NEW, IMPROVED METHOD TO RESUSCITATE FADED DUCTILE IRON

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ARTICLE TAKEAWAYS:

- Controlling silicon and magnesium in ductile iron
- Working with faded treated ductile iron in automatic pouring
- Ways of boosting magnesium content in faded ductile iron

Silicon and magnesium are two of the major elements in ductile iron. Both elements effect the amount and form of graphite and matrix structure and both have a profound effect on the physical properties of the iron. Unlike carbon, which can be adjusted easily to meet specification, controlling silicon and magnesium contents can be difficult. Much of this difficulty arises because in the sequence of making ductile iron, silicon is contributed at almost every stage:

1. Returns, which contain silicon, must be used in the melting furnace charge.

2. Magnesium ferrosilicon alloys, the most widely used additives, typically contain 40 to 50% Si.

3. Most post-inoculants used to promote graphite nucleation may contain up to 75% silicon.

The most common method used to produce ductile iron utilizes magnesium ferrosilicon. The silicon level in the untreated, base iron is intentionally kept low so that after the iron is treated with magnesium ferrosilicon and post-inoculated, both the carbon and silicon are within specification.

From this point forward, the foundry will have a finite time limit to pour castings (this limit varies but typically will be about 12-15 minutes). The moment ductile iron is treated with magnesium, the clock starts ticking. As time expires, the treated DI should be poured in a “pig mold” as the metal has faded, i.e. magnesium is lost and lower than specification due to oxidation/resulfurization reactions. This paper will primarily focus on magnesium fade in automatic pouring units and how this iron can be rejuvenated back to useable Ductile Iron.

The two most common automatic pouring systems are 1.) an un-heated pouring unit with a graphite/refractory stopper rod for indexing the molten metal directly into a highly automated green sand molding line, or 2.) a pressure pour channel induction furnace situated directly over a highly automated green sand molding line. Often, it will be necessary to rejuvenate "dead" or faded ductile iron if there is 1.) a molding line breakdown or 2.) a need to rejuvenate magnesium levels at the beginning of a shift or over a weekend (referred to as Monday morning iron).

When confronted with faded treated DI in automatic pouring, unheated pouring units can be drained and refilled with new treated DI with minimal difficulty.

However, most pressure pour channel furnaces holding treated ductile iron, will always maintain a minimum heel. The minimum heel left inside of the furnace at the end of the week, or during an unscheduled breakdown on a molding line, will require a magnesium "refreshment or rejuvenation".

There are several methods that can be utilized for increasing or boosting the magnesium content in faded ductile iron. The three most common methods are:

1.) treating faded DI with a high magnesium-containing ferrosilicon alloy such as a 9% Mg,

2.) treating DI with a nickel-magnesium (Ni-Mg) master alloy, or,

3.) treating DI with a proprietary 10-15% iron-magnesium (Fe-Mg) alloy briquette.

The first method commonly used method for increasing magnesium levels is using an elevated magnesium level in a magnesium ferrosilicon (MgFeSi) master alloy. Often, the magnesium levels in these special alloys will be in the range of 9 to 10%. Care must be used with these high magnesium ferrosilicon master alloys as their density is considerably lower than the more commonly used 5% MgFeSi alloys. The lower density from the high magnesium content favors alloy floatation and poor magnesium recovery.

Although using a high MgFeSi master alloy will increase magnesium levels compared to the common 5% alloy, its use will still result in an increase in un-wanted silicon. An example of how additional silicon affects the mechanical properties of a typical 60-40-20 as cast DI is shown in the table above.

	Sample 1	Sample 2	Sample 3
Total Carbon	3.37%	3.38%	3.42%
Silicon	2.45%	2.60%	2.89%
Carbon Equivalent	4.11	4.16	4.29
% Ferrite	95	95	80
% Pearlite	5	5	20
Tensile Strength (psi)	63,500	67,300	76,200
Yield Strength (psi)	44,800	48,900	59,600
Elongation, %	23.9	18.5	18.5
Brinell Hardness (BHN)	152	156	179

The 0.44% increase in the silicon content increases the tensile strength 12,700 psi (20%), while decreasing ductility or elongation by 5.4% (22.6%). Although not shown, as the silicon content increases, the brittle to ductile transition temperature increases.

A second method that is used to boost magnesium levels in faded DI is the use of a nickel magnesium master alloy (NiMg). A major advantage using Ni-Mg is that the density is higher than of the base iron and the alloy will sink, optimizing magnesium recovery. While the sinking characteristics of a 5% Ni-Mg alloy is well know, the higher Mg grades (NiMg15%) of this master alloy, do not sink and care must be taken to insure that the alloy doesn't float. A disadvantage is in using Ni-Mg master alloys is two-fold: 1.) the additional presence of nickel that may or may not be a chemistry requirement for most DI grades, and 2.) the high cost of the nickel alloy.

