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Three-zone system simulation model of a multiple-chiller plant

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Abstract

This paper presents a system simulation model of an oil-injected screw chiller. The refrigerant (shell and tube) heat exchangers are modeled, using a three-zone approach, to study the effects of the operational parameters on the fractional area allocated to each phase within the heat exchangers. All major components of the system such as, an oil-injected screw compressor, a shell and tube condenser, a flooded evaporator and a high side-float valve, are modeled in a modular format. The predicted results are validated with experimental data collected from a multiple-chiller plant at a process industry. The results show that the part-load ratio and the temperature of glycol-water entering the evaporator affect the system performance significantly and have strong influence on the fractional areas allocated to each phase within the condenser.

Keywords: Screw compressor; Chiller; Simulation; Process; Shell and tube heat exchanger; Part load; COP

1. Introduction

Industrial chillers that use shell and tube condensers and evaporators with refrigerant condensing and boiling outside the tube bundles respectively, are commonly used in process cooling industries and air-conditioning applications. The steady state behaviour of these chillers has been studied through modeling and experimental investigations [1,2,6–16]. The physical steady state system models as proposed by Browne and Bansal [1,2] require both thermodynamic and transport property data as well as equipment geometric parameters. The complicating factor in refrigeration-type heat exchangers is that the refrigerant is not in two-phase over its full length

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Nomenclature

Symbols

A	area (m^2)
B	parameter
COP	coefficient of performance
c_p	specific heat (J kg^{-1} K^{-1})
d	diameter (m)
$\mathrm{d}p/\mathrm{d}z$	pressure gradient
f	friction factor
F	suppression factor
g	gravitational acceleration (m s^{-2})
G	mass flux (kg m^{-2} s^{-1})
h	enthalpy, heat transfer coefficient (J kg^{-1}, W m^{-2} K^{-1})
k	thermal conductivity (W m^{-1} K^{-1})
K	characteristic of expansion device
$\dot{m}$	mass flow rate (kg s^{-1})
n	power of friction factor
N	vertical column rows
NTU	number of transfer units
P	pressure (Pa)
PLR	part load ratio
Pr	Prandtl number
ΔP	pressure difference (Pa)
q'	heat flux (W m^{-2})
$\dot{Q}$	heat transfer rate (W)
R	thermal resistance (m^2 K W^{-1})
Re	Reynolds number
R_{wq}	power input per unit refrigeration capacity
S	suppression factor
T	temperature (°C)
ΔT	temperature difference (K)
u	velocity (m s^{-1})
U	overall heat transfer coefficient (W m^{-2} K^{-1})
v	specific volume (m^3 kg^{-1})
$\dot{W}$	rate of work (W)
x	vapour quality
Y	Chisholm parameter

Greek symbols

α	void fraction
β	parameter
ε	effectiveness