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Experimental performance of a silica gel–water adsorption chiller

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Abstract

A newly developed adsorption water chiller is described and tested. In this adsorption refrigeration cycle system, there is no refrigerant valve. Thus, the problem of mass transfer resistance occurring in the conventional systems when methanol or water is used as refrigerant and resulting in pressure drop during the flow of refrigerant inside the tubing is eliminated. To make the utilization of low heat source with temperature ranging from 70 to 95 °C possible, silica gel–water was selected as working pair. The experimental results proved that it is able to produce a cooling power of 6.3 kW with a COP of about 0.4. The test results demonstrate that, through the heat recovery, the COP can be increased by 34.4% while mass recovery has the effect of increasing the cooling power by 13.7% and the COP by 18.3%. The performances of the system were analyzed for varied condensation temperature and for varied evaporation temperature. Based on the first prototype, the second prototype is designed and manufactured to improve the performance. Primary test results demonstrate that the performance is highly improved. It has a COP of about 0.5 and cooling power 9 kW for 13 °C evaporation temperature.

Keywords: Adsorption; Refrigeration; Water chiller; Cooling power; COP; Silica gel–water

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Nomenclature

COP coefficient of performance of the adsorption chiller
c_p specific heat of water, kJ/kg °C
m_{ch} flow rate of chilled water, kg/s
$m_{h,w}$ flow rate of hot water, kg/s
$P_{adsorber}$ adsorber pressure, kPa
P_c condensing pressure, kPa
P_e evaporating pressure, kPa
$T_{adsorber}$ adsorber temperature, °C
T_{a1} adsorber temperature at the end of adsorption process, °C
T_{a2} adsorber temperature at the beginning of adsorption process, °C
$t_{ch,in}$ chilled water temperature entering into the load tank, °C
$t_{ch,out}$ chilled water temperature out of the load tank, °C
T_{g1} adsorber temperature at the beginning of desorption process, °C
T_{g2} adsorber temperature at the end of desorption process, °C
$t_{h,in}$ hot water temperature entering into the chiller, °C
$t_{h,out}$ hot water temperature out of the chiller, °C
Q_h heat supplied to the chiller, kJ
Q_{ref} cooling generated by the chiller, kJ
X_{eq} equilibrium uptake in the adsorbent, kg water/kg silica gel

1. Introduction

Adsorption refrigeration cycles driven by waste heat are environmentally benign and energy saving. They neither use ozone-depleting chlorofluorocarbons as refrigerant nor do they use electricity or fossil fuels as driving energy sources. Adsorption refrigeration cycles, however, are known to be inefficient due to their low coefficient of performances. This paper proposes a new adsorption water chilling cycle driven by heat sources at temperature ranging from 70 to 95 °C. In this range of temperature, solar heating system and heat rejected from engines can be used to power the water chiller.

Many adsorbent/adsorbate pairs have been used in adsorption refrigeration/heat pumping systems. Very few pairs, however, can be used to utilize low grade thermal energy (specially below 100 °C temperature waste heat) as driving source [1]. But the silica gel–water pair is well suited to this temperature range. Saha et al. [2], Boelman et al. [3], Chua et al. [4] and Alam et al. (2001) [5] studied conventional adsorption refrigeration cycle using silica gel–water pair, which can be driven by 80 °C heat source temperature with 30 °C cooling source. Later Saha et al. [2,6] proposed three and two stage cycles to utilize low-grade waste heat source at temperature 50–60 °C. Though, the two and three stage cycles can be used with very low temperature driving heat sources, but the COP and specific cooling capacity of these cycles are inferior to those of conventional one [5]. In addition, conventional adsorption chillers need a lot of switch valves to con-