

Iron Segregation Roasting as a Potential Decarbonization Pathway for Ironmaking

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Abstract. Ironmaking accounts for 80% of steelmaking greenhouse gas (GHG) emissions, while steelmaking accounts for 8% of global GHG emissions. These significant contributions to GHG emissions illustrate the value of decarbonizing ironmaking through the implementation of iron segregation roasting where applicable.

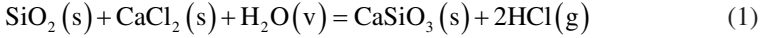
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Decarbonization · Segregation roasting

1 Introduction

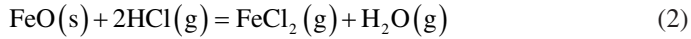
Ironmaking accounts for 80% of steelmaking greenhouse gas (GHG) emissions, while steelmaking accounts for 8% of global GHG emissions. These significant contributions to GHG emissions illustrate the value of decarbonizing ironmaking through the implementation of iron segregation roasting where applicable.

Iron segregation is ideally used with difficult-to-beneficiate iron ores where the ore is roasted at an elevated temperature with a carbonaceous reductant and a chloride additive in a closed reactor to allow for reducing conditions and contain the volatile chlorides. Although iron segregation roasting need not be limited to complex iron ores, oxide minerals of aluminum, titanium, and chromium are complex in nature and are frequently associated with ferrous/ferric oxides, vanadium, niobium and tantalum oxides, and rare-earth-bearing oxides [1]. Iron segregation roasting provides a potential upgrading solution for these complex ores as it allows for the ferrous and ferric oxides to be separated and upgraded to metallic iron thereby simplifying subsequent processing of the desired elements while producing a widely used value-added product. Powder metallurgy samples generated in this manner have high purity, ideal physical properties for powder metallurgical processing due to their cubic structure while they are resistant to oxidation at atmospheric conditions and are, in turn, not pyrophoric [2]. The iron product that does not meet the requirements for powder metallurgy can be subsequently briquetted and transported to an electric arc steelmaking facility or fed into an iron blast furnace as a scrap iron substitute.

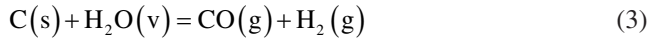
The chemistry of segregation is essentially the same for iron as for copper and nickel where a halide salt is hydrolyzed by steam in the presence of gangue (usually a silicate) producing substantial HCl exothermically at an elevated temperature, but significantly below the melting point of the metal (~950 °C for iron):



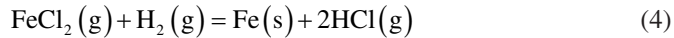
The HCl then reacts endothermically and relatively slowly with the metal oxide in turn mobilizing iron for transport:



Hydrogen is formed endothermically by the carbonaceous reductant:



The metal chloride is then reduced by hydrogen on or near the carbonaceous reductant. In turn, segregating it from the metal oxide's original position and liberating HCl to react with additional metal oxide completes the cycle and resulting in a catalytic behavior as a less than stoichiometric amount of chloride:



The process is followed by some form of physical separation to liberate the metallic iron from the gangue.

Iron segregation roasting lends itself well to decarbonization as the reactor type is ideally an indirect fired kiln or screw conveyor furnace, in order to contain the volatile chlorides, which act as a transport catalyst within the reactor [3–11]. Efforts to develop a direct-fired process have been studied and they have been met with limited success [12]. In turn, an electrically heated reactor can take advantage of a renewable electrical energy source.

An additional benefit that comes from the transport catalyst phenomena is that comminution energy requirements can be significantly reduced by avoiding the necessity of fine grinding as the iron is transported away from the gangue material. In turn, capital expenditures can also be reduced in this case, as less grinding equipment is needed.

Unlike coke required to maintain bed stability and a reducing atmosphere in traditional blast-furnace ironmaking, iron segregation roasting can use different types of renewable biochar, as the bed is not fluidized.

At the same time, hydrogen injection at the end of the process can also be used to increase metallization and further reduce the amount of carbon reductant necessary for ironmaking. Although the exact ratios possible have not been optimized, the concept has been proven [4].

While iron segregation roasting has only been tested in the laboratory and up to the small-pilot scale, it holds great potential for difficult to beneficiate ores, especially in the context of decarbonization in ironmaking.

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