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Performance analysis of an eight-layered bed PSA process for H_2 recovery from IGCC with pre-combustion carbon capture

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ABSTRACT

Integrated gasification combined cycle (IGCC) plants that are also capable of CO_2 capture have received significant attention as the next generation of coal-based power plants for the co-production of H_2 and electrical power. Accordingly, for a cost-effective and environmentally friendly poly-generation IGCC process, efficient techniques need to be developed to recover H_2 from the syngas of an IGCC plant with carbon capture.

In this study, an eight-layered bed pressure swing adsorption (PSA) process using activated carbon and zeolite simultaneously was developed to produce high purity H_2 from the H_2-rich syngas of an IGCC plant. As a first step, the separation performance was compared between four-and eight-layered bed PSA processes. The eight-layered bed PSA process led to higher recovery of H_2 at the condition of a similar H_2 purity owing to a greater number of pressure equalization steps in the operational step configuration. It is noteworthy that the productivity could be greatly improved as the purge gas was replaced from the product gas to residual gas in a bed. When the adsorption bed was purged by using the residual gas after the first pressure equalization step, recovery improved by about 3 ~ 6 % at the condition of 99.99 + mol% H_2 purity in comparison with the product-purge PSA configuration. On the other hand, the highest H_2 recovery that could be obtained for the requirement of 99.99 mol% H_2 purity, was ~ 89.7 % from the eight-layered bed H_2 PSA process when the purge gas was provided from the residual gas of the adsorption bed after the last depressurization pressure equalization step. However, as the concentration of CO in the desired H_2 product was higher in the PSA configuration when using residual gas compared to the product gas, the operational configuration of PSA needed to be decided by the desired H_2 purity and impurity constraints for application. Furthermore, the tail gas from the PSA contained 45–66 mol% of H_2 and CO, depending on the applied PSA configurations, and could be used to drive a gas turbine without any loss of the syngas, even though the recompression energy loss required evaluation.

1. Introduction

Global warming caused by greenhouse gas (GHG) emissions has become one of the most important issues faced by mankind today. In order to combat the increasing levels of CO_2 in the atmosphere, several governments have strengthened regulations on coal-fired power plants. According to an International Energy Agency report regarding growth projections for renewable energy [1], coal will still be a major source of energy in 2040, even as the issue of climate change caused by increasing levels of carbon dioxide becomes more urgent. However, since coal combustion is responsible for more than 70 % of the global CO_2 emissions from electrical power generation plants, this industry is being confronted by the challenges of supplying energy with simultaneous mitigation of CO_2 emissions.

Carbon capture and storage (CCS) technology for fossil fuel power plants can offer the requisite improved energy and commercial value from fossil fuels by greatly decreasing the impact from GHG emissions [2–4]. Consequently, there is a need for an advanced coal-fired power plant, which is more efficient than conventional coal power generation and discharges a limited amount of environmental pollutants.

An integrated gasification combined cycle (IGCC), which utilizes a coal gasifier with oxygen at high temperature and pressure, is an advanced coal power plant that shows promise in addressing aforementioned environmental issues because of its high efficiency [5–7]. The syngas generated from the gasifier is used as a fuel for the combined-cycle power generation after removing hydrogen sulfide [5,6,8]. Furthermore, since the power generation industry aims to adopt eco-friendly processes, the technical demands from an IGCC process include

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