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Magnetic and buoyancy effects on melting from a vertical plate embedded in saturated porous media

Bourhan Tashtoush *

Department of Mechanical Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan

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Abstract

The magnetic and buoyancy effects on melting processes about a vertical wall embedded in a saturated porous medium are investigated. The Forchheimer extension is considered in the flow equations, and the magnetic work is included in the energy equation. A similarity solution for the transformed governing equations is obtained, and the combined effect of magnetic field on heat transfer rate is discussed. Numerical results for the velocity and temperature profiles as well as Nusselt number have been presented. The effect of inertial forces on flow and heat transfer in porous media is analyzed. The Nusselt number was found to decrease at the solid–liquid interface as the melting parameter increases.

Keywords: Mixed convection; Porous media; Melting heat transfer

1. Introduction

Study of the combined free and forced convection boundary layer flow along a vertical surface embedded in porous media has received a lot of interest, since it occurs in many physical phenomena and has considerable industrial application in a variety of fields. Such applications are

* Tel.: +96227095111; fax: +96227010196.
E-mail address: bourhan@just.edu.jo

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Nomenclature

B_o	magnetic flux density [T]
C_p	liquid specific heat capacity [J/kg K]
C_s	solid specific heat capacity [J/kg K]
Da	Darcy number, $\frac{K}{x^2}$
Ec	Eckert number, $\frac{U_\infty^2}{c_p(T_\infty - T_\mathrm{m})}$
F	inertia coefficient
f	dimensionless stream function
Gr	Grashof number, $\frac{Kg\beta(T_\infty - T_\mathrm{m})x}{v^2}$
h	heat transfer coefficient [W/m^2 K]
Ha	Hartmann number, $\sqrt{\frac{\sigma B_o^2 K}{\rho v}}$
K	permeability of porous media [m^2]
k	thermal conductivity [W/m K]
L	plate length [m]
M	melting parameter, $\frac{c_p(T_\infty - T_\mathrm{m})}{1 + C_s(T_\mathrm{m} - T_\mathrm{s})}$
Nu	Nusselt number $\frac{hx}{k}$
Pe	Peclet number $\frac{U_\infty x}{\alpha}$
q_w	heat flux [W/m^2]
Re	Reynolds number $\frac{U_\infty x}{v}$
T	temperature [K]
T_m	melting temperature [K]
T_s	solid temperature [K]
T_∞	liquid temperature [K]
U_∞	external flow velocity [m/s]
u, v	velocity in x and y directions [m/s]
x, y	coordinate axes along and perpendicular to plate [m]

Greeks

α	thermal diffusivity [m^2/s]
β	coefficient of thermal expansion [1/K]
η	dimensionless similarity variable $Pe^{0.5}\frac{y}{x}$
ρ	liquid density [kg/m^3]
v	kinematic viscosity [m^2/s]
σ	electrical conductivity of fluid [mho m^{-1}]
θ	dimensionless temperature, $\frac{T - T_\mathrm{m}}{T_\infty - T_\mathrm{m}}$
Λ	dimensionless inertia parameter, $ReF\sqrt{Da}$
ψ	dimensional stream function [m^2/s]

geothermal energy technology, crude oil extraction, filtration processes, packed bed reactors and underground disposal of chemical and nuclear waste [1,2]. In addition, heat transfer accompanied by melting and/or solidification has numerous thermal engineering applications. Phase change