INVESTIGATION OF INOCULATION PROCESSESS IN CAST IRON BY MEANS OF HIGH-TEMPERATURE VOLTAIC CELLS

(UDC 669.13)

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Translated from Zavodskaya Laboratoriya, Vol. 30, No. 5,
pp. 568-570, May, 1964

The construction of a high-temperature voltaic cell with an intermediate MgO electrode for determining the activity of magnesium in liquid cast iron according to the course of inoculation is described.

Data showing the influence of Mn and Si on the activity of magnesium are presented and the mechanism of the formation of spheroidal graphite is examined.

High-temperature voltaic cells with an intermediate oxygen electrode of magnesium oxide are used for studying the thermodynamic characteristics of metallurgical melts [1-4]. At high temperatures, MgO possessess appreciable electrical conductivity and definite oxygen activity. Thus, the e.m.f. of the cell Pt|Fe, FeO|MgO|Ni, Nio|Pt at 1100°C has been found to be equal to 0.285 ± 0.1 V [5]. Kiukkola and Wagner [6] obtained a similar value for the e.m.f. of a cell having a solid electrolyte possessing ionic conductivity. From the agreement between these results, it was concluded that MgO possesses ionic conductivity at high temperatures [5, 7];

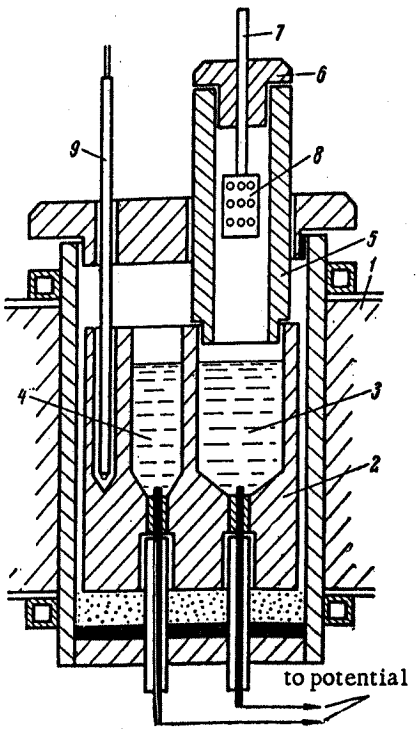

Fig. 1. Diagram of voltaic cell for e.m.f. measurement during the inoculation process.

Since magnesium oxide, possessing ionic conductivity, contains O^{2-} and Mg^{2+} ions, it may be used as solid electrolyte for determining the activity of magnesium-containing alloys and for studying the processes occurring during the inoculation of cast iron.

The voltaic cell W | Mg, Ni | MgO | Fe, C, Mg | W, shown dagrammatically in Fig. 1, was used in the present work for determining the solubility of magnesium in cast iron.

The magnesite cell 2 with two compartments, 25 mm in diam. and 75-80 mm in height, was inserted in the carbon resistance furnace 1. The method of preparing the cell has been decribed previously [8]. The investigated cast iron 3 was placed in one compartment; alloy, containing 15% Mg and 85% Ni was used as standard 4. When the iron and standard had melted, a tightly fitting graphite tube, closed by a stopper 6 of the same material, was placed on the first compartment, and a steel rod 7, carrying a sheet-metal cartridge 8 containing magnesium, was passed through a hole in the stopper. When a constant temperature of 1420-1430°C and a steady initial potential had been reached, the cartridge was immersed in the iron and measurement of the e.m.f. continued.

