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Integration of sorption modules in Sydney type vacuum tube collector with air as heat transfer fluid

Olof Hallstrom[a], Gerrit Füldner[b]

[a] *Mälardalen University, Mälardalens högskola, Box 883, 721 23 Västerås, Sweden*
[b] *Fraunhofer-Institut für Solare Energiesysteme ISE, Heidenhofstraße 2, 79110 Freiburg, Germany*

Abstract

Reduced thermal losses and simplified system integration have previously been identified as main opportunities to improve the concept of collector integrated sorption modules for solar heating and cooling. A concept for a façade integrated sorption collector using Sydney type vacuum tube technology and air based heat transfer has been developed and tested in the laboratory. The results from the tests have been used to validate an existing TRNSYS model that has been modified for use with air as heat transfer fluid. The work has been conducted within the FP7 EU iNSPiRe project with the aim to develop a plug & play solar cooling and heating solution.

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Keywords: solar cooling, absorption, integrated sorption collector, sorption heat pump, air collector

1. Introduction

Solar thermal cooling has difficulty in emerging as an economically viable solution for small-scale systems mainly due to high investment costs and system complexity [1]. A collector integrated sorption system was proposed as one solution to this issue in 2013 [2]. The paper concluded that the collector losses were the main efficiency driver and hence the area of most interest for further research. The collector integrated concept has thus been developed further with focus on reducing collector losses and simplifying system integration. The main idea has been to use air as heat transfer medium with the goal to integrate the collector into the façade of buildings and deliver heating and cooling directly to the conditioned space or to the outdoor environment (heat rejection).

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Nomenclature

η_0, eta_0, a_1, a_2	Collector efficiency parameters
η, eta	Total efficiency of collector (-)
η_{cool}, eta_{cool}	Thermal cooling efficiency of the collector (cooling energy, kWh/ total insolation, kWh)
η_{heat}, eta_{heat}	Thermal heating efficiency of the collector (heating energy, kWh/ total insolation, kWh)
R	Heat transfer resistance (inverse of UA) (K/W)
solar	Heat input (kJ/hr)
N_{tube}	Number of sorption modules in a collector (-)
T_{re}	Internal temperature of reactor (salt solution) (°C)
T_{ce}	Internal temperature of condenser/evaporator (refrigerant) (°C)
$T_{re,abs}$	Temperature of reactor heat exchanger node (absorber) (°C)
$T_{ce,abs}$	Temperature of condenser/evaporator (C/E) heat exchanger node (°C)
$T_{rx,i}$, $T_{rx,o}$	Inlet/Outlet temperature to reactor heat exchanger, after manifold losses (°C)
$T_{cx,i}$, $T_{cx,o}$	Inlet/Outlet temperature to condenser/evaporator (C/E) heat exchanger, after manifold losses (°C)
$T_{su,rx,i}$, $T_{su,rx,o}$	Inlet/Outlet temperature to reactor heat exchanger, before manifold losses (°C)
$T_{su,cx,i}$, $T_{su,rx,o}$	Inlet/Outlet temperature to C/E heat exchanger, before manifold losses (°C)
$C_{re,abs}$	Thermal mass of reactor absorber (kJ/K)
$C_{re,ins}$	Thermal mass of reactor absorber insulation (collector casing) (kJ/K)
UA_{rx}	Heat transfer coefficient between fluid loop and reactor absorber (W/K)
UA_{cx}	Heat transfer coefficient between fluid loop and condenser/evaporator absorber (W/K)
$UA_{re,abs}$	Heat transfer coefficient between reactor absorber and reactor (W/K)
$UA_{ce,abs}$	Heat transfer coefficient between condenser/evaporator absorber and condenser/evaporator (W/K)
$UA_{re,abs,ins}$	Heat transfer coefficient between reactor absorber and reactor insulation (collector casing) (W/K)
$UA_{ins,amb}$	Heat transfer coefficient between reactor insulation and ambient (outer Sydney tube) (W/K)
$UA_{rx,amb}$	Heat transfer coefficient between reactor manifold and ambient (W/K)
$UA_{cx,amb}$	Heat transfer coefficient between condenser/evaporator manifold and ambient (W/K)
UA_{int}	Internal heat transfer coefficient between reactor and condenser/evaporator (W/K)

2. Method

Sorption tubes based on LiCl and water have been integrated into a Sydney type vacuum collector. CFD simulations in combination with small scale lab tests have been used to develop aluminium heat exchangers that can efficiently heat and cool both parts of the sorption tube (reactor and condenser/evaporator). A full scale collector consisting of 4 sorption tubes has been manufactured and tested in a solar simulator. An existing mathematical model for TRNSYS environment has been adapted for air heat transfer and validated based on the measurements. The model has then been used to find key performance indicators.

The sorption modules are identical to the ones used in [2]. A salt solution of LiCl and water is used to create a temperature difference between the reactor and the condenser/evaporator part of the module. Vapour can flow from the salt solution in the reactor to the condenser/evaporator if heat is supplied to the reactor and rejected from the condenser/evaporator in such a way that the pressure is maintained higher on the salt side of the module. Vapour will go the other way as soon as heat is no longer supplied to the reactor and the salt solution temperature is sufficiently low.