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Optimal design of pure lanthanum based MgFeSi alloy for high performance ductile iron ladle treatment

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Lanthanum containing MgFeSi has been used in ductile iron production for 40 years. First solely for "in the mould" processes, and then in the last 12 years it has seen increased use as a ladle alloy. There are several reasons why these alloys have gained popularity, such as shrinkage reduction, improved microstructure properties, and a lower level of La in the alloy compared to the total rare earth (RE) level from mischmetal based alloys. During the rare earth price crisis in 2010-2012, this turned into an appreciable cost advantage for the lanthanum based alloys. This article will explore some of the benefits of using La as the sole source of rare earth in the MgFeSi.

Keywords: *Ductile iron, MgFeSi-alloys, Lanthanum.*

1. Introduction

In 2004, a paper by Dr. Torbjørn Skaland was presented to the WFC, winning the best paper award. The title of the work was “A new method for chill and shrinkage control in ladle treated ductile iron”.

The paper was a study of the effects of La and Ce based MgFeSi in ladle treatment [1] and it clearly demonstrated that La based alloys had a far wider application than in mould.

In the 12 years that have passed since WFC 2004, there has been a profound shift, where La based MgFeSi have gone from a niche product to becoming the basis of over 1.5 million tons of ductile iron production based on current market figures.

2. Iron and Rare Earth (RE) elements

After RE lost to Mg as the main route for nodularizing ductile irons in the 1940’s, many benefits of RE have since been discovered, and these elements are now an essential part of ductile iron production. Controlled levels were shown to reduce edge carbides and increase nodule count [2,3,4]. Trace element control is deemed crucial for making good ductile iron, especially in present times as steel scrap quality deteriorates and RE has been found to neutralize the effect of deleterious trace elements, such as Pb, Sb, Bi, As [5].

The first use of La as the sole source of RE in MgFeSi dates back to the early days of in the mould process, where reduced shrinkage tendency was demonstrated by the introduction of pure La MgFeSi [6]. Since their introduction as ladle alloys 12 years ago they have grown in market shares based upon industry success with reduced shrinkage tendency, improved mechanical properties and improved machining surface finish.

So what is special about La? It is part of the Rare Earth family, of similar molecular size and reactivity as Ce. As other RE’s, it is a strong deoxidant and desulphuriser, helping Mg in tying up S and O. It gives an improved inoculation effect, higher nodule counts and reduced carbide formation. It shares the particular ability of other RE’s to tie up subversive elements [5].

However, it has shown a tendency to give a characteristic nodule distribution, linked to its efficiency at reducing and eliminating shrinkage and chill [1]. The use of lanthanum in the nodulariser has been seen to give a skewed nodule distribution with small late forming nodules adding a late expansion effect to reduce shrinkage porosity.

3. Optimal La level in alloys

The original development work was carried out at a MgFeSi addition rate of 1.5% and the optimum chill reduction, nodule count and thermal analysis properties were found at an addition of 0.5% La to the nodulariser. Since that time, there has been a significant industry shift towards lower MgFeSi addition rates and this has been driven by improvements in ladle design, increases in Mg recovery, the desire to reduce costs and the RE crisis previously mentioned. The average MgFeSi addition rate in ladle practice is now estimated to be around 1.2%. Thus, in many cases the total ppm of La has been reduced and it is pertinent to determine if this La level in the MgFeSi is still valid.

Below is the result of three studies of La concentration in MgFeSi and the effect on nodule count nodule count [1,10,11].

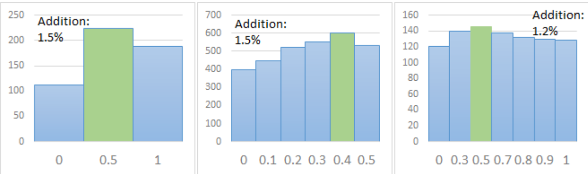

Fig. 1: Optimum. La in MgFeSi.
(%La in MgFeSi on x-axis, nodule count on y-axis No/mm²)

Adjusted for addition rate, studies 2[10] and 3[11] show the exact same peak level, corresponding to a total addition of *0.006% La to the iron via the alloy*. Also noted during the experimental studies were significant changes measured using thermal analysis. The most nucleated irons were found at the 0.5% La in the MgFeSi, lower nucleation being seen at both higher and lower La levels.

There are, however, reasons to be slightly cautious about using the same level for any process. Given the importance of La in balancing detrimental elements, the quality of the base iron should always be taken into consideration. At a minimum it seems reasonable that a stoichiometric balance should be obtained, which can be estimated as *RE/Subversive Elements=0.5*. (Sub.Elem. = Pb, As, Bi and Sb) [12]. A total concentration of Pb, As, Bi, Sb of 0.008 would require a La addition of 0.004%.

4. Case study: Shrinkage in steering knuckle

An automotive foundry had been having shrinkage issues in a steering knuckle. The foundry was using a 1.3% addition of MgFeSi (5.5%Mg, 1.5%RE). After treatment, the iron goes into a pouring ladle, with a 0.4% addition of a CaBa inoculant used.

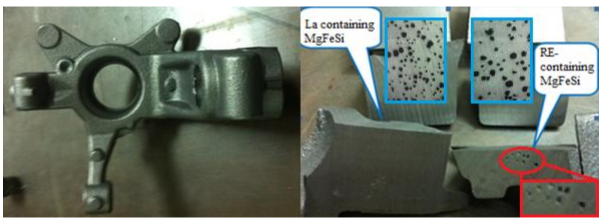

Fig. 2: Steering knuckle (L), result comparison (R)

The foundry then changed the MgFeSi to one containing 5.9%Mg and 0.5%La, and reduced the addition rate to 1.2% to aim for the same residual Mg. The result was better microstructure and a strong reduction in shrinkage tendency as shown in fig 2.

5. Conclusion

Much has changed in the decade that has passed since the original presentation and foundries have improved their processes. However, the original observations about the ideal levels and the advantages of lanthanum based MgFeSi still holds true.

Foundrymen still need to be aware that decreasing addition rates, less pure raw materials and higher amount of trace elements, both will increase the need for La needed in the alloy. As always flexibility in alloy design is important.

When changing from a RE based MgFeSi it is better not to overcompensate the reduction in RE when changing to La based grades. By having La levels in the alloy above optimum, many of the observed benefits regarding shrinkage and structure will be reduced, in addition to causing a higher alloy cost.

Overall, when applied correctly, there are strong benefits from La-based MgFeSi, therefore there is no reason why these grades should not continue to increase in popularity in the years to come.

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