

available at www.sciencedirect.comjournal homepage: www.elsevier.com/locate/ijrefrig

Optimal adsorbent for adsorptive heat transformers: Dynamic considerations

Yuriy I. Aristov*

Boreskov Institute of Catalysis SB RAS, Lavrentieva Av., 5, Novosibirsk 630090, Russia

ARTICLE INFO

Article history:

Received 10 November 2008

Received in revised

form 22 January 2009

Accepted 24 January 2009

Published online 3 February 2009

Keywords:

Adsorption system

Heat transformer

Review

Adsorbent

Diffusivity

Heat transfer

Mass transfer

ABSTRACT

Kinetic properties of the adsorbent can strongly affect dynamics of an adsorptive heat transformer. In this paper we describe a current methodology and start discussing a new approach for dynamic characterization and optimization of the system “adsorbent-heat exchanger” under conditions typical for heat transformation. Effect of the adsorbent nature, its grain size, residual non-adsorbable gas, heating rate, local shape of adsorption isobar on the adsorption dynamics and specific cooling (heating) power was studied for promising adsorbents of water (Fuji silica RD, FAM-Z02, SWS-1L). Based on these results some demands to an adsorbent optimal from the dynamic point of view have been discussed.

© 2009 Elsevier Ltd and IIR. All rights reserved.

Transformateurs de chaleur à adsorption : adsorbant optimal et aspects dynamiques

Mots clés : Système à adsorption ; Transformateur de chaleur ; Enquête ; Adsorbant ; Diffusivité ; Transfert de chaleur ; Transfert de masse

1. Introduction

An adsorbent is a key element of adsorptive heat transformers, AHT (heat pumps, chillers and amplifiers) and its proper choice is of prime importance. Intelligent choice of adsorbent should be based on comprehensive analysis that

takes into consideration both thermodynamic and dynamic aspects. Thermodynamic requirements to an optimal adsorbent which ensures the best cycle performance under prescribed operating conditions were reported for non-regenerative AHT cycles in Aristov (2005, 2007a,b). These requirements for a basic cycle reversibly operating at the fixed

* Tel./fax: +7 383 3309573.

E-mail address: aristov@catalysis.ru

0140-7007/\$ – see front matter © 2009 Elsevier Ltd and IIR. All rights reserved.

doi:10.1016/j.ijrefrig.2009.01.022

Nomenclature

A	constant, s
B	constant, s/mbar
c	specific heat, J/(kg °K); concentration in the gas phase, g/cm ³
D	diffusivity, m ² /s
E	activation energy, J/mol
h	heat transfer coefficient, W/(m ² °K)
H	enthalpy, J/mol
K	rate constant, 1/s
m	mass, g
P	pressure, mbar
q	adsorbate concentration, g
r	pore radius, m
R	grain radius, m; universal gas constant, J/(m K)
S	area, m ²
T	temperature, K, °C
t	time, s
V	volume, m ³

W	specific power, kW/kg
ε	grain porosity
μ	molar mass, g
τ	characteristic time, s
Δ	increment

Subscripts

a	adsorbent, activation
A	air
c	condenser
e	evaporator
ef	effective
eq	equilibrium
f	final
kn	Knudsen
max	maximum
p	particle; pore; at constant pressure
t	temporal
0	initial
∞	infinity

evaporator temperature T_e and condenser temperature T_c are based on an universal relation between three cycle temperatures (T_e , T_c and the minimal desorption temperature T_2) (Critoph, 1988) $T_2 \cdot T_e = T_c^2$, that directly comes from the empiric Trouton's rule (Alefeld and Radermacher, 1994) or the Polanyi principle of temperature invariance (Aristov et al., 2008a). The conclusion was drawn that the optimal adsorbent should have a step-like adsorption isobar with the step positioned exactly at $T = T_2$ (at $P = P_o(T_c)$). Because of zero temperature difference between an adsorber and an external heat source the entropy generation is absent and the AHT efficiency can reach the Carnot efficiency (Aristov et al., 2008a). On the other hand, there is no driving force for heat transfer that results in zero power.

Kinetic properties of the adsorbent strongly affect the dynamic behaviour of AHT and contribute to the specific power of the unit (Aristov et al., 2008b). In the last International Sorption Heat Pump Conference (ISHPC2008) in Seoul many papers have been focused on dynamic analysis of adsorbents and adsorption units (Aristov, 2008; van der Pal et al., 2008; Wittstadt et al., 2008; Schnabel and Schmidt, 2008; Schicktzanz and Nunez, 2008). This paper gives an overview of the current state of the art in this field and describes a novel approach focused on studying adsorption dynamics under conditions typical for AHT. This approach closely imitates boundary conditions of isobaric stages of AHT when adsorption (desorption) is initiated by a fast drop (jump) of the temperature of a heat exchanger (HE) wall which is in thermal contact with the adsorbent (Aristov et al., 2008b; Okunev et al., 2008a; Glaznev and Aristov, 2008; Glaznev et al., 2008a,b; Dawoud, 2007). This method allowed experimental modelling the dynamics of isobaric stages of AHT. The effects of adsorbent nature, its grain size, heating rate, residual non-adsorbable gas, etc. on the uptake evolution and AHT specific power were experimentally examined for promising adsorbents (Fuji silica RD, FAM-Z02, SWSs). Applicability of the Linear Driving Force (LDF) model is discussed. Based on this method as well as on literature data some requirements to a dynamically

optimal adsorbent and configuration of its layer are considered.

2. The current state of the art

As stated above, the adsorbent kinetic properties can strongly affect the dynamic behaviour of well-designed AHT and its specific power. Common way for taking these complex effects into account is a mathematical modelling of the AHT dynamics. These models are used for describing experimental behaviour of real AHT, predicting the performances, understanding the influence of the adsorbent properties, optimization of AHT operation, etc. Depending on the complexity, the dynamic models may be classified as lumped parameters (LP) and heat and mass transfer (HMT) models.

The HMT models take into account variation of the adsorbent temperature T_a , pressure P and adsorbate concentration q both in time and space. Hence, the governing equations are partial differential equations. The complex and nonlinear character of coupled heat and mass transfer requires sophisticated and time-consuming numerical methods for solving these equations and simulation of adsorbent bed dynamics. Because of this the HMT models are not wide-spread and the most popular are LP models which give a simplified representation of the adsorption process, neglecting any space gradients. The following assumptions are generally made: a) the temperature T_a is uniform in the adsorbent layer; b) the refrigerant (adsorbate, working fluid) is distributed in the adsorber uniformly and can be described by the average concentration; and, c) the intrinsic adsorption is fast and at any time the equilibrium between solid and gas phases are attained. In the LP models only the heat transfer resistance between a HE wall and an adsorbent is considered, while that inside the adsorbent layer is neglected (Yong and Sumathy, 2002). A common LP model includes three main equations representing the energy balance, mass balance and adsorption equilibrium. This model was applied for analysis

Download English Version:

<https://daneshyari.com/en/article/789844>

Download Persian Version:

<https://daneshyari.com/article/789844>

[Daneshyari.com](https://daneshyari.com)