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Challenges and solutions for process characterisation of hydrogen plasma smelting reduction (HPSR) at pilot scale and beyond.

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Hydrogen plasma smelting reduction (HPSR) is an emerging low-CO2 technology which can accomplish steel production from iron ore in just a single step. This is done using a high-power DC-transferred plasma arc generated between a hollow graphite electrode, which conveys the hydrogen gas into the reactor, and an iron-containing molten oxide bath. This plasma arc serves as both the primary furnace heat source and creates high temperature, highly reactive hydrogen species which accomplish the metal reduction. The extreme thermal and radiative conditions of the arc as well as the harsh thermochemical properties of the oxidic melt make process monitoring and on-line characterisation difficult to accomplish. Any engineering solutions are even further complicated by the closed-system operation which is a necessary safety measure in the operation of high-H2 atmospheres.

Solutions to these challenges of process characterisation have been vital in the optimisation and development of a first-of-its-kind pilot-scale HPSR plant operated by K1-MET GmbH at voestalpine Stahl Donawitz, Austria. The collection of low-latency, high-resolution data have provided a means to understand process failures, describe behaviours, and investigate system models. Computational tools and the identification of optimal parameters can allow the creation of process control routines and help maintain operational stability. These measurement solutions include: the collection of visual data in the form high speed imaging and optical emission spectroscopy; high resolution electronic characterisation of arc voltage and current; temperature measurement of the molten bath; and sampling of the metallic and slag fractions of the molten bath.

Insight into the innovative characterisation solutions will be discussed in the context of these challenges, referring to system constraints, technology gaps, and scientific unknowns, with a view to industrial-scale implementation beyond TRL 6. The technologies and tools shown demonstrate the importance of multidisciplinary approaches to achieve rapid development and meet global goals of industrial decarbonisation.

Primary author: QUICK, Cameron (K1-MET GmbH)

Presenter: QUICK, Cameron (K1-MET GmbH)

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