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Inoculation – Higher potency alternatives to Barium Calcium alloys

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At this moment, around 60% of the new iron castings of the world are under production in Asia, and it is a market that is rapidly growing. The predominant Asian choice for inoculation, when not simply Ferro Silicon, has traditionally been a Barium Calcium inoculant. Aside from alloy cost, some reasons are ease of use, availability, ability to provide sufficient casting quality for most iron grades and casting types. However, the Asian market is evolving: Quality demands from end customers are increasing. New iron grades demand new process solution. The availability of raw materials forces changes in base iron composition. Cast iron must also meet the challenge from other alternative materials. For many foundries struggling to adapt to this new situation, higher potency inoculation can be instrumental in resolving these issues.

Keywords: *Ductile iron, Grey iron, inoculants.*

1. Introduction

CaBa inoculants almost has as long a history as ductile iron. In addition, while well-known, low cost, versatile, and readily available, they do not come without their own inherit problems.

Firstly, they are of low-medium potency. Typical addition rates are high, increasing cost and additional Si units; which is undesirable for some foundries.

They offer poor protection from shrinkage defects in the final castings. It is important for foundry men, as processes evolve, to weigh any advantage against total cost, and be aware of the potential reduction in final properties.

2. Nucleation, inoculation and active elements

Ductile irons are live, dynamic materials, which go through many different complex stages as the material solidifies, based on a multitude of factors from raw materials to process temperatures to alloy addition [1]. The process of nucleation is a general term for the mechanisms governing the growth sites of graphite. The higher the amount of nucleation sites available in the melt, the greater the graphite growth. Without available nucleation sites, graphite will not grow, and carbon end up as undesirable random inclusions or iron carbide.

Since the 1920s, the addition of inoculants to cast iron has been known to improve the properties and reproducibility of iron. Inoculation is a method that influences what happens to the graphite in the iron as it cools and solidifies, as graphite precipitation and growth during solidification has a strong effect on the final properties of the iron. By introduction of active elements, such as Ca, Ba or Ce, it is possible to minimize under-cooling and increase the number of nucleation sites during solidification. [1]

All inoculants will fade over time due to a coarsening of inclusions and result in increased undercooling, greater chill, reduced number of nodules, lower nodularity and a general degradation of properties. Thus, it is beneficial to add the inoculant as late in the process as possible [2]. Different inoculants and active elements have different characteristics and resistance to fading [3].

Calcium although of medium potency and fast fading is an essential element for cast iron inoculation for its role in graphite nucleation and chill control.

Barium is also a low/medium potency element that promotes graphite growth, but with a good fade resistance. It is often used in combination with Ca.

Other elements prevalent in ductile iron inoculants are Al, Zr, Mn, Ce, La and Bi. Some high potency inoculants are also coated with S and O to provide a late stage boost to nucleation potential [4,5].

3. Shrinkage and inoculation

One of the issues foundries struggle with for some types of casting is shrinkage defects. Shrinkage occurs when an internal shell forms that cannot be deformed by the difference in pressure with the atmosphere during the later stages of solidification [6], leaving voids that can severely reduce the properties of castings. While there are many valid strategies to avoid shrinkage [4, 6, 7], the choice of inoculant has been shown to have a strong effect [4, 5].

One recent internal study [8] has made similar observations, finding a CaBa inoculant far more shrinkage prone than a Ce-based inoculant at the same addition rate. The image below shows the shrinkage result from two different tests, with different inoculation schemes.

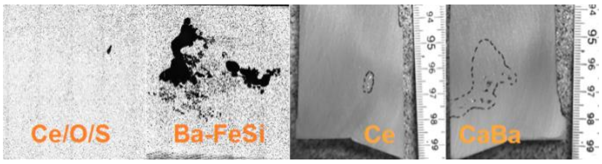

Fig. 1: Shrinkage samples; Study 1 [4] (l), Study 2 [8] (r)

Part of the reason for the difference in shrinkage characteristics can be found in the difference in nodule count and size distribution. Having a sufficient amount of small, late forming nodules is helpful in countering the contraction in last liquid phases before solidification [9]. Below are structure images from the shrinkage samples of study 2 in fig.1.

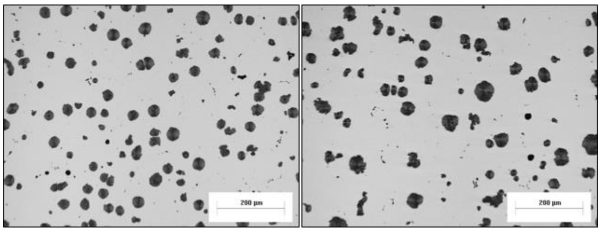

Fig. 2: Structure Ce(l) and CaBa(r)-inoculant., w. RE-free MgFeSi [9]

A powerful tool that has helped many foundries to identify and combat shrinkage as well as optimizing their inoculation solution in general is thermal analysis. It is possible to predict the kind of shrinkage behaviour shown here using thermal analysis curves [6,9].

4. Case study: Ductile iron turbocharger housing

An automotive foundry producing crankshafts in ductile iron grade 800/2 was having problems with shrinkage in a 30mm thick section. The MgFeSi (6.0%Mg/0.5%RE) with a 0.4% addition of BaCa inoculant in the transfer ladle and a 0.1% addition of Ba/Ca inoculant in the metal stream was replaced with a single 0.2% high potency Ce-based O&S-coated inoculant in the metal stream. As a result the shrinkage was reduced from 15% to 3% of the castings.

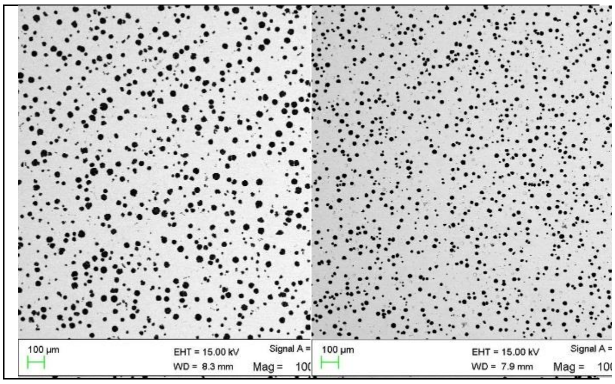

Fig. 3: Structure of old(l) and new(r) process

5. Conclusion

Calcium Barium inoculants still have a place in today’s industry. If there are no complex, shrinkage prone casting geometries, if there are no difficult specifications to be achieved and if only a simple process using one inoculant for everything preferred. Then a CaBa inoculant might adequately cover those needs. However, foundries looking to solve issues of shrinkage, fading and increasing demands on iron properties should look to higher potency inoculation alternatives.

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