

CO₂ Capture by Membrane Applied to Steel Production Process

Authors : Alexandra-Veronica Luca, Letitia Petrescu

Abstract : Steel production is a major contributor to global warming potential. An average value of 1.83 tons of CO₂ is emitted for every ton of steel produced, resulting in over 3.3 Mt of CO₂ emissions each year. The present paper is focused on the investigation and comparison of two O₂ separation methods and two CO₂ capture technologies applicable to the iron and steel industry. The O₂ used in steel production comes from an Air Separation Unit (ASU) using distillation or from air separation using membranes. The CO₂ capture technologies are represented by a two-stage membrane separation process and the gas-liquid absorption using methyl di-ethanol amine (MDEA). Process modeling 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 CO₂ capture technologies in terms of efficiency, performance and sustainability, the following cases have been investigated: Case 1: steel production using O₂ from ASU and no CO₂ capture; Case 2: steel production using O₂ from ASU and gas-liquid absorption for CO₂ capture; Case 3: steel production using O₂ from ASU and membranes for CO₂ capture; Case 4: steel production using O₂ from membrane separation method and gas-liquid absorption for CO₂ capture and Case 5: steel production using membranes for air separation and CO₂ capture. The O₂ separation rate obtained in the distillation technology was about 96% and about 33% in the membrane technology. Similarly, the O₂ purity resulted in the conventional process (i.e., distillation) is higher compared to the O₂ 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 CO₂ capture rate of 93.97% was obtained in the membrane case while the CO₂ capture rate for the gas-liquid absorption was 89.97%. A quantity of 6,626.49 kg/h CO₂ 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 6,173.94 kg/h CO₂ 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 CO₂ removal for steel production. An environmental evaluation using Life Cycle Assessment (LCA) methodology was also performed. Considering the electricity consumption, 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 hydrodealkylation, and chlorine and sodium hydroxide are produced using mixed technologies.

Keywords : CO₂ capture, gas-liquid absorption, Life Cycle Assessment, membrane separation, steel production

Conference Title : ICECCE 2021 : International Conference on Environmental Chemistry and Chemical Engineering

Conference Location : Venice, Italy

Conference Dates : November 11-12, 2021