Separation and Purification Technology 181 (2017) 95–106

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Analysis of thermal parameter effects on an adsorption bed for purification and bulk separation

Dong-Kyu Moon [a], Yongha Park [a], Shin-Hyuk Kim [b], Min Oh [c], Chang-Ha Lee [a,*]

[a] Department of Chemical and Biomolecular Engineering, Yonsei University, Seoul, Republic of Korea
[b] Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea
[c] Department of Chemical Engineering, Hanbat National University, Daejeon, Republic of Korea

ARTICLE INFO

Article history:
Received 28 November 2016
Received in revised form 3 March 2017
Accepted 12 March 2017
Available online 14 March 2017

Keywords:
Adsorption
Thermal effect
Internal heat transfer
Heat of adsorption
IGCC
BFG

ABSTRACT

Understanding separation behavior in an adsorption bed is crucial for well-designed adsorption processes. Since adsorption phenomena depend on temperature, thermal parameters, such as the internal heat transfer (h_i), isosteric heat of adsorption (Q_{st}) and axial thermal conductivity of the bed (K_w), can affect the adsorption dynamics and performance of the bed. In this study, the effects of these thermal parameters on the adsorption dynamics and breakthrough curves were analyzed with the experimental results using integrated gasification combined cycle gas from the carbon capture process (IGCC gas; H_2:CO:N_2:CO_2:Ar = 88:3:6:2:1 mol%) as a purification gas and blast furnace gas (BFG; H_2:CO:N_2:CO_2 = 20:0.1:44.5:35.4 mol%) as a bulk separation gas. The results were then compared with the isothermal and adiabatic results. Considering the variation of the internal heat transfer coefficient and isosteric heat of adsorption along with the propagation of gas in the bed, the temperature profiles inside the bed could be predicted better than in the case using constant values. The axial thermal conductivity of the bed significantly affected the temperature profiles as the temperature excursion was sharp. In the prediction of breakthrough curves, these variable thermal parameters could be replaced by suitable constant values estimated from experimental and theoretical approaches when well-fitted isotherm parameters were applied considering the partial pressure of each component in the feed.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Hydrogen is considered to be one of the most important energy carriers for the future because it enhances the sustainability of the energy-supply chain in terms of economic growth and eco-friendliness. Using the current energy system, massive amounts of hydrogen can be obtained from processes that use fossil fuels, such as coal, petroleum and natural gas. A separation technology is necessary to efficiently produce hydrogen from various processes that have a hydrogen effluent.

Adsorption technology is understood to be a promising separation process for many effluent gases because of its high efficiency and low cost. As a well-proven technology, the PSA (pressure swing adsorption) process to recover H_2 from various effluent gases has been widely applied to reforming gas, coke oven gas, water gas shift reaction gas, and coal syngas. The demands of advanced adsorption processes are continuously increasing because of the importance of energy-saving processes and new hydrogen sources, such as BFG (blast-furnace gas) and IGCC (Integrated Gasification Combined Cycle) gas. Therefore, the adsorption dynamics of a fixed bed have been studied extensively to develop PSA processes for purification or bulk separation of gaseous mixtures because its dynamic characteristics play a key role in the process design [1,2].

Since adsorption is exothermic, heat is generated in an adsorption bed, and the amount of heat depends on the amounts of impurities and the type of adsorbate. In the analysis and estimation of the adsorption behavior in a fixed bed, heat effects are important because the heat, that is generated, leads to a change in the adsorption equilibrium and rate of adsorption. Heat transfer through the column wall can affect the thermal dynamics inside the bed. Therefore, information related to heat generation and release during adsorption in a bed is important in interpreting the adsorption behavior and designing the PSA process. Furthermore, the experimental and theoretical prediction of heat transfer in the bed is essential for understanding the adsorption dynamics of the PSA process.

It has been reported that the numerical values of the heat transfer coefficients should be applied differently to dynamic simulations according to the variation in the operating conditions [3].

* Corresponding author.
E-mail address: leech@yonsei.ac.kr (C.-H. Lee).

http://dx.doi.org/10.1016/j.seppur.2017.03.015
1383-5866/© 2017 Elsevier B.V. All rights reserved.