Pinholes and Blowholes (1)

Question

   We produce electric furnace merchant grade manganese-silicon killed grades with around 0.24 % C. The rolling mill has been observing a higher than normal level of surface seams. At the discharge table of the continuous caster we have been seeing some surface blowholes. When we cut a transverse billet sample using a band saw we were able to see subsurface pinholes. Oxygen probe tests have shown dissolved oxygen contents in the liquid steel to be around 10 ppm. Could you please give us some clues on causes and solutions to the pinhole and blowhole problem? G.R. USA

Answer

   Dissolved gasses evolving from the molten steel at the time of solidification cause surface blowholes and subsurface pinholes. As the temperature drops and steel solidifies the solubility of CO, H and N drop, dramatically. According to Turkdogan[1], " When the sum of the equilibrium partial pressures of these solutes in the enriched interdendritic liquid exceeds the local external pressure, gas bubbles will be generated, resulting in the expulsion of the interdendritic liquid into the neighboring regions, hence the formation of blowholes or pinholes." The following equation summarizes the onset of blowholes and pinholes:

$$p_{H_2} + p_{N_2} + p_{CO} > P_s + P_f + 2\sigma/r$$

where P_s = atmospheric surface pressure on the liquid in the mold
         P_f = ferrostatic pressure at the location of the blowhole
         σ = surface tension of the liquid steel in contact with the gas bubble of radius r.

Pinholes and blowholes form when $p_{H_2} + p_{N_2} + p_{CO} > 1.05$ atm.

   In order to solve this problem you need to lower the sum of partial pressure of the gasses at the time of solidification below 1.05 atm. There are various charts available in the technical literature for calculating the partial pressures of carbon monoxide, hydrogen and nitrogen. Upon cooling, CO is evolved from the steel. So the operator must consider both the

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dissolved oxygen and carbon content of the steel. In your case, the p_{CO} = 0.23 atm. This is well below the limit of 1.05 atm. The dissolved nitrogen and hydrogen contents of the liquid steel must be contributing to the problem.

Since you did not specify nitrogen content let us assume a 90 ppm level for steel made from scrap in a fast modern EAF. In order for the combination of nitrogen and hydrogen to contribute 0.83 atm to the total partial pressure so it is greater than 1.05 atm, the hydrogen content must be 5 ppm or greater.

To solve your problem, start looking for possible sources of hydrogen. The simplest source of hydrogen is moisture contained in fluxes, ferroalloys and refractories. Look at the storage bins and feeding systems to make sure that water is not leaking onto the fluxes and ferroalloys. Always make sure the refactories are dried according to the suppliers' specifications.

Perhaps another hydrogen source is the mold lubricating oil. An easy test is to put a drop of oil on a hot plate and see if it sizzles. Water coming out of the oil turns to steam and causes it to sizzle. For casters using mold powder have the lab check for moisture.

Check your stirring gas supply lines to make sure that you are stirring with the correct gas. If you are stirring with nitrogen measure the content in the solid steel product to make sure that the pressure of nitrogen does not cause the combined partial pressure of all the gasses to exceed 1.05 atm. You may need to switch to stirring with argon.

Reference:

1. E.T. Turkdogen, *Fundamentals of Steelmaking* (London: The Institute of Materials, 1996), pg 303.

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