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Process Intensification of EAF-A New Perspective with Plasma

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Against the backdrop of the steel industry's low-carbon transition, short-route production centered on the electric arc furnace (EAF) is attracting increasing attention because it can couple with renewable electricity and reduce CO_2 emissions substantially. However, current EAF operations face several challenges, when melting materials such as direct reduced iron (DRI), especially DRI from hydrogen reduction process, which contain high levels of oxides. As the share of DRI in the metallic charge continuously increase, higher demands are placed on heat utilization, energy distribution, and operational stability in EAF processing. The presence of high oxides content in DRI leads to low thermal conductivity of charging materials in EAF, heat transfer efficiency is often insufficient, leading to high furnace lid temperatures and low melting efficiency. This is especially problematic when higher proportions of DRI are used, as the heat transfer within the furnace becomes inadequate, resulting in uneven melting and affecting the temperature distribution and compositional homogeneity of the melt. These constraints may ultimately deteriorate productivity, increase energy consumption, and compromise endpoint consistency. To address the requirements of efficient, stable, and low-emission operation under high-DRI conditions, we propose a plasma-assisted EAF intensification route. Building upon conventional arc heating, a controllable high-temperature plasma jet/heat source is introduced to establish a coupled "arc–plasma–melt bath"intensification configuration. Owing to the high energy density and directional controllability of plasma, the proposed concept enables more concentrated and better-regulated heat input and promotes more effective heat penetration into the melt. Furthermore, plasma-assisted heating can significantly enhance the thermal conductivity of the charge, thereby facilitating faster heat transfer within the furnace and accelerating the melting process. In addition, the momentum delivered by the plasma jet enhances bath convection and interfacial renewal, thereby accelerating thermal equilibration and compositional mixing and creating more favorable transport conditions for melting and refining-related processes. By coordinating plasma operation with conventional process levers such as oxygen supply, carbon input, and stirring, the proposed approach aims to improve the electrical efficiency, thermal efficiency, as well as the process repeatability without requiring substantial changes to the main furnace architecture. This integrated intensification strategy is expected to mitigate operational fluctuations and reduce specific energy demand, thereby lowering indirect emissions associated with electricity consumption and supporting further decarbonization of EAF-based short routes. Overall, plasma-assisted EAF processing offers a scalable solution to improve energy efficiency and emissions in DRI–EAF operations, supporting EAF innovation and green manufacturing.

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