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Computational Analysis of Means to Enhance Hydrogen-Based Direct Reduction in Shaft Furnaces

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The steelmaking sector has to suppress its CO2 emissions to mitigate climate change, but the blast furnace-basic oxygen furnace route that dominates today cannot substantially reduce the emissions without carbon capture of the arising gases. Direct reduction (DR) in a shaft furnace followed by melting in an electric arc furnace is presently considered a viable option to reduce the environmental impact of steelmaking, and a gradual replacement of natural gas by hydrogen in the DR furnace could almost eliminate the carbon emissions from the reduction step. However, even though natural gas-based DR is well established, the counterpart with high (> 80%) concentration of hydrogen in the feed gas comes with several challenges. These include process economics (green hydrogen is expensive) and also technical aspects, e.g., how to provide sufficient heat to compensate for the endothermic nature of hydrogen reduction of iron oxides. The present work focuses on the second issue, i.e., the operation of a DR shaft furnace using hydrogen-rich gas.

The presentation describes results of a computational analysis of the DR furnace with the goal to detect challenges and bottlenecks in the hydrogen-based operation and to suggest possible remedies. A two-dimensional static CFD model that considers fluid flow, heat and mass transfer and chemical reactions is used for the analysis. After studying the impact of an increasing share of hydrogen in the feed gas, remedies addressing the arising problems are suggested and assessed by simulation, including modifications of the gas injection points or the furnace geometry. Particular attention is also focused on the role of carbon monoxide in the feed gas as it serves to mitigate the negative effects of hydrogen caused by the endothermic reactions in combination with a lower molar heat capacity of the H2-H2O compared to CO-CO2.

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