Applied Thermal Engineering 40 (2012) 258–266

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Calorimetric assessment of adsorbents bonded to metal surfaces: Application to type A silica gel bonded to aluminium

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ARTICLE INFO

Article history:
Received 29 July 2011
Accepted 9 February 2012
Available online 16 February 2012

Keywords:
Calorimetric
Kinetic rate constants
Adsorption
Silica gel
Adsorption chiller

ABSTRACT

A recent publication concerned the use of a thermoelectric module to control temperature in an inert sample and to meter heat flow to the sample. This technique has been adapted for an active sample containing a layer of Type A beaded silica gel particles, bonded to aluminium at which point the sample temperature was measured. The adsorption of water vapour was considered, as might occur in adsorption chillers. During experiments, nominal sample temperatures were maintained to within 0.2 K and accuracy of heat flow measurement generally to within 11% not withstanding a correction for heat losses. The rejected heat of adsorption was fitted to an exponential recovery with $r^2 > 99\%$ yielding the adsorption capacity and kinetic rate constant for each experiment. For the silica gel selected (Type A) and in the loading range 3%–30%, previous data published by a different research team were reproduced to within 10% (3 mm diameter particles) and 20% (1 mm diameter particles). Kinetic rate constants were far bigger than would be inferred from Knudsen diffusion alone. The constants fell onto straight lines on Arrhenius plots; the inferred activation energies were far less than two independent measurements for RD type silica gels, but in line with one theoretical expectation. Kinetic rate constants did not vary in inverse proportion to the square of particle diameter; the same discrepancy is partly evident in other publications.

1. Introduction

This paper concerns a new method of dynamic measurement applied to the heat rejection from silica gel beads adhered to aluminium surfaces. Measurements relate to adsorption chillers, wherein ideally sorbent should be maintained at typically ≤30 °C to maintain capture of sorbate vapour (or "refrigerant") at typically 10 °C. The poor thermal conductivities of the granular adsorbents promote the idea of bonding them directly to heat exchanger tubes and fins [1] rather than packing them in beds or between fins [2]. The adsorbents also might either take the form of coated layers [3] or be directly synthesised on the heat exchanger surface [4]. Thereupon, the system of substrate-bond-sorbent could well behave differently from a simple collection of sorbent particles. Differences arise when the bond "poisons" the sorbent, as for zeolite pellets linked with binder [5]. Alternatively, the bond and substrate present an improved path for heat transfer. Our aim has to been to develop a method of measurement that can access the equilibrium loading and dynamics of metal surfaces coated with adsorbent. "Equilibrium" refers to the adsorptive capacity, the mass of refrigerant adsorbed on a unit mass of dry adsorbent at a specified pressure and temperature. "Dynamics" refers to the rate of adsorption in terms of mass per unit time; the related rate of heat rejection approximates a chiller's specific cooling power. Data on equilibrium are more prevalent in the published literature.

Many dynamic measurements are gravimetric or volumetric, relating to the adsorbed mass or vapour pressure measurement rather than the heat rejected. In the gravimetric method, the sample is required to hang freely inside the test section, and is prone to self-heating, and maintains a constant temperature only if the change in loading is very low (<<1%). Under this constraint, modern automated thermogravimetric balances, such as the Rubotherm magnetic suspension balance [6,7], Cahn TG2121 [8] and Cahn 2000 [9] offer a precision better than 10 μg and can provide both dynamic and equilibrium adsorption data. Small pieces of copper wire are added to separate individual beads within the adsorbent samples so as to avoid hot spots [9]. Such instruments are expensive (∼$10^5), and probing the dynamics across a range of loadings – say adsorption capacities in the range 0%–30% – requires multiple measurements. Gravimetric methods have not been used for metal-bond-sorbent systems. The McBain Bakr spring balances are cheaper but precision is ∼100 [10]

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1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2012.02.021