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Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Effect of Si Content on the Ferrite-to-Austenite Transformation during Austenitizing in Spheroidal Graphite Cast Iron

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The effect of Si content on the ferrite-to-austenite transformation during austenitization in spheroidal graphite cast iron with a ferrite matrix was investigated. In this study, ferritic ductile cast irons with two different Si contents, 2.3 mass%Si (JIS-FCD400) and 3.8 mass%Si (SSFDI), were used. Microstructural observation revealed that the rate of the ferrite-to-austenite transformation for SSFDI was slower than for FCD400. In addition to the experiments, a simulation of the austenitization was performed for FCD and SSFDI using the DICTRA software package employing kinetic and thermodynamic databases. The simulations reproduced the experimental results on the austenitization behavior for both FCD and SSFDI well.

Keywords: *spheroidal graphite cast iron, transformation, silicon, segregation, diffusion.*

1. Introduction

Spheroidal graphite cast iron is widely used for various structural components because of its high strength and ductility compared to flake graphite cast iron. Recently, solution-strengthened ferritic ductile cast iron (SSFDI) has been developed by increasing the Si content in the matrix [1]. The austempering process is one of the strengthening methods for spheroidal graphite cast iron, and the rate of austenitization is controlled by carbon diffusion from the graphite nodules [2]. However, microsegregation of constituent elements occurs in the matrix, and this may affect the austenitization of the cast iron. In this study, the microsegregation in spheroidal graphite cast irons with varying Si content was evaluated. In addition, the effect of Si content on the ferrite-to-austenite transformation during austenitization in spheroidal graphite cast iron with a ferrite matrix was investigated.

2. Methods

2.1 Experimental procedures

The materials used in this study were two types of spheroidal graphite cast iron with different Si content, namely 2.3 mass% (JIS-FCD400) and 3.8 mass% (EN-GJS-500-14), hereafter referred as to FCD and SSFDI, respectively. The chemical composition and number of graphite nodules of the two cast irons are listed in Table 1. The samples were immersed in molten Al alloy baths heated at temperatures between 850 °C and 900 °C and held at these temperatures for various periods, after which the samples were quenched in water to interrupt the ferrite-to-austenite transformation. Microstructural observation was carried out using optical microscopy and the fraction of martensite obtained after quenching was evaluated as the fraction transformed to austenite during austenitization. The microsegregation of constituent elements was investigated by means of electron probe micro analysis (EPMA).

Table 1 Chemical composition (mass%) and number of graphite nodules (mm^{-2}) of specimens.

Samples	C	Si	Mn	P	S	Cu	Mg	Graphite nodules
FCD	3.6	2.3	0.2	0.02	0.01	0.02	0.04	397
SSFDI	3.2	3.8	0.3	0.02	0.01	0.02	0.04	372

2.2 Calculation procedure

To evaluate the diffusion behavior of carbon and other alloying elements, the simulations were performed using the DICTRA software package [3] employing the mobility database MOB2 and the thermodynamic database SGTE SSOL4. The geometrical model used in the DICTRA simulations was a closed system with one spherical cell with a graphite nodule at the center surrounded by the ferrite matrix. Austenite was assumed to form between the graphite nodule and the ferrite matrix. The size of the graphite nodule and ferrite matrix and the composition of the ferrite were taken from the present experimental data. The simulation was performed for the austenitizing temperatures between 850 °C and 900 °C and was stopped at the time step of 3600 s (1 h).

3. Results and discussion

EPMA showed that both the as-cast FCD and SSFDI samples exhibited microsegregation of Si and Mn near the graphite nodules and at the eutectic cell boundary, respectively. The progress of the isothermal austenitic transformation at 850 °C for the FCD and SSFDI specimens based on the microstructural observation is plotted with symbols in Fig. 1, together with fitted curves with the Johnson–Mehl–Avrami equation [4,5]. The obtained result indicated that the rate of ferrite-to-austenite transformation for SSFDI was slower than for FCD. It is well known that the addition of Si in steels raises the austenitizing temperature. In addition, the carbon concentration in austenite at both the ferrite/austenite and austenite/graphite interfaces, which is one of the factors controlling the austenitizing rate, is affected by the increase in the transformation temperature. Thus, the slow-down of the rate of the ferrite-to-austenite transformation for SSFDI compared with FCD may be caused by the differences in the carbon concentration in austenite at the interfaces.

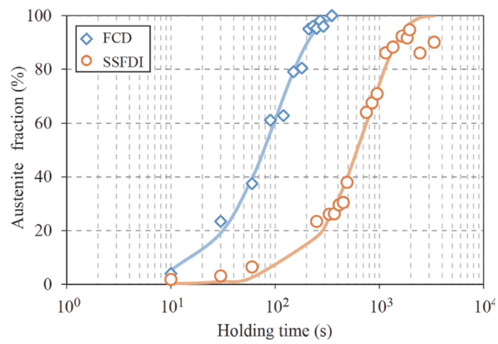

Fig. 1 Isothermal austenitic transformation at 850 °C for the FCD and SSFDI specimens.

Figure 2 shows the calculated carbon concentration profiles in SSFDI after holding at 850 °C for 10, 100, and 1000 s. The data are plotted as a function of distance from the center of the graphite nodule. The discontinuity in the profiles around the distance of 20–30 μm corresponds to the interface between ferrite and austenite, and it was found that the austenite region became larger with an increase in the time step. The calculated progress of the isothermal austenite transformation for FCD and SSFDI at various temperatures was found to reproduce the observed curves well.

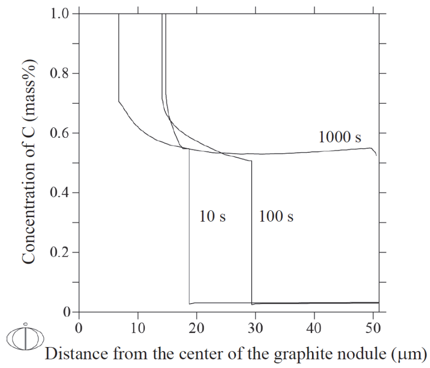

Fig. 2 Calculated carbon concentration profiles in SSFDI after holding at 850 °C for 10, 100, and 1000 s.

4. Summary

The effect of Si content on the ferrite-to-austenite transformation in ferritic ductile cast iron with a ferrite matrix was investigated. The results obtained are summarized as follows.

(1) The progress of isothermal austenite transformation for SSFDI was retarded compared with the conventional FCD.

(2) The DICTRA simulations reproduced the experimental austenite transformation for both FCD and SSFDI.

Acknowledgements

The authors are grateful to Hinode, Ltd. for providing the materials used in this study.

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