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On-line prediction of carbon equivalent on high-nickel austenitic ductile iron

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Abstract

In this paper, experiments have been made on high-nickel ductile iron for controlling the property by the computer-aided thermal analysis system. The experimental results have been analyzed with statistics and applied to on-line predicting and controlling carbon equivalent, which obtained satisfying result. The experiments show that the relationship between the carbon equivalent of high-nickel ductile iron and its liquidus temperature is linear, which can be expressed as: CEL = 15.7826 − 0.0096575 × T_L. In order to ensure the tensile strength greater than 400 MPa with the probability up to 99%, the liquidus temperature of high-nickel austenitic ductile iron must be in the range of [1203–1226 °C].
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Keywords: Carbon equivalent; High-nickel ductile iron; On-line prediction; Cooling curve

1. Introduction

Despite its cost, high-nickel austenitic ductile iron is one of the most widely utilized materials in corrosive environments due to its excellent heat and corrosive resistance [1]. An abnormal type of graphite may occur in high-nickel austenitic ductile iron with nickel contents ranging from 13 to 37%. This type of graphite forms as fine flake-like chunks in the most slowly cooled portions of casting. It was reported that the carbon, silicon and nickel contents in austenitic ductile iron are adjusted according to the formula: [2].

$$\mathrm{TC\%} + 0.2\,\mathrm{Si\%} + 0.06\,\mathrm{Ni\%} \leq 4.4$$

$$(\mathrm{TC\%} = \text{total carbon}\,\%)$$

If not, the presence of chuck graphite can be detected in many cases. According to ANSI/ASTM A439–89, D5-S high-nickel austenitic ductile iron contains: C% ≤ 2.30; Si% 4.90–5.00; Ni% 34.0–37.0; the left-side value of formula is easily over 4.4. The lower the carbon content, the longer is the dendrite arm and castings will exist much shrinkage [3]. So, it is important to control the level of carbon equivalent for the high quality of high-nickel austenitic ductile iron castings.

The thermal analysis used to study Mg-treated nodular graphite iron that can be traced to the early 1970s [4]. Computer-aided thermal analysis system can provide information about the composition of alloy and determine degree of modification and grain refining on aluminum alloy and graphite morphology on cast iron [5,6].

The main objective of the research effort presented in this paper has been to set up the relationship between solidification model and carbon equivalent, in order to control the composition and property of high-nickel austenitic ductile iron castings.

2. Experimental procedures

The composition of metal charge was C%: 1.5–2.0, Si%: 4.5–5.0, Mn%: 0.15–0.20, Ni%: 34.0–37.0, Cr%: 1.6–2.0, P% ≤ 0.02, S ≤ 0.02, which was melted by coreless induction furnace of 150 kg capacity. The melt was superheated at 1600–1620 °C. After superheating the melt was treated in the ladle with nodulizing alloys (magnesium–nickel ferrosil-

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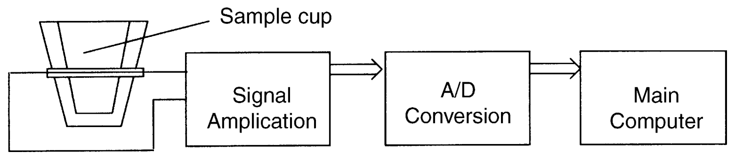

Fig. 1. Structure of thermal analysis system.

icon) by the trigger method. After the reaction was completed and slagged off, post inoculation was performed with 75% ferrosilicon at 1530–1550 °C.

The shell cup of 50 mm in diameter and 60 mm in height, into which a type of Rt–Rh thermocouple was inserted and poured and a cooling curve was recorded by computer-aided analysis system (Fig. 1). At the same time other samples were poured for microstructure and mechanical property.

3. Experimental result and discussion

3.1. Typical thermal analysis curve of high-nickel austenitic ductile iron

Fig. 2 shows a cooling curve, a first-derivative curve also called cooling rate curve and a second-derivative curve also called cooling acceleration curve, which contain a great deal of information about solidification of cast iron. Two platforms at the cooling curve, T_L (temperature of liquidus arrest) and T_{EU} (temperature of eutectic undercooling), are widely applied at pouring station for quality control [7]. Two peaks at the first-derivative curve, which are called austenite peak and eutectic peak, can be used to calculate the amount of austenite and eutectic [8]. Though the cooling acceleration curve was much undulant, it may help to determine the critical point.

3.2. The effect of carbon equivalent on the character of cooling curve

As known to all, cast iron with different carbon equivalent has a different form of cooling curve. In general, the lower of carbon equivalent the higher the temperature of austenite arrest and the lower eutectic action, the same result also take place in high-nickel austenitic ductile iron shown in Fig. 3.The carbon equivalent of high-nickel austenitic ductile iron can be calculated as the following formula: [9]

$$\begin{aligned}\text{CEL} &= \text{C\%} + 0.33(\text{\%Si}) + 0.047(\text{Ni\%}) \\ &\quad -0.0055(\text{\%Ni})(\text{\%Si})\end{aligned}$$

In this paper, the carbon equivalent was also calculated as the formula and the data in Table A.1 were the result of this experiment (see Appendix A).

3.3. Linear regression

Suppose that the relationship between carbon equivalent and liquidus temperature is linear, by the least squares method

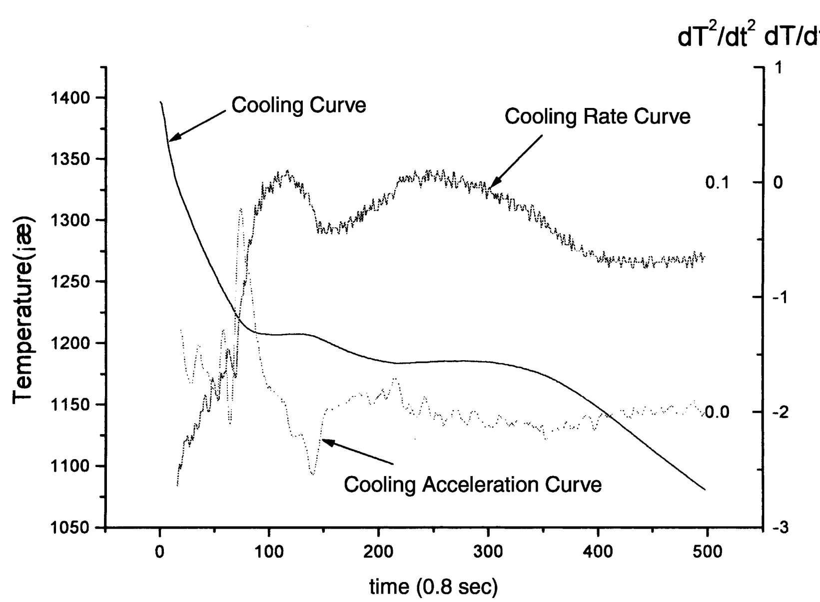

Fig. 2. Typical thermal analysis curves.

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