AIN SHAMS UNIVERSITY

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GRAVITY-ASSISTED HEAT PIPES

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By

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بسم الله الرحمن الرحيم

In the Name of Allah, Most Gracious, Most Merciful.

انما امره اذا اراد شيئا ان يقول له كن فيكون • فسبحن الذى
بيده ملكوت كل شىء واليه ترجعون •

Verily, when he intends a thing, his command is, "Be" and it is! So Glory be to him in whose hand is the dominion of all things; and to him you all will return.

AL-QURAN XXXV1: 82-83

الله

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ABSTRACT

Heat pipes are devices capable of high heat transfer rates under isothermal conditions. Operation is restricted according to various physical limits, namely, sonic flow of the vapour, entrainment, liquid flow and boiling. In the present study the entrainment limit was investigated for gravity-assisted heat pipes both with and without wicks.

The wicking limit was investigated for the gravity-assisted heat pipes with wicks for both laminar and turbulent liquid flow.

Experiments with copper-water and copper-acetone pipes have been carried out. The maximum performance due to the entrainment limit and the wicking limit have been measured. For simplicity cylindrical geometry only has been used.

Out of many possible controlling variables, the effects of the following have been studied:

a. The diameter of the pipe.
b. The evaporator length.
c. The adiabatic length.
d. The working fluid.

e. The operating pressure and temperature.

f. The heat flux.

g. The wick size and the number of wicking layers.

The experimental results have been assessed and compared with existing theories and previous experimental work. There is seen to be good correlation between published and measured results of the present study with regard to the wicking limit, but for the entrainment limit there is inconsistency between different authors. This thesis presents a correlation for entrainment limit which is validated experimentaly for two working fluids with use of experimental results using three different sizes of thermosyphons and two different sizes of heat pipes.

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NOMENCLATURE

A	cross-sectional area	m^2
a	speed of sound in vapour	m/s
B_o	Bond number	-
D	diameter	m
D_E	equivalent diameter	m
E_t	dimensionless entrainment parameter	-
g	local gravitational acceleration	m/s^2
F	Liquid fill, $V_e/(A\ell_e)$	-
G_r	Grashof number	-
G	mass of liquid	kg
h	heat transfer coefficient	$W/(m^2K)$
H	depth	m
h_{fg}	specific latent heat of vaporization	J/kg
K	fluid permeability of wick	m^2
K_u	Kutadeladje constant	-
K_p	dimensionless pressure parameter	-
ℓ	length	m
M	Mach number, V_v/a	-
n	mesh size	per inch
nL	Number of mesh layers	-
P	pressure	
P_a	atmospheric pressure	P_a

q	rate of heat transfer per unit area	W/m^2
Q	rate of heat transfer	W
Q_e	dimensionless power	-
R	gas constant	J/(kgK)
R_e	liquid-film Reynolds number	-
R_{ev}	axial Reynolds number in vapour	-
r	radius	m
r_σ	minimum capillary radius	m
S	surface area	m^2
T	temperature	C°
T_{eff}	effective operating temperature	K
t	thickness	m
V	volume	m^3
V_ℓ	volume of liquid in unheated pipe	m^3
X	characteristic length in entrainment equation	m
Z	thermal resistance	K/W
α	velocity profile correlation factor	-
β	inclination of pipe to horizontal	deg
ΔP_ℓ	pressure drop in liquid	P_a
ΔP_v	pressure drop in vapour	P_a
ΔP_σ	maximum capillary pressure difference	P_a
ΔT	temperature difference	K
ϵ	porosity, (volume of pores)/(volume of porous wick)	-

θ	contact angle	deg
λ	thermal conductivity	W/(mK)
μ	dynamic viscosity	Ns/m^2
ρ	density	kg/m^3
σ	surface tension	N/m
ν	kinematic viscosity	m^2/s
γ	ratio of specific heats	-
δ	surface depth	m
δ^*	reference surface depth	m

SUBSCRIPTS

a	adiabatic section
c	condenser
d	dummy subscript representing c or e
e	evaporator
eff	effective value of a quantity
ent	entrainment
f	liquid film
g	gravity head
h	hydrostatic head
i	internal dimension
ℓ	liquid
m	mean
max	maximum
O	external dimension