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Review

Review of solar thermal air conditioning technologies

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ABSTRACT

Solar cooling is a good example of addressing climate changes. In this paper, we provide overviews for working principles of solar thermally operated cooling technologies and reviews for advancements of such technologies from the most recent publications. Researches of solar absorption cycles investigated new refrigerant–absorbent pairs and various system configurations that could lead to increasing solar fraction and extending the cycle operation. Researches of solar adsorption cycles focused on the development and testing of various adsorbent–refrigerant pairs, improving cycle components, and increasing the system efficiency. For the ejector cycles, many studies focused on using computer models and experimental works to investigate the performance of the ejector and find the key parameters affecting its operation. Although many researches have conducted for solar thermal cooling technologies, their overall efficiencies are lower than that of the vapor compression cycles. Therefore, improving efficiency of solar thermally operated cooling technologies is an essential future research topic.

Synthèse des technologies de conditionnement d'air solaire

Mots clés : Solaire ; Thermique ; Conditionnement d'air ; Absorption ; Adsorption ; Thermo-mécanique

1. Introduction

According to Internal Energy Agency (2012), the world energy demand will increase by 35 percent from 2010 to 2035. This increase is associated with world population growth and economic growth, especially in developing countries. Increased energy demands lead to more greenhouse gas emissions and accelerated global warming. In 2012, the average temperature across the U.S. was 3.2 °C higher than normal. Hotter weather and economic growths will result in more use of air conditioning systems, and contribute to accelerated energy demands. One positive trend against adverse effects of human activities is expansion of renewable

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Nomenclature

Abbreviations

A/C	air conditioner
ABC	absorption cycle
ACF	activated carbon fiber
ADC	adsorption cycle
ARI	American Refrigeration Institute
C/R	collector/regenerator
COP	coefficient of performance
CPC	compound parabolic concentrator
CPVT	concentrating photovoltaic/thermal
DC	direct current
DEC	desiccant and evaporative cooling
DMEU	dimethylethylenurea
DW	desiccant wheel
EC	evaporative cooler
ETC	evacuated tube collector
EW	enthalpy wheel
Exp	experimental
FPC	flat plate collector
GA	Genetic Algorithm
GHGGWP	Greenhouse GasGlobal Warming Potential
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HX	Heat eXchanger
IEC	indirect evaporative cooling
LDC	liquid desiccant cycle
MGF	multi-function generator
MR	moisture removal
MRC	moisture removal capacity
NTUODP	number of transfer unitozone depletion potential
PTC	parabolic trough collector
PV	photovoltaic
PVT	photovoltaic/thermal collector
RPH	revolution per hour
SCC	specific cooling capacity
SCE	specific cooling effect
SCP	specific cooling power
SDC	solid desiccant cycle
SDCS	solar desiccant cooling systems
SHX	sensible heat exchanger
Sim	simulation
SW	sensible wheel
TPL	triple pressure level
TRNSYS	transient systems simulation
VCC	vapor compression cycle
VMETS	variable mass energy transformation and storage

Parameters

P	electric power, W
T	temperature, °C
t	thickness, mm
$\dot{V}$	volumetric flow rate, $m^3\,h^{-1}$
W	humidity ratio, gw kga^{-1}
ω	rotational speed, RPH

Subscripts

a	air
ABC	absorption cycle
ADC	adsorption cycle
ads	adsorbent
amb	ambient
C	cooling
comp	compressor
cond	condenser
dw	desiccant wheel
EJC	ejector cycle
evap	evaporator
gen	generator
reg	regeneration
VCC	vapor compression cycle
w	water vapor

energy usages. Through the support of governmental policies in many countries, renewable energies, (particularly solar and wind energies) are expanding their primary energy use share of electricity generation. The Internal Energy Agency (2012) projects that renewable power generation will increase threefold from 2010 to 2035, reaching 31 percent of total power generation.

Meanwhile, one solution for addressing worldwide energy demand increase and climate changes will be utilizing renewable energies to providing cooling instead of fossil fuel-consuming air conditioning systems, making solar cooling technologies important for our future. Hwang et al. (2008) provided reviews of various solar cooling technologies based upon publications published until 2007 and classified them into three groups as shown in Fig. 1. Since utilizing solar electrical for cooling is very much straightforward, this paper provides overviews for working principles of solar thermally operated cooing technologies and reviews for advancements of such technologies based upon publications since 2008. As shown in Fig. 1, there are three main cycles in solar thermally operated cooling technologies: open cycles, closed cycles, and thermo–mechanical cycles.

2. Solar thermal cooling technologies

In this paper, these three types of systems are described starting from their working principles in order for all readers to understand the operation of the cycle. Then the updates on the technologies are summarized. It should be noted that this

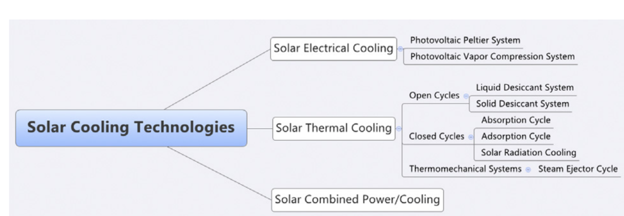

Fig. 1 – Solar cooling technology options.