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Mathematical Modeling of Rapid Temperature Swing Adsorption; The role of influencing parameters

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Abstract

CO_2 capture from power plant emissions has posed a great challenge in recent decades. The key factor to respond to such a challenge is to develop a separation process consuming less energy, but producing high purity and recovery compared to the available commercial technologies such as amine absorption. Adsorption process is one of the promising leads to achieve this goal. However, it suffers from the large time period required for the regeneration step. One remedy to overcome this problem is employing Rapid Temperature Swing Adsorption (RTSA). In this study, a two dimensional mathematical model of a RTSA process was developed. A sensitivity analysis was also carried out to determine how different transport parameters and simplifying assumptions influence the calculated breakthrough curve. It was concluded that the external and inter-particle mass transfer resistances were negligible. Also, the effects of the key operating variables such as water velocity in the adsorption and desorption steps (0.01-1 m/s), gas velocity (0.5-5m/s), adsorption time period (40-200s), adsorption temperature (5-40^{o}C), desorption temperature (80-120^{o}C), and hollow fiber thickness (80-680 µm) on RTSA performance were investigated. The RTSA performance was analyzed in terms of recovery, purity, productivity, the amount of separated pure carbon dioxide in 24 h, and specific energy consumption. The following conclusions were drawn for the base-case scenario: 1) the best thickness of the hollow fiber is 260 µm in which purity, recovery, and the amount of separated pure CO_2 are at the maximum values 2) a decrease in adsorption step period time tends to an increase in the productivity and recovery, e.g. the productivity and recovery decrease by half if the adsorption step continues after reaching breakthrough time up to fully saturation state, 3) increasing the gas velocity leads to increasing the productivity and decreasing the recovery with the appropriate value of 2.7 m/s. 4) the water velocity in the adsorption and desorption steps were selected 0.4 m/s. and , 5) higher adsorption temperature and desorption temperature resulting in less specific energy consumption.

Keywords: CO_2 capture; cyclic adsorption; hollow fiber; Mathematical model; RTSA

1. Introduction

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