A more economical approach for boosting faded DI in pressure pour furnaces as well as unheated ladles is to use an iron-magnesium iron (Fe-Mg) master alloy. There are current two grades of iron-magnesium alloys available, a 10% Fe-Mg grade along with a 15% Fe-Mg grade. The biggest advantage with these alloys is the overall unit cost of the magnesium units when compare to the magnesium nickel. Also, these products are iron based which fits well with treated DI. There is no need to add an alloy that is not needed. The density of the Fe-Mg alloys is less than the Ni-Mg and requires a cover material (such as cover steel or other dense ferroalloy cover). Besides controlling silicon levels, using

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Figure 1: Nodu-Bloc Briquettes

Fe-Mg alloys allows increased levels of foundry returns in the furnace charge make-up, often resulting in significantly reduced melting costs.

ASI International, Ltd. has developed a new generation of Fe-Mg alloys (Nodu-Bloc) that address improved ductile iron boosted treatments. Nodu-Bloc alloys provide significant cost advantages compared to using 9 to 10% MgFeSi alloys or Ni-Mg master alloys. Although pressed Fe-Mg additives have been available in the past, research by ASI has determined that there is a preferred surface area to volume ratio. The size, shape and weight of Nodu-Bloc tablets or briquettes has been found maximize magnesium recovery with minimal pyrotechnics when used as directed.

Nodu-Bloc iron-magnesium alloys are manufactured using well-developed powder-metallurgy techniques. Pure magnesium, high-purity iron powder and other additives are carefully blended and compacted under extremely high pressure. Since a furnace smelting process isn't employed, magnesium levels can consistently be controlled in the range of +/- 0.05 percent. Nodu-Bloc briquettes are pillow shaped, are silver-gray in appearance, measure 2.0 inches long, by 1.0 inch wide and approximately 0.875 inch thick, and typically weight 65 grams (see Figure 1).

To date, numerous foundries have substituted Nodu-Bloc for high 9% MgFeSi or Ni-Mg alloys as an integral part of their daily production. Nodu-Bloc is used in a variety of ladle configurations, ranging from open ladles, the sandwich process or the tundish cover process. The most favorable results are obtained with ladles having a width to height ratio of 1 to 2.5.

Many foundries make additions to the treatment ladle in a specific order. Typically, this involves sandwiching the Nodu-Bloc between alternate layers of magnesium ferrosilicon followed by adding up to 1% cover steel. In most cases, a lesser amount of MgFeSi is used along with the Nodu-Bloc addition, contributing some silicon units, but at a significantly reduced level. In all cases, cover steel is required to prevent alloy floatation. Magnesium recoveries typically range from 50 to 75% based on metal temperature, pouring speed and amount of cover steel.

A real-life case study is foundry DI. Foundry DI is a coreless melt shop and uses 2 pressure pour channel furnaces holding and pouring various treated ductile iron grades into automated molding lines. Every weekly start-up includes a 5 to 6 ton "faded" ductile iron heel in each pressure pour furnace that has virtually no remaining magnesium left. Often referred to as "superboost" Mg treatments, Foundry DI uses one or two full 6,000 lb ladles (temperature 2650-2700oF) which contain a composite "sandwich" of alloys and cover steel in the ladle pocket to add sufficient Mg to replenish the "faded" low molten metal heel in pressure pour furnace. The following sequence of alloys used in the "superboost:

45 lbs of MgFeSi,

30 lbs of 10%Mg Nodu-Bloc,

45 lbs of MgFeSi,

30 lbs of clean, dry cover steel in the final layer.

For pearlitic grades, 6 lbs of copper is added. Using this procedure, the magnesium level in the pressure pour furnace is restored to 0.040 – 0.044% Mg.

The need to use "superboosts" is also required when there is a significant downtime on the molding lines such as a mechanical breakdown. However, the quantity of different alloys will vary depending on the residual magnesium content in the pressure pour. Foundry DI has used this "superboost" treatment for many years and has been able to have reliable restarts of the pressure pour furnaces for the last 8 years. In the past, a nickel magnesium master alloy was used, however, there was no requirement for nickel in their ductile iron grades. This was a major cost savings without any negative consequence.

Nodu-Bloc usage has steadily increased over the past dozen years and is expected to continue it's upward climb as foundries look for cost saving production methods. Nodu-Bloc use allows simple control of final silicon and thereby enables a foundry to produce sound castings economically to the desired mechanical and chemical specifications.

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