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Performance analysis of solar air cooled double effect $LiBr/H_2O$ absorption cooling system in subtropical city

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ABSTRACT

Due to the absence of cooling tower and independent on water, the air cooled solar double effect $LiBr/H_2O$ absorption cooling system is more convenient to be used in commercial building and household use. The performance with collector temperature is an important field for such system. The paper mainly deals with the performance with collector temperature for the solar air cooled double effect $LiBr/H_2O$ absorption cooling system in subtropical city. The parameters of system are: aperture area of collector array is 27 m^2, tilted angle of collector with respect to the horizontal plane is 20 toward to south evaporator temperature is 5 °C and the cooling capacity is 20 kW. The simulation is based on the meteorological data of monthly typical day which was summarized from a year round measured data. A corresponding parametric model was developed. The hourly and average performance with the collector temperature for monthly typical day was obtained and discussed. It was found that the suitable working range of inlet temperature of collector is 110–130 °C to improve performance and lower the risk of crystallization. The difference of hourly total efficiency in 9:00–16:00 is less, and the monthly total efficiency from May to October is approximate. The yearly performance of system including total efficiency, cooling capacity per area of collector and solar fraction was given. Furthermore, the effect of effectiveness of heat exchanger and pressure drop on total efficiency and solar fraction was studied and compared. The paper can serve as a preliminary investigation of solar air cooled double effect $LiBr/H_2O$ absorption cooling system in subtropical city, and provides the foundation of further study.

1. Introduction

The climate of subtropical city is hot and humid so that the air conditioning is very essential in this region. Therefore, the consumption of air conditioning usually results in the insufficient supply of electricity power in summer. The application of solar refrigeration technology is thought to be an effective way to decline the consumption of air conditioning in respect that the cooling demand of commercial building is coincident to solar irradiance. A comprehensive investigation of solar desiccant cooling system for institutional building in subtropical Queensland was carried out by Baniyounes et al. [1]. The experimental study of solar desiccant cooling system was done subsequently, and the results showed that the prototype can achieve 18% energy savings with maximum coefficient of performance (COP) and 48% desiccant efficiency [2]. Moreover, the performance of solar desiccant cooling system was somewhat better than that of solar absorption refrigeration system for an institutional building in Queensland by simulation [3]. Fong presented the improvement of desiccant solar refrigeration system for subtropical building [4]. The simulation result showed that this equipment can save 35.2% year round primary energy consumption against the conventional air conditioning. The comparative of five types of solar cooling system in subtropical Hong Kong was studied by Fong et al. [5]. It was concluded that the energy saving potential of solar electric compression cooling and solar absorption cooling is the best. Furthermore, some new designs and improvements of solar cooling system that can deal with the high latent heat load more effectively were proposed and investigated by Fong et al. [6–9].

The higher energy saving potential of solar refrigeration system can be obtained as the system is based on the multi effect $LiBr/H_2O$ absorption chiller. Gomri pointed out that the performance of double effect system is approximately twice that of single effect system and that the COP of triple effect system is slightly less than

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Nomenclature

COP	coefficient of performance
h	altitude angle of sun (°), enthalpy (kJ/kg)
I	solar irradiance (W/m^2)
m	mass flow rate (kg/s)
Q	energy (kW)
SF	solar fraction
T	temperature (°C)
t	hour angle of sun (°)
ΔT	temperature difference (°C)
x	concentration of solution

Greek symbols

α	energy distribution ratio of generator
θ	tilted angle of collector (°)
δ	declination of sun (°)
η	efficiency of collector
ε	heat exchanger effectiveness
ψ	total efficiency of system

