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Performance analysis of a continuous multi-bed adsorption rotary cooling system

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Abstract

A multi-bed adsorption rotary cooling system can make use of the concept of heat regeneration cycle and recently developed technology of heat enhancement in adsorbent bed. In the present study, the performance parameters such as COP and specific cooling power (SCP) of the rotary system are initially analyzed based on heat recovery temperature difference and counter-flow heat exchanger, and meaningful parameters related to the heat transfer fluid (HTF) and the system design are identified. Then, an integrated thermodynamic and heat transfer model of the system is developed and used to evaluate the effect of important design and operational parameters. Results show that the performance of system with certain adsorbent/adsorbate pair is sensitive to Reynolds and Prandtl number of heat transfer fluid. Also, the module number and module heat transfer area play an important role in improving the system COP and SCP. This study shows that, the performance of the system could be improved further by optimizing the cycle time.

Keywords: Adsorption; Multi-bed, rotary system; Coefficient of performance; Specific cooling power

1. Introduction

Adsorption refrigeration systems present the advantages of being absolutely benign for the environment: zero ozone depletion potential (ODP) as well as zero global warming potential

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Nomenclature

A	area (m^2)
c_p	specific heat at a constant pressure (kJ/kg K)
d	diameter (m)
COP	coefficient of performance
h	heat transfer coefficient (W/m^2 K)
ΔH	heat of adsorption (J/kg)
k	thermal conductivity (W/m K)
l	incremental length of the adsorbent module
L	latent heat of vaporization/condensation (J/kg)
m	mass (kg)
N	number of modules in desorption zone or adsorption zone
Nu	Nusselt number, $Nu = hd/k$
p	pressure (Pa)
Pr	Prandtl number, $Pr = c_p \mu k$
q	adsorbate intake (kg/kg adsorbent)
Q	heat energy (J)
r	radial coordinate in the adsorbent bed
Re	Reynolds number, $Re = \rho v d/\mu$
SCP	specific cooling production (W/kg)
t	time (s)
T	temperature (K)
ΔT	temperature difference
v	velocity of the heat transfer fluid

Greek letters

α	thermal diffusivity (m^2/s)
δ	thickness of the metal tube (m)
ε_t	total porosity of adsorbent bed
μ	viscosity (N s/m^2)
ρ	density (kg/m^3)
σ	convergence criterion
τ_c	cycle time

Subscripts

a	adsorbate
ad	adsorbent
c/e	combined condenser/evaporator
eff	effective
en	environment
i	index of module number