines the nature of the redistribution of Me_nO_m between the metal and the slag:

$$L_{(Me_nO_m)} = \frac{(Me_nO_m)}{[Me_nO_m]} \tag{6}$$

The concentration of free oxide (Me_nO_m) in the slag will decrease if any compounds that do not react (react weakly) with the metal are added to the slag. Me_nO_m will begin to transform into slag, reducing the concentration of this oxide in the metal, i.e., reducing its oxidation in accordance with the distribution constant. As a result of this process, oxide Me_nO_m diffuses through a metal layer of a certain thickness into the slag.

If Me_nO_m in the slag is bound into complex compounds, a similar process will take place. Due to the fact that the distribution coefficient is influenced only by the concentration of free oxide (Me_nO_m), not bound into complex compounds, the content of [Me_nO_m] will decrease. Me_nO_m will move from metal to slag by diffusion.

The general laws of such a process can be determined by the following reaction having the corresponding equilibrium constant:

$$Me^{'}O + Me^{''}O_2 = Me^{'}O \cdot Me^{''}O_2 \tag{7}$$

$$K = \frac{\left(Me^{'}O\right)\left(Me^{''}O_2\right)}{\left(Me^{'}O \cdot Me^{''}O_2\right)} \tag{8}$$

where $Me^{'}O$ is the main oxide of the metal, representing, for example, the base of the alloy;

$Me^{''}O_2$ is an acidic oxide that forms complex compounds with the basic oxide $Me^{'}O$, which are insoluble in the metal $Me^{'}$.

Therefore, the content of oxygen dissolved in the form of oxide $Me^{'}O$ in the metal decreases with an increase in the content of free oxide $Me^{''}O_2$ in the slag, and the resistance of complex compounds $\left(Me^{'}O \cdot Me^{''}O_2\right)$, determined by their concentration in the welding slag.

Therefore, when deoxidizing the weld pool of an iron-based alloy, an acidic type oxide (TiO_2 or SiO_2) is required to bond the basic FeO oxide in the slag into complex compounds. With an increase in the concentration of free oxide TiO_2 or SiO_2, the degree of metal deoxidation increases, giving oxides of the main type.

However, with a significant increase in the SiO_2 content, the technological properties of acidic slags decrease, they become viscous and long, and their activity also decreases. In this regard, the combined effect of slags and deoxidizers increases their technological properties, for example, manganese is used for acidic slags. In the course of this reaction, iron is restored from nitrous oxide:

$$(FeO \cdot SiO_2) + [Mn] = (MnO \cdot SiO_2) + [Fe], \tag{9}$$

In welding slags with a significant content of oxides of the main type, in which acidic oxides are bound into complex compounds, during automatic arc welding under a layer of ceramic flux of low-carbon and low-alloy steels, which form basic oxides, the deoxidation processes by the action of these slags cannot proceed. Therefore, it is necessary to use deoxidizers, which are introduced in a free state in the form of ferroalloys.

IV.CONCLUSION

Scientifically grounded selection of the composition of slag and deoxidizers in automatic arc welding under a layer of ceramic flux of low-carbon and low-alloy steels makes it possible to deoxidize liquid metal to the required degree and obtain a deoxidized weld metal, despite the short duration of metal processing under welding conditions and the inaccessibility of equilibrium in the interaction of metal with the environment during a decrease in temperature and crystallization of the weld pool.

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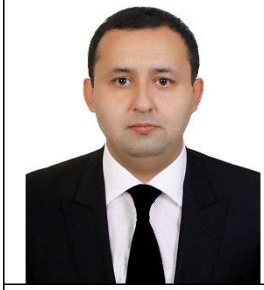	**Khudoyorov Sardor Sadullaevich** , Associate Professor, Doctor of Philosophy in Technical Sciences (PhD), was born March 7, 1989 year in Tashkent city, Republic of Uzbekistan. Has more than 30 published scientific works in the form of articles, journals, theses and tutorials. Currently works at the department of “Technological machines and equipment” in Tashkent State Technical University.
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