Subscripts

AB	absorber
a	surrounding
CD	condenser
cry	crystallization
DH	horizontal surface
$D\theta$	tilted surface
EV	evaporator
HG	high pressure generator
HT	high temperature
i	inlet
LG	low pressure generator
LT	low temperature
o	outlet
s	solar

thrice that of single effect system [10,11]. The comprehensive comparison including energy, exergy and economy of single and double effect absorption chiller was carried out by Avanessian and Ameri [12]. The performance and economy of double effect absorption refrigerator for different configurations was analyzed and compared by Garousi Farshi et al. [13,14]. Although the COP of multi effect absorption chiller is better, the system complexity also gets higher to lower its feasibility. Therefore, the recent solar multi effect absorption cooling system is mainly based on the double effect cycle since the system performance is improved and its complexity is acceptable. Yattara et al. carried out the comparative study between the solar single effect and single effect double-lift absorption machines, and found that the primary energy saving of latter is larger than the one of former [15]. Liu and Wang presented a solar/gas driving double effect $LiBr/H_2O$ absorption cooling system in which the high pressure generator (HPG) is driven by natural gas and the low pressure generator (LPG) is assisted by solar [16]. The analysis showed that this system is feasible and economical. The performance of solar double effect $LiBr/H_2O$ absorption cooling system was simulated based on the meteorological data of summer Algiers and it was found that the energy saving potential of system is 86% [17]. The performance of a 16 kW solar double effect $LiBr/H_2O$ absorption refrigeration system for space cooling and heating was studied experimentally [18]. It was concluded that the system can provide 39% cooling and 20% heating energy. Han simulated the performance of solar double effect $LiBr/H_2O$ absorption cooling system and it was gotten that the total efficiency of system is up to 0.825 [19]. The economical study of solar double effect $LiBr/H_2O$ absorption refrigeration system in subtropical Guangzhou was carried out by Li and the minimum discount payback period of system is 7.59a [20]. Besides, the optimal temperature of collector for solar double effect $LiBr/H_2O$ absorption cooling system in subtropical city was obtained [21]. A theoretical study of solar double effect absorption chiller for sub-zero evaporation temperature was carried out by Vasilescu and Ferreira [22].

Comparing with the water cooled system, the solar air cooled double effect $LiBr/H_2O$ absorption cooling system can be used more conveniently and widely due to the absence of cooling tower and independent on water. It was concluded that the thermodynamic properties of air cooled absorption chiller is closed to that of water cooled absorption refrigerator [23]. Nevertheless, the condensation temperature and absorber temperature of air cooled system varies with surrounding temperature and that is easy to lead to the low performance and crystallization when surrounding temperature is high. The crystallization of solar air cooled $LiBr/H_2O$ absorption cooling system was investigated by Izquierdo et al. [24]. It was gotten that the highest condensation temperature without crystallization of double stage absorption system is higher than that of single effect absorption system. An Indirect air cooled solar single effect $LiBr/H_2O$ absorption chiller of which the absorber and condenser are firstly cooled by water and then the heat of cooling water is rejected to environment through the finned tube heat exchanger and fan, was designed and tested by Izquierdo et al. [25]. The average coefficient of performance (COP) was 0.37 with the dry bulb temperature is 35–41.3 °C and the outlet temperature of chilled water is over 15 °C. Subsequently, the prototype of solar direct air cooled single effect $LiBr/H_2O$ absorption chiller was designed and measured [26,27]. The performance of direct air cooled absorption chiller was larger than the performance of indirect one by experiment [28]. An air cooled $LiBr/H_2O$ absorption chiller which can work in extreme hot surrounding temperature was presented by Kim and Infante Ferreira [29]. The simulation result showed that the cooling power as ambient temperature is 50 °C is still 36% of that as ambient temperature is 35 °C. The crystallization in air cooled double effect $LiBr/H_2O$ absorption chiller was analyzed by Garousi Farshi et al. [30]. He pointed out that the series flow system has the largest risk of crystallization in the same working conditions. A new small air cooled double effect $LiBr/H_2O$ absorption prototype driving by fuel was studied experimentally by Izquierdo et al. [31]. Marcos et al. presented a new method to optimize the performance of air cooled double effect $LiBr/H_2O$ absorption chiller [32].

It is found that the recent study of solar refrigeration system in subtropical city less deals with the system based on the double effect absorption cycle. However, the solar double effect $LiBr/H_2O$ absorption chiller has higher energy saving potential in respect that its performance is greater. Because of the absence of cooling tower and independent on water, the air cooled solar double effect $LiBr/H_2O$ absorption cooling system is more convenient to be used in commercial building and household use. Therefore, more attention should be paid to the solar air cooled double effect $LiBr/H_2O$ absorption refrigeration system. From the related investigation, it is known that solar air cooled double effect $LiBr/H_2O$ absorption