Investigating the Use of Shaft-Level Tuyere Injection With Computational Fluid Dynamics




As blast furnace operators pursue higher-rate fuel injection to minimize both cost and CO_2 emissions, methods by which the associated limitations could be circumvented have become increasingly desirable. Researchers have explored the use of shaft-level tuyeres for delivery of syngas, hydrogen, or recycled top gas into the furnace above the cohesive zone as one such solution to enable lower carbon intensity in the process. This work applies computational fluid dynamics models, validated against industrial conditions, to provide insight into the impacts of shaft-level reducing gas supply on gas and burden temperatures, reduction rates, and coke consumption.

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Despite advances in lower-carbon-emission steel production, the blast furnace (BF) remains a significant contributor to overall carbon emissions from steelmaking in North America. It is also a critical piece of the steelmaking process, contributing high-quality hot metal produced from virgin iron ore at significant production rates. Hence, control over the energy efficiency and carbon emissions from the BF is a vital research area for steelmaking and in the global fight against climate change. Reducing gas in the BF serves three primary functions: providing the thermal energy needed to melt ore, the chemical energy needed to reduce the ore to Fe, and the thermal energy needed to drive the chemical reactions. It is the chemical requirement which makes the BF process so dependent on carbon, given the exothermic nature of CO moderated reduction. Hypothetically a second ring of tuyeres surrounding the furnace above the cohesive zone could permit better control by beginning to decouple the thermal demand of melting ore from the chemical and thermal demands of ore reduction. Previous work has explored the notion of mid-shaft injection through experimental and modeling work, and generally agrees that the depth of penetration into the furnace is among the main factors affecting the impacts of mid-shaft injection.[1,2]

Due to the scale and economic importance of industrial furnaces, operational experiments are often unfeasible, leaving operators with limited options to explore the impacts of concepts which may present pathways toward lower-carbon-emission BF operation. The need to maintain production and avoid damage to the process means that research on alternative operation schemes must often rely upon other methods beyond trial and error on the BF before attempting potentially expensive scaled-up physical implementation. Computational fluid dynamics (CFD) is one such tool which has been employed for relatively rapid and low-cost evaluation of potential modifications to the BF process.

A sizable body of research on BF computational modeling has been published, with methods employing a broad range of assumptions (PNW) ranging from simple heat mass balance models to detailed CFD models that incorporate the impacts of chemical kinetics and more detailed physics.[3–7] These models have been used to analyze the impacts of varied operating conditions, modified designs, fluid flow, heat transfer, chemical reactions under standard conditions and more.