V. I. LAKOMSKII

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Abstract

Full Text

V. I. LAKOMSKII

SOLUBILITY OF HYDROGEN IN LIQUID IRON UP TO THE BOILING TEMPERATURE

(Presented by Academician B. E. Paton, July 7, 1962)

In arc electric welding or arc refining remelting of metals, which in recent years has found wide application in the metallurgy of high-quality steels, droplets of metal, passing through the interelectrode gap, are superheated to $2300 \pm 200^{\circ}$ ([1]). Upon entering the weld pool, the metal droplets are assimilated by the pool and their temperature decreases. The average temperature of the pool is $1770 \pm 100^{\circ}$ ([1]). To calculate the processes of interaction between the metal and the gas phase, it is necessary to know the equilibrium solubility of gases in iron over a wide temperature interval from the melting point to the boiling point. Among the gases that interact with iron during arc welding, hydrogen is of greatest interest, as the principal cause of many defects in weld metal. The solubility of hydrogen is known only up to 1685° ([2]).

Fig. 1. Dependence of $[H]$ on $\sqrt{P_{H2}}$

To determine the solubility of hydrogen in liquid iron up to the boiling temperature, the following procedure was adopted.* A sample of Armco iron 9 mm in diameter and height was melted and superheated to the desired temperature in a high-frequency inductor. The inductor was placed in a quartz beaker, through which a stream of dried hydrogen, purified of impurities, mixed with an inert gas was passed. The partial pressure of hydrogen was selected so that its content in the metal did not exceed 7–8 ml/100 g. After the specified temperature had been reached and the sample held, the iron sample was dropped into a test tube. The very high rate of crystallization of the metal in the test tube, with a comparatively low hydrogen content, ensured reliable fixation in the solid specimen of the hydrogen dissolved in liquid iron. The temperature of the sample was measured with a TsEPIR-010 color pyrometer, having a total instrumental error below 1%. Knowing the partial pressure of hydrogen in the gas and its content in the specimen, for each temperature the solubility of hydrogen was determined from Sieverts' equation.

Fig. 2. Solubility of hydrogen in liquid iron up to the boiling point of iron

Figure 2: Fig. 2. Solubility of hydrogen in liquid iron up to the boiling point of iron

Preliminarily, for each group of experimental data obtained at the same temperature, the exponent n in the isotherm equation was determined. From Fig. 1 it is seen that the iron–hydrogen system obeys Sieverts' law even at high temperatures. However, at temperatures of 2500–2670°, the value of n decreased to 0.36–0.39. The average value of n over the entire investigated temperature range is 0.47.

The solubility curve found for hydrogen in iron is presented in Fig. 2 in the coordinates $\lg S — \frac{1}{T}$.

The analytical expression for this curve may be represented in the form

$$\lg S = -\frac{A}{T} + B + 0.5 \lg \left(1 - Ce^{-\frac{Q}{RT}}\right),$$

* B. M. Karpinskii took part in the work.

where A, B are empirical constants, $Ce^{-\frac{Q}{RT}}$ is the vapor pressure of iron at temperature T, in atm.

At the beginning of the temperature range beyond the melting point of iron, when the vapor pressure of iron is low and the quantity $Ce^{-\frac{Q}{RT}}$ is small compared with unity, an increase in temperature leads to a rectilinear increase in the logarithm of the solubility. With further growth of the temperature and of the vapor pressure of iron, the dependence acquires a curvilinear character and passes through a maximum. When, at the boiling point of iron, the quantity $Ce^{-\frac{Q}{RT}}$ becomes equal to unity, the solubility decreases to zero. The reason for the decrease in the solubility of hydrogen in the metal with increasing vapor pressure of the metal lies in the reduction of the partial pressure of hydrogen at the metal–gas interface.

Fig. 2. Solubility of hydrogen in liquid iron up to the boiling point of iron

If the same experimental data are plotted in the coordinates

$$\lg S - 0.5 \lg \left(1 - Ce^{-\frac{Q}{RT}}\right) - \frac{1}{T},$$

in which the influence of the vapor pressure of iron is eliminated, then the dependence becomes rectilinear (Fig. 3). The heat of solution of hydrogen in liquid iron, determined from this dependence, is 15,700 cal/mole.

Fig. 3. Dependence of $\lg S - 0.5 \lg \left(1 - Ce^{-\frac{Q}{RT}}\right)$ on reciprocal temperature

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Figure 3: Fig. 3. Dependence of $\lg S - 0.5 \lg \left(1 - Ce^{-\frac{Q}{RT}}\right)$ on reciprocal temperature

Institute of Electric Welding
named after E. O. Paton
Academy of Sciences of the Ukrainian SSR

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REFERENCES

1. I. I. Frumin, *Automatic Submerged-Arc Surfacing*, Moscow, 1961.

2. A. N. Morozov, *Hydrogen and Nitrogen in Steel*, Moscow, 1950.

Note: Figure translations are in progress. See original paper for figures.