One Solution For "Monday Morning" Iron

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“Monday Morning” iron is a phenomenon that every iron casting facility faces. It is iron that has been sitting in some type of holding furnace over an extended period of time, which has lost its nucleation potential. The use of various tools can decrease the amount of time in which it takes to re-nucleate the iron, as well as, detect when the iron’s susceptibility for shrink defects often associated with “start-up” iron has decreased enough to make quality defect free castings. In order for the reader to fully comprehend the practices being talked about in this paper they must understand the operation in which they are being used. The author from this point forward will be referring to Neenah Foundry Company’s Ductile Iron production facility.

Neenah’s Ductile Iron foundry is a cupola melt shop. The cupola is a Modern 84” shell refractory lined to 66”. Recuperative hot blast along with supersonic oxygen injection is utilized. The cupola is capable of melting approximately 30 tons per hour. The iron from the cupola is transferred via a five-ton bull ladle to two 60-ton 800kW Whiting holding furnaces. From the furnaces, the iron is treated using a mod-tundish ladle process treating 7,500 pounds of iron at a time. The treated iron is then poured into two pressure furnaces, one on a 2070 Disamatic and one on a 2013 Disamatic. Finally, a late stream inoculant is added as the iron is being poured into the molds.

One advantage Neenah Foundry has is the ability to make salable municipal castings during start-up due to the fact the castings only have to meet 35-ksi tensile strength; this decreases the amount of iron “pigged” out during the start-up process. Even with this ability a quicker conversion to quality, defect free industrial casting production is always desirable. The start-up process at Neenah used to take upwards of two hours with a greater risk of making scrap castings, now with the tools that will be talked about in this paper Neenah can switch to full industrial casting production in usually one half to one hour. The tools and techniques being used will now be discussed.

Thermal Analysis systems give a great deal of insight into the solidification characteristics of a particular iron. Utilizing the full ability of each system along with normal control tools (chemistry, microstructural analysis and mechanical property information, etc.) and knowing the key parameters to look for can be invaluable when trying to decrease start-up times and find the iron’s nucleation potential. Neenah Foundry utilizes Novacast’s Adaptive Thermal Analysis System (ATAS)® Verifier version 4.1.1. The samples are poured into non-Tellurium cups after magnesium treatment and just prior to in-stream inoculation.

Another tool optimized by Neenah Foundry is adding a “pre-conditioning” inoculant to the start-up ladles. Neenah uses an inoculant with 10 X 25 mesh sizing and the following contents:

~73% Silicon
Neenah has found that the addition of this inoculant to the tundish ladle treatment has added significant robustness to the iron’s nucleation, helped to offset the impact of extra magnesium additions at start-up, and it has also helped to delay graphite precipitation until late in solidification. Neenah has found that addition rates of between .3% and .1% are sufficient to achieve the benefits listed above. All these benefits will be evidenced later in the paper.

The author will now go through a typical Neenah Foundry start-up and show the related ATAS curves. As stated before 7,500 pounds is the normal treatment size, however to save capacity in the pressure pour furnaces during start-up Neenah uses a 6,500 pound treatment on the first ladle added. Typical alloys added include 5% MgFeSi, 50% FeSi, 10% Mg alloy, carbon raiser, pre-condition inoculant and copper as needed to make grade requirements. Normal holding furnace temperatures over the weekend are between 2600-2700 degrees Fahrenheit, and normal pressure pour holding temperatures are 2500-2600 degrees Fahrenheit. Normal chemistry results, which are taken about an hour before start-up are as follows:

**Pressure Pour Furnaces**

\[
\begin{align*}
Si &= 2.30 \\
Mg &= .002 \\
S &= .012
\end{align*}
\]

**Holding Furnaces**

\[
\begin{align*}
Si &= 1.30 \\
S &= .018
\end{align*}
\]

From these base chemistry results alloy addition recipes are calculated and the start-up process begins.

Once pouring begins ATAS samples are taken after each ladle addition. The curves below show the impact of the “pre-conditioning” inoculant and the ability of the ATAS system.

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1st Curve of the Day, taken at 4:05 AM about 10 minutes after ladle was added to pressure pour.
**Items to note:** Large yellow area (S1) which indicates a large amount of primary austenite. This is a critical measurement to show macroshrinkage tendency. The more primary austenite, the larger the dendritic growth making feeding with risers more difficult.

**Items to note:** Very erratic cooling, shown here by the 1st derivative curve. Graphite Factor 1 (GRF1) is low, indicating a low amount of eutectic graphite and Graphite Factor 2 (GRF2) is high, which is a measurement of the angle at the solidus on the 1st derivative curve. These two factors are an indication that the nucleation status of the iron is poor, which will lead to a lower nodularity and nodule count with an increased risk for shrinkage defects.
Items to note: Very erratic graphite precipitation. The eutectic two value is quite low, 37.8, indicating that only 37% of the graphite is coming out in the last stages of solidification to help offset microshrink that occurs at the end of solidification. This eutectic two measurement can be used as another measurement of metallurgical conditions, a higher value is desirable.

ATAS screen showing the iron's solidifications characteristics are not within limits set by Neenah Foundry.

The chemistry of the above curve is as follows:

\[ \text{Si} = 2.56 \]

\[ \text{Mg} = 0.043 \]

\[ \text{S} = 0.018 \]
Even though this chemistry is respectable the above ATAS curves are showing poor metallurgical conditions, therefore Neenah would not switch over to industrial production. In the past once these chemistries would have been reached full industrial production would begin with an increased risk of making scrap castings.

2nd Curve of the day taken at 4:33 AM, sample taken after second ladle has been added to pressure pour furnace.

Items to note: S1 value is low indicating very little primary austenite. The chances for macroshrinkage are significantly decreased.

Items to note: Even cooling throughout solidification. The angle at the solidus is less indicating a better nucleation status, which should yield better nodularity and higher nodule count.
**Items to note:** Much smoother graphite precipitation. The Eutectic 2 value is much higher 55, showing 55% of the graphite precipitated is late stage. This will give a much higher nodule count and help offset macroshrink.

ATAS screen showing all the parameters fall within Neenah Foundry limits and it is OK to pour industrial castings.

The Chemistry of the above curve is as follows:

\[
\begin{align*}
\text{Si} &= 2.47 \\
\text{Mg} &= .042 \\
\text{S} &= .003
\end{align*}
\]

The chemistry results of this second curve are not that much different than the first one however, the solidification characteristics of the iron are much different as shown by the ATAS curves. At this point it would be acceptable to switch over to full industrial
production, with a significantly decreased risk of making scrap. The process of re-nucleating the iron used to take up to two hours and this particular start-up took about one-half hour.

In conclusion the author would like to make the following points. Using a thermal analysis system and being able to find the parameters key to each particular operation can give foundry people a much better insight as to their iron’s metallurgical personality. Using a “pre-conditioning” inoculant can add robustness to a foundry operator’s iron and aid in reducing start-up times with a decreased risk of making scrap castings. All of the above mentioned can be a significant cost savings for the foundry operation.

References

1) ATAS® Verifier “User’s Guide” NovaCast Ronneby-Sweden