IMPROVED INOCULATION IN TODAY'S IRON FOUNDRIES

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Article Takeaways:

1. Increasing cell count in grey iron, especially for thin section castings
2. Understanding the sulfur effect in treated ductile iron for a given magnesium content
3. Why you should improve standard calcium bearing 75% ferrosilicon inoculation in cast irons

When pouring grey and ductile iron castings, the development of the proper graphite morphology is critical for meeting desired physical properties. To achieve the desired graphitization and shape, it is mandatory to have sufficient "seeds"(nuclei) within the molten iron to provide for proper graphitization. The inoculation procedure of these irons provides for the necessary "seeds" to form.

The effectiveness of all inoculants is directly related to the dissolved levels of sulfur and oxygen in the molten irons. It has been demonstrated by numerous credible investigators that high purity ferrosilicon containing no Group II or IIIA elements, is not effective in inoculating grey or ductile irons. The dissolved levels of sulfur and oxygen inherent in molten iron often determine the effectiveness of conventional inoculants. If sufficient levels of sulfur and/or oxygen are not present, then the number of substrate particles is greatly reduced. Since it is difficult and if not impossible to manufacture a smelted ferrosilicon that contains controlled levels of sulfur and oxygen, the only alternative is to add sulfur and oxygen during the inoculation process.

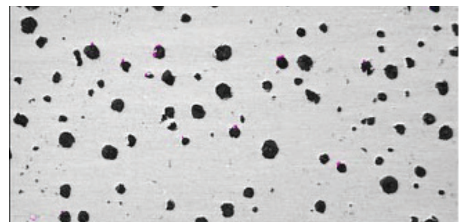

Fig. 1 Standard Inoculation 100x

Ductile Iron Inoculation - The following is a real life example of a foundry that struggled with sporadic carbides and random shrink defect on a ductile iron ASTM grade A536, 65-45-12, casting, and how they were able to resolve their defects.

The base iron was melted in two medium frequency coreless induction furnaces. The treatment ladles were 700 lb tundish ladles, with side pocket for the 6% Mg FeSi alloy. Each treatment was split into 2 - 350 lb pouring ladles using 0.42% Calcium bearing 75% FeSi into the stream during filling.

Figure 1 shows a microstructure of treated ductile iron with a standard calcium bearing 75% FeSi inoculant

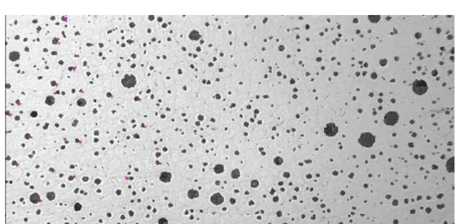

Fig. 2A Inoculant Enhancer Unetched

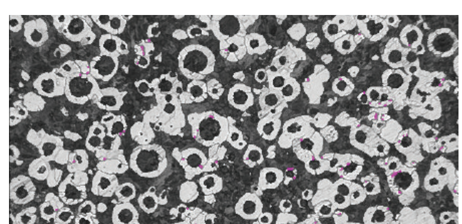

Fig. 2B Inoculant Enhancer Etched

addition to the stream of pouring ladle. (100X magnification) The final sulfur content was 0.006% with a magnesium content of 0.037%

Figure 2 shows microstructures of similar treated ductile iron from a 350lb pouring ladle with exact amount of standard 75% FeSi and another 0.02% addition of oxysulfide inoculant enhancer to the stream filling the ladle. (100X Magnification, unetched and etched). Final sulfur content was 0.010% and magnesium content is 0.040%. There is desirable bulls-eye ferrite and pearlite in the matrix, and a myriad of different sized graphite nodules dispersed throughout the iron. This is shown by comparing the photomicrographs in Figure 1 to Figure 2. The resulting mechanical properties from the ductile iron in Figure 2, showed no loss of yield or tensile strength while gaining on % elongation. This is especially critical on the challenge to meet elongation properties for the higher strength ductile irons such as 80-55-06, or the 100-70-03 grades.

Grey Iron inoculation - The photomicrographs shown in Figure 3 were part of a 1970 AFS sponsored research project (J.F. Wallace and R. Naro) describing the effects of "Minor Elements in Grey Iron". In this report, it described the further effect of increasing sulfur as related to manganese, rare earth metals, etc, to prove the beneficial contribution of sulfur as related to increased eutectic cell count. Also, the flake size would increase as the sulfur content was raised for a given amount of manganese in the iron.

An example of improved grey iron inoculation, Foundry X was pouring Class 30 grey iron. They added a 0.02% separate addition of the inoculant enhancer (increasing sulfur from 0.03 to 0.06 final) to the existing 0.30% addition of Ca containing Ferrosilicon based inoculant. The results were improved eutectic cell count, controlled flake size and chill tendency was eliminated. Mechanical properties remained unaffected.

Whether increasing eutectic cell count in grey iron, or increasing the diverse nodule distribution in treated ductile iron, sulfur is not the only element to control for good microstructure in grey or ductile iron. As mentioned earlier, the presence of oxygen will dramatically affect the "seeds" of nucleation. I. Riposan had often described the formation of manganese oxide silicates for grey iron, or the various oxides of Ca, Mg, Rare Earth Metals, Ba, etc. for seeds for graphite nodularization for ductile iron, late oxygen additions have proven effective to increase nodule count. The inoculant enhancer, Sphere-o-dox G, as described earlier, also contains dissolved oxygen levels to help accommodate this need.

Ideally for grey iron, the final sulfur range can be from 0.05 - 0.11%. If grey iron sulfur is low, the flake development and sizing may be less, affecting the mechanical properties directly and could cause carbides/ chill depending on section size.

For treated ductile Iron, the final sulfur range should be from 0.007 - 0.014%. This range may be slightly lower for larger section castings. With lower sulfur content less than 0.005%, less nodules will form / less carbon will precipitate, leading to increased shrinkage defects. With higher sulfur contents above 0.019%, the excess sulfur will react with the magnesium to form increasing vermicular graphite within the

Fig. 3A - 0.01% S

Fig. 3B – 0.04% S

microstructure and subsequent loss of nodules, approaching compacted graphite iron structure.

When using the sulfur containing inoculant enhancer (Sphere-o-dox G), incremental amounts added as separate additions in the post inoculation stage seemed to give excellent results whether for grey or treated ductile iron. The key is to determine the critical amount that will act as a supplement to the current calcium bearing inoculation practice. Having a consistent base sulfur % in the iron before inoculation, will help to determine the final sulfur needed. The inherent amount of oxygen with the booster will further assist in the development of the oxide seeds for nucleation.

The true measure of good inoculation is the amount, the sizing and development of graphite within the molten iron during solidification. The presence of Sulfur and Oxygen will definitely influence this development.

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