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# Investigation of the characteristics of the composition of the gas phase in submerged arc welding of low-carbon and low-alloy steels

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**ABSTRACT:** This article provides a study of the composition of the gas phase in submerged arc welding of low-carbon and low-alloy steels

**KEY WORDS:** arc welding, flux, low alloy steel, ceramic flux, slag, gas phase

## I. INTRODUCTION

The use of electric arc welding for the manufacture of critical structures, the welds of which are subject to increased requirements for their toughness and ductility, has become possible by limiting the harmful effects of oxygen and nitrogen in the air on the metal remelted under welding conditions by using ceramic fluxes.
The slag resulting from the melting of the flux is transferred in the arc partly in the form of drops, and partly in the form of a slag cover on and inside the metal drops. In addition, gases in some cases are also formed inside the droplets, for example, as a result of the oxidation of carbon in steel and the formation of CO. In this regard, most droplets, especially small ones, are hollow, with a low average specific gravity.
Ceramic fluxes are a mixture of slag and gas-forming substances that protect the metal from exposure to air during the welding process and produce the required metallurgical processing of the metal by introducing various metal additives.

## II. LITERATURE SURVEY

In the welding zone, metals, liquid or heated to a temperature close to the melting point, are found not only with oxygen, but also with complex gases, such as CO; $CO_2$; $H_2O$; $C_nH_m$ resulting from the dissociation of carbonates or gases:

$$2CO_2 \leftrightarrow 2CO + O_2;$$
$$2H_2O \leftrightarrow 2H_2 + O_2;$$
$$CaCO_3 \leftrightarrow CaO + CO_2;$$

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$$Me + H_2O \leftrightarrow MeO + H_2$$ [1,2]

As a result of the interaction, metals can undergo oxidation or, conversely, reduction, depending on the temperature and the concentration ratios of the components of the gaseous atmosphere.
System C - O. Carbon, combining with oxygen, forms $CO_2$ or CO:

$$C + O_2 \leftrightarrow CO_2;\ \Delta G_1^0 = -393500 - 2{,}83T$$
$$2C + O_2 \leftrightarrow 2CO;\ \Delta G_2^0 = -221000 - 178{,}29T$$ [3,4]

Using the values of the Gibbs energies for the first and second reactions, we determine the temperature at which both processes will be in equilibrium:

$$\Delta G_1^0 = \Delta G_2^0 \rightarrow T = 983{,}13K$$ [5,6]

## III. METODOLOGY

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

$$CaCO_3=CaO+CO_2. \quad (1)$$

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

$$2CO_2 = 2CO + O_2 \quad (2)$$

The constant of the above reaction is determined by the equation:

$$\lg K_{(CO_2)} = \lg \frac{p_{CO}^2 p_{O_2}}{p_{CO_2}^2} = -\frac{29072}{T} + 8{,}81 \quad (3)$$

The partial pressure of free oxygen as a result of the dissociation of $CO_2$ at 3000° 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:

$$CO_2+Fe_{ж}=[FeO]+CO \quad (4)$$

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 [32].
In submerged arc welding, metal from the electrode is transferred from the electrode into the weld pool in the form of droplets heated to temperatures significantly higher than the melting point, and in the form of vapors.
The slag resulting from the melting of the flux is transferred in the arc partly in the form of drops, and partly in the form of a slag cover on and inside the metal drops. In addition, gases in some cases are also formed inside the droplets, for example, as a result of the oxidation of carbon in steel and the formation of CO. In this regard, most droplets, especially small ones, are hollow, with a low average specific gravity [35, 36].

The high temperature of the arc and the metal transferred through the arc causes an intensive evaporation process, and therefore, in the gas phase surrounding the metal, under the conditions of these welding methods, a significant amount of vapor appears, reducing the partial pressure of other gases present in the arc gap.

To determine the possible metal vapor pressure at different temperatures, you can use the simplified Clapeyron-Clausnus equation

$$p = -\frac{\Delta H}{4{,}575T} + B \quad (5)$$

where p — is the vapor pressure over the liquid metal; ΔH — is the heat of evaporation, taken as a simplified constant;
T — is the absolute temperature;
B — is a constant depending on the properties of the metal and the accepted pressure units.
In welding practice, the metal phase is usually an alloy of several elements. Of these, the element with the lowest vapor pressure evaporates most strongly [37].

Fluxes in some cases can be a source of a significant amount of oxygen. So, for example, if the charge contains about 50% marble, the amount of released free oxygen ($CaCO_3 \longrightarrow CaO + CO + \frac{1}{2}O_2$) will be about 2.5% of the weight of the metal, that is, about 10 times more than it is contained in an air cylinder with a diameter of 5.0 cm.

Such a large amount of oxygen, which in principle can participate in the oxidation of the metal, is located in the immediate vicinity of the electrode rod and can actively interact with it. In this regard, the flux, by isolating the reaction space of the arc from air, protects the metal from nitriding, but does not protect it from oxidation, and against this phenomenon it is necessary to use deoxidizers and treatment of the metal with slag obtained by melting the flux.

## 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.

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