P-2

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

# Application of Rare Earth Less and Rare Earth Reduced Spherodizer

Yusuke Kiguchi[1], Takahiro Sato[2]
[1] Head Plant Engineering Dept., Aisin Takaoka Co., Ltd.
[2] Casting Production Engineering Dept., Aisin Takaoka Co., Ltd.
1 Tennoh, Takaokashin-machi, Toyota, Aichi, 473-8501 Japan

The reduction in rare earth (hereinafter referred to as "RE") exports has created a crisis situation where it is difficult to procure spherodizers (Fe-Si-Mg-RE). Since REs contribute to fading suppression and the increase in the number of graphite grains [1-3], we used RE-less and RE-reduced spherodizers containing Ba as the substitute for RE, because Ba has higher oxygen affinity than Mg, and combined inoculants in order to confirm material properties, chill, and internal defects. RE-less spherodizers had satisfactory material properties, but chill and internal defects worsened. RE-reduced spherodizers exhibited similar material properties to the mass-produced spherodizers. Since RE-less spherodizers demonstrated large supercooling and a short eutectic solidification time from recalescence, we deduced that the RE-less spherodizers had a low number of graphite nuclei.

***Keywords***: *Spheroidal graphite cast iron, spherodizer, rare earth ,fading, number of graphite grains*

## 1. Introduction

In 2010, the imports of RE elements became less, making it difficult to secure spherodizer (Fe-Si-Mg-RE). Therefore, studies were conducted on the RE-less and RE-reduced spherodizer.

## 2. Experimental procedure

### 2.1 Verifying the effects of RE

As a preliminary experiment to confirm the fading suppression effect of RE, the following process was performed: The return materials, steel scraps, graphite electrodes, and Fe-75% Si alloy were melted in a 100 kg high-frequency melting furnace at 1550 °C in order to produce sample material with the final composition of 3.6% C-2.7% Si-0.2% Mn. Then, the sandwich method was applied to treat various spherodizers (RE = 0%, 0.5%, 1.0%, and 1.6%), and the sample material was poured into a 20-mm-diameter round bar at 1-minute intervals.

### 2.2 Studies on the application of RE-less and RE-reduced spherodizers

Ba was used as an RE replacement element of Mg because it had higher oxygen affinity than Mg. A spherodizer (Fe-45% Si-4.5% Mg-2.6% Ca-0.5% Ba) was used. Ba- and Zr-based primary inoculants and Zr-, S-, Fe-Si-, and Ba-based secondary inoculants were combined. The test specimens and products were prepared using the above materials. The materials were cast into 20-mm-diameter round bar, step bar, and Y-shaped test specimens, and products 15 minutes after performing the treatment to check the nodularity, the number of graphite grains, mechanical properties, chill, and internal defects. The same process was performed for the RE-reduced spherodizer.

.

## 3. Results

### 3.1 Results of confirming RE effects

Fig. 1 shows the relationship between the elapsed time after treatment and the nodularity of various spherodizers. As the amount of RE decreases, the nodularity degrades faster. If a spherodizer contains Ba, however, the spherodizer containing 0.6% RE achieves a nodularity that is equivalent to that of the mass-produced spherodizer containing 1.6% RE.

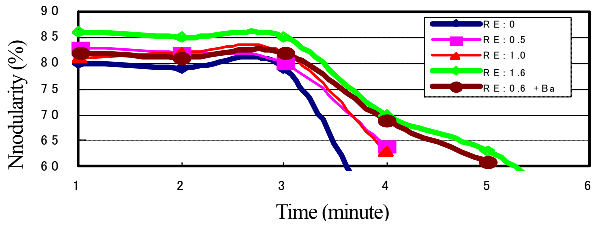



Fig. 1 Relationship between elapsed time after treatment and nodularity

### 3.2 Studies on the application of RE-less and RE-reduced spherodizers

1) Results of confirming the test specimens

Fig. 2 show the relationship between various inoculants and nodularity of 20-mm-diameter round bars. According to Fig. 2, the nodularity of spherodizers without secondary inoculation deteriorated to 70% or less while the nodularity of all spherodizers with secondary inoculation resulted in at least 80%. The number of graphite grains in the mass-produced spherodizers did not vary with wall thickness. In contrast, the number of graphite grains in the RE-less spherodizers containing the combined inoculants tested in this study decreased as the wall thickness increased. The mechanical properties of the RE-less spherodizers were not much different compared with ass-produced spherodizers. The material properties of the RE-less spherodizers were equivalent to those of conventional products due to the secondary inoculation. On checking chill using the 15 mm step bar test specimens, we found that chill was large in the absence of secondary inoculation. Even with secondary inoculation, chill worsened depending on certain combinations of the inoculants. Regardless of the conditions, the internal defects worsened considerably.

