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Heat Transfer Mechanisms in Electric Smelter Furnaces for Ironmaking

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ABSTRACT

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Steel production involves the reduction, melting, and refining of iron ore. In this processing route, the Electric Smelter Furnace (ESF) is employed to melt the ore and produce molten iron for subsequent refining. Unlike traditional blast furnaces, which rely heavily on carbon-intensive coke, electric smelters utilize electrical energy to drive the smelting process, offering a substantial reduction in carbon emissions. Furthermore, they possess the capability to process low-grade iron ores, a feature that is becoming increasingly vital as high-grade mineral reserves deplete globally. As a subset of the ESF, the Open Slag Bath Furnace (OSBF) functionally represents a hybrid technology. It combines the operational principles of the Submerged Arc Furnace (SAF), typically used for ferroalloys, and the high-energy capabilities of the Electric Arc Furnace (EAF) used in steelmaking. A distinguishing feature of the OSBF is its utilization of the 'brush arc' mode. In this configuration, the electric arc is partially submerged in the slag. This allows for the effective dispersion of thermal energy directly into the molten slag bath while simultaneously minimizing radiative heat losses to the furnace walls and roof. This study focuses specifically on the brush arc within the OSBF to characterize the primary heat generation and transfer mechanisms. To investigate these phenomena, a single-electrode Computational Fluid Dynamics (CFD) model was developed, incorporating Magnetohydrodynamic (MHD) principles to simulate the interaction between the electric arc and the fluid domain. This study provides a pathway to understand heat transfer mechanisms in the smelter, enabling the minimization of energy losses and the mitigation of thermal damage to the furnace roof and refractory sidewalls, ultimately ensuring a more efficient smelting operation.

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