Technical Introduction

Use of Rare Earth Metals in the Production of Cast Irons

General Introduction
Although not particularly rare, concentrated deposits of rare earth minerals are only found in a limited number of sites in the world. Environmental issues in their extraction and refinement also limit potential sites being developed. In the last 20 years, aggressive pricing from China forced the closure of other countries mines and their share of world production rose from 25% to over 97% today.

Consequently, with growing demand and a monopoly on production and supply, prices for rare earth minerals are rising at an alarming rate. Sites in Canada, USA and Australia are planned to reopen but these are not expected to be fully commissioned until at least 2014.

Applications for rare earth elements have also increased, with the majority used in electronics and hi-tech industries. Many of these applications are highly specific and substitutes are either inferior or unknown.

The foundry industry is a relatively minor consumer of rare earths but they are a vital constituent of some specific foundry alloys, and play an important role in the quality of the final cast product. Due to the rising cost and reduced availability, the foundry industry needs to be aware of why the additions are made and question if the addition rates can be reduced or removed.

The Role of Cerium and Lanthanum in Ferro Alloys
The family of rare earth elements contain 17 elements of which four; Cerium (Ce), Lanthanum (La) Praseodymium (Pr) and Neodymium (Nd) are the most abundant and are present to varying levels in foundry alloys containing rare earths. Of these four elements, two are important for the iron foundry; Cerium and Lanthanum.

These elements are used in 3 important stages of cast iron production: -
- Base metal preconditioning.
- The nodularisation / Magnesium treatment process
- The inoculation process

The major role of Cerium is to negate the effect of certain deleterious elements which can enter the charge makeup. These elements include Bismuth (Bi), Lead (Pb), Antimony (Sb), Arsenic (As) and Titanium (Ti) all of which can have an adverse effect on graphite shape but the list could also include Tin (Sn), and Aluminium (Al). These elements need to be carefully controlled to low levels, or conversely, counteracted with Cerium. Cerium is particularly effective at neutralising the detrimental effect of lead, which if too high, promotes a ‘Widmanstatten’ graphite form, resulting in poor mechanical properties.

Preconditioning of Base Iron
Cerium also helps to precondition (improve nucleation status) of the base iron. Poor quality charge materials or iron held at high temperatures for a prolonged time is starved of any inherent nucleation. When combined with Sulphur and Oxygen from the melt, Cerium will form high temperature stable nuclei which are carried through to the final cast product. This helps to improve cell / nodule count, graphite morphology, and potentially Magnesium addition efficiency.

Magnetism Ferro Silicon (MgFeSi)

Nodularisers
Rare earths are routinely integrated into the chemistry of propriety Magnesium Ferro Silicon (MgFeSi) alloys with TRE levels available from zero to 5%. Cerium is typically 50% of TRE although certain alloys can contain high levels of Lanthanum. The primary reason for the addition of rare earths is to counteract deficiencies in base iron chemistry.

High additions of rare earths are sometimes incorporated into MgFeSi alloys specifically for the production of compacted graphite irons. Rare earth is uniquely able to control Oxygen and Sulphur content with the aim of achieving the correct balance of Mg-S-O for the consistent production of this temperamental material.

Inoculation with Lanthanum and Cerium Inoculants
Lanthanum is a useful element for the promotion of a high nodule count in nodular iron, which in combination with controlled rates of graphitisation will help to reduce the occurrence of microporosity. It is more effective when incorporated as an inoculant, preferably as a late stream addition.

Cerium is also an effective inoculant, helping to produce grey iron with ‘A’ type structures and reduced risk for microporosity. A slow rate of fade also helps to ensure good nucleation levels are maintained throughout the pour.

Risks Associated with Rare Earth Additions
For all their potential benefits for cast irons, the rare earths can also introduce problems for a foundry: -

- Rare Earths are associated with carbide promotion in thin section work, chunky and exploded graphite defects in nodular production.
- Rare earth additions should not be employed when producing high Nickel containing cast irons (Ni-Resist) due to risk of chunk graphite.
- The choice of inoculant needs to be considered. For example, Strontium based inoculants are neutralised by rare earths, reducing their effectiveness.
- The rare earths are susceptible to solute segregation. With slow cooling / heavy section castings, rare earths tend to be pushed forward of the solidifying front. The last metal to solidify will contain high concentrations of rare earth which could promote defects associated with chunk and exploded graphite, and possibly inverse chill. These defects can be negated with deliberate small additions of Bismuth (Bi) or Antimony (Sb).

Methods Employed to Reduce Reliance on Rare Earths
Rare earths additions are vital to counteract deleterious elements or to promote specific structures. However to reduce the reliance on rare earth additions, it is important to consider the measures outlined below: -

- Check trace element count of all metallurgical materials used.
- The careful selection of charge materials to help ensure low levels of deleterious trace elements in the base charge; including high purity pig iron, low residual steel, low Sulphur / Nitrogen graphite, and good grades of Silicon Carbide and Ferro Silicon.
- Use of Silicon Carbide in the charge to help control and stabilise base oxygen and nucleation levels.
- Just prior to tapping, use of Barium (Barcast 90 TM) or Aluminium (Alcast 4 TM) based preconditions to help improve Magnesium recovery and increase both nodule count in S.G., and cell count in Grey Iron.
- Control holding temperature and time to help preserve base metal condition.
- For nodular iron, use efficient Magnesium addition methods to limit addition rate and maintain metal quality.
- Use efficient and effective inoculation procedures to ensure final as cast structures are achieved.
- Control pouring temperatures and times to limit Magnesium and inoculant fade.
- Control and segregate foundry returns to ensure alloying elements are controlled with low levels of cross grade contamination.
- Consider adding a separate source of rare earth addition (rare earth silicide or Cerium mischmetal) when necessary.
- Use advanced thermal analysis (ATAS®) to monitor the metallurgical process.

Asmet’s Range of Rare Earth Products
Asmet has a wide range of specialist Rare Earth containing alloys for all stages of your process, including: -

- Rare Earth Silicide
- Cerium Mischmetal
- Reox™ Preconditioner for Base Iron
- Ertalloy™ MgFeSi alloys contain from zero to 3.25% TRE
- Ertalloy 65 La™ (Lanthanum based MgFeSi alloy)
- LNS0™ (Lanthanum inoculant)
- Biscast 10™ (A Cerium/Bismuth inoculant)
- Recast 4™ (Cerium inoculant)

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