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CO_2 Capture by Membrane Applied to Steel Production Process

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Abstract : Steel production is a major contributor to global warming potential. An average value of 1.83 tons of CO_2 is emitted for every ton of steel produced, resulting in over 3.3 Mt of CO_2 emissions each year. The present paper is focused on the investigation and comparison of two O_2 separation methods and two CO_2 capture technologies applicable to iron and steel industry. The O_2 used in steel production comes from an Air Separation Unit (ASU) using distillation or from air separation using membranes. The CO_2 capture technologies are represented by a two-stage membrane separation process and the gas-liquid absorption using methyl di-ethanol amine (MDEA). Process modelling and simulation tools, as well as environmental tools, are used in the present study. The production capacity of the steel mill is 4,000,000 tones/year. In order to compare the two CO_2 capture technologies in terms of efficiency, performance, and sustainability, the following cases have been investigated: Case 1: steel production using O_2 from ASU and no CO_2 capture; Case 2: steel production using O_2 from ASU and gas-liquid absorption for CO_2 capture; Case 3: steel production using O_2 from ASU and membranes for CO_2 capture; Case 4: steel production using O_2 from membrane separation method and gas-liquid absorption for CO_2 capture and Case-5: steel production using membranes for air separation and CO_2 capture. The O_2 separation rate obtained in the distillation technology was about 96%, and about 33% in the membrane technology. Similarly, the O_2 purity resulting in the conventional process (i.e. distillation) is higher compared to the O_2 purity obtained in the membrane unit (e.g., 99.50% vs. 73.66%). The air flow-rate required for membrane separation is about three times higher compared to the air flow-rate for cryogenic distillation (e.g., 549,096.93 kg/h vs. 189,743.82 kg/h). A CO_2 capture rate of 93.97% was obtained in the membrane case, while the CO_2 capture rate for the gas-liquid absorption was 89.97%. A quantity of 6,626.49 kg/h CO_2 with a purity of 95.45% is separated from the total 23,352.83 kg/h flue-gas in the membrane process, while with absorption of 6,173.94 kg/h CO_2 with a purity of 98.79% is obtained from 21,902.04 kg/h flue-gas and 156,041.80 kg/h MDEA is recycled. The simulation results, performed using ChemCAD process simulator software, lead to the conclusion that membrane-based technology can be a suitable alternative for CO_2 removal for steel production. An environmental evaluation using Life Cycle Assessment (LCA) methodology was also performed. Considering the electricity consumption, the performance, and environmental indicators, Case 3 can be considered the most effective. The environmental evaluation, performed using GaBi software, shows that membrane technology can lead to lower environmental emissions if membrane production is based on benzene derived from toluene hydrodealkilation and chlorine and sodium hydroxide are produced using mixed technologies.

Keywords : CO_2 capture, gas-liquid absorption, Life Cycle Assessment, membrane separation, steel production
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