Applied Mathematical Modelling 39 (2015) 1597–1615

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Simulation of unsteady heat and mass transport with heatline and massline in a partially heated open cavity

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ARTICLE INFO

Article history:
Received 9 September 2013
Received in revised form 29 August 2014
Accepted 15 September 2014
Available online 2 October 2014

Keywords:
Heat and mass transfer
Unsteady
Open cavity
Massline
Heatline

ABSTRACT

A computational work is performed to investigate the transient heat and mass transfer inside a ventilated enclosure. The enclosure has two ventilation ports as inlet and outlet. Three different configurations are tested according to location of outlet ports while location of inlet port is fixed. In case 1, the outlet port is located on the top of the left vertical wall, in case 2 at the right and case 3 at the middle of the ceiling. Finite element method is employed to solve the governing equations of flow, heat and mass transfer. Also, the heatline and massline techniques are used to visualize the heat and mass transfer patterns. Obtained results show the evolution of various contours of stream function, isotherms and iso-concentrations as well as various parameters such as Nu and Sc numbers. It is found in particular that in order to reach highest heat and mass transfer rates for $Gr = 10^7$, the outlet port should be located near the top of the left vertical wall. On the other hand, the effect of outlet location is insignificant for the lower values of Gr.

1. Introduction

Air-conditioning systems are very important on thermal comfort and life quality. Energy consumption is very high in these kinds of systems. Thus, the efficiency of the designed systems is a valuable subject for their sustainability and cost. In those systems, heat and mass transfer occurs in general simultaneously. Besides, the analysis of the flow distribution associated with the heat and mass transfer is very important for the design and efficiency of such AC systems.

The flow, heat and mass transfer in cavities with inlet and outlet ports are analyzed for these kinds of problems in various previous works. Liu et al. [1] studied the simultaneous transport of heat and moisture in a partially open enclosure with a thick wall. They used heatlines and masslines visualization techniques to simulate heat and moisture transport. They observed that the heat transfer potential, mass transfer potential, and volume flow rate can be promoted or inhibited. The effective parameters are wall materials and size as well as thermal and moisture Rayleigh number.

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http://dx.doi.org/10.1016/j.apm.2014.09.022
0307-904X/

Nomenclature

Br	buoyancy ratio
c	dimensional concentration of species
C	dimensionless species concentration
D	species diffusivity
g	gravitational acceleration
Gr	Grashof numbers
H	height of the cavity
h	sizes of inlet and outlet
L	length of the cavity
Le	Lewis number
L_s	length of the heat and mass sources
Nu	Nusselt number
n	unit normal to the surface
p	dimensional pressure
P	dimensionless pressure
Pr	Prandtl number
Re	Reynolds number
Sh	Sherwood number
T	dimensional temperature
t	time
u, v	dimensional velocity components
$\bar{V}$	(U, V) dimensionless velocity components
x, y	dimensional Cartesian coordinates
X, Y	dimensionless Cartesian coordinates

Greek symbols

α	thermal diffusivity
τ	dimensionless time
β_T	thermal expansion coefficient
β_c	compositional expansion coefficient
ν	kinematic viscosity
θ	dimensionless temperature
ρ	mixture density
ψ	streamfunction
Γ	general dependent variable
∇^2	Laplacian operator
ξ	heatfunction
ζ	massfunction

Subscripts

av	average
c	referring concentration
h	higher value
L	lower value
p	referring pressure
T	referring temperature
i	inlet

Transient laminar forced convection heat transfer leading to periodic state within a square cavity with inlet and outlet ports due to an oscillating velocity at the inlet port is presented by Saeidi and Khodadadi [2]. They indicated that the mean Nusselt numbers on the four walls clearly exhibit large amplitudes of oscillation and periodicity for St = 0.1 and increasing of St number, the amplitudes of oscillation on various walls are degraded. In another work, they presented forced convection results by investigating location of inlet and outlet ports [3]. Rahman et al. [4] studied the effects of heat generation and Reynolds and Prandtl numbers are studied for the same geometry [5]. Liu et al. [6] modeled numerically the indoor air quality with a new window-type air conditioner. They observed that the reduction of indoor pollutant levels can be accomplished either by increasing the fresh air ratio, or by decreasing the strength of indoor heating source. Oztop [7] worked on a mixed convection heat transfer in an enclosure with inlet and outlet ports and observed in particular that the location of the outlet port affects significantly the heat transfer and fluid flow. Besides, the inclination effects is an important parameter for natural