

Experimental comparison of the sorption and refrigerating performances of a CaCl_2 impregnated composite adsorbent and those of the host silica gel

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Abstract

In this paper, the adsorption and refrigerating performances of a composite adsorbent (S40) and its host microporous silica gel matrix (S0) are investigated comparatively in which water is used as refrigerant. The composite adsorbent is developed by impregnating the silica gel (S0) with calcium chloride. A lab-scale single-bed adsorption chiller system, functioning without any valve on its refrigerant circuit, is designed and used as test rig. The mass ratio (MR), defined as the ratio of the specific cooling power (SCP) of S40 to that of S0, is found to be higher than 2, while the COP has been improved by 25%, in average. The S40 has been tested to have, not only the capacity of adsorbing water vapour more than twice as much as the S0 does, but also, kinetically, to adsorb and desorb faster. The cycled amounts of refrigerant (CAR), calculated from measured isobaric adsorption levels, further show that the S40 can be regenerated at lower temperatures, with respect to S0.

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Keywords: Adsorption system; Water; Silica gel; Experiment; Comparison; Adsorbent; Additive; Calcium chloride; Performance

Comparaison expérimentale des performances frigorifique et de sorption d'un adsorbant composite imprégné de CaCl_2 et d'un adsorbant au gel de silice

Résumé

Dans cet article, les performances frigorifiques et d'adsorption d'un adsorbant composé (S40) et son hôte gel de silice microporeux (S0) sont étudiées de façon comparative. Le S40 a été fabriqué en confinant du chlorure de calcium dans les volumes poreux de S0. Un système expérimental de refroidisseur, à un seul lit, fonctionnant sans aucune vanne sur le circuit du réfrigérant a été conçu et construit. Le rapport massique (RM), défini comme le rapport de PSR (Pouvoir spécifique de refroidissement) de S40 à celui de S0, est testé d'être supérieur à 2, pendant que le COP a été amélioré de 25% en moyenne. Les expériences

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effectuées ont montré que, non seulement le composé S40 a deux fois plus de capacité d'adsorber la vapeur d'eau que le S0, mais aussi, cinétiquement, adsorbe et désorbe plus rapidement. Les quantités cyclées de réfrigérant (QCR), calculées à partir des niveaux d'adsorption isobariques mesurés, montrent, en plus, que le S40 peut être régénéré à de faibles températures, en comparaison avec le S0.

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Mots clés : Système à adsorption ; Eau ; Gel de silice ; Expérimentation ; Comparaison ; Adsorbant ; Additif ; Chlorure de calcium ; Performance

Nomenclature

COP	Coefficient of performance	S40	Composite adsorbent (S0 impregnated with CaCl ₂ – water solution at 40% mass concentration)
C_p	Specific heat at constant pressure (J kg ⁻¹ K ⁻¹)	SCP	Specific cooling power (W kg ⁻¹)
I	Distance (Interval) corresponding to one graduation on the graduated tube (cm)	T	Temperature (°C)
L	Adsorption (desorption) level (kg kg ⁻¹)	$t_{1/2}$	Half cycle time (minutes)
L_h	Latent heat of evaporation (kJ kg ⁻¹)	W_1	Amount of water adsorbed level during half cycle time (kg kg ⁻¹)
M	Mass of the dry adsorbent (kg)	<i>Subscripts</i>	
m	Measured value of adsorption or desorption level at each time step of measurement (kg kg ⁻¹)	c	Cooling
MR	Mass ratio	e	Evaporator
Q_{sup}	Average heat supplied (W)	f	Final
RAR	Relative adsorption rate (%)	i	The number of measurement point, initial
RDR	Relative desorption rate (%)	l	Limit, level
SCP	Specific cooling power (W kg ⁻¹)	liq	Liquid
S0	Pure host matrix microporous silica gel	n	Total numbers of measurements

1. Introduction

Owing to the rising international concerns regarding both the ozone layer depletion and the global warming, the adsorption air conditioning technology has regained the attention of researchers. The efforts are mainly directed at addressing its main drawbacks in order to uplift its competitiveness against the vapour compression system. The most serious of those drawbacks are the low efficiency and the bulkiness.

The design of heat and mass transfer enhanced adsorbers, as well as the heat and mass recovery schemes are used to boost the COP, contributing to reduce somewhat the amount of adsorbent needed. Another way of raising the competitiveness would be the use of high adsorption capacity and low temperature regenerated adsorbent. Thus, the amount of adsorbent used can be reduced along with the utilisation of free energies, such as waste heats and solar energy as driving heat sources, obviating the need for high concerns about the low operating efficiency. Silica gel–water is the most frequently used working pair when it comes to utilising low temperature waste heats or harnessing solar energy to drive the adsorption refrigeration systems. However, its water

uptake can hardly exceeds 40 wt.%. Wang et al. [1,2] reported a silica gel–water chiller of 10 kW cooling power, driven by hot water between 55 and 90 °C, the experimental COP is close to 0.4 when driven by 85 °C hot water. Liu et al. [3,4] investigated a unit of adsorption water chiller, using silica gel as adsorbent (26 kg in the unit). A COP of 0.5 and a cooling capacity of 9 kW were obtained at the desorbing temperature between 70 and 95 °C. Saha et al. [5] built a silica gel–water cascading system that enabled the use of waste heats with a temperature level as low as 55 °C. But the configuration is a complex system.

Utilisation of waste heats within the temperature range of 60–80 °C in non-complex adsorption air conditioning systems requires adsorbents with lower regeneration temperature than that of the pure silica gel. Researches on inorganic salt impregnated composite adsorbents were initiated and are still ongoing in the Borekov Institute of Catalysis, in Russia. The researchers of that institute have published numerous papers [6,7] reporting works pertaining to the feasibility, theoretical and experimental studies. A theoretical cooling COP of 0.7 has been predicted and an experimental value of 0.6 was actually measured [8] on systems employing composite adsorbents

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