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Study on a dual-mode, multi-stage, multi-bed regenerative adsorption chiller

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Abstract

In this paper, a detailed parametric study on a dual-mode silica gel–water adsorption chiller is performed. This advanced adsorption chiller utilizes effectively low-temperature solar or waste heat sources of temperature between 40 and 95 °C. Two operation modes are possible for the advanced chiller. The first operation mode will be to work as a highly efficient conventional chiller where the driving source temperature is between 60 and 95 °C. The second operation mode will be to work as an advanced three-stage adsorption chiller where the available driving source temperature is very low (between 40 and 60 °C). With this very low driving source temperature in combination with a coolant at 30 °C, no other cycle except an advanced adsorption cycle with staged regeneration will be operational. In this paper, the effect of chilled-water inlet temperature, heat transfer fluid flow rates and adsorption–desorption cycle time effect on cooling capacity and COP of the dual-mode chiller is performed. Simulation results show that both cooling capacity and COP values increase with the increase of chilled water inlet temperature with driving source temperature at 50 and 80 °C in three-stage mode, and single-stage multi-bed mode, respectively. However, the delivered chilled-water temperature increases with chilled-water inlet temperature in both modes.

Keywords: Adsorption; Dual-mode; Multi-bed; Parametric study; Silica gel–water; Solar energy utilization

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Nomenclature

Symbols

C_p	isobaric heat of adsorption (J/kg K)
D_s	surface diffusivity (m^2/s)
D_{so}	pre-exponential constant in Eq. (4) (m^2/s)
E_a	activation energy (J/kg of mole)
$k_s a_p$	overall mass transfer coefficient (1/s)
m	mass flow rate (kg/s)
$P_s(T)$	saturated vapor pressure (kPa)
q^*	equilibrium amount adsorbed (kg/kg)
Q_{chill}	cooling capacity (kW)
Q_{hot}	driving heat (kW)
R	real gas constant (J/kg of mole K)
T	temperature (°C)
t	time (s)
W	mass (kg)
Δ	difference

Subscripts

ads	adsorption
chill	chilled water
cond	condenser
cool	cooling water
des	desorption
eva	evaporator
Hex	heat exchanger
hot	hot water
in	inlet
out	outlet
regen	regeneration
s	adsorbent (silica gel)
w	water
water	heat transfer fluid

1. Introduction

An advanced, dual-mode, silica gel–water chiller utilizing low-grade waste heat or renewable energy source between 40 and 95 °C as the driving heat source with a cooling source at 30 °C was introduced by the authors [1]. Two operation modes are possible for the advanced chiller. The first operation mode will be to work as a high efficient conventional chiller where the driving source temperature is between 60 and 95 °C. The