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Study on adsorption of methanol onto carbon based adsorbents

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ABSTRACT

This paper presents the isothermal characteristics of methanol onto two specimens of activated carbons namely Maxsorb III and Tsurumi activated charcoal. Dubinin Raduskevich (D-R) equation is used to correlate the adsorption isotherms and to form the pressure–temperature–concentration diagram for both of the assorted pairs. Experimental results show that the maximum adsorption capacity of Maxsorb III/methanol pair is 1.76 times that of activated charcoal/methanol pair. Employing a time-independent mathematical model, the performance of adsorption cooling cycle using Maxsorb III/methanol and activated charcoal/methanol pairs has been studied and compared with that of three other types of carbon based adsorbent/methanol pairs. Theoretical calculations show the superiority of Maxsorb III/methanol pair for both of air-conditioning and ice-making applications.

Etude sur l'adsorption du méthanol sur des adsorbants à base de charbon actif

Mots clés : Système à adsorption ; Méthanol ; Charbon actif ; Expérimentation ; Comparaison ; Adsorbant

1. Introduction

Thermally powered adsorption cooling systems using natural or alternative to CFCs, HCFCs and HFCs refrigerants have attracted world-wide attention due to increasing awareness of global warming and Ozone depletion problems. The main features of these systems are; (i) the ability to operate by low temperature heat source typically below 100 °C that would be

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abundantly available from waste heat or solar energy (Saha et al., 2003), (ii) almost no electricity usage, and (iii) the simplicity in construction and operation. However, the main drawback of solid–vapor adsorption cooling/heat pump systems is their poor performance in terms of cooling capacity and COP. Adsorption characteristic of the adsorbent/refrigerant pair is one of the most essential parameters that affect the system performance. It is thus indispensable to realize and understand the adsorption features of the employed pairs in terms of adsorption isotherms, adsorption kinetics and heat of adsorption. Extensive research efforts have been conducted to investigate the adsorption characteristics of different adsorbent/refrigerant pairs for adsorption cooling/heat pump applications. Sward et al. (2000) studied a solid–vapor system using zeolite/water pair. Studies of the water adsorption on zeolites and modified mesoporous materials have been conducted by Jänchen et al. (2004) for seasonal storage of solar heat. The complex compound/salts adsorption cycle for vehicles and residential air-conditioning has been studied by Beijer and Horsman (1994). The silica-gel/water system powered by waste heat of temperature below 100 °C was investigated analytically by Saha et al. (1995) and experimentally by Boelman et al. (1995) for air-conditioning purposes. Furthermore, it is possible to operate these systems with heat sources temperatures as low as 50 °C if multi-stage scheme is performed (Saha et al., 1997, 2006). The heat and mass recovery cycles were presented by Wang (2001) to improve the system performance. Adsorption of water and ethanol onto 13× molecular sieve, silica-gel and activated carbon has been discussed by Cui et al. (2005) for cooling applications. Other promising adsorbents for adsorption cooling applications are activated carbons as they have high adsorption capacity, high surface area and large pore volume. Moreover, adsorption/desorption processes of activated carbon (AC) are completely reversible, which makes AC for unlimited number of times usage in principle. The performance of adsorption cooling/heat pump cycles employing AC with different refrigerants was investigated by Critoph (1989). A novel activated carbon/ammonia based adsorption cycle at which adsorbent heat transfer can be enhanced by forced convection was also proposed and investigated by Critoph (1994). Wang et al. (1997) studied the adsorption characteristics of AC/methanol and activated carbon fiber (ACF)/methanol pairs. Jing and Exell (1993) measured adsorption equilibrium of methanol onto several types of activated charcoals. Bentayeb et al. (1995) presented a mathematical model to simulate the operation of solar refrigerator employing activated carbon–methanol pair taking into account the climatic conditions in terms of ambient temperature and insolation. The authors reported that, the behavior of the refrigerator is significantly affected by the climate conditions. The performance of adsorption refrigerator powered by a compound parabolic concentrating solar collector using activated charcoal and methanol as absorbent/refrigerant pair has been investigated by Headley et al. (1994). They reported that, the proposed system has the ability to produce ice even on overcast days. A hybrid water heating and refrigeration system has been investigated experimentally by Wang et al. (2002). The system consists of a heater, a water bath, an activated carbon/methanol adsorption bed and an ice box. Results show that the hybrid solar water heating and ice-make are reasonable for practical applications. El-Sharkawy et al. (2006a,b, 2008) investigated experimentally the isothermal characteristics of ethanol onto various types of carbon based adsorbents for adsorption cooling applications. Recently, AC/methanol pair has been used by Clausse et al. (2008) for solar adsorption air-conditioning by means of an enhanced compound parabolic solar collector. The authors have obtained a mean solar cooling COP of 0.23 from 9 a.m. to 9 p.m. for the indoor thermal comfort, which is maintained at temperature between 24 and 25 °C. Thus the exploration of functional carbonaceous adsorbent materials such as pitch based activated carbon of type Maxsorb III and activated charcoal for methanol adsorption seems promising for adsorption cooling and refrigeration applications.

The present study is therefore dealing with the experimental investigation of adsorption isotherms of Maxsorb III/methanol and Tsurumi activated charcoal/methanol pairs for a possible use in adsorption cooling system application. The measured adsorption isotherms data are correlated from which the pressure–temperature–concentration (*P*–*T*–*W*) diagrams are plotted and used to investigate the performance of adsorption cooling cycle. The performance of adsorption cooling and ice making cycles using the assorted two pairs have been compared with that of three other types of carbon based adsorbent/methanol pairs.

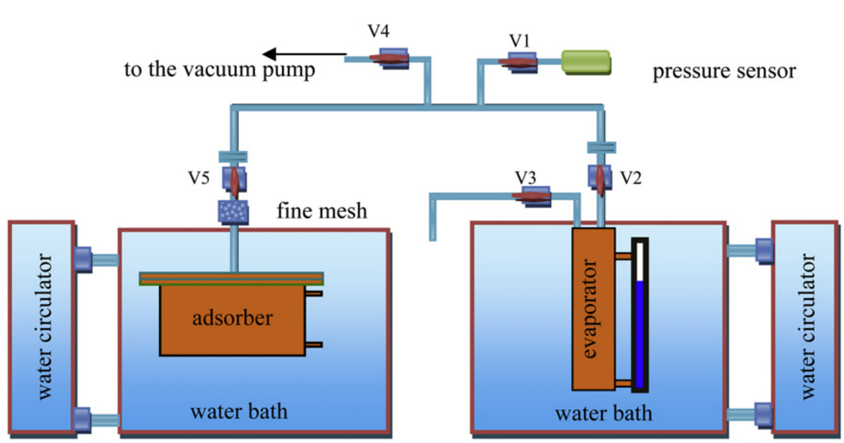

Fig. 1 – Schematic layout of the experimental set-up.