Excessive oxidation of base iron

by David Sparkman Oct 6, 2009 all rights reserved

Oxygen plays an important role in the production of iron as an undesirable element. Problems related to high oxygen content is excessive slag, higher consumption of inoculants and, in the case of ductile iron, higher magnesium consumption or lower recovery. Excessive slag can increase the labor involved in slaging the furnace, and, if not controlled, can appear as slag stringers in castings, or block up filters that have been added at extra cost to prevent slag from reaching the casting. For those unfamiliar: slag is a metal oxide, a glass that can be present in a casting as a defect. It has no strength so it acts as an internal crack in the casting.

The oxygen comes from rusty melting stock, a scrap steel preheater with hot spots, and from holding iron over time. That pile of rusty pig that your purchasing agent got at a discount, may not save you money after all. And that 1 hour breakdown just killed all the inoculation in the holding furnace and the iron is now oxidized and needs reinoculation.

There are three methods of measuring the problem: the first looks at high inoculation levels by detecting actual slag arrests. The second looks at the degree of inoculation, and the third directly measures oxygen activity. Each method has its strong points. This article looks at detecting slag arrests in the furnace. Future articles will cover the other two methods.

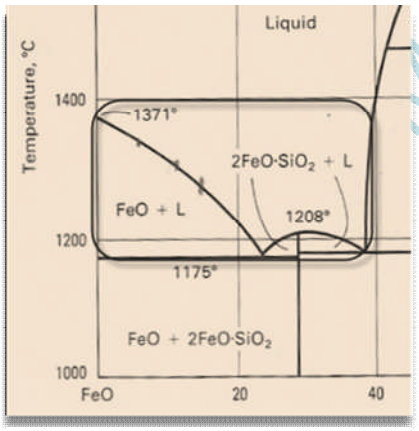

Figure 1 Mulite phase diagram from ASM Handbook, vol. 15, pg 94 fig 13.

Measuring for oxygen in base furnaces is quickly done with base iron thermal analysis that includes oxide detection. From the ASM volume 15 handbook on Castings, page 94, figure 13 shows a phase diagram of mulite, the slag composed of FeO and Si02. Small arrests in the preliquidus region of the thermal curve indicate the presence of sufficient oxygen to create slag arrests within a cup. If you watch the top of a cup, you can sometimes see a button of slag forming on the top of the cup, but in this case, we are talking about slag forming inside the iron, not just on top.

This type of arrest can be caused by: a) rusty scrap, b) hot spots in the preheater or heating the scrap so hot that it oxidizes, c) too much oxygen enrichment in the hot blast of a cupola, d) long holding times in a furnace. Besides eliminating the cause, melters can also use low levels of silicon carbide (2% max to prevent furnace wear), and can rebalance their chemistry to favor Carbon Monoxide over Silicon Oxide production. In the second method, the melting silicon is lowered below 1.60%, and

the balance silicon is added in the transfer ladle. This causes the oxygen to combine with carbon instead of silicon and burn out of the metal as small blue flames (carbon monoxide burning to carbon dioxide) you often see coming out of the slag. The oxygen then comes out during the melting process. The problem with this method is, that the ladle addition may have to be the more expensive 75% ferrosilicon instead of the cheaper 50% ferrosilicon typically used in the melter. Some discussion of this practice can be found in the QIT books on the production of Ductile Iron. The main statement in these books is that oxygen is retained in molten iron by the silicon, and that oxygen is removed by the reaction SiO2 + 2 C => Si + 2 CO. QIT suggests that lower silicon and higher temperatures both promote this reaction.

For gray iron, transfer inoculation generally consists of some ferrosilicon with some calcium. The calcium is both very good and very bad. It is good, because nothing is stronger at removing oxygen than calcium. It is also bad in that calcium oxide is a very runny slag and not always well removed from the transfer ladle. I do recommend using calcium. I just caution that the runny slag needs to be removed.

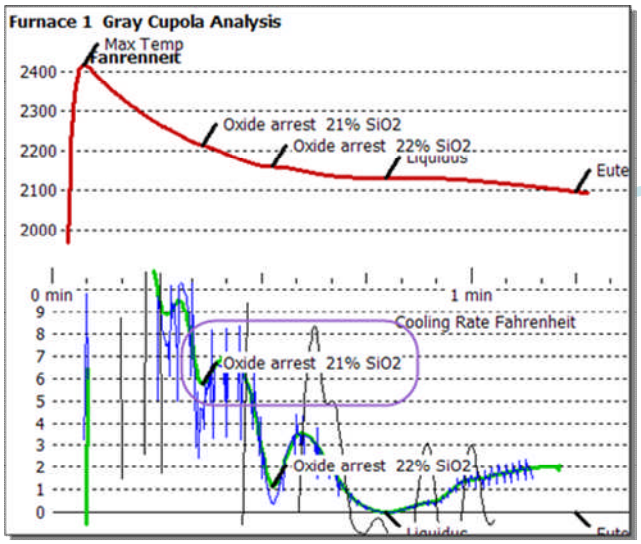

Figure 2 highly oxidized base iron from a MeltLab sample showing multiple oxide arrests from a highly oxygenated iron.

For ductile iron, the transfer ladle is generally where the magnesium addition is made, either though a flow-trek, or a tundish type of design, the exception being a Georg-Fisher type of treatment or a plunging method. At this point, it is expensive to remove oxides. Any oxygen present in the iron will first be consumed by calcium, then by magnesium, then by aluminum. Magnesium sulfides will be converted to magnesium oxides, freeing the sulfur. It is important to remember that spectrometers do not differentiate between free/active magnesium and magnesium oxide or magnesium sulfide. While you can calculate the MgS by the sulfur content, spectrometers do not measure oxygen, so, although you may have a magnesium content of 0.035 and a sulfur content of 0.010, you may find a holding furnace so contaminated with oxygen as we once did, to not be able to make 80% nodularity (foundry name withheld). In my experience, the minimum active magnesium level needs to be 0.020. Below that, you do not meet 80% nodularity. A better and safer operating range would be 0.025% to 0.030% active magnesium: active magnesium being defined as total magnesium less both Mg0 and MgS.

Conclusion: Monitoring the metal for excessive oxygen can account for changes in the quality of your product, and allow you to take corrective action before it becomes a problem. Reducing high oxygen levels will also improve inoculation and magnesium treatment costs in gray and ductile irons.