Investigation of the interaction of metal with complex gases in the development of the composition of ceramic fluxes for automatic arc welding of low-carbon and low-alloy steels

S.S. Khudoyorov, L.V. Galperin, N.S. Dunyashin, Z.D. Ermatov, N.T. Rahmatullayeva M.Z. Abdullaev

Associate Professor, Doctor of Philosophy in Technical Sciences (PhD), Department of Technological machines and equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan
Researcher, Doctor of Philosophy in Technical Sciences (PhD), Department of Technological machines and equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan
Head of the Department, Doctor of Technical Sciences, Professor, Department of Technological machines and equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan
Professor, Doctor of Technical Sciences, Department of Technological machines and equipment, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan
Senior lector of the department of "Technological machines and equipment" of Tashkent State Technical University named Islam Karimov, Tashkent, Uzbekistan.
Assistant of the department of "Technological machines and equipment" of Tashkent State Technical University named Islam Karimov, Tashkent, Uzbekistan.

ABSTRACT: This article presents a study of the interaction of molten metal with complex gases in the development of the composition of ceramic fluxes for automatic arc welding of low-carbon and low-alloy steels.

KEY WORDS: arc welding, flux, low alloy steel

I. INTRODUCTION

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 [1].
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.

II. LITERATURE SURVEY

In many fluxes, carbonates are used as gas-forming components, in the form of marble, dolomite, and chalk. When heated, carbonates decompose according to the scheme [2]:

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

At high temperatures, carbon dioxide dissociates according to the scheme [3]:

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

The constant of the above reaction is determined by the equation [4]:

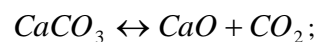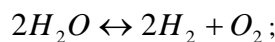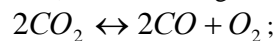$$\lg K_{(CO_2)} = \lg \frac{p_{CO}^2 p_{O_2}}{p_{CO_2}^2} = -\frac{29072}{T} + 8,81 \tag{3}$$

The partial pressure of free oxygen as a result of the dissociation of CO2 at 3000º K is approximately the same as the partial pressure of oxygen in air. Therefore, CO2 is an oxidizing agent for a number of metals, including liquid iron:

$$CO_2 + Fe_ж = [FeO] + CO \tag{4}$$

In the presence of CO2 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 N2 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 [5,6].
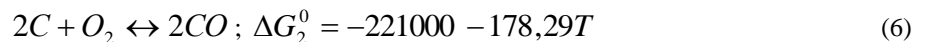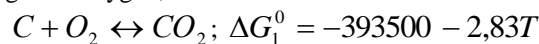
III. METODOLOGY

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:

$$2CO_2 \leftrightarrow 2CO + O_2;$$
$$2H_2O \leftrightarrow 2H_2 + O_2;$$
$$CaCO_3 \leftrightarrow CaO + CO_2;$$
$$Me + H_2O \leftrightarrow MeO + H_2 \tag{5}$$

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:

$$C + O_2 \leftrightarrow CO_2; \ \Delta G_1^0 = -393500 - 2,83T$$
$$2C + O_2 \leftrightarrow 2CO; \ \Delta G_2^0 = -221000 - 178,29T \tag{6}$$

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:

$$\Delta G_1^0 = \Delta G_2^0 \rightarrow T = 983,13K \tag{7}$$

At temperatures above 983.13 K, carbon will oxidize to CO. CO_2 dioxide will be more stable at low temperature. Graphs of the Gibbs energies for possible reactions in the C - O system are shown in fig. 1.
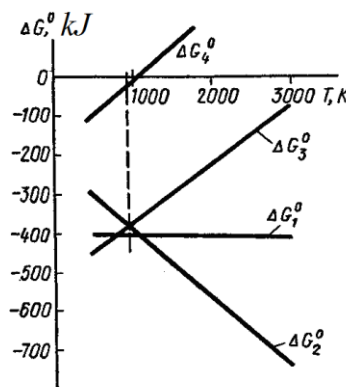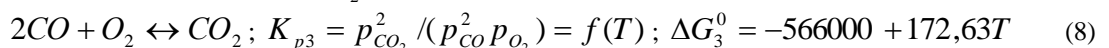

Fig. 1. Diagram of the standard Gibbs energy in the carbon-oxygen system as a function of temperature.

