Case Studies in Thermal Engineering 7 (2016) 1–7

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

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

Heat transfer in an annular space fitted with heating isothermal blocks: Numerical bifurcation for low blocks height

Ahmed Idrissi, Abdelkhalek Cheddadi *, Mohammed T. Ouazzani

Research Team "Thermal Systems and Real Flows", Mohammadia School of Engineers, Mohammed V University, P. O. Box 765 Agdal, Rabat, Morocco

ARTICLE INFO

Article history:
Received 12 May 2015
Received in revised form
25 November 2015
Accepted 26 November 2015
Available online 28 November 2015

Keywords:
Free convection
Annular space
Heating blocks
Numerical simulation
Bifurcation

ABSTRACT

A numerical study of the thermoconvective effects induced by the placement of two heating blocks on the inner surface of an air filled cylindrical annular space is presented. The radii ratio is kept constant $R=2$. This study investigates the influence of initial conditions on the flow structure and the overall heat transfer rate, when the height of the blocks is varied up to $h=0.10$. The interval of variation of the Rayleigh number, Ra, is $[10^{3},10^{4}]$. The main result is the existence of a bifurcation point separating two flows regimes: uni- and bi-cellular, corresponding to a critical value of the Rayleigh number Ra_c, close to 3598. For Rayleigh numbers higher than Ra_c, the bicellular flow allows substantial enhancement of the heat transfer rate up to 18% in the considered interval of Ra.

1. Introduction

The multiplicity of practical applications (thermal insulation, heat exchangers…) where natural convection is involved in a fluid medium in horizontal cylindrical annuli, justifies the growing interest in this geometry. Therefore, many numerical and theoretical investigations published in the last decades have as objective the study of the rate of heat transfer and the flow patterns generated (single-cell flow, multicellular structures, etc..) in such cavities. This type of problem has been studied by Cheddadi et al. [1], among others, who showed that the heat transfer and flow generated depend in general on the Rayleigh number, the aspect ratio of the cavity and strongly depend on initial temperature and flow conditions. More recently, numerical investigations are dealing with annular cylindrical geometries equipped with heating blocks/fins, in order to determine the optimal conditions for a suitable heat transfer. Taher et al. [2] show that increasing the width of the heating blocks, placed in the center of the space, for a range of Rayleigh number from 10^3 to 10^4, enhances the heat exchange. Farinas et al. [3] studied the location of three types of fins (fine, rounded or divergent) for $10^3 \leq Ra \leq 10^6$, and the rounded fin was associated with the best efficiency. Rahnama et al. [4] used two different configurations to reveal the effect of the height and arrangement of the fins for a Rayleigh number between 10^6 and 10^9 in the case of turbulent convection. In a more general way, several investigations were conducted to study the placement of internal heat sources or blocks in a cavity. Examples are Sankar et al. [5], De et al. [6] and Bakkas et al. [7]. All these studies have shown the influence of these disturbances on the rate of heat transfer and on the flow. In addition to the previous studies, the natural convection in enclosures in combined configurations where the internal and external walls have various geometrical forms was performed. Sheikholeslami et al. [8] give numerically the influence of the Rayleigh number, amplitude and number of

* Corresponding author.
E-mail address: cheddadi@emi.ac.ma (A. Cheddadi).

http://dx.doi.org/10.1016/j.csite.2015.11.002

Nomenclature

R	radii ratio, r'_o/r'_i.
g	gravity acceleration, m s^{-2}.
h	dimensionless height of the blocks.
l	dimensionless width of the blocks.
Nug	overall Nusselt number.
Pr	Prandtl number $Pr= \nu/\alpha$.
r	dimensionless radial coordinate.
r'_o	outer cylinder radius, m.
r'_i	inner cylinder radius, m.
Ra	Rayleigh number, $Ra=g\beta(T'_i-T'_o)rr'^3_i/\nu\alpha$.
T'_o	outer cylinder temperature, K.
T'_i	inner cylinder temperature, K.
u	dimensionless radial velocity.
v	dimensionless angular velocity.

Greek letters

ν	kinematic viscosity, m^2 s^{-1}.
β	thermal expansion coefficient K^{-1}.
φ	polar angle.
φ_m	angular position of the blocks.
ψ	dimensionless stream function.
ω	dimensionless vorticity.
α	thermal diffusivity, m^2 s^{-1}.

Indices/exponents

o	outer
i	inner.
c	critical.
max	maximal
$'$	dimensional

undulations in the case of natural convection between a circular enclosure and a sinusoidal cylinder using a control volume based finite element method. A numerical study has been presented by Yongsiri et al. [9], dealing with turbulent flow and heat transfer in a channel with inclined detached-ribs; the study revealed that the inclined ribs with $\varphi=60°$ and $\varphi=120°$ give higher heat transfer rates and thermal performance factors. Nagarani et al. [10] show that, through 70 reviewed articles related to different types of fins, the utilization of extended surfaces in the field of heat transfer was increased over the last 15 years from 1999 to 2013. The use of the heating blocks attached to the walls of enclosures or not is among the technologies of the heat transfer enhancement used by many authors. We quote, as examples, the numerical researches on square enclosures fitted with one or multiple heating blocks, realized by Raji et al. [11], Oztop et al. [12], Bilgen et al. [13], Jani et al. [14] and Xu et al. [15]. In the same way, the triangular geometry provided with a protruding isothermal heater was studied by Varol et al. [16]. Furthermore, Liu et al. [17] give a description of the transient and quasi-steady state flows adjacent to a finned sidewall of a differentially heated cavity. Hu et al. [18] make a comparison investigation in annular enclosures with complex configurations for the cold water near its density maximum and show that the variation of the density inversion parameters creates different positions of the thermal plume for each parameter. All these studies have shown the influence of perturbations on the rate of heat transfer and flow.

In this paper, we present a numerical simulation of thermoconvective effects induced by the placement of two heating

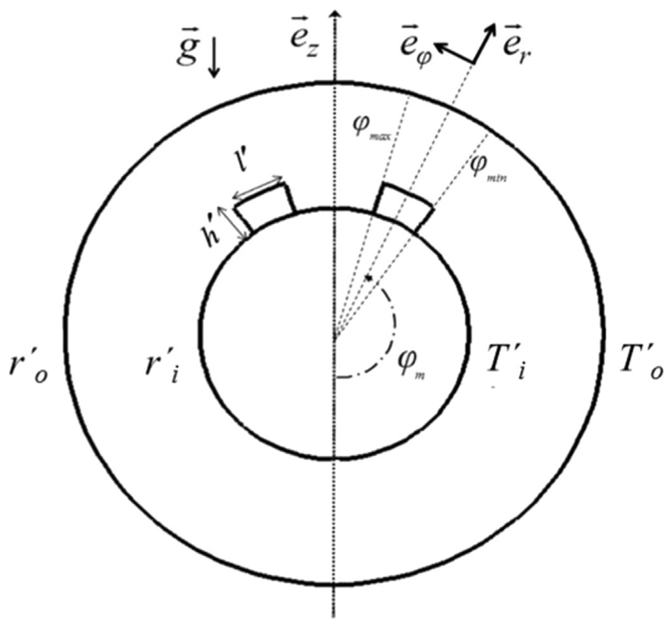

Fig. 1. Problem geometry.