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Kinetics of Direct Reduction of iron ore pellets: understanding rate-limiting steps in hydrogen-based reduction of low- and high-grade pellets

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The steel industry is committed to eliminating fossil fuels to reduce CO_2 emissions, requiring innovative technologies and alternative reducing agents. Hydrogen-based direct reduction is currently the most viable solution for transforming iron ore into metallic iron with minimal environmental impact.
This study investigates the kinetic mechanisms governing the hydrogen-based direct reduction of iron ore pellets, with a comparative analysis between low-grade and high-grade pellets. Despite their higher gangue content, low-grade pellets are of primary interest due to their preferential industrial use. Understanding their reduction kinetics is essential for optimizing reactor design and process conditions.
Laboratory-scale reduction tests were conducted to evaluate the effects of temperature (800–1200℃), gas velocity, reaction time, and pellet quality. Pellets were analyzed in terms of weight loss, SEM imaging, porosity, and metallization degree. The results indicate that reaction time, temperature, and hydrogen flow rate are key factors in the reduction process. In the tested conditions, the reaction yield increases up to 60 minutes, then stabilizes. Temperature has a minor effect above 1000℃, while a higher hydrogen velocity enhances reduction efficiency by improving mass transfer and reagent contact.
This research highlights the importance of tailoring reduction parameters based on pellet quality, particularly for low-grade raw materials, to ensure optimal process efficiency. The insights gained contribute to the optimization of hydrogen-based direct reduction for large-scale applications, aligning with the objectives of the HYDRA project, which focuses on developing next-generation hydrogen-based reduction technology.
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