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Nitrogen Refining Kinetics in Current and Future Oxygen Steelmaking Process: Modelling and industrial validation

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Nitrogen is a critical element with regards to steel quality. Depending on the application, the maximum allowable N-concentration varies between 20 to 120 ppm. Over the years, the BOF (Basic Oxygen Furnace) route of steelmaking is known to be superior in N control, largely due to the stripping effect of CO gas bubbles generated during decarburisation reactions. However, in the future low-CO2 routes of steelmaking, using low-carbon liquid metal is expected to pose an unfavourable scenario for N control in the BOF process.

In this study, a multi-zone kinetic model for nitrogen prediction in liquid steel was developed by incorporating the fundamental understanding on [N] mass transfer across three reaction zones :(1) Jet impact (2) slag-metal droplet and gas emulsion and (3) bottom stirring through bulk metal. Industrial trials using special sub-lance probes were conducted and additional steel samples at 40% and 60% of the total oxygen blow were taken. The concentration of nitrogen and carbon in steel samples were measured by combustion analyser and the data are used to validate the model predictions.

The variation of measured nitrogen during the oxygen blowing period was analysed in relation to the process parameters such as bottom stirring gas (N2 and Ar), initial hot metal composition, scrap, oxygen and N2 injection via top lance. From the results of nitrogen and carbon analyses, four major stages with distinct nitrogen removal and pick up have been identified, primarily based on the sampling points. The dominant factor for de-N rate control in these stages are also identified. The insights on the de-N rate control factors can aid in designing better process parameters such as bottom stirring schemes, top lancing (O2/N2), hot metal composition, scrap type & nitrogen level, allowable nitrogen impurity (in O2 gas, coal, etc.).

The dynamic nitrogen model suggests that the emulsion zone is a primary zone for [N] removal with residence time of the N2 gas in the emulsion phase being critical for the accurate prediction of [N] in liquid steel. Additionally, the model was used to investigate the effect of variation of carbon in hot metal and bottom gas purging methods on control of final [N] in liquid steel in future REF (Reducing Electric Furnace)-BOF route.

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