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Resorption system with simultaneous heat and cold production

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ABSTRACT

A resorption system with simultaneous cold and heat production was studied. The heat produced could be used for sanitary or process purposes, or to drive another heat-powered machine. The resorption reactors had $MnCl_2$ and NH_4Cl as reactant (which are impregnated in expanded graphite) and NH_3 as refrigerant. The combined coefficient of performance and amplification (COPA) of this system reached 1.3 when the cooling effect was produced at 0 °C and heating effect at 75 °C with the regeneration temperature of 140 °C. Its COP was 0.35 with a specific cooling power (SCP) of 1.12 MJ kg^{-1} day^{-1}, and the heat sink in this case remained below the cooling temperature for more than 5 h. Because of the heat production at certain temperature level (from 70 °C to 80 °C) in this study, the released heat could be used to power a silica gel-water adsorption chiller and the overall COP of the combined system would increase dramatically.

Système à résorption produisant de la chaleur et du froid simultanément

Mots clés : Résorption ; Système à adsorption ; Chauffage ; Refroidissement ; Récupération

1. Introduction

Sorption system can be considered as an effective alternative for wiser energy management, and that could meet the sustainable development requirements (Wang and Oliveira, 2006; Meunier et al., 1996). Compared with the conventional vapour compression system's impact on global warming issue and its high electricity consumption, sorption system utilizes refrigerant with zero ozone depletion potential like water, ammonia or methanol, and can be driven by solar energy or with waste heat; and thus, helping reduce the CO_2 emissions.

Among the categories of sorption system, liquid-gas absorption process used for heating and cooling production has been widely discussed for a long time (Bjurström and Raldow, 1981). However, absorption system will cause solution crystallization and metal corrosion because of the liquid

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Nomenclature

COP	coefficient of performance
COPA	coefficient of performance and amplification
HTS	high temperature salt
LTS	low temperature salt
HPP	high pressure phase
LPP	low pressure phase
T_M	middle temperature (K)
T_{H1}	temperature of heating effect production of high temperature salt (K)
T_{H2}	regeneration temperature of high temperature salt (K)
T_L	low temperature (K)
P_H	high pressure (Pa)
P_L	low pressure (Pa)
T_{ch}	salt temperature close to the gas channel (K)
T_w	salt temperature near the wall (K)
SCP	specific cooling power (W kg^{-1})
SHP	specific heating power (W kg^{-1})
E.G.	expanded graphite
C_{pSalt}	specific heat of salt (kJ kg^{-1} K^{-1})
C_pNH_3	specific heat of ammonia (kJ kg^{-1} K^{-1})
$C_{pE.G}$	specific heat of expanded graphite (kJ kg^{-1} K^{-1})
$C_{pS.S}$	specific heat of stainless steel (kJ kg^{-1} K^{-1})
$m_{E.G.}$	mass of expanded graphite (g)
m_{Salt}	mass of salt (g)
m_{Rc}	mass of reactor (g)
$\overline{m}$	mean mass of ammonia inside the reactor (g)
Q_u	useful heat (kJ)
Q_s	sensible heat (kJ)
Q_R	reaction heat (kJ)

Greek letters

ΔH	enthalpy of reaction (kJ mol^{-1})
Δm_{NH3}	transferred mass of ammonia (g)
ΔT	temperature difference (K)
η	thermal transformation efficiency

using. There is no such concern in solid-gas adsorption system, and the adsorption technology also has its merit of wider range of working temperature. If a secondary reactor is employed in place of the evaporator and the condenser, the system can be called resorption system, where two reactors with different reactive salts exchange refrigerants. Since the reaction enthalpy between the salts is almost double the vaporization enthalpy of refrigerant, the resorption systems can achieve a higher coefficient of performance (COP) than the conventional solid sorption systems for the same heat input.

In previous studies, many working pairs have been tested to identify the performance of the working pair in a resorption system. $BaCl_2$ (Goetz et al., 1997; Vasiliev et al., 2004; Bao et al., 2010), NH_4Cl (Oliveira et al., 2008, 2009), NaBr (Bao et al., 2010; Oliveira et al., 2009), $PbCl_2$ (Lepinasse et al., 2001) were the LTS in these studies, whereas the HTS was $MnCl_2$ (Vasiliev et al., 2004; Bao et al., 2010; Oliveira et al., 2008, 2009; Lepinasse et al., 2001) or $NiCl_2$ (Goetz et al., 1997; Vasiliev et al., 2004). Oliveira et al. (2008) showed the feasibility of simultaneous heating and cooling effects at 50 °C and −5 °C, respectively, with COP at 0.19 and COPA of 1.03.

We extended the previous mentioned work, by studying feasibility of simultaneous heating and cooling effects at other temperature levels to enlarge the application field.

The system was designed to provide simultaneously cooling and heating effects at respectively 5 °C and 70 °C, 0 °C and 75 °C, and 5 °C and 80 °C. The level of heating effect production was chosen to allow the utilization of this heat to power a silica gel-water adsorption chiller, and can also be used for sanitary or process purposes.

2. Experimental procedures

The solid type resorption system is a type of sorption system, where two reactors with different reactive salts exchange refrigerants. The salts involved have different equilibrium temperatures under the same pressure. One of the salts substitutes the evaporator and the condenser, which are normally found in the other sorption systems. This salt is named low temperature salt (LTS) because of its low equilibrium temperature, while the other one is known as high temperature salt (HTS). As shown in Clapeyron diagram (Fig. 1), there are two reactive periods in the basic resorption cycle. During one period, the cycle presents high pressure phase (HPP) and in the other period, it presents low pressure phase (LPP). The left-side line in Fig. 1 (S/G1) represents the solid-gas equilibrium of the LTS, whereas the right-side line (S/G2) is related to the HTS. In the high pressure period, heat from an external heat source is supplied to the HTS reactor at the temperature T_{H2}, while the LTS releases heat to a heat sink at the temperature T_M. In the low pressure period, LTS desorbs refrigerant, producing the cooling effect at T_L, while the HTS adsorb refrigerant and release heat to a heat sink at T_{H1}. If the heat rejected by HTS in the LPP is at high temperature level, it can be recovered, and used in another process of interest. In this case, the system would have a simultaneous production of useful heating and cooling effects.

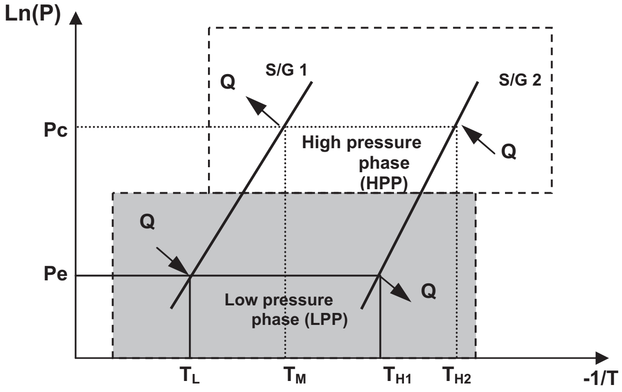

Fig. 1 – Clapeyron diagram.