Decarbonizing the Integrated Steel Mill With Efficient Hydrogen Integration







Hydrogen is one pathway to decarbonize the iron and steel sector. Given the investment costs for both hydrogen production and integration, and the operating costs associated with hydrogen, there are trade-offs between most efficient use of hydrogen against the overall system costs. Hydrogen integration in blast furnace ironmaking was studied to assess hydrogen usage efficiency; the implications for the plantwide energy balance were compared with the potential abatement costs. This article considers various configurations of direct and indirect hydrogen usage. The authors will describe conditions where hydrogen use is viable to reduce integrated steel mill CO_2 emissions from a technoeconomic perspective.

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Introduction

Iron- and steelmaking is an emission-intensive industry with important economic, strategic and geopolitical importance. Steel demand is projected to increase, reaching annual steel production of approximately 2.7 billion metric tons by 2050.[1,2] In 2024, the global steel industry emission intensity was 1.9 metric tons CO_2 (t CO_2)/metric ton crude steel (t CS) based on 71% of steel produced via the blast furnace (BF)-basic oxygen furnace (BOF) route and 29% produced via electric arc furnace (EAF) when melting scrap, pig iron and/or direct reduced iron (DRI). With its dominant position, it is critical that process improvements to the integrated (BF-BOF) steel production route are identified and implemented to achieve a meaningful reduction in emissions. The BF is the largest emitter, responsible for approximately ~70% of integrated steel mill emissions attributed to the final steel product, and is an essential area for emission reduction initiatives.[3]

There has been a growing interest in using hydrogen (H_2) to replace fossil fuels in BF ironmaking as a decarbonization pathway. The direct H_2 injection into BFs is of interest as it only requires a change to the injection lances and mild operational changes to maintain stable operating conditions. The implementation of direct H_2 injection has challenges to implement: it is expensive, and with the BF only having a hydrogen utilization in the range of 42–48%, more than half of the injected hydrogen will exit in the blast furnace gas (BFG) without doing any chemical reduction work. This has led developers to consider integrating H_2 injection into the top gas recycling-oxygen blast furnace (TGR-OBF) concept to allow for recycling of the unreacted H_2.

H_2 injection into the BF has other challenges, including:

- Heat balance issues due to endothermic iron oxide reduction by hydrogen.
- High specific heat capacity of hydrogen, which demands a large amount of energy to heat the injected hydrogen to raceway conditions, negatively impacting the raceway adiabatic flame temperature (RAFT).
- Challenges around safely transporting, handling and storing H_2 due to its small molecular size.
- Damage potential caused by H_2 embrittlement of existing steel components.