DIRECT CONTACT CNDENSATION ON SUBCOOLED TURBULENT LIQUID FILM

A THESIS
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BY

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بِسم اللّه الرحمن الرَحيم

أقـرأ بأسم َربُكَ الذي خَلقَ * خلقَ الانسانَ من عَلقٍ *
أقـرأ َوربُـك الاكرمُ * الذي علم بِالقلم * علم
الانسانَ ما لم يَعلَم *

صدقَ اللّه العَظيم

الأهداء

الى الذين أوصا بهم اللّه احسانا ......

والدي و والدتي

CERTIFICATE

I certify that this thesis is prepared under my supervision for the University of Basrah, as partial requirement for the degree of Master in Mechanical Engineering.

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ABSTRACT

An analytical study of direct-contact condensation of saturated vapor on a turbulent subcooled liquid film flow is developed. The analysis is performed for vertical and horizontal plate. A simplified theoretical model is developed for adiabatic wall based on the heat balance and simplified energy equation. The flow of liquid layer is considered to be steady, fully developed and turbulent.

The velocity distribution in the thin liquid layer is found from solution of the momentum equation, and the used model of turbulence is the Mudawwar and El-Masri model with some modifications introduced to take into account the effect of interfacial shear stress. This modified model is used for counter-current and cocurrent vapor-liquid flow for both, vertical and horizontal plates.

The local Nusselt number and nondimensional bulk liquid temperature are found to depend on parameters such as Prandtl number, Reynolds number, subcooled number and interfacial shear stress parameter.

The results of the theoretical model are compared with that of some experimental data extracted from the literature, to justify the validity of the developed model. Two more turbulence models by other authors are used to justify the choice of the present modified model.

CONTENTS

NOMENCLATURE

SYMBOLS

A	area	m^2
A^+	empirical constant	___
C	specific heat of liquid	$kJ/kg.^{\circ}C$
D	damping factor for eddy viscosity defined by equation (3.62)	___
f	friction factor	___
g	gravitational constant	m^2/s
h	local heat transfer coefficient	$W/m^2.^{\circ}C$
h_{fg}	latent heat of condensation	kJ/kg
k	thermal conductivity of liquid	$W/m.^{\circ}C$
Ka	Kapitza number ; $\frac{\mu^4 g}{\rho \sigma^3}$	___
l	mixing length	m
$\dot{m}$	local mass flow rate of liquid film	kg/s
Nu	local Nusselt number ; $\frac{h \delta_i}{k}$	___
P	pressure (N/m^2), wetted perimeter	m
Pr	Prandtl number; $\frac{\nu}{\alpha}$	___
Pr_t	turbulent Prandtl number ; $\frac{\varepsilon_m}{\varepsilon_H}$	___
Q	volumetric flow rate	m^3/s
Re	film Reynolds number ; $\frac{4\Gamma}{\mu}$	___
S	subcooled number ; $\frac{C(T_s - T_i)}{h_{fg}}$	___
s^3	dimensionless parameter ; $\frac{\rho g \delta}{\rho g \delta \mp \tau_i}$	___
T	temperature	$^{\circ}C$
u	axial film velocity	m/s
u^*	shear velocity ; $(\tau_w/\rho)^{1/2}$	m/s

x	coordinate parallel to flow	m
x_{lam}	laminarization parameter; $1-\frac{\delta^{+}_{cirt}}{\delta^{+}}$	——
y	coordinate normal to flow	m

GREEK SYMBOLS

α	thermal diffusivity	m^2/s
Γ	mass flow rate per unit wall width	Kg/s.m
δ	film thickness	m
δ^{+}_{crit}	critical film thickness ; $0.865\ (Re_{crit})^{1/2}$	——
ε_m	momentum eddy diffusivity	m^2/s
ε_H	thermal eddy diffusivity	m^2/s
θ	inclination angle	degree
K	Von Karman constant; 0.40	——
μ	dynamic viscosity	kg/m.s
ν	kinematic viscosity	m^2/s
ρ	density	kg/m^3
σ	surface tension	N/m
τ	shear stress	N/m^2
τ_i^*	dimensionless parameter ; $\frac{\tau_i}{\rho\ (g\ \nu)^{2/3}}$	——

SUBSCRIPTS

a	adiabatic
crit	critical
f	bulk
i	liquid film-vapor interface, at the inlet
l	liquid

lam	laminar
m	mean
s	saturation
t	turbulent
v	vapor
w	wall
x	axial position

SUPERSCRIPTS

+	dimensionless
*	dimensionless, friction velocity
.	time rate
–	mean