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Investigating the performance of Electric Smelting Furnace for green iron and steelmaking using feed material of varying quality: Insights from pilot-scale melting and hydrogen-based reduction trials

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The Electric Smelting Furnace (ESF) process represents a promising route for sustainable ironmaking by enabling the production of hot metal and slag suitable for steel and cement industries. A critical requirement for steel plant integration is achieving hot metal with a minimum carbon content of 3.0–3.5 wt% and controlled silicon levels (~0.4 wt%), while simultaneously producing marketable slag with low iron oxide content (<2 wt%). However, the mechanisms governing carburisation and melting in ESF remain insufficiently understood, particularly at relevant scales.

To address this, a series of pilot-scale melting trials were conducted at SINTEF, Norway between April 2022 and January 2024. The initial trial demonstrated the feasibility of melting 415 kg HBI with anthracite and fluxes, yielding hot metal with 2.4 wt% C and 0.1 wt% Si, but highlighted challenges in sampling and temperature control. Subsequent trials focused on increasing carbon input and improving operational practices. The second trial achieved 3.5 wt% C but resulted in elevated silicon (0.9 wt%) and slag contamination due to iron entrainment. The third trial introduced carbon-bearing DRI pellets, achieving consistently high carbon levels (~4.1 wt%) and acceptable silicon (~0.5 wt%), suggesting that internal carbon in DRI significantly enhances carburisation efficiency compared to external carbon sources. Nevertheless, slag iron oxide variability remained a concern, with values ranging from 1 to 21 wt%.

Complementary hydrogen-based reduction trials were performed to assess the suitability of TSN BF pellets with higher gangue content for ESF melting. In a rotary kiln metallisation degree of 85.0% was achieved under varying H_2 flow rates and durations, revealing limitations in reactor performance and declining H_2 utilisation at higher metallisation degrees. The partially reduced pellets from these trials were subsequently employed in a fourth melting trial in the SINTEF SAF furnace, which successfully demonstrated melting and carburisation under ESF conditions.

These investigations provide critical insights into the carburisation mechanism, the role of feedstock properties, and operational parameters influencing hot metal and slag quality in ESF. The findings underscore the importance of carbon distribution within the charge, slag-metal interactions, and reduction efficiency for scaling up ESF technology. Future work will focus on optimising slag chemistry and refining melting and carburisation strategies to meet industrial specifications.

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