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Laminar film condensation on an elliptical tube embedded in porous media

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Abstract

Laminar film condensation of saturated vapor flowing over an isothermal elliptical tube embedded in a porous medium is analyzed for conditions of free and forced convection. The flow field in the porous medium is described by the Darcy–Brinkman–Forchheimer model. The effect of vapor shear on condensation is determined by simultaneous solution of the two phase vapor boundary layer and condensate film momentum equations. The numerical results, which are presented in the form of local film thickness and local Nusselt number, show a dependence of these physical parameters on practical dimensionless parameters such as Reynolds number, Darcy number, Bond number and eccentricity.

Keywords: Condensation; Porous media; Elliptic tube; Convection

1. Introduction

The problem of laminar film condensation in porous media has received considerable attention because of its importance in many engineering application such as heat exchangers, chemical reactors, heat pipes and enhanced oil recovery in reservoir engineering and many other applications.

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Nomenclature

a	semi-major axis length
b	semi-minor axis length
Bo	Bond number
C_E	coefficient of Ergun
C_f	inertia coefficient
Da	Darcy number
D_e	equivalent diameter of tube
e	eccentricity of elliptical section $\left(\frac{b}{a}\right)$
Gr	Grashoff number $\left(\frac{(\rho_l-\rho_v)\varepsilon g D_e^3}{\rho_l \nu_l^2}\right)$
h_{fg}	latent heat of condensation
Ja	Jacob number $\left(\frac{c_p(T_s-T_w)}{h_{fg}}\right)$
k_e	effective thermal conductivity of porous medium
k_l	thermal conductivity of condensate
K	permeability of porous medium
P	pressure
Pr	Prandtl number
Re	Reynolds number $\left(\frac{U_\infty D_e}{\nu_l}\right)$
R	radius of curvature
s	dimensionless streamwise length $\left(\frac{2x}{\pi D_e}\right)$
T_s	temperature of saturation
T_w	temperature of wall
u_l	peripheral liquid velocity
u_v	peripheral vapor velocity
U_∞	vapor velocity far from tube section

Greek letters

σ	superficial tension
δ	thickness of liquid film
θ	dimensionless temperature
$\tilde{\mu}$	dynamic viscosity ratio
$\tilde{\nu}$	kinematic viscosity ratio
$\tilde{\rho}$	density ratio
ε	porosity

For open space (without porous medium), the problem of laminar condensation over an elliptical cylinder has received considerable attention, e.g. Mosaad [1], Memory et al. [2] and Yang and Hus [3]. Use of an elliptical section tube is considered as a passive technique to improve the vapor