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Ecological performance analysis of an endoreversible regenerative Brayton heat-engine

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Abstract

A performance analysis based on an ecological performance criterion has been performed for an endoreversible regenerative Brayton heat-engine. In the model, the heat-transfer irreversibilities were considered and other irreversibilities were neglected. The ecologic objective-function, defined as the power output minus the loss rate of availability is taken as the optimization criterion. The optimum performance parameters that maximize the ecological objective function are investigated. The effect of the regenerator effectiveness on the global and optimal performance have been discussed. The results obtained are compared with those of the maximum-power criterion.

Keywords: Brayton heat engine; Ecological optimization; Regenerator effectiveness

1. Introduction

In recent years, many optimization studies for heat engines based on the endoreversible and irreversible models have been carried out by considering finite-time and finite-size constraints under various heat-transfer modes, especially linear and nonlinear ones. The reader interested in these optimization studies could refer to literature surveys written by Bejan [1], Chen et al. [2] and Durmayaz et al. [3]. Usually in these studies, the power and the thermal efficiency were chosen according

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Nomenclature

List of abbreviations

A	heat-transfer area (m^2)
$\dot{C}$	thermal capacitance rate (W/K)
$\dot{E}$	ecological objective function (W)
N	number of heat-transfer units, defined as $N = UA/\dot{C}_W$
$\dot{Q}$	heat-flow rate (W)
S	entropy (J/K)
$\dot{S}_g$	entropy-generation rate (W/K)
T	temperature (K)
$\dot{W}$	power output (W)
U	overall heat-transfer coefficient (W/(m^2 K))

Greek letters

ε	heat-exchanger effectiveness
ϕ	isentropic-temperature ratio
η	thermal efficiency
τ	temperature ratio defined as $\tau = T_H/T_L$
φ	constraint function

Subscripts

0	environment
H	high-temperature heat source
L	low-temperature heat source
me	maximum thermal efficiency conditions
mp	maximum power-output conditions
max	maximum
R	regenerator
W	working fluid

Superscripts

–	dimensionless
*	maximum ecological-function conditions

to the optimization criteria and the design parameters at maximum power (MP) and/ or at maximum thermal efficiency were investigated.

In the literature, many optimization studies have been completed for non-regenerative Brayton heat-engines. Most of these previous works have concentrated on power and power-density optimizations [4–12]. Hernandez et al. [13] analysed the effect of a regenerative heat-exchanger in a gas turbine by using a regenerative Brayton-cycle model. In the model, the compressor and turbine isentropic efficiencies and all global irreversibilities in the heat exchanger were taken into account. They presented results for the behaviour at maximum efficiency, efficiency at maximum power,