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Performance analysis of two stage combined heat pump system based on thermoeconomic optimization criterion

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Abstract

A thermoeconomic performance analysis based on a new kind of optimization criterion has been performed for a two stage endoreversible combined heat pump cycle model. The optimal performances and design parameters that maximize the objective function (heating load per unit total cost) are investigated. The optimal temperatures of the working fluids, the optimum performance coefficient, the optimum specific heating load and the optimal distribution of the heat exchanger areas are determined in terms of technical and economical parameters. The effects of the economical parameter on the global and optimal performances have been discussed.

Keywords: Finite time thermodynamics; Thermoeconomic optimization; Two stage heat pump

1. Introduction

High temperature heat pumps play important roles in improving the efficiencies of industrial processes [1]. The temperature range they involve may be too large for a single stage for the vapor compression heat pump to be practical. One way of dealing with such situations is to perform the heating process in stages, that is, to have two stage or multi-stage combined heat pump systems that operate in series. The performance of a single stage, vapor compression and

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Nomenclature

a	investment cost parameter for heat exchangers (ncu/(year m^2))
A	heat transfer area (m^2)
b_1	investment cost parameter for compressor and its driver (ncu/(year kW))
b_2	energy consumption cost parameter (ncu/(year kW))
b	$b_1 + b_2$
C	cost (ncu/year)
F	objective function (kW/(ncu/year))
k	a/b
ncu	national currency unit
$\dot{Q}$	rate of heat transfer (kW)
$\dot{q}$	specific heating load (kW/m^2)
S	entropy (kJ/K)
T	temperature (K)
$\dot{W}$	power input (kW)
U	overall heat transfer coefficient (kW/(m^2 K))
β	coefficient of performance

Subscripts

e	energy consumption
H	heated space
i	investment
L	heat source
max	maximum
X	warm working fluid of first cycle
W	warm working fluid of second cycle
Y	cold working fluid of first cycle
Z	cold working fluid of second cycle

Superscripts

*	optimum conditions

absorption heat pump systems using the technique of finite time thermodynamic analysis has been investigated quite extensively in recent years [2–10]. Relatively few efforts on the performance optimization of two stage combined heat pump systems have been made [11,12]. In the above referenced works, the objective functions chosen for optimization are usually coefficient of performance, heating load, total heat transfer area and specific heating load (heating load per unit total heat transfer area). In these studies, one of the performance characteristics is chosen as an objective function, while taking the rest as constraints. Some of these optimization criteria are related to investment costs, and some of them are related to energy consumption costs. For a more realistic optimization, the objective function must include both the investment and energy consumption costs. In this context, Sahin and Kodal