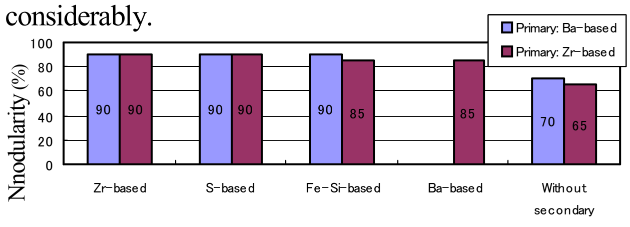



Fig. 2 Relationship between secondary inoculants and nodularity (20-mm-diameter round bar)

2) Results of confirming the products

We checked our company's main product, a differential case made of FCD600 material, which is characterized by large variations in wall thickness. Fig. 3 shows microstructure photos of this product.

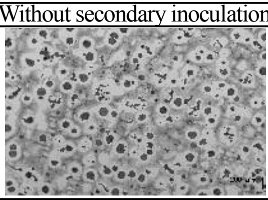
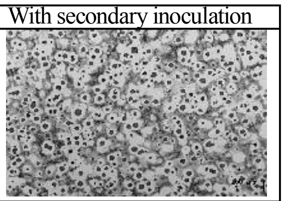
| Without secondary inoculation | With secondary inoculation |
|---|---|
|  |  |
| Spheroidizing ratio: 73%<br>No. of graphite grains: 195 grains/mm$^2$ | Spheroidizing ratio: 84%<br>No. of graphite grains: 351 grains/mm$^2$ |

Fig. 3 Result of metallographic observation

Based on Fig. 3, we conclude that the RE-less spherodizer with secondary inoculation possesses satisfactory material properties. However, internal defects were increased. Chill was noted in the thin portion of this product regardless of the conditions. Based on the above, we determined that application of the RE-less spherodizer is difficult in terms of the casting quality. The spherodizer containing 0.8% RE and Ba-based secondary inoculant showed satisfactory casting quality.

## 4. Discussion

Internal defects and chill worsened when the RE-less spherodizers were used. Thus, it can be inferred that the solidified form of the spherodizers changes. Fig. 4 shows the results of a thermal analysis of mass-produced, RE-reduced and RE-less spherodizers.The spherodizers vary in their solidified form depending on whether RE is present or not. Supercooling caused rapid graphite nucleation in the spherodizers with 1.6% RE and 0.8% RE. It is inferred that a large number of graphite nuclei are present at the initial stage of eutectic solidification. On the other hand, recalescence of the RE-less spherodizers from supercooling is gentle. It is presumed that the casting quality deteriorates because of the low number of graphite nuclei at the initial stage of eutectic solidification.

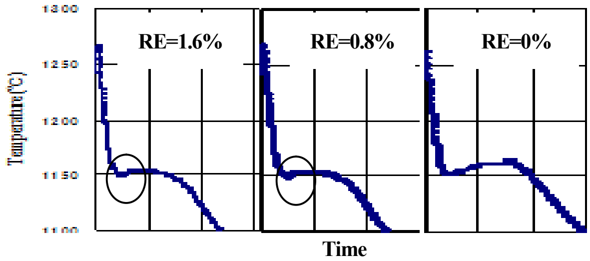



Fig. 4 Amount of RE in spherodizers and thermal analysis curves

## 5. Conclusions

We evaluated the microstructure, material properties, mechanical properties, internal defects, and chill of the RE-less and RE-reduced spherodizers using test specimens and products in an effort to reduce the amount of RE contained in spherodizers.

(1) The RE-less spherodizer suppressed fading with the addition of Ba and the secondary inoculation, showing satisfactory material properties. We confirmed, however, that spherodizers had differences in their solidified form, and internal defects and chill worsened.

(2) The solidified form of the RE-reduced spherodizer was similar to that of the mass-produced spherodizer. The internal defects and chill were significantly improved by secondary inoculation.

## References

[1] T. Kusakawa, H. Lin, X. Xu: Report of the Castings Research Laboratory, Waseda University. (1985) 29-34

[2] W. A. Henning: Transactions of the American Foundry Society, 91 (1983) 71-76

[3] T. Kimura, C. R. Loper, Jr, H. H. Cornell: Transactions of the American Foundry Society, 89 (1981) 395-368