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Performance analysis of a solar heating system with the absorption heat pump and oil/water heat exchanger

Man Fan[a], Hongbo Liang[a], Shijun You[a], Huan Zhang[a,*], Baoquan Yin[b], Xiaoting Wu[b]

[a]*School of Environmental Science and Engineering, Tianjin University, Tianjin 300350, China*
[b]*Tianjin Architecture Design Institute, Tianjin 300074, China*

Abstract

A solar heating system with the absorption heat pumps (AHPs) and oil/water heat exchanger (OWHE) was set up for space heating. The system was driven by parabolic trough solar collectors (PTCs). In this study, heat transfer models were built and experiments were conducted to evaluate the performance of PTCs. Collector efficiencies of 40-55% were obtained under different weather conditions. For the solar driven AHP system and OWHE system, primary energy ratio (PER) values were calculated and compared. The results showed that in overcast days with low direct normal insolation (DNI), the operation of the PTC system was not cost-effective. In cloudy days with high DNI lasting for a short period (e.g. 2 hours), the operation of OWHE system was better than the operation of AHP system as the AHP system needed more preheating energy before the system operation. While in sunny days with high DNI lasting for a longer period (e.g. 8 hours), the AHP system was suggested to be operated for it owned higher PER values.

Keywords: parabolic trough solar collector; absorption heat pump; oil/water heat exchanger; primary energy ratio

1. Introduction

The continuously growing demand of energy consumption and worsening atmospheric environment are becoming increasingly prominent [1]. At present, fossil fuels are the main sources of energy, and their pollutant emissions are huge challenges for human beings. Until 2015, the 10-year average annual growth of global coal consumption was 2.1%, and meanwhile coal consumption in China accounted for almost half of the world's total consumption [2]. The

* Corresponding author. Tel.: +86 22 2789 2626; fax: +86 22 2789 2626.
E-mail address: zhhuan@tju.edu.cn.
Zhanghuantju@163.com.

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consumption of large amounts of coal in China results in a severe problem of atmospheric pollution. In North China, the problem is seriously urgent as the haze occurs frequently, especially during the heating season. To alleviate this phenomenon, governments and industries are actively involved in taking actions.

The use of solar energy for building cooling, heating and hot water supply, can provide a possible solution to these problems. Particularly, the solar assisted absorption heat pump (AHP) stands out as a promising technology in view of its high energy saving potential and low environmental impact [3]. Single- and double-effect absorption machines with H_2O/LiBr and NH_3/H_2O (refrigerant-absorbent pairs) as working fluids are relatively mature applications [4]. The flat-plate, evacuated, compound parabolic concentrator (CPC) and parabolic trough collectors (PTCs) usually serve as driving heating sources. Hammad and Zurigat [5] described the performance of a 1.5 ton solar cooling unit driven by 14 m^2 flat-plate solar collectors. Ahmed et al. [6] assessed an integrated cooling plant with both free cooling system and evacuated solar collectors powered H_2O/LiBr absorption chiller. Qu et al. [7] studied a solar thermal integrated cooling and heating system driven by PTCs, and found this system could potentially supply 39% of cooling and 20% of heating energy for the building space.

Considering that previous studies mainly investigated the refrigeration cycle for space cooling driven by medium temperature solar source, little concentration has been focused on the heat pump cycle which can produce hot water for space heating. Although Wang et al. [8] presented an assessment of the performance of solar assisted AHP system with PTCs through experiments and simulations, they didn't estimate the effect of temperatures of heat transfer fluids (HTFs) on the collector and heat pump performance. In this study, the performance of a solar heating system with AHP and OWHE will be examined at medium and low working temperatures respectively. Both theoretical analysis and in-site measurement will be performed by monitoring the collector and system operation parameters, along with meteorological parameters.

Nomenclature

Q	heat transfer capacity (W)	*Greek symbols*	
Q_u	useful energy gained by solar collectors (W)	δ	declination (deg)
Q_g	heating capacity of the system (W)	ω	hour angle (deg)
Q_r	heat provided by gas boiler (W)	φ	latitude (deg)
S	solar irradiation absorption (W)		
W_p	electricity consumption by the heat pump and oil pump (W)	*Subscripts*	
		f	heat transfer fluid
t	temperature (K)	r	absorber
η_g	gas boiler efficiency	g	glass
η_1	power supply efficiency	a	ambient

2. System description

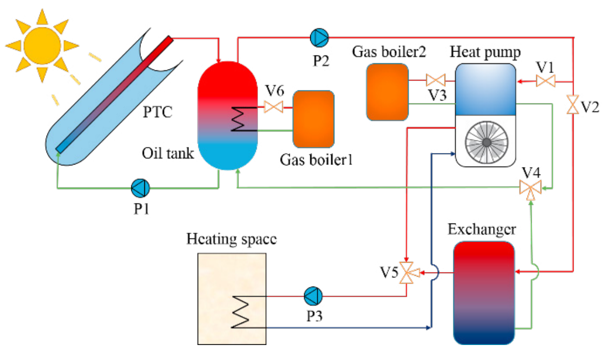

Fig. 1. Schematic diagram of the solar heating system with the absorption heat pump and oil/water heat exchanger.