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Review

A review of gas separation technologies within emission reduction programs in the iron and steel sector: Current application and development perspectives

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ABSTRACT

Worldwide steel production is still mainly achieved from primary manufacturing by carbon-intensive processes in integrated steel mills, making this industry the first in terms of direct CO_2 emissions. Both carbon capture and storage (CCS) and carbon capture and utilization (CCU) approaches are currently considered to offer a solution to the high carbon-footprint of primary steel production. Design of available or development of new gas separation-purification technologies are at the heart of these strategies, and often represent the largest share of the total project cost. This work presents the current state of development of the main technologies that have shown potential thus far at pilot or industrial scale for the treatment of gases within the steelmaking industry. An analysis of the opportunities and limitations of each technology is presented, related to their ability to separate existing gas streams into the two main carbon-bearing species, CO_2 and CO. Recovery of H_2, available in important quantities, is also considered. Main results from previous and ongoing research are presented and analyzed to draw a picture of the current situation, and offer key points for future development.

1. Introduction

The iron and steel industry, after the cement industry, is the second most important in modern society in terms of production volumes, and it is the first in terms of direct CO_2 emissions. Iron and steel industry emissions in 2006 accounted for 30% of the 7.2 Gt of direct CO_2 industrial emissions, followed by the cement industry which was responsible for 26% [1]. Overall, these CO_2 emissions account for 5–7% of the total anthropogenic emissions [2,3]. Steel production has increased rapidly since the beginning of the century and this trend is expected to continue. Fig. 1.1 presents the reported annual global steel production.

Steel production doubled between 2000 and 2014 after having increased only 19% between 1980 and 2000. Most of this recent increment in production comes from emerging economies, namely China, which produced 49% of the world's steel in 2014 at a level over six times higher than its production in the year 2000. CO_2 emissions in industry can be direct or indirect, direct emissions are generated by the transformation processes specific to each industry while indirect emissions are generated from the production of energy needed for such transformation processes to take place. These emissions depend mainly of factors such as the production technology, final products, product and energy efficiency and the percentage of fossil energy used. In average, production of one ton of steel generates 1.8 tons of CO_2 [4].

Steel production is a complex process comprising several steps depending of the desired final products, available raw materials, available energy sources and investment capacity. However, two production routes dominate global production [5]:

- Integrated steel mills (ISM's), based on the blast furnace-basic oxygen furnace (BF-BOF) process. Iron ore is reduced with coke in the blast furnace, and the resulting metal, named pig iron, is fed to the basic oxygen furnace along with a percentage of steel scrap to produce steel.
- Mini-mills, based on the electric arc furnace process (EAF). Metal scrap is melted directly to produce steel.

Fig. 1.2 presents these two steel production routes along with other common process variations. Integrated steel mills, using the BF-BOF process, dominate global production with around two thirds of the world's steel coming from this route. Production through EAF's is the second most important with around one fourth of the global steel

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