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Effects of combined heat transfer on the thermo-economic performance of irreversible solar-driven heat engines

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Abstract

A thermo-economic performance analysis and optimization has been carried out for an irrversible solar-driven heat engine with losses due to heat transfer across finite temperature differences, heat leak and internal irreversibilities. In the considered heat engine model, heat transfer from the hot reservoir is assumed to be simultaneous radiation and convection mode and the heat transfer to the cold reservoir is assumed to be convection mode. The effects of the technical and economical parameters on the thermo-economic performance have been investigated in order to see the collective effects of the radiation and convection modes of heat transfer. Also the optimal performance parameters of the heat engine, such as the thermal efficiency, temperatures of the working fluid and the ratio of heat transfer areas have been discussed in detail.

Keywords: Irreversible; Optimization; Thermo-economic performance; Solar-driven heat engine

1. Introduction

Performance optimization studies of heat engines using finite-time thermodynamics were started by Chambadal [1] and Novikov [2] and were continued by Curzon and Ahlborn [3]. Firstly, Curzon and Ahlborn [3] studied the performance of an endoreversible Carnot heat engine at maximum power output. During the last decade, many optimization studies for

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Nomenclature

a	investment cost parameter for hot-side (ncu/year m^2)
A	heat transfer area (m^2)
b	investment cost parameter for cold-side heat exchangers (ncu/year m^2)
C	cost (ncu/year)
$\dot{C}_I$	internal conductance
F	objective function
f	economical parameter $a/(a+b)$
ncu	national currency unit
$\dot{Q}$	rate of heat transfer (W)
R	internal irreversibility parameter
T	temperature (K)
U	overall heat transfer coefficient (W/m^2 K for convection or W/m^{2}K^4 for radiation
$\dot{W}$	power output (W)

Greek symbols

β	$(U_{HR}/U_{HC})T_H^3$
η	thermal efficiency
τ	source temperature ratio ($\tau = T_H/T_L$)
ψ	U_{LC}/U_{HC}

Subscripts

ai	annual investment
H	heat source
HC	high temperature side convection
HR	high temperature side radiation
HT	total heat rate from the hot reservoir
L	heat sink
LC	low temperature side convection
LK	leakage
max	maximum
R	ratio
X	warm working fluid
Y	cold working fluid

Superscripts

*	maximum thermo-economic function
—	dimensionless