PREDICTION OF FINAL PROPERTIES OF BORON-CONTAINING ALLOYS WITH USING OF CONTROLLED COOLING CONDITIONS

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Abstract

The regularities of dendritic liquation development in boron-containing samples have been investigated. Analytical solution has been carried out for the correlation of boron diffusion fullness in the coexistent liquid and solid phases in the crystallization process. It is shown, that controlled conditions of cooling of the sample allow to regulate the chemical heterogeneity degree and to improve the final properties of boron-containing alloys.

1. INTRODUCTION

The considerable chemical heterogeneity takes place in boron-containing alloys, made at the slow cooling. In particularly, the fundamental harmonic of chemical heterogeneity, determined with F-parameter of boron, fluctuates between 14.0 – 123.0. At the same time, quintile of F-distribution equals to 3.0. Moreover, the chemical heterogeneity deserves the attention because it influences on the mechanical properties of boron-containing alloys. This influence has the inverse dependence [1]. That is, the increase of the chemical heterogeneity causes the reduction of mechanical properties of alloys. Therefore, the permanent zone heterogeneity and dendritic segregation must be taken into account at the development of technologies and the evaluation of exploitation characteristics of the metal. The elimination of the dendritic segregation in these alloys can be reached by means of utilization of the quickly cooling [2] of the molten metal. However, the influence of the rapid cooling on the quantitative level of the dendritic segregation of elements in boron-containing alloys does not enough studied. In consequence of this the investigation of the influence of the cooling rate on the dendritic segregation of elements in boron-containing alloys are carried out.

2. MATERIALS AND METHODS

The boron-containing alloys of Fe-B system with beyond eutectic structure were the subject. This metal was characterized with the presence of crystals of iron borides of big dimensions such as sizes of the sample. Boron macroheterogeneity in Fe-B alloys had the character of inverse segregation [3]. In connection with this phenomenon the dendritic segregation of boron was studied in a center of ingot. The other words, the center was distinguished with the permanent zone heterogeneity of boron. The information about the segregation of boron was received by the method of optical atomic emission spectroscopy. The F-parameter was used as the quantitative measure of heterogeneity of boron in boron-containing alloys. It was determined [4] by the comparison of the dispersions of the related intensities of the spectral lines alloying (s1^2) and matrix basic (s2^2) elements on the F-distribution: F = s1^2 |s2^2. If F > F1-p \{f1,f2\}, then the divergence between the selective dispersions (s1^2) and (s2^2) was significant at the selective level of the significance p, equaled to 0.05, and the number of degrees of freedom f1 and f2 and the distribution of alloying elements in investigated materials was heterogeneous. In the contrary case the tested dispersions can be considered, as belonging to the single general dispersion and the distribution of alloying elements would be homogeneous. The F_{0.95} was equal to 3.0. The related error of F determinations was 0.8 – 1.8%. The cooling rate \( V_{\text{cooling}} \) was registered by means of loop oscillographY-700. In addition, chromel- alumel and platinum –platinum-rhodium thermocouples of 0.2 mm diameter were used. The \( \varepsilon \) was measured by the procedure [5]. The relative standard deviation \( s_r \) was 0.04 – 0.05.
3. RESULTS AND DISCUSSION

The behavior of experimental values of boron heterogeneity $F$ at the change of the cooling rate of alloys is demonstrated in Figure 1.

![Figure 1](image)

Fig. 1. The influence of cooling rate $V_{\text{cooling}}$ on the dendritic segregation of boron $F$ in boron-containing alloys of Fe-B system

As shown in Fig. 1 the degree of dendritic segregation rises up the maximum and after it falls. The observed influence of the cooling rate on the distribution of boron is caused by the mechanism of the solidification of boron-containing alloys. For the revealing of the mechanism of the solidification the regularities of dendritic segregation development in boron-containing samples have been investigated. Analytical solution is carried out for the correlation of boron diffusion fullness in the coexistent liquid and solid phases in the crystallization process. The degree of boron dendritic segregation is calculated by Golikov [2] analytical solution (1):

$$\frac{F_f - F_0}{f_0} = K[\left(\frac{U}{KD} + 1\right)^{-\kappa} - 1]$$

(1)

Where the $\frac{F_f - F_0}{f_0}$ is the degree of the dendritic segregation of element, for example boron. The $K$ is the constant of the distribution. The $D$ is the coefficient of the element diffusion in the solid phase. The $\frac{D}{Ul}$ is the fullness of the element diffusion in the phase. The left part of the equation (1) introduces the degree of the dendritic segregation. The right part represents the mathematical expression, depended only on the fullness of the diffusion $\frac{D}{Ul}$ of the
The element in the solid phase and the constant of the distribution. The behavior of the calculated values of the degree of boron dendritic segregation repeats the direction of the dependence of the experimental data of boron heterogeneity on the cooling rate at the conditions of the crystallization, in which the following processes of the diffusion in the liquid and solid phases take place. Evidently, the increase of cooling rate is accompanied with the reduction of the diffusion fullness in the liquid phase. It causes the appearance of the significant gradients of the mass part of boron in initial and final layers of the solid phase. The presence of gradients of boron concentration is confirmed with made calculations. At the same time, gradients of boron concentration cause the rise of the diffusion fullness of boron in the solid phase. The value of the diffusion fullness of boron in the solid phase is shown by the expression of \( \frac{1}{U_l} \)

because the diffusion coefficient is considered as the constant in the crystallization process. The obtained results testify about the increase of diffusion fullness from 0.21 (m\(^2\)/s\(^{-1}\)) at the cooling rate, equaled to 300 K/s, to 10.2 (m\(^2\)/s\(^{-1}\)) at the \( V_{cooling} = 1 \cdot 10^3 \) K/s. This phenomenon promotes to the significant reduction of dendritic segregation of boron from starting point of cooling rate, equaled to 800 K/s. At the same time, the improvement of mechanical properties of boron-containing alloys is observed [1] because the following dependence exists:

\[
\varepsilon = 3.31 - 0.017 F[1]
\]

(2)

Thence, the increase of the relative wear resistance with the growth of the cooling rate of boron-containing alloys is written by the equation (3):

\[
\varepsilon = 0.000011 V_{cooling}^2 - 0.0077 V_{cooling} + 2.15
\]

(3)

Hence, controlled conditions of cooling can allow to regulate of the degree of the dendritic segregation of elements, such as boron, and thus to improve the properties of boron-containing alloys.

**BIBLIOGRAPHY**


