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Sustainable steelmaking route for mitigation of CO2 emissions: Transition from blast furnace (BF) to electric smelting furnace (ESF)

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It has been known that approx. 7% emissions of CO2 arises from the steel industry sector. Hence, many steel companies are trying to develop the electric arc furnace (EAF) and/or electric smelting furnace (ESF) steelmaking processes instead of blast furnace (BF) and basic oxygen furnace (BOF) integrated routes by employing high amounts of hydrogen gas direct-reduced iron (H2-DRI) to mitigate CO2 emissions. The high-grade iron ores (Fe>68%) are economically used in EAF, whereas low-grade iron ores (Fe<65%) are targeted to be used in ESF. The integrated steel mills have focused on the ESF process by keeping conventional BOF to produce high-end quality products. The H2-DRI will be charged in ESF in conjunction with fluxes and carbon sources, producing hot metal. Using solid carbon alone as a reductant, FeO reduction proceeded through three distinct stages: incubation, steady state, and degradation, forming a characteristic sigmoidal curve. The carbon requirement for complete FeO reduction and at least 3wt% carbon in hot metal (HM) was calculated as 66 kg-carbon/ton-HM. Introducing a hot heel with dissolved carbon accelerated FeO reduction, lowering the FeO concentration to approximately 3wt% in the slag and producing hot metal with 2.8wt% C. Also, it was confirmed that Si transfer from slag to molten iron under ESF conditions occurs through the SiO2 reduction reaction, which produces SiO gas at the slag/metal interface, and the Si pick-up reaction, in which the SiO gas reacts with carbon in the molten iron. We performed a kinetic analysis to evaluate how temperature, slag basicity, and sulfur content in hot metal influence the SiO2 reduction and Si pick-up rates at the slag/metal interface. The current study provides fundamental data for optimizing slag design to achieve rapid FeO reduction, carburization as well as silicon control in ESF.

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