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Thermoeconomic optimization of subcooled and superheated vapor compression refrigeration cycle

Reşat Selbaş, Önder Kızılkan*, Arzu Şencan

Technical Education Faculty, Department of Mechanical Education, Süleyman Demirel University, Isparta 32260, Turkey

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Abstract

An exergy-based thermoeconomic optimization application is applied to a subcooled and superheated vapor compression refrigeration system. The advantage of using the exergy method of thermoeconomic optimization is that various elements of the system—i.e., condenser, evaporator, subcooling and superheating heat exchangers—can be optimized on their own. The application consists of determining the optimum heat exchanger areas with the corresponding optimum subcooling and superheating temperatures. A cost function is specified for the optimum conditions. All calculations are made for three refrigerants: R22, R134a, and R407c. Thermodynamic properties of refrigerants are formulated using the Artificial Neural Network methodology.

Keywords: Thermoeconomic optimization; Subcooling; Superheating; Heat exchangers; Refrigeration

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1. Introduction

Refrigeration systems transfer heat from a low-temperature medium to a high-temperature medium. Refrigeration systems are cyclic processes that employ refrigerants to absorb heat from one place and move it to another. Mainly, a refrigeration system consists of a condenser, an evaporator, a compressor, and an expansion valve. In a refrigeration system, the refrigerant vapor leaves the evaporator and enters the compressor as a saturated vapor at the vaporizing temperature and pressure and the liquid leaves the condenser and enters the expansion valve as a saturated liquid at the condensing temperature and pressure [1].

The design of a vapor compression refrigeration system is often done by a conventional method, based on experimental work and experience. Therefore, most refrigeration systems operate over capacity, which means a loss of money both for the producer and the customer. To prevent this, a thermoeconomic optimization approach was developed as an advanced tool for such energy systems. This approach combines thermodynamic analysis by the first and second laws with principles of economics [2].

Several studies of exergy-based thermoeconomic optimization are available. For example, Wall [3] and D'Accadia and Rossi [4] used the exergetic-costing method for thermoeconomic optimization. Usta and İleri [5]

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*Corresponding author. Tel.: +90 246 2111428; fax: +90 246 2371283.
E-mail address: kizilkan@tef.sdu.edu.tr (O. Kızılkan).

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Nomenclature

A	area (m^2)
a^{C}	capital recovery factor
b^{C}	the part of the annual cost which is not affected by the optimization
$C^{\varepsilon}{}_{\mathrm{IN}}$	unit cost of input exergy
$C^{\mathrm{C}}{}_{l}$	capital cost of the lth element of the system
$C^{I}_{k,I}$	local unit cost of irreversibility
c_{p}	specific heat capacity (J/kgK)
E	exergy (kW)
g	gravitational acceleration (m/s^2)
h	specific enthalpy (kj/kg)
I	rate of irreversibility (W)
I_n	normalized input value
K	overall heat transfer coefficient (kW/m^2 K)
LMTD	logarithmic mean temperature difference (°C)
$\dot{m}$	mass flow rate (kg/s)
NET	sum of net collected data
Q	heat transfer rate (kJ)
S_{gen}	rate of entropy generation (kW/K)
s	specific entropy (kj/kgK)
T	temperature (°C)
t_{OP}	period of operation per year
W	work (kJ)
W_n	weights
V	bulk velocity of the stream (m/s)
x_n	inputs
y	output
Z	altitude of the stream from sea level (m)

Greek letters

$\sigma_{k,i}$	coefficient of structural bonds
$\zeta_{k,I}$	capital cost coefficient
ε	specific exergy (kJ/kg)
Σ	summation function
$F(\Sigma)$	activation function

Subscripts

C	condenser
CI	condenser first region
CII	condenser second region
COM	compressor
E	evaporator
EV	expansion valve
IN	inlet
OUT	exit
R	refrigerant
SH	superheating
SC	subcooling