AISTech 2025 — Proceedings of the Iron & Steel Technology Conference
5–8 May 2025, Nashville, Tenn., USA
DOI: 10.33313/389/101

Fundamentals of Slag-Steel-Inclusion Multiphase Reactions for Producing Clean Steels During Secondary Refining and Continuous Casting Process

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ABSTRACT

The probability of alumina inclusion is strongly affected by slag chemistry and deoxidation practices. Moreover, the viscosity of the slag should also be carefully controlled to suppress this harmful inclusion at the secondary refining stage. The effect of physicochemical properties of Fe_tO-bearing calcium aluminate based system RH slag on the removal rate of alumina inclusions in Al-killed steel has been investigated by considering the interfacial reaction between steel melts and the slag layer. The alumina removal rate is strongly proportional to the physicochemical factor of the slag. The addition of Fe_tO to the RH slag with $CaO/Al_2O_3 \leq 1.3$ effectively breaks the aluminate network structure, while the structure is less affected by the Fe_tO in the slags with $CaO/Al_2O_3 \geq 1.6$. Consequently, even though the Fe_tO in the RH slag enhances the atomic oxygen pick-up (i.e., reoxidation) from slag to steel melt, it contributes to the inclusion absorption and dissolution by lowering viscosity of the slag in conjunction with the depolymerization of aluminate frame structure. Therefore, the relatively basic slag (i.e., CaO/Al_2O_3= 1.2–1.4) with appropriate amounts of Fe_tO (T.Fe=7–9%) would be recommended as an operational window to improve the cleanliness of molten steel in RH degasser.

Keywords: Alumina inclusion, Slag chemistry, Deoxidation, Viscosity, Ruhrstahl-Heraeus (RH), Aluminate structure

INTRODUCTION

It is well known that the alumina-rich non-metallic inclusion (NMI), which is spontaneously formed by aluminum deoxidation of molten steel during the steelmaking processes, cause both the deterioration of the mechanical properties and severe problems during continuous casting processes.[1] Therefore, it is necessary to remove the alumina-rich inclusions using top slags during the secondary refining processes, for example, Ruhrstahl-Heraeus (RH) reactor. A dissolution of inclusion particles into the slag phase has been known to be rate controlling process in terms of removal of alumina-rich inclusions. When the dissolution of inclusions is controlled by diffusion and the Stokes-Einstein relation is used for estimating the diffusion coefficient in the molten slag, Valdez et al.[2] defined that the total dissolution time (τ) of inclusions will be:

$$\tau = \frac{\rho \cdot R_0^2 \cdot 3\pi a\eta}{2kT\Delta C} \tag{1}$$

where R_0 is the initial radius of particle, ρ is the density of particle, k is the Boltzmann constant, T is the temperature, a is the ionic diameter, ΔC is the difference between the saturation and bulk concentration of target oxide component, and η is the viscosity of the molten slags. Consequently, the dissolution time of NMI is strongly dependent on the physicochemical factor, *viz.* the $\Delta C/\eta$ ratio, in the molten slags.

The addition of Al_2O_3 to calcium silicate melts increases the viscosity and activation energy for the viscous flow of the melts because the tetrahedrally coordinated aluminum, i.e., $[AlO_4]$, polymerizes the silicate networks,[3,4] whereas the viscosity and activation energy of calcium silicate or aluminate melts decreases with the addition of iron oxide, Fe_tO, even if Fe^{3+} is in