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Assessment of Oxide Alloying Elements in the Hydrogen Plasma Smelting Reduction (HPSR) Process

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The steel industry accounts for roughly 7–9% of global CO_2 emissions, largely because traditional production relies on carbon-based reduction methods. Reaching climate neutrality demands alternative process routes that eliminate direct CO_2 emissions. The Hydrogen Plasma Smelting Reduction (HPSR) process is a promising carbon-free approach that uses hydrogen plasma simultaneously as a heat source and a reducing agent, enabling the direct conversion of iron ore to steel in a single step.
This work explores the potential of the HPSR process not only for reducing iron oxides, but also for the concurrent reduction of oxidic alloying elements such as NiO, MoO_3, and WO_3. This capability would allow the direct production of alloyed steels from mixed oxide feeds. Experimental campaigns were conducted in a laboratory-scale HPSR reactor at the Chair of Ferrous Metallurgy, Technical University of Leoben, Austria.

The investigations focused on reduction behaviour, temperature evolution, and key process parameters and were supported by gas analysis during operation and detailed characterization of the produced materials using scanning electron microscopy. The results demonstrate the strong reduction capability of hydrogen plasma and confirm that multiple alloying oxides can be efficiently reduced under appropriate operating conditions. Overall, the findings show that the direct production of pre-alloyed steels from mixed oxide charges in a single-step, CO_2-neutral HPSR process is technically feasible. This approach offers a meaningful pathway toward more sustainable and climate-friendly steelmaking.

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