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Novel ammonia sorbents “porous matrix modified by active salt” for adsorptive heat transformation: 5. Designing the composite adsorbent for ice makers

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ABSTRACT

The novel adsorbent of ammonia based on binary salt system $BaCl_2 + BaBr_2$ inside vermiculite pores was intently designed for adsorption cooling cycle specialized for ice-making. On the base of analysis of the working conditions of the cycle the requirement for the optimal adsorbent was formulated in terms of the equilibrium temperature of reaction between the salt and ammonia and the real composite adsorbent $(BaCl_2 + BaBr_2)$/vermiculite with required properties was prepared. The dynamics of ammonia adsorption on the composite was studied by a Large Temperature Jump method under working conditions of the ice-making cycle. The maximum cooling power W_0 realized at $t \to 0$ was estimated as 1.2 kW/kg. The composite allows the production of 2 kg/(kg h) of ice. Such a good performance demonstrates an advantage of the target-oriented design of the composite adsorbent with predetermined properties matching the particular conditions of the cooling cycle.

1. Introduction

Performance of cycles of adsorption heat transformation (AHT) is strongly affected by adsorption equilibrium of the working pair “adsorbent–adsorbate” [1–3]. The Coefficient Of Performance (COP) of adsorption chillers was shown to be a function of the amount of refrigerant exchanged per cycle [4]. The selection or synthesis of adsorbents, whose properties match the operating conditions of the particular heat transformation cycle, is one of encouraging ways to enhance the cycle performance [5–7]. The operating conditions of AHT cycles depend on the number of factors, in particular, the purpose of transformation, temperature of the heat source driving the cycle, climatic conditions of the area where the device is used, etc. Thus for each AHT cycle an adsorbent, which optimally fits its working conditions, can be selected or intently tailored [8].

The composite adsorbents “salt inside porous matrix” (CSPM) have recently been developed for AHT and other applications [9–12]. The adsorption equilibrium of CSPMs with the basic refrigerants (water, methanol and ammonia) can be intently modified that gives a wide scope for designing the composite optimal for the particular cycle [2,13]. The salt S, which is an “active component” of the composite, reacts with refrigerant vapor V forming the salt solvate S*NV that results in large sorption capacity. Recently the composite sorbent of ammonia based on $BaCl_2$ inside vermiculite pores has been proposed for adsorption air conditioning [14]. $BaCl_2$ forms complex with ammonia according to the reaction

$$BaCl_2 + 8\ NH_3 = BaCl_2 \cdot 8NH_3 \quad (1)$$

that allows absorption of $w = 0.65$ g of ammonia per 1 g of the salt. Vermiculite is used as a matrix which disperses the salt and promotes the mass transport of the refrigerant to the salt. Furthermore, it damps the salt expansion during reaction and prevents the natural tendency of the salt particles to agglomeration. This composite can provide effective operation of the air conditioning cycles using a low potential heat source (353–363 K) giving COP as high as 0.54 ± 0.01 and Specific Cooling Power (SCP) ranging from 300 to 680 W/kg [14].

Adsorption ice makers have been proposed for food preservation, vaccine storage etc. [12,15–19]. The typical working pairs used in these cycles are following: composite LiCl/silica–methanol [12], LiBr/silica–water, zeolites 13X–water [15], activated carbon–methanol [16], $CaCl_2$/expanded graphite–ammonia [17], and activated carbon–ammonia [18]. The common temperature of the heat source driving the cycles ranges from 393 to 423 K [15,17,18]. The heat with lower temperature level of 353–373 like

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