

TECHNICAL SESSION NO.8

DEOXIDATION AND INGOT MAKING

(PANEL DISCUSSION)

Chairman : Dr V.A. Altekar

Dr. T. Mukherjee, Tisco:

While I would like to congratulate Dr Ohno for his excellent presentation, I cannot help saying that there are two areas where there is likely to be disagreement with the established theories.

Long time back Clark & Nicholson have published a work in which they had welded a half round tube on an ingot mould and filled it up with refractory. When the ingot was cast inside they found that below the refractory zone (below that half round tube) there was a crack. Since then we have several observations to confirm that if you have an area on the ingot where the solidification front is moving much slower than the rest of the solidification front, i.e. when there is a dip in the solidification front, perhaps due to lower conductivity for one reason or the other, either slag or a hole in the mould, we do get cracks in that region and those cracks are associated with the movement of interdendritic fluid going towards that point. This is an area of weakness and the strain is concentrated in this region and when there is a gap formed which in other words can be considered as an area of partial vacuum, interdendritic liquid is sucked out. This view is also published in many other literatures. So your theory appears to be somewhat different from my belief on this particular subject. Another one is the way the A segregates form. I still believe in the theory which was first brought forward by MacKollon and later proved by many others - that interdendritic fluid motion is necessary for this A type segregate and without this interdendritic fluid motion I don't think there could be any explanation as to how so much of segregation can come at the top end of the ingot.

Mr. S.N. Sinha, Rourkela Steel:

In a brief report published by CRM, Belgium, it has been indicated that presence of a small quantity of aluminium in ferro silicon used for deoxidation even in the range of 1 to 2% is very deleterious for cleanliness of steel. Will you please throw some light on the deoxidation behaviour of ferro-silicon containing aluminium even in the range given above?

Dr. A. Ghosh:

If you look at Fig.1 of our paper, you will see that the aluminium is a much more powerful deoxidiser as compared to silicon. At the same dissolved oxygen level, the dissolved aluminium content is about

1/100 as compared to the concentration of dissolved silicon. From this point of view small percentage of aluminium should be quite effective in ferro-silicon. However, you will also have to realise that in actual industrial practice sometimes the deoxidation product is not the same as is expected from thermodynamics. It could be a non-equilibrium deoxidation product, but in the iron, silicon and aluminium system, there could be formation of FeO , SiO_2 and alumina complex deoxidation products. However, FeO is quite unstable. So my expectation would be that by the time the deoxidation operation is complete, there perhaps should not be much of FeO in the deoxidation product, it will be silica and alumina and silica-alumina system does not show a low melting point compound at steelmaking temperature. Thus, it is expected that small concentration of aluminium will change the de-oxidation behaviour of the silicon. However, a little caution has to be used in making a statement because there could be other non-equilibrium situations.

Dr. S. Jha, R&D, SAIL:

No doubt correct value of thermodynamic data is important for proper deoxidation practice. However, I think more important factor is the kinetics of deoxidation reaction and for separation of inclusions from steel, the behaviour of inclusions during solidification and plastic deformation is also important. Are you planning any studies in this direction?

Dr. A. Ghosh:

No - because first of all we have to understand thermodynamics of deoxidation. Although kinetics may be important, but when we are trying to apply theory to deoxidation, we have to first of all do thermodynamic calculations because thermodynamics constitutes the framework against which we can start thinking. If we don't do thermodynamic calculations, we cannot explain many things. Therefore, whether kinetics is controlling or flotation is controlling the de-oxidation, we have to start first with thermodynamic calculation.

Mr. S.D. Sharma, Bokaro Steel:

Has any experimentation been done with mild steel casting in ingot moulds to probe the separation theory?

Mr. J. Ohno:

I have not done, but experiments have been done by many other Japanese and results are obtained in the case of continuous casting.

Mr. V.K. Laxmanan, Tisco:

Are the densities of alumina inclusions and the primary crystals formed on the steel solidification comparable? If not, then Prof. Ohno's theory of separation and your observation of alumina concentration at the lower region do not seem to be compatible?

Dr. T. Mukherjee:

The densities are not at all compatible. The density of the inclusions would be around 2.7 gms per cc. The density of the liquid steel at this time (of the crystal forming) will be more than 7 gms per cc, but the density is not the only factor. If you consider the density only then you would expect all inclusions to float up, but you know that all the inclusions do not float-up - many of them get entrapped and this is because all particles do not develop enough speed and before it has floated up, it gets entrapped. In these cases as the inclusions form they either slowly get entrapped by other dendrites or it is possible that they would themselves nucleate the primary crystals.

Dr. J. Beach:

I would like to make a comment about the formation of ingot zones. We are all having our own philosophy of life in general and we go around trying to find evidence to fit our own philosophy and satisfy ourselves. I think you could take the ammonium fluoride model that Mr. Ohno took in his experiment and you can see that some ingot crystals were forming. Both Prof. Ohno and I can do another experiment using ammonium fluoride where you would at a later stage see that the ingot crystals are generated by fluid flow from the growing alumina crystals. It is also possible that if one casts at much lower superheat he will see something like Prof. Ohno described. I would rather say that the ingot crystals grow from the wall and temperature of the liquid close to the mould wall will decrease rapidly because it is much cooler and you can see again that the crystals will be generated, but generated not by separation mechanism but by multiplication mechanism. So, I think there are two possibilities you can have at the beginning - including separation.

Mr. Narayan, Bhilai Steel Plant:

Have you been able to develop reuse of hot tops? So far the steel industry has been using only dispensable hot tops.

Mr. Bloodworth:

Work has been done in this area and to the best of my knowledge all of which have been unsuccessful.

Dr. A.P. Lingras, U.S.A.: You referred to a computer model to predict the surface profile of the metal in the hot top. Does the model include the thermo-physical properties of the hot top boards and compounds as a function of temperature? How were these properties obtained?

Mr. Bloodworth:

I presume it does. It was mentioned during Rapporteur's summary that the model which we developed includes the thermo characteristics of products.

Dr. Bhattacharya, ASP, Durgapur:

In certain cases the APC compound gets trapped in the circulation stream leading to inclusions in the steel. What precautions can prevent this?

Mr. Bloodworth:

First of all I would like to say that I don't agree with the question. It is something which we can separately discuss here. It ~~is~~ by no means a general problem; in fact it is very rare. These materials were very much inclined to give a crusty type of composition after the exothermic reaction was over and such a material tended to break-up into relatively massive pieces which could lead to inclusions. The more modern materials tend to have a much more powdery nature after the exothermic reaction is over and as such they do not get entrapped easily. So I think the later products, which have been developed by us, overcome the problem which you referred to and as such the precautions to be taken are to use the more modern developed products.