Simulation-Aided Evaluation of Alternative Reducing Agent Conversion Experiments

Authors

Markus Bösenhofer (left), TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria; K1-MET GmbH, Linz, Austria
markus.boesenhofer@tuwien.ac.at

Thomas Nanz, TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria; K1-MET GmbH, Linz, Austria

Matthias Kiss, TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria; K1-MET GmbH, Linz, Austria

Christine Gruber, K1-MET GmbH, Linz, Austria

Johannes Rieger, K1-MET GmbH, Linz, Austria

Hugo Stocker, voestalpine Stahl Donawitz GmbH, Leoben, Austria

Christoph Feilmayr (right), voestalpine Stahl GmbH, Linz, Austria

Michael Harasek, TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria

The thermochemical conversion of alternative reducing agents (ARAs), such as pulverized coal, in the blast furnace raceway zone is a complex and hard-to-examine process due to the harsh conditions. Real-world experiments provide nonideal conversion conditions, e.g., inhomogeneous temperature and velocity and concentration fields. Ignoring these inhomogeneities falsifies the experimental results and can give misleading information. A digital model of an ARA test reactor is created to validate the operation conditions and evaluate potential inhomogeneities. Furthermore, the digital model will be used to reproduce experiments and perform detailed investigations of the particle states during conversion to identify bottlenecks during the ARA conversion.

Introduction

The evaluation of experiments always relies on assumptions because spatial resolution of the recorded data is coarse. Therefore, uniform temperature and species distribution is assumed as well as plug flow. The latter assumption is necessary to identify residence times inside the experimental equipment. Computational analysis of experimental equipment[1] revealed temperature and species concentration stratification inside experimental equipment. Furthermore, flow conditions are typically not similar to plug flow, and significant variations of the residence time can occur. Both deviations from idealized conditions influence the experimental evaluation and extraction of reaction rates.

Computational fluid dynamics (CFD) is used to create a digital model of the experimental setup. The model is then used to (i) validate the reactor design and (ii) to recreate the experiments and derive spatially resolved experimental conditions. The CFD results are then employed to obtain representative particle tracks through the reactor and evaluate the true conversion conditions they experience along their trajectories. The reactor design is validated from an alternative reducing agent (ARA) particle perspective. This means that the expected particle temperatures, heating rates, etc., are compared to the simulated ones. Furthermore, a 1D particle model is used to identify bottlenecks during the thermochemical ARA conversion.

Experimental Setup

K1-MET's ARA Reactor located at and operated with TU Wien is an entrained pressurized flow reactor designed to reproduce blast furnace raceway conditions.[2] Typical blast furnace raceway conditions are summarized and compared to the ARA Reactor's design parameters in Table 1.

The ARA reactor consists of seven key components. The dosing unit provides a constant particle flow into the reactor. The flow heater preheats the main co-flow stream to up to 1,100°C before the hydrogen burner provides a high-temperature zone and radiative heat flux for the particle heat-up. Furthermore, the particle stream and co-flow come together in the burner and are directed into the electrical heated reaction