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Influence of Raceway Shape on Species Concentration

Authors

Eva-Maria Wartha (pictured)
Project Assistant, TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria
eva-maria.wartha@tuwien.ac.at

Markus Bösenhofer
TU Wien, Institute of Chemical, Environmental and Bioscience Engineering, Vienna, Austria; and Simulation and Analyses, K1-Met GmbH, Linz, Austria

Franz Hauzenberger
Primetals Technologies Austria GmbH, Linz, Austria

Hugo Stocker
voestalpine Stahl Donawitz GmbH, Leoben, Austria

Christoph Feilmayr
voestalpine Stahl GmbH, Linz, Austria

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

An entire utilization of alternative reducing agents inside the raceway zone is favorable to increase the coke replacement ratio in blast furnaces and utilize waste products in the ironmaking process. The extreme conditions prohibit measurements, but computational fluid dynamics incorporating validated models can help to understand the processes occurring in the raceway zone. An accurate prediction of the raceway size and shape is essential to correctly predict the thermochemical processes and resulting species distribution. This article will demonstrate this based on a laboratory test setup and, furthermore, identify interstitial fluid effects to be essential to accurately predict the raceway shape.

The main steel production route is the blast furnace route, which accounts for ~60% of the overall steel production in Europe.[1] Although being used for centuries, the process is still under intensive investigation. The large energy consumption and high carbon emissions in the blast furnace process increase the need for process optimization and offer possibilities for improvements. The heart of the blast furnace is the raceway zone, where the hot blast enters, forming the raceway cavity. The blast oxidizes the coke and the auxiliary reducing agents, providing the necessary heat and creating reducing gases to reduce the iron oxides.

Due to the high temperatures, detailed measurements inside or near the raceway zone are practically impossible. Therefore, computational modeling techniques can be an excellent opportunity to study the processes in the raceway zone and gain insight into the processes occurring.

However, the large scale of the plant, its high temperatures and reactions, and the interaction between solid and gas flow also pose challenges in modeling and computational cost. Therefore, a sensitive choice of models, balancing the computational cost and the required accuracy, is essential for profound predictions. This article will demonstrate a strategy that can be applied to large-scale applications, i.e., the blast furnace raceway. The model setup is validated based on a comparison with experimental data, and the article will exemplify the importance of the model choice for predicting the raceway shape and consequently the species concentrations.

Modeling Theory

The most detailed way to model solid particle movement is the discrete-element method (DEM). Because the particle-particle interactions are resolved there, the description is very accurate but leads to high computational demand. Therefore, the application of DEM to large-scale applications, such as the blast furnace, is still hindered by its high computational cost.[2,3]

An Eulerian description of the solid flow reduces detail but can describe dense solid flows on large scales. The submodels used to model solid movement in such a framework need to be carefully chosen to maintain reasonable prediction accuracy. This article exemplifies the influence of such model choices on the prediction of solid's movement and distribution and how it also influences the species concentration prediction in the gas phase.

In the Eulerian framework, all phases are modeled as interpenetrating continua. The momentum