Oxidation reaction of carbon monoxide CO to CO_2 dioxide

$$2CO + O_2 \leftrightarrow CO_2; \ K_{p3} = p_{CO_2}^2 / (p_{CO}^2 p_{O_2}) = f(T); \ \Delta G_3^0 = -566000 + 172,63T \tag{8}$$

is called the afterburning reaction and is of great importance in metallurgy. Let us determine the oxygen pressure in the equilibrium gas mixture from the expression for the equilibrium constant K_{p3} and obtain the following equation:

$$p_{O_2} = \left(1/K_{p3}\right)p_{CO_2}^2 / p_{CO}^2 = f(T). \qquad (9)$$

If the temperatures are not too high (~2000 K), then the partial pressure of oxygen will be small and instead of partial pressures p_{CO_2} and p_{CO} can take their volume fractions in the gas mixture.

Thus, the oxygen pressure will be a function of two variables: temperature and composition of the gas mixture:

$$\lg p_{O_2} = -\lg K_{p3} + 2\lg a , \qquad (10)$$

where $a = \%CO_2 / \%CO$ characterizes the oxidizing capacity of the gaseous atmosphere.

If a $\%CO_2 \to 100\ \%$, a $\%CO \to 0$, then $a \to \infty$ and $\lg p_{O_2} \to \infty$, that is, the atmosphere will be oxidizing, and if $\%CO_2 \to 0$ and $\%CO \to 100$, then $a \to 0$ and $\lg p_{O_2} \to -\infty$ - restorative.

The graph of equation (1.41) for a temperature of 2000 K is shown in fig. 2.
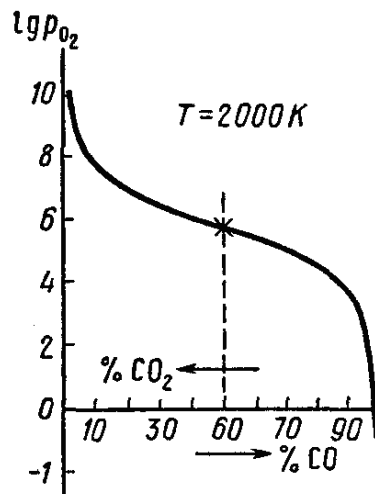

Fig. 2. Dependence of the logarithm of the oxygen pressure on the composition of the gaseous atmosphere (T = const)

The nature of the curve shows that by a corresponding change in the concentrations of CO and CO_2, it is possible to change the oxidizing capacity of the atmosphere in a wide range under conditions of constant temperature. The composition of the gaseous atmosphere as a function of temperature is shown in fig. 3.
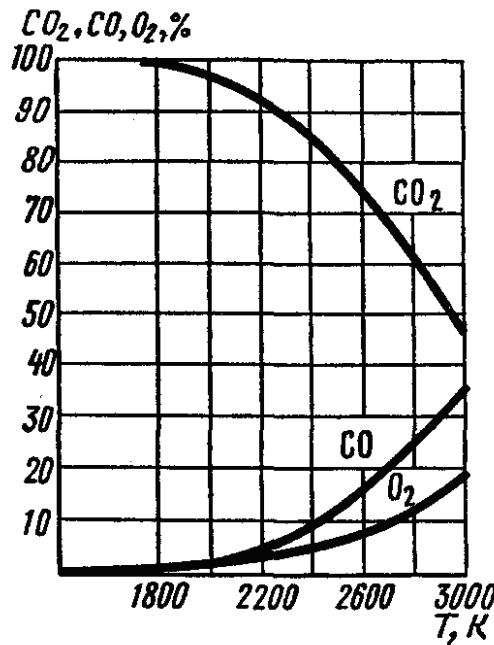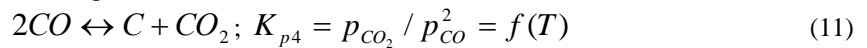
Fig. 3. Dissociation of carbon dioxide depending on temperature.

