Alexandria Engineering Journal (2016) 55, 991–1004

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Alexandria Engineering Journal

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ORIGINAL ARTICLE

Three dimensional analysis of natural convection and entropy generation in a sharp edged finned cavity

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Received 24 January 2016; revised 27 February 2016; accepted 29 February 2016
Available online 12 March 2016

KEYWORDS

Entropy generation;
Inclined fin;
Natural convection;
Three dimensional

Abstract A computational study has been performed to make a computational analysis of natural convection and entropy generation in a sharp edged finned cavity. Three dimensional analysis has been done by solving governing equations with a written computational code in Fortran. The study is performed for fin inclination angles from $-60°$ to $60°$, Ra = 10^5, Pr = 0.7, R_c (conductivities ratio) changes from 0.01 to 100 and irreversibility coefficient is taken as $\varphi = 10^{-5}$. It is observed that higher values of thermal conductivity ratio (Rc $\geqslant$ 1) do not affect entropy generation due to heat transfer and Bejan number.

1. Introduction

Natural convection heat transfer occurs in many field of engineering such as cooling of electronic equipment, solar collectors, heating of buildings, heat exchangers and many other applications. Control of energy is extremely important to save energy consumption. Thus, entropy generation analysis is highly important to answer the question of why or where energy is consumed in the system?

Using of passive systems such as baffle, fin or obstacle is a simple way to control heat and fluid flow due to natural convection in cavities. Varol et al. [1] studied the laminar natural convection heat transfer in an inclined fin located cavity by solving two dimensional governing equations. Also, they performed an experiment to compare their results and found the inclination angle of the fin is the important parameter to control heat and fluid flow. As a similar work, Ozgen et al. [2] tested the effects of Prandtl number and baffle location on natural convection. Li and Byon [3] studied the orientation effect on the thermal performance of radial heat sinks with a

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Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.02.030

Nomenclature

Be	Bejan number
Cp	specific heat at constant pressure (J/kg K)
g	gravitational acceleration (m/s^2)
k	thermal conductivity (W/m K)
l	cavity width
n	unit vector normal to the wall
N_s	dimensionless local generated entropy
Nu	local Nusselt number
Pr	Prandtl number
Ra	Rayleigh number
Rc	thermal conductivity ratio
S'_{gen}	generated entropy (kJ/kg K)
t	dimensionless time $(t' \cdot \alpha/l^2)$
T	dimensionless temperature $[(T' - T'_c)/(T'_h - T'_c)]$
T'_c	cold temperature (K)
T'_h	hot temperature (K)
T_o	bulk temperature $[T_o = (T'_c + T'_h)/2]$ (K)
$\vec{V}$	dimensionless velocity vector $(\vec{V}' \cdot l/\alpha)$
x, y, z	dimensionless Cartesian coordinates $(x'/l, y'/l, z'/l)$

Greek symbols

α	thermal diffusivity (m^2/s)
β	thermal expansion coefficient (1/K)
φ	irreversibility coefficient
θ	fin inclination
ρ	density (kg/m^3)
μ	dynamic viscosity (kg/m s)
ν	kinematic viscosity (m^2/s)
$\vec{\psi}$	dimensionless vector potential $(\vec{\psi}'/\alpha)$
$\vec{\omega}$	dimensionless vorticity $(\vec{\omega}' \cdot \alpha/l^2)$
ΔT	dimensionless temperature difference

Subscripts

av	average
x, y, z	Cartesian coordinates
fr	friction
f	fluid
av	average
nf	nanofluid
s	solid
th	thermal
tot	total

Superscript

$'$	dimensional variable

circular base, concentric ring, and rectangular fins both experimentally and numerically. They observed that the radial heat sink in orientation 0 is found to have slightly better thermal performance than that of 180. Saravanan and Sivaraj [4] performed a numerical work on combined natural convection and thermal radiation in a square cavity with a non-uniformly heated plate. Effects of heat generating baffles on natural convection in a square cavity were studied by Saravanan and Vidhya Kumar [5]. In their study, the baffles were kept centrally separated by a distance d in the cavity and assumed to generate heat uniformly. They observed that flow inhibition mechanism was dominating only when the baffles are away from the cavity walls. Other related works on two-dimensional analysis of natural convection in inclined fin attached cavities are studied in Refs. [6–8,1].

Importance of analyses of entropy generation from the energy efficiency point of view is presented in reviewable work of Öztop and Al-Salem [9] and Sciacovelli et al. [10]. They mainly focused on entropy generation in natural and mixed convection heat transfer. Shuja et al. [11] solved a problem on natural convection in a square cavity with a heat generating body by considering entropy generation. Khorasanizadeh et al. [12] performed a numerical study of natural convection and entropy generation of Cu-water nanofluid within an enclosure with a conductive baffle embedded on bottom hot wall. They solved the governing equations numerically with Finite Volume Method by using the SIMPLER algorithm. They showed that assuming a constant irreversibility factor, χ, with change of Ra and ϕ is not correct.

Entropy generation due to natural convection in an enclosure heated locally from below with two isoflux sources was investigated by Mukhopadhyay [13]. They studied unequal heater length and heater strength, the effects of heater length and strength ratios. It is found that minimum entropy generation rate was achieved for the same condition at which the minimum peak heater temperature was obtained. Famouri and Hooman [14] studied the entropy generation in two-dimensional domain to investigate the entropy generation for natural convection by heated partitions in a cavity.

Dalir [24] studied numerically the entropy generated by laminar forced convection flow and heat transfer of an incompressible Jeffrey non-Newtonian fluid over a linearly stretching, impermeable and isothermal sheet. Results indicate that the generated entropy increases with the increase in Deborah number and decreases by the increase in ratio of relaxation to retardation times. Das et al. [25] investigated the entropy generation in a MHD pseudo-plastic nanofluid flow through a porous channel with convective heating. Three different types of nanoparticles were considered and several parameters were varied to find the minimum of entropy generation.

Studies on three dimensional domain of natural convection are very limited. In this context, Wakashima and Saitoh [15] and Fusegi et al. [16] made studies to analyze the natural convection in three dimensional domains.

The main aim of this work was to study the effects of presence of inclined fin on natural convection heat transfer fluid flow and heat transfer in a three dimensional domain of cavity. Entropy generation is calculated by using obtained data of velocity and temperature. Entropy generation due to heat transfer, fluid flow and total entropy generation are presented via contours and variation according to thermal conductivity ratio.