Effect of the Porosity Distribution on the Industrial-Scale DRI Reforming Process

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In the direct reduced iron (DRI) reforming process, the quality of reducing gas (i.e., $CO+H_2$) depends on the local porosity distribution in the reformer tubes, which in turn depend on the catalyst design. In the present work, a computational fluid dynamics model is developed to simulate the industrial-scale DRI reforming process that includes the multicomponent gas mixture flow in reactor tubes and burners, reforming reactions in catalyst-filled tubes, and combustion in burners. The model predictions of tube outlet reformed gas composition and temperature are validated with plant data. The model is further used to investigate the effect of the local porosity distribution: (i) constant bed porosity and (ii) variable radial porosity due to catalyst design on the local flow field, reforming reaction rates, and ultimately on reformed gas quality and temperature.

Introduction

The shaft furnace-direct reduced iron (SF-DRI) process utilizes reducing gas primarily composed of CO and H_2 for the reduction of iron-ore in the SF. Therefore, SF-DRI-electric arc furnace (EAF) process generates significantly lower CO_2 emissions (1.0–1.2 tons of CO_2/ton of steel)[1] compared to the traditional blast furnace (BF)-basic oxygen furnace (BOF) route (~1.8–2.2 tons of CO_2/ton of steel)[2] and has experienced significant growth and a positive outlook as an alternative to reduce the carbon footprint of steel. The DRI reforming process consists of a bottom-fired reformer with hundreds of reforming tubes and burners for combustion which are isolated from tubes (see Fig. 1). The feed gas composed of top gas from the SF and natural gas (NG) is fed to the reformer tube, which is packed with catalyst particles (see Fig. 1). In the bottom-fired burners, fuel gas and air are given as input for the generation of energy through combustion (see Fig. 1). This energy is provided to the reformer tubes to promote the endothermic reforming reactions to produce reducing gases, such as hydrogen (H_2) and carbon monoxide (CO), which are transported to the SF for iron ore reduction. The gas quality and temperature are most often the limiting factors that determine the metallization rate/degree and overall productivity in the SF. The reduced gas quality is dictated by the local reforming reaction rates that in turn depend on the catalyst design and burner/tube process conditions (i.e., flowrate, composition and temperature). Therefore, understanding the influence of the gas dynamics inside the reformer tubes, temperature, and velocity distributions on the local reforming reaction mechanisms and ultimately on the reformed gas quality and temperature is important to further improve the performance of the reformer. In addition, the temperature distribution inside the reformer tubes is also influenced by the burner configuration and flow variables (i.e., fuel and combustion air flowrate and temperature). In this regard, computational fluid dynamics (CFD) is a useful tool that can provide a detailed understanding of the gas dynamics, heat transfer, and reaction mechanisms in the burner and tube side of the reformer.