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Performance analysis of thermosyphon heat exchanger under electric field

S. Wangnipparnto [a], J. Tiansuwan [a], T. Kiatsiriroat [b,*], C.C. Wang [c]

[a] *School of Energy and Materials, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*
[b] *Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand*
[c] *Energy and Resources Laboratories, Industrial Technology Research Institute, Hsinchu 310, Taiwan*

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Abstract

This paper presents a numerical method to analyze the thermosyphon heat exchanger with and without the presence of electrohydrodynamics (EHD). The proposed model is capable of handling both balanced and unbalanced thermosyphon heat exchangers. For the balanced thermosyphon heat exchanger, the calculated results of heat transfer rate for water and R-134a agree well with experimental data. For the unbalanced thermosyphon heat exchangers, it is found that the performance improvement increases with the ratio of $\dot{m}_e/\dot{m}_c$ when EHD is applied at the condenser alone. Conversely, the performance improvement decreases with the ratio of $\dot{m}_e/\dot{m}_c$ when EHD is applied at the evaporator alone.

Keywords: Thermosyphon; Electrohydrodynamic; Heat transfer enhancement

1. Introduction

At present, waste heat recovery is an important subject for energy conservation. The thermosyphon air preheater is one of the major equipments for energy recovery because of its high thermal conductivity, low cost and easy construction. A schematic of the working principle of the heat pipe heat exchanger is shows in Fig. 1. When heat is added to the evaporator section, the working fluid inside the tube vaporizes and carries heat from the high temperature heat source to the low temperature heat sink, where the working fluid releases the heat to the condenser section. The condensate then returns to the evaporator by gravitational force.

* Corresponding author. Tel.: +66-53-221699; fax: +66-53-944145.
E-mail addresses: tanong@dome.eng.cmu.ac.th, tanongk_k@hotmail.com (T. Kiatsiriroat).

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Nomenclature

A	heat transfer area (m^2)
c_p	specific heat at constant pressure ($kJ\,kg^{-1}\,K^{-1}$)
D	tube outside diameter (m)
E	supplied voltage (kV)
E_{max}	breakdown voltage (kV)
F	filling ratio of evaporator zone
g	gravitational acceleration ($m\,s^{-2}$)
h	heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
k	thermal conductivity ($W\,m\,K^{-1}$)
L	length (m)
$\dot{m}$	mass flow rate ($kg\,s^{-1}$)
Nu	Nusselt number
P	EHD power consumption (W)
Pr	Prandtl number
Q	heat transfer rate (W)
ΔQ	$Q_{EHD} - Q_{NO\_EHD}$
R	thermal resistance ($K\,W^{-1}$)
Re	maximum Reynolds number
T	temperature (°C or K)
ΔT_{LM}	log mean temperature difference (K)
UA	overall heat transfer coefficient ($W\,K^{-1}$)

Subscripts

b	boiling
c	condenser, cold, electric charge
e	evaporator, electric field
f	film
exp	experimental value
EHD	electrohydrodynamic
NO_EHD	without electrohydrodynamic
in, i	inlet, inside
l	liquid
Max	maximum
out, o	outlet, outside
pred	predicted value
sim	simulation
T	total
v	vapor
w	wall, water