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Experimental study on dynamic performance analysis of a flat-plate solar solid-adsorption refrigeration for ice maker

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Abstract

A flat-plate solid-adsorption refrigeration ice maker has been built for demonstration purposes. The working pair consists of methanol used as the refrigerant and activated carbon as the adsorption medium. The adsorbent bed is constructed of two flat-plate collectors, with a total surface area of 1.5 m^2. Solar radiation can be simulated with quartz lamps and some important parameters such as temperature and pressure of each subsystem can be handled by a computer. The experimental results show that this machine can produce 4–5 kg of ice after receiving 14–16 MJ of radiation energy with a surface area of 0.75 m^2, while producing 7–10 kg of ice after receiving 28–30 MJ of radiation energy with 1.5 m^2. These are the most advanced results for a solar ice maker so far. All these successful achievements will speed up the commercial processing of a solar ice maker. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Dynamic analysis; Solid adsorption; Ice maker; Solar energy

1. Introduction

The application of solar energy instead of electricity to refrigeration appears logical for countries with a good supply of solar energy. In west China, there are many remote areas where electricity is absent, but the solar irradiation is plentiful, thus the utilization of solar energy to produce cold in these areas is very important. A

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Nomenclature

C_{pa}	specific heat of adsorbent (J/kg K)
C_{pl}	specific heat of refrigerant liquid (J/kg K)
C_{pm}	specific heat of metallic plate (J/kg K)
COP_{solar}	coefficient of performance (solar power refrigeration)
COP_{cycle}	coefficient of performance (refrigeration cycle)
h_a	heat of adsorption (J/kg)
H_a	integrated heat of adsorption (J)
h_d	heat of desorption (J/kg)
H_d	integrated heat of desorption (J)
$i(t)$	intensity of solar radiation (W/m^2)
L_e	latent heat of evaporation of the refrigerant (J/kg)
M_a	mass of adsorbent (kg)
M_m	mass of metallic plate (kg)
Q_{cc}	cooling consumed to cool down refrigerant from condensing temperature to evaporation temperature (J)
Q_{ref}	refrigeration effect (J)
T	temperature (°C)
T_{a1}	temperature of starting adsorption (°C)
T_{a2}	temperature of ending adsorption (°C)
T_c	condensing temperature (°C)
T_e	evaporation temperature (°C)
T_{g1}	temperature of starting desorption (°C)
T_{g2}	temperature of ending desorption (°C)
T_s	saturated temperature (°C)
x	adsorption capacity (kg refrigerant/kg adsorbent)
x_{dil}	adsorption capacity at desorbed state (kg/kg)
x_{conc}	adsorption capacity at adsorbed state (kg/kg)
x_0	adsorption capacity at a saturated pressure p_s corresponding to T_s (kg/kg)
Δx	adsorption capacity difference between adsorption phase and desorption phase, $\Delta x = x_{conc} - x_{dil}$ (kg/kg)

solar-powered solid-adsorption refrigeration machine uses solar energy as the power, and has the added advantage that there are no moving parts in its running process, it is extremely easy to handle, and working pairs can easily be found, etc. Many researchers have demonstrated their research results on these machines, including Iloeje [1], Pons and Guilleminot [2], and Erhard et al. [3]. However, in recent years, the number of reports on solid-adsorption refrigeration has decreased. One of the main reasons is that the properties of the adsorption refrigeration machine are variable. It is interesting to further analyze the properties of solar refrigeration so as to speed up the application of the solar-adsorption refrigerator in commerce.