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Research Paper

Configurations of solar air source absorption heat pump and comparisons with conventional solar heating

Wei Wu[a,*], Baolong Wang[b], Tian You[b], Wenxing Shi[b], Xianting Li[b,*]

[a] School of Energy and Environment, City University of Hong Kong, Hong Kong, China
[b] Department of Building Science, School of Architecture, Tsinghua University, Beijing 100084, China

HIGHLIGHTS

- Solar air source absorption heat pump (ASAHP) was analyzed for solar heat supply.
- Different solar ASAHP configurations were compared to conventional solar heating.
- Parabolic-trough collector single-effect cycle improves the solar efficiency by 24%
- Parabolic-trough generator-absorber-heat-exchange cycle improves efficiency by 36%
- Applicability domains of solar ASAHP obtained for better development of solar systems.

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ABSTRACT

A solar air source absorption heat pump (ASAHP) is analyzed to explore the suitable configurations of advanced solar heating systems. A single-effect (SE) and a generator-absorber heat exchange (GAX) ASAHP, driven by a flat-plate collector (FPC), evacuated tube collector (ETC), compound parabolic concentrator (CPC) and parabolic-trough collector (PTC) are modeled. A parametric study and comparative analysis of different solar heating systems indicate that the CPC-SE, PTC-SE, and PTC-GAX are suitable configurations. Comparisons with the conventional direct solar heating (DSH) show that the ETC-DSH performs the best among all the DSH systems, only the PTC-SE and PTC-GAX are advantageous over it under a solar radiation of 800 W/m^2. At an ambient temperature of 7 °C, the CPC-SE performs better than the ETC-DSH only when the solar radiation is above 1000 W/m^2. The PTC-GAX becomes worse than the PTC-SE if the solar radiation is below 650 W/m^2 and even becomes inferior to the ETC-DSH if the solar radiation is below 400 W/m^2. Besides, the applicability domain of the CPC-SE is very narrow, the efficiency improving rate (EIR) of the CPC-SE is about 15% under a favorable condition. The PTC-SE and PTC-GAX had a much wider applicability domain, and the maximum EIR value is about 24% and 36%, respectively. Reducing air pollution is very important for the applications of the solar ASAHP systems.

1. Introduction

Heat supply, including space heating and domestic hot water, is attracting increasing attention of researchers all over the world because of its high energy consumption and associated air pollution [1]. The energy and environmental problems caused by heat supply are especially serious in countries with a coal-dominated energy structure. China is a convincing example, as building heating is widely demanded and is mainly based on fossil fuel-burning at present [2]. In the interest of energy saving as well as environmental protection, heat supply systems using renewable energy and efficient technologies are strongly encouraged through government policies and financial incentives [3].

As one of the most widely used renewable energies, solar energy can play an important role in reducing building energy consumption and pollution emission as a sound alternative heat supply solution. The need for large solar collector areas and installation roofs, however, greatly limits its application in high-rise buildings, especially in high-density cities. For this reason, solar collectors are usually integrated with heat pump technologies, called as solar heat pumps, to improve the utilization efficiency of solar energy [4,5].

There have been a lot of studies on solar heat pump technologies, including the solar-assisted heat pump (SAHP) and the solar-powered heat pump (SPHP). Depending on the energy source supplied to the evaporator, the SAHP systems can be classified as series, parallel and

* Corresponding authors.
E-mail addresses: wuwei61715253@126.com (W. Wu), xtingli@tsinghua.edu.cn (X. Li).

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Nomenclature

a	heat loss coefficient
b	modifier coefficient
c_p	specific heat, kJ/(kg K)
h	specific enthalpy, kJ/kg
I	solar radiation, W/m^2
K	incident angle modifier
m	mass flow rate, kg/s
Q	heat duty, kW
T	temperature, °C
UA	the product of heat transfer coefficient and heat transfer area, kW/K
x	mass fraction of ammonia in the solution, kg/kg