Fig. 2a shows the variation in e.m.f. during inoculation. The first portion of the curves (before the introduction of the magnesium) corresponds to the attainment of steady initial potentials in the investigated circuit. Their value is comparatively small and decreases with increase in the carbon content of the investigated alloy. The value of the e.m.f. is equal to the difference

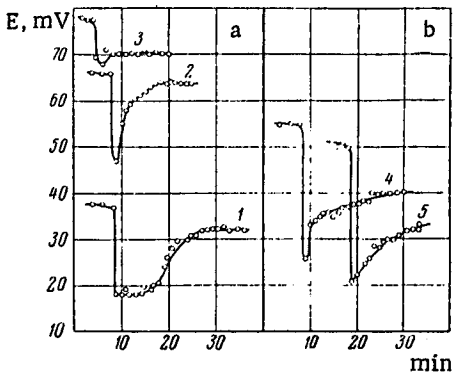

Fig. 2. Variation of e.m.f. of voltaic cell containing Fe-C melts (a) and Fe-Mn-C melts (b). 1) For the melt Fe + 4% C; 2) Fe + 2.5% C; 3) Fe + 1.8% C; 4) Fe-C + 4% Mn; 5) Fe-C + 2% Mn.

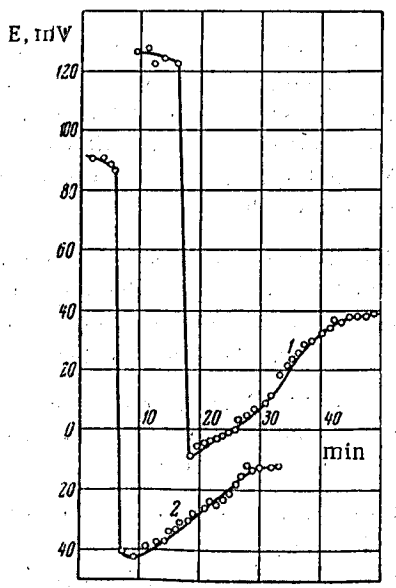

Fig. 3. Variation of e.m.f. in voltaic cell with the melts: 1) Fe-C + 0.8% Si; 2) Fe-C + 2.0% Si.

between the two potentials E_1 at the Mg, Ni | MgO boundary and E_2 at the Fe, C | MgO boundary. Both potentials are determined by one process $Mg = Mg^{2+} + 2e$, taking place in different directions. The values of these potentials are respectively equal to

$$E_1 = E_0 + \frac{RT}{2F} \ln \frac{a^0_{Mg}}{a'_{Mg}},$$

$$E_2 = E_0 + \frac{RT}{2F} \ln \frac{a'_{Mg}}{a_{Mg}}.$$

Whence the e.m.f. of the cell is expressed by the equation

$$E = \frac{RT}{2F} \ln \frac{a^0_{Mg}}{a_{Mg}}.$$

The sharp drop in all the curves in due to the introduction of magnesium in the cast iron. The magnitude of this drop increases with increase in carbon content. The gradual rise in e.m.f. following the drop is due to the decrease in the magnesium content of the cast iron after treatment. Comparison of curves 1, 2, and 3 Fig. 2a shows that carbon helps to retain magnesium in the cast iron.

Fig. 2b shows curves of e.m.f. versus time obtained in the treatment of Fe-C-Mn melts. The initial potentials and the value of the e.m.f. on the introduction of magnesium differ little from those found in Fe-C melts. Evidently, in our case, the replacement of iron by manganese had relatively little effect on the thermodynamic properties of the dissolved carbon. Fig. 3 shows the variation of e.m.f. with time on the introduction of magnesium into Fe-C-Si melts. The value of the initial potentials increased with decrease in the silicon content; the e.m.f. drop was much greater than for Fe-C melts. The change in sign of the e.m.f. indicates that at that moment, the activity of the magnesium was higher than in the standard.

The experimental data obtained enable us to follow the influence of C, Mn and Si on the behavior of magnesium in the inoculation process. Since magnesium reduces the solubility of carbon in iron [9], a region of increased carbon activity is formed around the small gas bubbles or microinhomogeneous inclusions. Where the magnesium concentration attains a considerable value, carbon activity approaches unity and the carbon tends to separate out as an independent phase. The presence of silicon in the melt by increasing the activity of the magnesium and reducing the solubility of the carbon, assists the separation process, especially in regions of high magnesium concentration. Manganese, on the other hand, by reducing the acitivity of the magnesium, inhibits the separation of graphite.

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