Title: Inclusion Removal by Synthetic Slag: An Experimental Investigation and Simulation Study

Abstract

Enhancement in steel cleanliness for low carbon aluminium killed steel (LCAK) is essential for their high performance applications in structural, automotive, defence and strategic sectors. The non-metallic inclusions deteriorate the properties of the steel and inclusions have to be necessarily minimized or modified by controlling their morphology, composition and size.

In the present study, the inclusion evolution behaviour in the LCAK steels and identification of the appropriate synthetic slags for inclusion treatment have been achieved using computational thermodynamics. Experimental investigation on the inclusion evolution using various synthetic slags at laboratory scale induction furnace has been carried out. Fluid flow and particle trajectory analysis of the liquid steel bath has also been carried out to quantify the efficacy of inclusion removal using coupled CFD-DPM approach for different plug configurations in the full scale ladle.

From the thermodynamic analysis it was concluded that the fluoride and alumina rich slags dissolved magnesia from refractory and formed solid inclusions, even though they had the required inclusion removal capability. Effective inclusion removal without refractory erosion has been observed in the MgO containing slag only. In addition, MgO bearing slags, especially with higher MgO content (20 wt %) are found to have wide range of melting, efficient in desulphurization and do not form high melting complex solid inclusions.

Experimental investigation in induction furnace and subsequent optical microscopy and image analysis of the collected sample at different process steps, yielded the evolution of inclusion

in terms of composition, size, morphology and number density. It was found that inclusions form and eventually get removed. Typical inclusions were alumina-silicate type, irregular with size around 1 µm. A procedure has been devised from the experimental investigations, to estimate the inclusion removal rate from the steels treated with different synthetic slags based on the metallographic and chemical methods. Except slag 1 and 2, all other slags showed an encouraging trend in removing inclusions and in particular slag 5 with high magnesia showed a maximum removal rate (2.14×10^{-7} kg/m^2-s) of the inclusion when compared to other slags.

Application of CFD (computational Fluid Dynamics)-DPM (Discrete Phase Model) for fluid flow and particle trajectory analysis, comprehended that the asymmetric R/3 plug configuration performed well when compared to other plug configurations in terms of fluid mixing. Although the axis-symmetric plug is found ineffective in terms of fluid mixing, those are found to be good in terms of inclusion removal and comparable to asymmetric plug at radius R/3 and this has been attributed to flow pattern and turbulent kinetic energy distribution conducive for inclusion coalescence and removal.

Key words: Steelmaking, Low Carbon Aluminium Killed Steel, Inclusion, Synthetic Slag, modeling, Discrete Phase Model