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Estimation of Optimum Heat Exchanger Area of Vapor Compression-Absorption Integrated System Using Modified Irreversibility Approach

Vaibhav Jain[a,*], Gulshan Sachdeva[b], Surendra S Kachhwaha[c]

[a]Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-110085, India [b]Department of Mechanical Engineering, National Institute of Technology, Kurukshetra-136119, India
[c]Department of Mechanical Engineering, Pandit Deendayal Petroleum University, Ghandinagar-382007, India

Abstract

This paper presents the optimum size and cost estimation of vapor compression-absorption integrated system (VCAIS) using coefficient of structural bonds (CSB) method of thermoeconomic optimization. The optimum area of heat exchanger is estimated provided overall heat transfer coefficient, operational and cost parameters are known along with CSB values. The modified as well as conventional Gouy-Stodola equation is used to compute the irreversibility and CSB of VCAIS and its components. The CSB method based on modified method predicts significant reduction in total annual cost of plant operation as compared to base case. The total optimized annual cost of plant operation determined by structural method is lower by 8.1% (conventional method) and 7.0% (modified method) as compared to base value. Comparison of structural method with an integrated optimization algorithm from Engineering Equation Solver (EES) shows that the modified method predicts the total annual cost of plant operation in a more accurate manner.

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Keywords: Vapor compression; absorption; integrated system; optimum area; CSB; modified Gouy-Stodola law

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* Corresponding author. Tel.: +91-98-68-004700;
E-mail address: vaibhavursaathi@gmail.com

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1. Introduction

In consequence of electrical energy shortage and environmental issues related to the global warming and ozone layer depletion attributed to the application of vapor compression system (VCS), the return to the utilization of decarburizing and energy efficient cooling technology appears to be an appropriate alternative. Accordingly, the vapor compression-absorption integrated system (VCAIS), have recently received increasing attention [1]. Nowadays, integrated refrigeration system is considered as a feasible solution to increase the energy efficiency of system since it economizes the utilization of energy resources. From the thermodynamic view point, an integrated refrigeration system is simply a cascading of traditional vapor compression system with a single effect vapor absorption system (VAS). This system leads to substantial electrical energy saving and ultimately a significant contribution to the reduction of CO_2 emissions in the atmosphere [2]. In VCAIS, the VCS rejects heat to the cascade condenser which acts as the evaporator of VAS. The saving in electrical energy is achieved as the refrigerant temperature at compressor exit is lower.

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Nomenclature

a^c capital recovery factor A heat transfer area (m^2) b the part
of annual cost which is not affected by the optimization
B_i input exergy (kW)
C_i equivalent cost of input exergy (\$/kWh) unit cost
of input electricity (\$/kWh)
unit cost of input fuel exergy (\$/kWh)
capital cost of k subsystem (\$)
, local unit cost of irreversibility (\$/kW)
annual cost of the system (\$/year)
COP coefficient of performance
CSB coefficient of structural bonds
D_i, D_o inner and outer tube diameters (m)
F_i, F_o fouling factor at inner and outer surfaces (m^2K/kW)
h specific enthalpy (kJ/kg) h_i, h_o heat transfer coefficients at
inner and outer surfaces (kW/m^2K)
I irreversibility rate (kW) i
interest rate (%) k
thermal conductivity (kW/m
K) m mass flow rate (kg/s)
N period of repayment (years)
P pressure (kPa)
PER primary energy rate Q
heat transfer (kW) s
specific entropy (kJ/kg
K)
T temperature (K)
period of operation per year (hours) U
overall heat transfer coefficient
(kW/m^2K)
W power input (kW) x
concentration of LiBr
solution