Pinholes and Blowholes (2)

Question

We cast silicon-killed steel billets (C=0.25~0.30%; Si= 0.18~0.23% and Mn=0.60~0.60%) used for Epoxy coated/Seamless rebars. The maximum sulfur for this steel is 0.05%. Usually we are able to get the sulfur in the tundish around 0.035%. The casters don't have mold electromagnetic stirring. The EAF's use 75 to 80% of DRI. Some products are drawn into wire but my problem is not concerned with these products.

If we treat the steel with Al/CaSi the billets are sound but we then face problems with clogging of the metering nozzles (our ladle to tundish stream is unprotected) and higher production costs. If we don't use CaSi then subsurface blowholes become a recurring problem.

To avoid the problem we tested the injection of Al wire in the mold, which was quite effective in eliminating surface and subsurface porosity. We know that some rebar casters are still using this old practice to keep the costs down. Could you please comment on this practice or any alternative.

Thanks and regards, CAP, Kingdom of Saudi Arabia

Answer

Based on the information you have provided I would first suggest that you look at all sources of pinholes. Remember that pinholes occur when the sum of the partial pressures of CO + H2 + N2 in liquid steel in the billet mold exceeds 1.05 atm. With your factory using 80 % DRI I would suspect that the nitrogen levels are around 70 ppm or less. If the DRI and lime additions are dry then assume that the H2 levels are around 5 ppm. This would lead to a partial pressure of H2 + N2 of 0.6 atm. The partial pressure of CO must exceed 0.45atm for pinholes to occur. With a C level of 0.30 % there must be at least 30 ppm dissolved oxygen in the steel. Based on these deductions, I would suspect that CO evolution and in particular dissolved oxygen content is the primary cause of pinholes. Hydrogen could also contribute to the formation of pinholes due to moisture in refractories and would most likely be seen during the first heat on a ladle or tundish after a reline. Check to mold lube oil to make sure it is free of water.

After eliminating nitrogen and hydrogen concentrate on sources of oxygen. Furnace slag carryover can eat up FeSiMn, FeMn and FeSi alloy additions. The lower the tap carbon the higher the FeO in the slag and likewise the higher the dissolved oxygen level in the steel. Excessive furnace slag carryover can greatly increase the propensity for pinholes and increase alloying costs. Sometimes measuring EAF slag carryover in the steel ladle is difficult, so a study of phosphorous reversion can give a good indication of EAF slag problems. If the pinhole problems come and go but the final levels of Mn and Si in the cast product are the same, start looking at the tap carbon levels and EAF slag carryover. On heats with pinholes check a sample for the percentage of SiO_2 versus Si. Although the total Si may be in specification you will find a higher percentage of SiO_2 in the steel.

Adding aluminum wire in the continuous caster mold for deoxidation is an old practice which is still valid. Aluminum wire is a very effective deoxidizer. Aluminum wire feeders are difficult to maintain. The feeders will jam or breakdown at the most critical times. Aluminum in unkilled billets will form alumina but as long as there are no inclusion concerns regarding formability or mechanical properties, the quarterline inclusion band should be of no concern in the finished product. Slag deposits on the billet surface will increase due to alumina inclusion floatation. Shrouding from the tundish to the mold is made more difficult by aluminum wire feeding but is not impossible. One factory in the USA feeds aluminum wire into the mold through a sealed shroud. They use the aluminum for grain refinement rather than deoxidation. Their molds are equipped with EMS so any alumina that forms is dispersed throughout the newly solidified billet shell.

If you have a ladle furnace or stirring station, rather than using aluminum wire in the continuous caster mold you may want to consider using a small amount of aluminum during tapping. This would be much less expensive and more reliable than adding aluminum wire to the caster mold. The ladle slag could then be modified to absorb the alumina so that the need for Ca/Si wire is eliminated.

To summarize:

1. Look for all sources of dissolved gasses;
2. Determine the sum of the partial pressures;
3. Determine which gas or gasses are causing the pinhole problem;

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4. Correlate tap carbon with problem pinhole heats;
5. Correlate EAF slag level in ladle or phosphorous reversion with problem pinhole heats;
6. Reduce EAF tap slag in the ladle if necessary;
7. Add aluminum bar to the ladle at tap but modify the slag to absorb the alumina;
8. Add aluminum wire at the caster.

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