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ELSEVIER Applied Mathematics and Computation 171 (2005) 180–202
APPLIED MATHEMATICS AND COMPUTATION
www.elsevier.com/locate/amc

Double diffusive natural convection in a doubly stratified wavy porous enclosure

B.V. Rathish Kumar *, Shalini

Department of Mathematics and Scientific Computing, Indian Institute of Technology, Kanpur 208 016, India

Abstract

Combined heat and mass transfer process by natural convection along a vertical wavy surface in a thermal and mass stratified fluid saturated porous enclosure has been numerically analysed. Finite element method has been used and the influence of varying flow, heat and mass transfer governing parameters has been reported. Presence of thermal and mass stratification terms reduces the Nusselt number and Sherwood number values in all the cases. The flow circulation pattern which is anti-clockwise when the species buoyancy forces are opposing the thermal buoyancy forces, gets clockwise when the forces are aiding. When the two buoyancy forces are equal and opposing, a multi-cellular pattern with alternating circulation orientation manifests. Several other interesting features such as thermal and mass boundary layers, thermal plumes, secondary circulation zones, flow intensification etc. are noticed in the flow, temperature and concentration fields with varying flow, heat and mass transfer governing parameters.

Keywords: Double diffusion; Natural convection; Finite element method; Porous enclosure; Thermal and mass stratification; Wavy surface

* Corresponding author.
E-mail address: bvrk@iitk.ac.in (B.V. Rathish Kumar).

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doi:10.1016/j.amc.2005.01.061

Nomenclature

a amplitude of the wavy wall
B Buoyancy ratio $(=\beta_c(c_w - c_{\infty,0})/\beta_t(t_w - t_{\infty,0}))$
c dimensional species concentration
C non-dimensional species concentration $(=(c - c_{\infty,x})(c_w - c_{\infty,0}))$
D mass diffusivity
e typical element in finite element formulation
g gravitational acceleration
k thermal conductivity
K permeability of the porous medium
L length or the mean width of the porous cavity
Le Lewis number $(=\alpha/D)$
n outward drawn unit normal to the wavy surface
N number of waves considered per unit length
N_i quadratic interpolation function
Nu Nusselt number
QH_x cumulative heat flux
QM_x cumulative mass flux
Ra Rayleigh number $(=Kg\beta_t L(t_w - t_{\infty,0})/\alpha v)$
s_c dimensional mass stratification parameter $(=\mathrm{d}c_{\infty,x}/\mathrm{d}x)$
s_t dimensional thermal stratification parameter $(=\mathrm{d}t_{\infty,x}/\mathrm{d}x)$
S_C non-dimensional mass stratification parameter $(=1/(c_w - c_{\infty,0})*(\mathrm{d}c_{\infty,x}/\mathrm{d}X))$
S_T non-dimensional thermal stratification parameter $(=1/(t_w - t_{\infty,0})*(\mathrm{d}t_{\infty,x}/\mathrm{d}X))$
Sh Sherwood number
$S(\xi)$ arc length of the wavy wall
t dimensional temperature
T non-dimensional temperature $(=(t - t_{\infty,x})/(t_w - t_{\infty,0}))$
u, v dimensional velocity components in x and y directions
U, V non-dimensional velocity components in X and Y directions $(U = u/V_c, V = v/V_c)$
V_c convective velocity $(=g\beta K(t_w - t_{\infty,0})/v)$
w weight function used in the finite element formulation
x, y dimensional cartesian coordinates
X, Y non-dimensional cartesian coordinates $(X = x/L,\ Y = y/L)$
$\prec$ almost less than to
$\succ$ almost greater than to