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Experimental and modeling of CO_2 capture by dry sodium hydroxide carbonation

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ABSTRACT

In this work, CO_2 capture from the air using dry NaOH sorbents has been studied. The influences of the main operating parameters such as temperature, air humidity, and NaOH loading on the CO_2 removal rate have been experimentally investigated using Taguchi method. The results revealed that the appropriate value of the temperature to maximize the rate was in the range of 35–45 °C. A multilayer artificial neural network (ANN) was also used to model the process in order to find the optimal conditions. A procedure reported in the literature was modified and applied to design the ANN model. The model predictions were validated by conducting some more experiments. The experimental results proved the accuracy of the model to predict the optimal conditions. The effects of NaOH particle size and multiple carbonation cycles have also been investigated.

Keywords: CO_2 capture; Sodium hydroxide; Neural network; Adsorption

1. Introduction

IPCC[1] fourth report showed 0.74 °C increase in average global temperature during 1906–2005. The temperature is also expected to increase up to 6.4 °C till 2100 that leads to an increase in sea level up to 59 cm (IPCC, 2001).

Carbon dioxide is the major greenhouse gas among different greenhouse gases. Its production has been increased every year. The latest data from the U.S. National Oceanic and Atmospheric Agency's (NOAA) Earth System Research Laboratory indicates that in 2011 carbon dioxide level has reached to the highest value that the laboratory has ever recorded in its 50 year history (IEA, 2011; NOAA, 2011). Therefore, a number of researches have been conducted to find the methods of carbon dioxide emission reduction or capturing CO_2.

There are some separation techniques for CO_2 capture, such as chemisorption, physical absorption, cryogenic distillation, and membrane technology (Aaron and Tsouris, 2005; Abass, 2010; Duke et al., 2010; Ma et al., 2009; Mimura et al., 2003; Pennline et al., 2008; White et al., 2003; Yang et al., 2008). Currently, a commercially available process for flue gas CO_2 capture that is also capable of being retrofitted to the existing plants is based on amine solution scrubbing (Liang et al., 2004). However, this method has some disadvantages including high energy consumption for solvent regeneration (Duke et al., 2010; Hasib-ur-Rahman et al., 2010; Karadas et al., 2010; Yang et al., 2008), high rate of process equipment corrosion, high solvent losses due to evaporation (Hasib-ur-Rahman et al., 2010; Karadas et al., 2010), and high solvent degradation rate in the presence of oxygen (Duke et al., 2010; Yang et al., 2008).

Development of new methods for carbon dioxide capture is essential due to the major drawbacks of conventional CO_2 capture process (Duke et al., 2010; Dutcher et al., 2011; Sjostrom and Krutka, 2010; Yang et al., 2008; Zhao et al., 2010). It is of great importance to find an optimal technology for capturing CO_2 as well as to integrate and optimize the technology (Sipöcz et al., 2011). Therefore, CO_2 capturing using dry sorbents such as alkaline oxides and carbonates has been investigated as an alternative method (Dutcher et al., 2011; Liang et al., 2004; Nikulshina et al., 2009; Zhao et al., 2010). These sorbents have high capacity of CO_2 chemisorptions, lower heat capacity and could produce pure CO_2 in regeneration cycle (Dutcher et al., 2011; Sjostrom and Krutka, 2010). These sorbents have also environmental advantages for capturing CO_2 from the air, taking place far away from populated cities and without

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[1] Intergovernmental Panel on Climate Change (IPCC).

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