Another equilibrium in the C - O system is the equilibrium of Bell and Boudoir:

$$2CO \leftrightarrow C + CO_2 ; \ K_{p4} = p_{CO_2} / p_{CO}^2 = f(T) \tag{11}$$

This reaction, on the one hand, leads to the release of solid carbon from the gas phase, and on the other hand, it causes the formation of metal carbides upon contact with a gas atmosphere containing carbon monoxide CO:

$$MeO + 2CO \leftrightarrow MeC + CO_2 \tag{12}$$
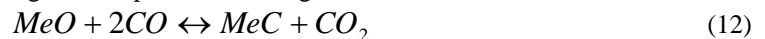
It is convenient to represent the Bell-Boudoir equilibrium in the coordinates % CO - T for the condition of constant pressure. At high temperatures (~980 K), carbon is intensively gasified and the concentration of CO in the gas phase increases.

H - O system. Hydrogen, combining with oxygen, forms two compounds: water H_2O and hydrogen peroxide (peroxide) H_2O_2 - the compound is not very stable and therefore does not occur in welding processes.

Water vapor at high temperatures dissociates in two directions:

$$2H_2O + O_2 \leftrightarrow 2H_2 + O_2 ; \ 2H_2O \leftrightarrow OH^* + H_2 \tag{13}$$

The OH^* radical is a very active oxidizing agent, the same as pure oxygen. The equilibrium constants and the Gibbs energy equations for these processes are very close and we can restrict ourselves to considering one process in the H-O system:

$$2H_2 + O_2 \leftrightarrow 2H_2O \ K_{p5} = p_{H_2O}^2 /(p_{H_2}^2 p_{O_2}) \tag{14}$$
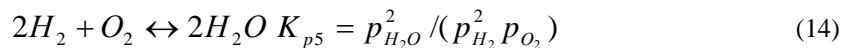
Let us determine the partial pressure of oxygen from the equilibrium constant equation:

$$p_{O_2} = (1/K_{p5}) p_{H_2O}^2 / p_{H_2}^2 \tag{15}$$

At temperatures of 3000...4000 K, this equation can be represented differently:

$$p_{O_2} = (1/K_{p5})(\%H_2O)/(\%H_2) \tag{16}$$

Attitude $(\%H_2O)/(\%H_2) = b$ will indicate the oxidizing power of the gaseous atmosphere.

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

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AUTHOR'S BIOGRAPHY

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 35 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.

Dunyashin Nikolay Sergeyeevich , Head of Department, Doctor of Science, Professor, was born February 13, 1978 year in Tashkent city, Republic of Uzbekistan. Has more than 140 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.

Ermatov Ziyadulla Dosmatovich, Doctor of Science, Professor,
was born in May 16, 1978th year in Tashkent city, Republic of Uzbekistan. He has more than 110 published scientific works in the form of articles, these and tutorials. Currently Professor of the department of "Technological machines and equipment" in Tashkent State Technical University, Tashkent, Uzbekistan.

Raxmatullaeva Nazima Toir kizi, Senior lector
was born September 1, 1989 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.

Abdullayev Muzaffar Zahidjonovich, Assistant,
was born in June 26, 1989th year in Tashkent city, Republic of Uzbekistan. He has more than 15 published scientific works in the form of articles, theses and tutorials. Currently works at the department of "Technological machines and equipment" in Tashkent State Technical University as an assistant teacher, Tashkent, Uzbekistan.