CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 2013–2022

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Research and Design

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

Electrothermal performance of an activated carbon honeycomb monolith

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ABSTRACT

The main advantage of Electric Swing Adsorption (ESA) process is related to the fast heating rates that can be achieved by Joule effect. Since this heating is done by passing electricity, its utilization should be efficient to reduce the overall losses of the system. This work discusses the heat transfer phenomena of an Electric Swing Adsorption (ESA) process in order to improve the overall energetic efficiency of the unit.

Experiments were done with an activated carbon honeycomb monolith and testing different electrodes and column arrangements. The experimental set-up with lower electrical resistance has shown lower losses: faster heating rates can be achieved and less heat is lost by natural convection to the surroundings. Brass electrodes employed with a Teflon® support have resulted in lower energy losses. Results obtained in a laboratory-scale unit allowed a heating efficiency of 52% employing an average power of 293 W. Most of the energy losses were to the electrodes and surroundings, reason why if the process is scaled-up, the efficiency of the unit should be better. Furthermore, the mass of adsorbent/mass of electrodes ratio can be reduced and then the overall efficiency can be increased up to 83%.

Keywords: Electric Swing Adsorption (ESA); Activated carbon; Monolith; Heating; Joule effect

1. Introduction

Adsorption based separation processes are commonly employed to perform diverse gaseous separations. Purification of oxygen (Li et al., 1998a,b; Sircar and Kratz, 1989), biogas upgrading (Alonso-Vicario et al., 2010; Grande and Rodrigues, 2007), propane-propylene separation (Da Silva and Rodrigues, 2000; Grande and Rodrigues, 2005; Rege and Yang, 2002), hydrogen purification (Golden et al., 1990; Lopes et al., 2011; Sircar and Kratz, 1988), air drying (Ahn and Lee, 2003), *etc.*, can be performed through adsorption processes.

Electric Swing Adsorption (ESA) and Temperature Swing Adsorption (TSA) are cyclic adsorption based separation processes in which the adsorbent is regenerated by increasing its temperature. The main difference between ESA and TSA is the method to promote the temperature increase required for adsorbent regeneration. The heating of a TSA unit is performed employing steam or a hot purge gas. Adsorbent heating in TSA is a time consuming task since the heat transfer limitation from the heat source to the adsorbent present long desorption times. When steam is employed to heat the adsorbent a further separation step may be needed. Employing a hot purge gas will origin diluted heavy product (Yu et al., 2007).

In ESA the heat is electrically generated, *i.e.*, an electric current passes through a conductor heating it by Joule effect (Burchell et al., 1997; Petkovska et al., 1991; Sullivan et al., 2004). The electrical conductor can be the adsorbent itself or some ancillary conductor, being the process called direct ESA or indirect ESA, respectively. In ESA, the heat is generated *in situ* presenting the advantage of allowing extremely fast heating steps (called electrification step) and the heating rate being independent from the purge gas properties and flow rate. The ability to control the purge gas independently of the heat transfer allows achieving much higher purities of the heavier compound (Sullivan et al., 2004). In ESA the heating

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Received 2 January 2012; Received in revised form 13 March 2012; Accepted 15 March 2012

http://dx.doi.org/10.1016/j.cherd.2012.03.010