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Modelling, simulation and analysis of solar absorption power-cooling systems

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ABSTRACT

The main objective of this paper is to simulate different solar absorption power-cooling systems that uses ammonia based working fluid mixture to simultaneously produce cooling and mechanical power with a single system. The power and cooling cycles through absorption are of great interest because they can use low temperature thermal energy sources as solar energy with a higher versatility than the separated production of power and cooling (refrigeration) to cover the typical variable cooling and power demands of the building. In this study we have considered several system configurations based on the Goswami and single-stage combined absorption power and cooling cycles and different solar thermal technologies: evacuated tube, parabolic trough and linear Fresnel solar collectors. To compare the configurations we have performed the energy and exergy analysis for a specific case located in Sevilla (Spain) with a coordinates of 37°22′38″N 5°59′13″W using TRNSYS software as simulation tool.

Modélisation, simulation et analyse du refroidissement de systèmes électriques fonctionnant grâce à l'absorption solaire

Mots clés : Energie solaire thermique ; Refroidissement combiné des systèmes électriques ; Absorption ; Ammoniac

1. Introduction

With rapid energy demand growth worldwide, human beings have to face more energy scarcity and environmental issues. The conventional technologies to produce useful energy products, such as electricity, normally results in considerable environmental pollution and non-renewable energy resource depletion. These interrelated challenges could be solved through the use of energy conversion enhancement, waste heat recovery and renewable energy resource utilization. In that sense, Solar Absorption Power-Cooling Systems (SAPCS) are a good example to improve significantly the energy utilization efficiency using solar energy (Fig. 1). The SAPCS are based on a thermodynamic cycle that was developed for the simultaneous production of power and cooling from low-grade energy sources such as solar thermal, geothermal and industrial waste heat. The combined power and cooling cycles through absorption are of great interest because they can use the low grade energy sources as solar energy with a higher versatility than the

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Nomenclature

Abbreviations

1…27	Thermodynamic state points
ABS	Absorber
APC	Absorption Power and Cooling
C	Cooler
CON	Condenser
DES	Desorber
ETC	Evacuated Tube Collector
EVA	Evaporator
EXP	Expander
FPC	Flat Plate Collector
H_2O	Water
LFC	Linear Fresnel Collector
LiBr	Lithium bromide
$LiNO_3$	Lithium nitrate
MIX	Mass flow stream mixer
NaSCN	Sodium thiocyanate
NH_3	Ammonia
PTC	Parabolic Through Collector
REC	Rectifier
REV	Refrigerant Expansion Valve
RSC	Refrigerant Sub-Cooler
SAPCS	Solar Absorption Power – Cooling System
SH	Superheater
SEV	Solution Expansion Valve
SHX	Solution Heat exchanger
SP	Solution Pump
SPLIT	Mass flow stream splitter
SR	Split Ratio
SSCA	Single-Stage Combined Absorption

Variables and Parameters

E	Solar energy received by solar collectors in a defined period [kW h]
Ex	Exergy [kW h]
h	Specific enthalpy [kJ kg^{-1}]
$\dot{m}$	Mass flow rate [kg s^{-1}]
Q	Thermal energy [kW h]
$\dot{Q}$	Thermal power
SF	Solar fraction [–]
t	Temperature [°C]
T	Temperature [K]
W	Mechanical work [kW h]
$\dot{W}$	Mechanical power
z	Ammonia mass fraction [kg kg^{-1}]

Subscripts

II	Second law
APC	Absorption power and cooling
cw	Cooling water or dissipated heat
chw	Chilled water
e	Mechanical power
heat	Hot water
hs	Heat source
in	Inlet
out	Outlet
ref	Refrigeration
SAPCS	Solar Absorption Power-Cooling System
x	Denotes heat, cold or dissipated heat

Greek symbols

η	Solar or effective first law efficiency
ε	Effective exergy efficiency

separated production of power and cooling (refrigeration) to cover the typical variable cooling and power demands of the buildings. In the particular case of the Mediterranean countries, this is especially important in spring and autumn, periods in which cooling demands could be very low and then most of the solar energy would be used to generate electricity.

One of the first combined absorption cycle proposed by Goswami (1995), combines the Rankine and absorption refrigeration cycles to provide mechanical power and cooling (sub-product) as useful outputs. Erickson et al. (2004) proposed an ammonia/water absorption cycle configuration which produces power and refrigeration interchangeably. A novel form of absorption cooling cycles for combined production of power and refrigeration has been presented by Ziegler (2007). Three different cycle configurations (namely parallel, series and compound cogeneration configurations) for the combined production of power and refrigeration have been suggested by Zhang and Lior (2007). The authors developed the configurations through the integration of refrigeration and power generating systems based on ammonia/water working fluid mixture. And also, a detailed review of several cycle configurations proposed for the production of mechanical power and refrigeration, simultaneously and/or alternatively have been presented in the literature (Ayou et al., 2013a). Finally, Ayou

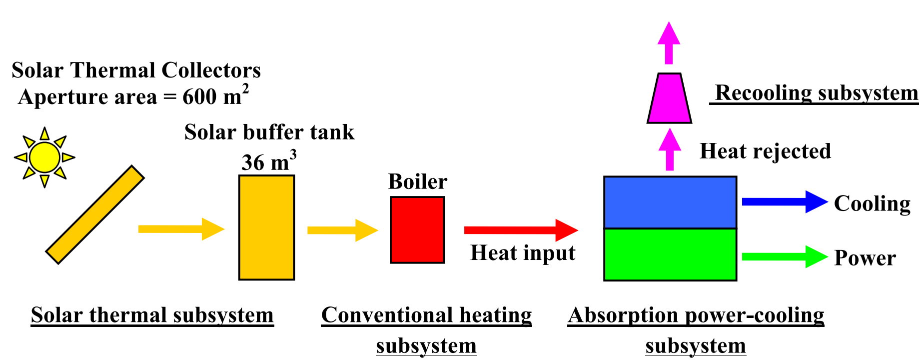

Fig. 1 – Block diagram illustrating the main components of the SAPCS.