Abbreviations

ASAHP	air source absorption heat pump
COP	coefficient of performance
CPC	compound parabolic concentrator
DSH	direct solar heating
ECA	externally cooled absorber
EES	Engineering Equation Solver
EHG	externally heated generator
ETC	evacuated tube collector
FPC	flat-plate collector
GAX	generator-absorber heat exchange
GAXA	GAX absorber
GAXG	GAX generator
LMTD	logarithmic mean temperature difference
PTC	parabolic-trough collector
SAHP	solar assisted heat pump
SCA	solution cooled absorber
SE	single-effect
SHG	solution heated generator
SPHP	solar powered heat pump

Subscripts

A	absorber
a	air
C	condenser
df	diffuse radiation
dr	direct radiation
E	evaporator
fi	flow inlet
fo	flow outlet
G	generator
h	heating
in	inlet
L	longitudinal
m	mean
out	outlet
P	pump
Pc	partial condenser of rectifier
Pr	precooler
T	transversal

Greeks

η	efficiency
θ	incident angle, °

dual systems. In a series SAHP [6], the heat pump cycle and the solar collecting cycle are connected through an evaporator, and the heat extracted by the evaporator derives completely from the solar collector. The circulating water is heated in the solar collector and then flows into the evaporator for heat exchange (sometimes there is a water tank or/and a middle heat exchanger), which is also called the solar-assisted water source heat pump. In a parallel SAHP [7], the heat pump cycle and the solar collecting cycle are independent of each other. The solar-heated hot water and heat-pump-produced hot water supply the building heating or domestic hot water together. In a dual source SAHP, two evaporators are configured so that the heat pump can draw energy from both the solar-heated circulating water and other energy sources, such as outdoor air [8,9] and shallow ground [10–12]. Based on the connection of the solar collector and the heat pump, the SAHP systems

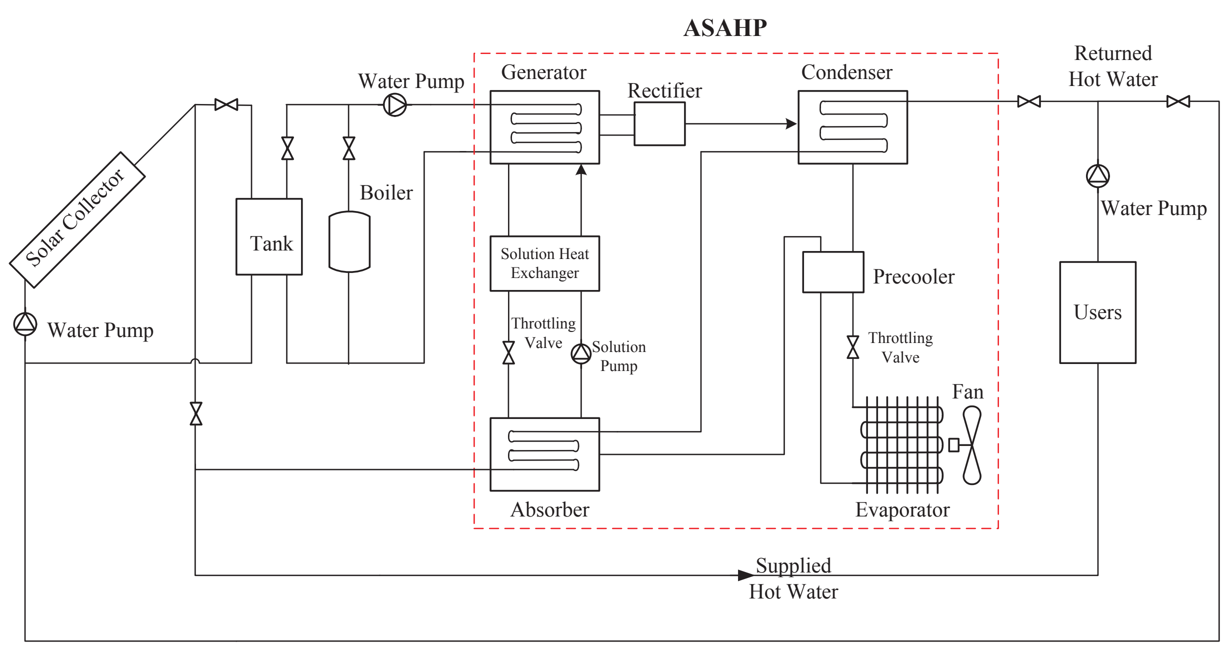

Fig. 1. Schematic of the solar ASAHP.