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Second law thermodynamic study of solar assisted distillation system: A review

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ABSTRACT

Solar energy is a clean source of energy and has been used widely for various applications. Exergy analysis, which discussed the grey areas of improvement in various application considers the entropy generations within the systems. Exergetic analysis has been widely used in the performance analysis and exergoeconomic analysis of renewable energy systems. The present study discusses the comprehensive review on exergetic analysis of solar assisted distillation systems with main focus on concentrated solar energy. For the same, general relations used for first law analysis, second law analysis, entropy generation and irreversibilities for each subcomponent is presented. Following this, the exergetic analysis work on Parabolic trough collectors (PTC), heat exchanger and distillation systems are reviewed comprehensively. The future direction for research work in the area of exergy analysis are identified and suitable conclusions are presented. It is expected that this comprehensive study will be beneficial to researchers involved in the second law analysis of solar based distillation systems.

Contents

1. Introduction

Fossil fuels, the largest resource of the world's energy demand, are being diminished fast, thus changing the trend to find alternative energy source and to utilize available energy efficiently. Energy balance of system discloses the efficiency of energy utilization in particular component and helps to optimize the same. Exergy, which is the defined as the work potential of the energy contained in the system had been widely used to identify the grey areas for improvement. Energy and exergy analysis of a system is considered to be an effective tool for conservation and accounting of energy in terms of quality and quantity [1]. It is used to detect

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Nomenclature

A	area (m^2)
Ap	aperture
Cp	specific heat of fluid (kJ/kg K)
CR	concentration ratio
D	diameter (m)
E	internal energy (kJ)
Ex	exergy (kJ)
FR	Flow factor/heat removal factor
G	Irradiance (W/m^2)
h	enthalpy (kJ/kg)
Ir	irreversibility (kJ)
L	length (m)
m	mass flow rate (kg/s)
M	molar mass
N	number of collector
p	pressure (kPa or bar)
ppm	parts per million
Q	heat transfer (kJ)
R	gas constant
s	specific entropy (kJ/kg K)
S	entropy (kJ/K)
Sgen	entropy generation (kJ/kg K)
t	time (s)
T	temperature (in °C or K)
U	heat transfer coefficient (kW/m^2K)
W	work (kJ)
x	mole fraction

Greek letters

α	absorptivity
δ	Sun cone angle
ε	emissivity
η	efficiency
ρ	reflectivity
τ	transmissivity
σ	Stefan–Boltzmann constant (W/m^2K^4)
μ	dynamic viscosity
ρo	density (kg/m^3)
$\tau\alpha$	effective transmissivity absorptivity product

Indices

a	ambient
abs	absorber
act	actual
b	beam
br	brine
c	collector
ch	chemical
cl	cold
conc	concentration
cond	condenser
dest	destruction
dist	distilled water
g	glass
h	hot
i	inlet/input
l	length
L	loss
m	mass
max	maximum
min	minimum
o	outlet/output
opt	optimum
ph	physical
r	receiver
rev	reversible
s	solar/sun
sea	salt concentration
sr	surface
st	steam
stag	stagnation point
sw	seawater
th	theoretical
u	useful
v	vapor
w	distilled water
wd	width
z	height, axial length (m)
0	dead state/sink
1	initial state
2	final state

and to evaluate quantitatively the causes of the thermodynamic imperfection of the process under consideration. The importance of exergy and its relation with energy is given by Dincer [2] as:

- The impact of energy resource utilization can be easily discussed by this tool.
- This method utilizes both conservation of mass and conservation of energy principles together with the second law of thermodynamics for the design and analysis of energy systems.
- It is a suitable method for achieving the goal of more efficient energy resource use, as it enables the locations, types, and true extent of wastes and losses to be determined.
- This method reduces the inefficiencies in existing systems by revealing whether or not and by how much it is possible to design more efficient energy systems.
- It is a key component to obtain a sustainable development.

Solar energy, which is a high exergy source, is clean, free and abundance source of renewable energy [3,4]. Energy and exergy analysis of solar thermal devices has drawn considerable interest among the researchers across the world. Solar energy heating application have been discussed in various studies which includes solar air heating duct [5], ground heat pump [6,7], solar heat exchanger [8,9] etc. Number of studies have been conducted to find out the energetic performance analysis of different solar components, however few researches have been done to find out the second law analysis of the same. The exergetic analysis of solar energy coupled with different applications has been discussed in the literature which includes greenhouse [10], ground heat pump [9,11], solar pond [12] etc. An extensive review on second law analysis and assessment of renewable energy sources was performed by Hepbasli [13]. Review work on research related to solar energy applications [14], heat exchangers [15] and solar distillation system [16–19] has also discussed work done on energy and exergy analysis of various systems.

Solar thermal technology, which uses direct heat energy of sun, is the best promising option for water distillation (or seawater desalination). Seawater has very high salinity with more than 40,000 ppm, with respect to permissible limit of 500 ppm of Total Dissolved Solids (TDS) in drinking water. In the literature it has