Available online at www.sciencedirect.com
ScienceDirect
Renewable and Sustainable Energy Reviews 13 (2009) 518–534
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

A review on adsorption working pairs for refrigeration

L.W. Wang *, R.Z. Wang, R.G. Oliveira

Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, China

Received 18 December 2007; accepted 31 December 2007

Abstract

Solid sorption refrigeration is a type of environmental benign and energy saving technology and the sorbents utilized can be divided into physical, chemical and composite sorbents, according to the nature of the forces involved in the adsorption process. The types, characteristics, advantages and disadvantages of different adsorbents, refrigerants and working pairs are summarized in this paper, together with the models that describe the adsorption equilibrium. Moreover, some of the procedures to prepare composite adsorbents are presented. The application of different working pairs for different situations is related with the adsorption heat, the adaptability to the driving temperature and to the desired working pressure. The methods to measure the adsorption quantity of different working pairs are compared, and future research directions of adsorption working pairs are also analyzed.

Keywords: Adsorption refrigeration; Working pair; Adsorbent; Refrigerant

Contents

* Corresponding author. Tel.: +86 21 34206056; fax: +86 21 34206814.
E-mail address: LWWang@sjtu.edu.cn (L.W. Wang).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2007.12.002

1. Introduction

Adsorption[1] refrigeration systems, which can be powered by low-grade heat and utilizes refrigerants with zero ODP and GWP, received increased attention since the 1990s [1–3]. Compared with absorption refrigeration, which can also be powered by low-grade heat, the advantages of solid sorption refrigeration are as follows:

(1) Solid sorption systems can be powered by sources with wide temperature range. Temperature as low as 50 °C can be used as heat source for adsorption systems, but in absorption systems the source should be at least at 70 °C, even if two-stage cycle is adopted. Heat sources with temperature close to 500 °C can be used directly in adsorption without producing any kind of corrosion problem, while in absorption systems, severe corrosion would start to occur for temperatures above 200 °C.
(2) Adsorption refrigeration systems are suitable for conditions with serious vibration, such as in fishing boats and locomotives [4,5], but absorption systems, due to the fact that the absorbent is in liquid state, have problems because the absorbent can flow from the generator to the evaporator or from the absorber to the condenser. When such a displacement of the absorbent occurs, the refrigerant became polluted and the system cannot work normally.
(3) Adsorption systems can be much simpler than absorption systems. For example, in the NH_3–H_2O absorption system, dephlegmate equipments must be coupled to the system because the boiling point of water is similar to that of ammonia.

The adsorption process is divided into physical adsorption [6–8] and chemical adsorption [9–11]. Physical adsorption is caused by van de Walls force between the molecules [12] of the adsorbent and the adsorbate. Physical adsorbents with mesopores can adsorb consecutives layers of adsorbate, while those with micropores, have the volume of the pores filled with the adsorbate. Physical adsorbents develop the selectivity to the adsorbate after the former undergo specific treatments, like react under a gas stream or with certain agents. The kind of treatment will depend on the type of sorbents [13].

Chemical adsorption is caused by the reaction between adsorbates and the surface molecules of adsorbents. Electron transfer, atom rearrangement and fracture or formation of chemical bond always occurs in the process of chemical adsorption [14]. Only one layer of adsorbate reacts with the surface molecules of chemical adsorbent. The adsorbate and adsorbent molecules after adsorption never keep their original state, e.g., complexation occurs between chlorides and ammonia. Moreover, there are the phenomena of salt swelling and agglomeration, which are critical to heat and mass transfer performance.

Composite adsorbents [15–17] started to be studied about 20 years ago [18], and they aimed to improve the heat and mass transfer performance of the original chemical adsorbents [16,19,20]. This kind of adsorbent is usually obtained by the combination of a chemical adsorbent and a porous medium, that can be or not a physical adsorbent, such as activated carbon, graphite, carbon fibre, etc. [16,21,22].

2. Adsorbents

2.1. Physical adsorbents

The common physical adsorbents for adsorption refrigeration are activated carbon, activated carbon fibre, silica gel and zeolite.

2.1.1. Activated carbon and activated carbon fibre

The activated carbon is made of materials such as wood, peat, coal, fossil oil, chark, bone, coconut shell and nut stone. The structure of activated carbon is shown in Fig. 1. The microcrystal for the activated carbon produced from bone is a six element carboatomic ring [13], and the adsorption performance is influenced by the functional groups that is connected to the carboatomic ring. For example, arene group increases adsorption, while sulfonic group decreases it. Acidic functional group increases adsorption selectivity. The functional groups on the surface of activated carbon are different if the original carbonaceous material and the activation method are different. The specific area of activated carbon is between 500 and 1500 m^2/g.

[1] Although some authors use the term absorption as a synonymous not only for liquid sorption but also for chemisorption. In the present text, absorption is used only as a synonymous for liquid sorption, and adsorption is used as a synonymous for solid sorption (both physical and chemical).