Study interaction of metal with complex gases containing oxygen in manual arc welding

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ABSTRACT: This article presents a study of the interaction of molten metal with complex gases containing oxygen in manual arc welding in arc welding and surfacing of low-carbon and low-alloy steels

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

I.   INTRODUCTION

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, and others.

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 density [1].

II.   LITERATURE SURVEY

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

According to the ionic theory of slags, slags have an ionic structure, that is, 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 particles of metals (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} other) [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].

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].

III. METODOLOGY

Metal oxidation is one of the characteristic processes occurring during manual arc welding.

The sources of metal oxidation are:

a) oxides present on the molten edges of the base and electrode metal;

b) oxides present in the slag and dissolving in the metal;

c) chemically active slags that donate oxygen to the metal as a result of exchange redox reactions;

d) gaseous free oxygen - the presence of complex oxygen-containing gases (carbon dioxide and water vapor), capable of releasing oxygen during decomposition).

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.

Oxidation of metal by gaseous free oxygen occurs according to the following reaction:

$$nMe + O_2 = mMe_{n/m}O_{2/m} \qquad (1).$$
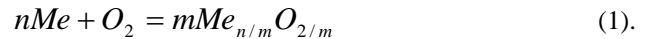
When welding alloys, the alloy base and impurities are oxidized, the degree and probability of oxidation of which depends on the temperature conditions and concentrations of impurities in the solution and is determined by their affinity for oxygen.

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

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 a gas phase containing free oxygen is determined by comparing P_{O_2} and partial pressure of free oxygen in the gas phase, which we denote { P_{O_2} }. If the pressure { P_{O_2} } more elasticity of oxide dissociation P_{O_2}, then oxidation will proceed; at { P_{O_2} }< P_{O_2} - recovery.

When { P_{O_2} }= P_{O_2} neither oxidation nor reduction occurs, which corresponds to equilibrium conditions. This case is not typical for welding as a final state. Elasticity of dissociation of oxides in solution p_{O_2}' differs from the elasticity of dissociation of free oxides P_{O_2}. Wherein $p_{O_2}' = p_{O_2} a_{ок}^m$, where $a_{ок}^m$ - degree of saturation of a metal solution with oxide [22].

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 decreasing 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:

$$p_{O_2}'' = p_{O_2} \frac{a_{ок}^m}{a_{Me}^n} \left(\frac{M_{Me}}{M_{раств}} \right)^n \qquad (2)$$

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

M_{me} and M_{solv} - molecular weights of metal and solvent [22].

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

In the melting zone, the oxidation of metal by surface oxides is carried out by remelting oxides located on the surface of the electrode metal and on the edges of the workpieces to be welded. The degree of metal oxidation by surface oxides increases the long-term storage of some types of coated electrodes, the absence of preliminary cleaning of the welded metal and electrode wire.

Occurring in connection with the redistribution of oxides between the slag and metal 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 distribute between the metal and slag phases, determined by the temperature-changing distribution constant $L_{MeO} = \dfrac{(MeO)}{[MeO]}$, where (MeO) and $[MeO]$ are, respectively, the concentrations of these oxides in the slag and metal.

For FeO, this distribution constant depends on temperature $\lg \dfrac{1}{L_{MeO}} = \lg \dfrac{[MeO]}{(MeO)} = -\dfrac{6300}{T} + 1{,}386$; from T_{melt} to $2500°$ C it increases from 0.011 to 0.125 [24].

Oxidation occurring in connection with exchange reactions by slags chemically active with respect to oxygen is described by the equation:

$$Me_x^{''}O_y + yMe^{'} = yMe^{'}O + xMe^{''} \qquad (3)$$
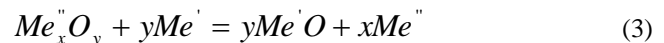
Silicon and manganese reduction processes in the presence of significant amounts of SiO_2 and MnO in the slag during welding of carbon steels occur according to this scheme. Oxidation of slag by silica and manganese oxide can be very intense if there are elements in the metal with a stronger affinity 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 content in the liquid metal of elements - deoxidizers, the certainty of the oxidation of the metal in the welding zone. Elements with a high affinity for oxygen at their sufficient concentration in the solvent metal are deoxidizers.

As follows from these dependences, even at concentrations $0{,}1\%$ at 1540°C, Mn has a lower oxide dissociation elasticity than oxygen-saturated iron and can act as a deoxidizer that removes 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) when welding iron-based alloys should not be significant.

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

Based on the known temperature dependences of the equilibrium constants of various reactions, the equilibrium concentrations of oxygen can be calculated in the presence of various concentrations of deoxidizers in molten iron. The products of carbon deoxidation are gaseous carbon monoxide. In this case, the tail of the weld pool bubbles. In this case, the bubbles that have not had time to leave the solidifying metal form spherical or rounded pores in the metal, filled with gas, which reduce the strength properties of the metal.

Carbonates are used as gas-forming components, in the form of marble, dolomite, chalk. When heated, carbonates decompose according to the scheme:

$$CaCO_3 = CaO + CO_2. \qquad (4)$$

At high temperatures, carbon dioxide dissociates according to the scheme [31]:

$$2CO_2 = 2CO + O_2 \qquad (5)$$

The constant of the above reaction is determined by the equation [31]:

$$\lg K_{(CO_2)} = \lg \frac{p_{CO}^2 p_{O_2}}{p_{CO_2}^2} = -\frac{29072}{T} + 8{,}81 \tag{6}$$

The partial pressure of free oxygen as a result of the dissociation of CO_2 at 3000º K is approximately the same as the partial pressure of oxygen in air. Therefore, CO_2 is an oxidizing agent for a number of metals, including liquid iron:

$$CO_2 + Fe_ж = [FeO] + CO \tag{7}$$

In the presence of CO_2 in the gas phase, it is necessary to deoxidize the oxidized metal or take measures to protect the metal from oxidation during welding. Therefore, the use of carbon dioxide can provide protection against N_2 air, but does not exclude oxidation. In this regard, to deoxidize the metal, deoxidizers are usually introduced into the electrode wire in the required amount, as a rule, Si and Mn, at a certain ratio between them.

IV.CONCLUSION

Scientifically based selection of deoxidizers in arc welding makes it possible 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.

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