Kinetic aspects of melting in electric arc furnace

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Kinetics of melting in the present context is largely a comparison with the rates of reaction prevailing in arc furnaces with scrap charges and normal melting practices prevailing with scrap melting alloying operations. Even the scrap melting differs in nature from type to type depending on whether it is heavy, medium, or light scrap; kinetics mainly refer to the oxidation, reduction reactions which occur during the refining process of steel.

In the conventional practice of steel melting in the arc furnaces earlier norms took shelter under the operating data available with the steel melters. In a good practice it used to be stipulated that the ore boil must reduce carbon @ 0.01% per minute and the final carbon in the melt must not be less by more than 0.4% of the opening carbon. This means if the final carbon desired after oxidizing period is 0.1% then the opening carbon at the melt down must not be more than 0.5%. It was mainly intended to restrict the oxidation period so that the bath may not be overoxidized. The condition use so adjusted that P, Mn, Si etc. also come down to pre-anticipated level. Later on when oxygen was put to use it served two purposes. One was that it aided melting and the other was that the slow ore boil was replaced by faster oxidation by oxygen itself. Several variations of oxygen blowing were adopted by different plants. The basic idea behind all such practices is to determine when to start oxygen blowing and in what quantity and pressure. Normally the blowing of oxygen started 10-12 minutes after arcing at 2-3 atmosphere pressure which was increased to 5-6 atmosphere near the melt down. The melt down composition of the bath was taken and the levels of various elements like Mn, Si, S, P indicated certain bath potentials. In good practices elaborate charts were made out for additions in accordance with the levels of various elements at the melt down to easier and simplify the work of melters. C, P, S, Mn, Si all go down during melt down and the subsequent to oxidation the reducing mix is to be prepared which differs from plant to plant depending on the final levels of S desired in the metal.

In our country the conventional electric arc melting got a change in sixties when HEC Ranchi and Alloy Steel Plant Durgapur went into production. Several grades of alloy steels were melted in these plants and the melting technology was given a boost. Stainless steels were melted frequently in these plants using the dictates of Ellingham diagram i.e. raise the temperature of the bath to above 1700°C when carbon oxidizes in preference to chromium. The process had to be achieved quickly because to keep roof and hearth refractories (particularly the roof) in a stable condition. These difficulties were overcome later by the use of VAD which these plants had installed. Bihar Alloy Steel Ltd. at Patratu followed this technology and the concept of secondary steel making got a spurt from here. These were the happenings in late sixties. In early seventies CFFP at Haridwar joined the fray. Advantage with CFFP was that they were manufacturing castings and forging for their in-house consumption and these comfortable pricing of the product in controlled economy of the country could sustain them. However the technique standardized with these organisations revolutionized the arc furnace steel making in India. Mahindra Ugine, Mukand, Zenith and so many other organisations took the technology to perfection and they continue with that with occasional set backs, mostly due to extraneous reasons.

Most of the theoretical concepts developed in the kinetics of steel making come from the treatments developed for open heath and LD steels which are not the practical significance in context to electric arc furnace because those treatments are based entirely on metallurgical thermodynamics in which the decision factors are various heats of formations and free-energies involved in reactions. While dealing with arc furnaces the two other parameters are added. One is electric field due voltage applied across the electrode and the molten pool (metal and slag) and the other is the effect of the arc plasma itself. There is a need to study these before a meaningful theoretical treatment could be conceptualized. Until such time it is better to continue with the practical performance data available from various practices and the improvements over them which are based on concepts like the basicity of the slag mobility of various constituents of the slag, prescribed slag-metal reactions.

Electric effects

It is a common knowledge that electrostatic effects are much powerful compared to gravity or chemical potentials. In Arc furnace we have a powerful electrostatic field between the electrode and liquid. Liquid slag comprises ions and these ions are acting as chemical potential carriers with ingredients of metal which one desires to remove through slag. These ions have preference to move towards surface creating voids in the liquid resembling schottky defects ions with smaller radii have lower free energies of migration to the surface and therefore they are denser on the open surface. The bias applied by the electrode either supports this migration to the surface or approves depending on the polarity. Free movement of ions thus is directionalised in case of arc furnace when compared to open hearth or LD. Therefore the reaction behaviour or the kinetics will grossly differ in case of arc furnaces and it needs study.

Arc

Arc plasma is also associated with electrostatics in the sense that there is a distinct ionisation of the medium in accordance with SAHA's equation and the effects describes under electrostatics come into force. Only other thing is that the forces due to electrostatics and Arc Plasma should be absolutely compatible for the stability of reactions.

Conclusion

In case of arc furnaces it is better to work with operating data available with the plant and use intuitive logic for improvement. There is a need to super impose metallurgical thermodynamic studies with the dictates of electrostatic field and Arc Plasma.