A dimensionless analysis of heat and mass transport in an adsorber with thin fins; uniform pressure approach

Gamze Gediz Ilis, Moghtada Mobedi, Semra Ülkü

A numerical study on heat and mass transfer in an annular adsorbent bed assisted with radial fins for an isobaric adsorption process is performed. A uniform pressure approach is employed to determine the changes of temperature and adsorbate concentration profiles in the adsorbent bed. The governing equations which are heat transfer equation for the adsorbent bed, mass balance equation for the adsorbent particle, and conduction heat transfer equation for the thin fin are non-dimensionalized in order to reduce number of governing parameters. The number of governing parameters is reduced to four as Kutateladze number, thermal diffusivity ratio, dimensionless fin coefficient and dimensionless parameter of \( \Gamma \) which compares mass diffusion in the adsorbent particle to heat transfer through the adsorbent bed. Temperature and adsorbate concentration contours are plotted for different values of defined dimensionless parameters to discuss heat and mass transfer rate in the bed. The average dimensionless temperature and average adsorbate concentration throughout the adsorption process are also presented to compare heat and mass transfer rate of different cases. The values of dimensionless fin coefficient, \( \Gamma \) number and thermal diffusivity ratio are changed from 0.01 to 100, 1 to \( 10^{-5} \) and 0.01 to 100, respectively; while the values of Kutateladze number are 1 and 100. The obtained results revealed that heat transfer rate in an adsorbent bed can be enhanced by the fin when the values of thermal diffusivity ratio and fin coefficient are low (i.e., \( \alpha = 0.01 \), \( \Lambda = 0.01 \)). Furthermore, the use of fin in an adsorbent bed with low values of \( \Gamma \) number (i.e. \( \Gamma = 10^{-7} \)) does not increase heat transfer rate, significantly.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Adsorption phenomena have broad range of applications in nature as well as in industry. It plays an important role in the catalytic reaction and separation/purification processes such as recovery of the chemical compounds, water purification, separation, and purification of air, drying, medical treatments, and recently thermally driven energy systems. The period and capacity of an adsorption process are two significant criteria that should be considered in design of an adsorption system. For instance, a high adsorption capacity in a short adsorption period is required in order to have high specific cooling or heating performance for an adsorption heat pump [1]. The adsorption rate in an adsorbent particle or an adsorbent layer is highly influenced from its temperature. Determinations of adsorption capacity and adsorption period of a process are not easy, since heat and mass transports are highly coupled. The solution of heat and mass transport equations for an adsorption process provides useful information that can be used for an adsorbent bed design.

Literature survey showed that theoretical and experimental studies were performed on heat and mass transfer in the adsorbent beds as well as in the desiccant wheels. Golubovic and Worek [2] studied the pressure effect on sorption process in rotary desiccant wheels. They used an implicit finite-difference scheme to detect condensation in regeneration portion of a desiccant wheel operating at high pressures. Al-Sharqawi and Lior [3] performed a conjugate computation study on heat and fluid flow in channels and over silica gel desiccant plates for laminar and turbulent flows of humid air. The results of their study showed that the heat and mass transfer coefficients decrease with increase of desiccant plate thickness. Sphaier and Worek [4] proposed a novel solution scheme for a periodic heat and mass transfer in a regenerator. The method consists of a combination of the finite-volume method and the numerical method of lines. Ruivo et al. [5] discussed the importance of surface diffusion which is the most important mechanism of water transport within the silica gel for desiccant wheels.

Studies on heat and mass transfer in closed adsorbers such as adsorbent bed of adsorption heat pumps were also reported in

---

**ARTICLE INFO**

Available online 22 March 2011

Keywords: Adsorption Heat and mass transfer Adsorbent bed Fin

**ABSTRACT**

A numerical study on heat and mass transfer in an annular adsorbent bed assisted with radial fins for an isobaric adsorption process is performed. A uniform pressure approach is employed to determine the changes of temperature and adsorbate concentration profiles in the adsorbent bed. The governing equations which are heat transfer equation for the adsorbent bed, mass balance equation for the adsorbent particle, and conduction heat transfer equation for the thin fin are non-dimensionalized in order to reduce number of governing parameters. The number of governing parameters is reduced to four as Kutateladze number, thermal diffusivity ratio, dimensionless fin coefficient and dimensionless parameter of \( \Gamma \) which compares mass diffusion in the adsorbent particle to heat transfer through the adsorbent bed. Temperature and adsorbate concentration contours are plotted for different values of defined dimensionless parameters to discuss heat and mass transfer rate in the bed. The average dimensionless temperature and average adsorbate concentration throughout the adsorption process are also presented to compare heat and mass transfer rate of different cases. The values of dimensionless fin coefficient, \( \Gamma \) number and thermal diffusivity ratio are changed from 0.01 to 100, 1 to \( 10^{-5} \) and 0.01 to 100, respectively; while the values of Kutateladze number are 1 and 100. The obtained results revealed that heat transfer rate in an adsorbent bed can be enhanced by the fin when the values of thermal diffusivity ratio and fin coefficient are low (i.e., \( \alpha = 0.01 \), \( \Lambda = 0.01 \)). Furthermore, the use of fin in an adsorbent bed with low values of \( \Gamma \) number (i.e. \( \Gamma = 10^{-7} \)) does not increase heat transfer rate, significantly.

© 2011 Elsevier Ltd. All rights reserved.