International Journal of Thermal Sciences 128 (2018) 1–14

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

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

A numerical study of the effect of fluid-structure interaction on transient natural convection in an air-filled square cavity

A. Raisi[a,*], I. Arvin[b]

[a] Engineering Faculty, Shahrekord University, Shahrekord, PO Box 115, Iran
[b] M.S. Student of Mechanical Engineering, Engineering Faculty, Shahrekord University, Shahrekord, PO Box 115, Iran

ARTICLE INFO

Keywords:
Fluid-structure interaction
Square cavity
Transient natural convection
Elastic baffle

ABSTRACT

The present study aims to investigate the transient natural convection in an air-filled square cavity based on the effects of fluid-structure interaction (FSI). The Prandtl number of air is assumed to be 0.71. A thin deformable baffle is horizontally located in the center of the cavity and the top wall of the cavity is also elastic. The horizontal walls are completely insulated. Initially, the cavity is set at T_c temperature, then the left side wall temperature is raised to T_h. The arbitrary Lagrangian-Eulerian approach is implemented to study the flow field in the presented model. The fluid field equations are discretized by Galerkin finite element method. Further, the dimensionless equations of flexible parts of the cavity are solved using the Newton-Raphson method. The study examines the effects of Rayleigh number and baffle length on flow and temperature fields, heat transfer rate and deformation of elastic parts of the cavity. The results show that an increase in the Rayleigh number enhances the natural convection and increases the elastic parts deformations. Finally, the increase of baffle length has different effects on thermal performance of cavity depending on the Rayleigh number and rigidness or flexibility of the system.

1. Introduction

In recent years, heat transfer has attracted a lot of attention. In a general category, the heat transfer issues were categorized into internal and external issues. Unlike the internal heat transfer issues, the external heat transfer issues have been received the most attention not due to more importance of external heat, but the more complex nature of internal heat transfer issues [1]. Natural convection in a closed enclosure has been much considered in many engineering applications because of its vital role in thermal engineering issues [2–6].

In fluid-structure interaction (FSI) problems, one or several deformable structures are interacted with a surrounding or internal fluid flow. FSI problems play a major role in many engineering fields. However, the study of these issues is very complex due to its multidisciplinary and nonlinearity nature [7,8]. Fluid-structure interaction occurs in a large number of physical phenomena and has many application in engineering, science and medicine such as airplane wings shaking, the deformation of wind turbine blades, building thermal design, reactor design, solar energy collector, filling air bags of cars, parachute dynamics, ships movement, pumping blood by heart along with its opening and closing, blood flow in the veins, filtration processes, breakwaters design, and the like [8,9].

Therefore, the use of each of the areas of fluid dynamics or structure mechanics alone is not appropriate for analyzing those various physical phenomena in which Fluid-Structure Interaction occurs. Hence, studying of the fluid-structure interaction problems is of great importance [10]. Fu and Shieh [11] examined the simultaneous effects of vertical vibration and gravity on natural convection heat transfer in an air-filled square cavity. In an another study, Fu and Shieh [12], investigated the simultaneous effects of air-filled square cavity vibration and gravity on transient natural convection by considering the Rayleigh number and the Grashof number of vibration as a constant. Their results indicated that the required time for reaching to steady state from stationary state decreased by increasing vibration frequency.

Tong and Cerner [13] examined the effect of a vertical rigid partition in an air-filled rectangular cavity on Steady state natural convection. Based on the results, the greatest reduction in the heat transfer rate occurred when the partition was placed in the vertical midsection of the cavity. Tatso et al. [14] reviewed experimentally the natural convection in a vertical rectangular cavity with insulated horizontal walls while the left and right side walls of the cavity were hot and cold, respectively. Also an out-of center vertical partition was placed between the vertical walls of the cavity. They found that the partition position had no effect on the heat transfer rate.

* Corresponding author.
E-mail addresses: raisi@eng.sku.ac.ir (A. Raisi), Arvin@stu.sku.ac.ir (I. Arvin).

https://doi.org/10.1016/j.ijthermalsci.2018.02.012
Received 21 July 2017; Received in revised form 9 February 2018; Accepted 10 February 2018
1290-0729/ © 2018 Elsevier Masson SAS. All rights reserved.

Nomenclature

a	cavity length, (m)
A	dimensionless cavity length
d	displacement, (m)
E	Young's modulus, (N/m^2)
F_v	body force, (N)
g	gravitational acceleration vector, (m/s^2)
Gr	Grashof number
k	thermal conductivity, (W/mK)
l	baffle length, (m)
L	dimensionless baffle length
h	baffle distance from bottom wall, (m)
H	dimensionless Baffle distance from Bottom wall
I	matrix unit
Nu	Nusselt number
$Nu_{m,ss}$	steady state average Nusselt number
Nu_y	local Nusselt number
p	pressure, (N/m^2)
Pr	Prandtl number
Ra	Rayleigh number
t	time, (s)
T	temperature, (K)
T_c	initial temperature, (K)
u	vlocity vector of fluid, (m/s)
u_g	Moving coordinate velocity, (m/s)
U, V	dimensionless velocity component
x, y	Cartesian coordinates, (m)
X,Y	dimensionless Cartesian coordinates

Greek symbols

α	thermal diffusivity, (m^2/s)
β	thermal expansion coefficient $(1/K)$
ε	strain
θ	dimensionless temperature
λ_s	First Lamé parameters
μ_s	Second Lamé parameter
ν	kinematic viscosity(m^2/s)
ρ	density, (kg/m^2)
σ	stress tensor, (N/m^2)
ϑ	Poisson coefficient
τ	dimensionless time
ψ	dimensionless stream function

Subscripts

c	cold
h	hot
s	solid
f	fluid
g	grid

Superscripts

*	dimensionless

Nishimura et al. [15] studied numerically and experimentally the natural convection in a separated rectangular cavity with several vertically rigid insulating partitions. Based on the results, using 2 or 5 partitions played a significant role on reducing heat transfer rate in the cavity by 70–90%. Turkoglu and Yucel [16] emphasized the natural convection in a separated rectangular cavity of several thermal conductor rigid partitions both numerically and experimentally. They concluded that an increase in the number of partitions led to a decrease in the average Nusselt number. Further, an increase in Rayleigh number increased the average Nusselt number for all partitions number.

Shi and Khodadadi [17] examined numerically the laminar natural convection in an air-filled square cavity with adiabatic horizontal walls,

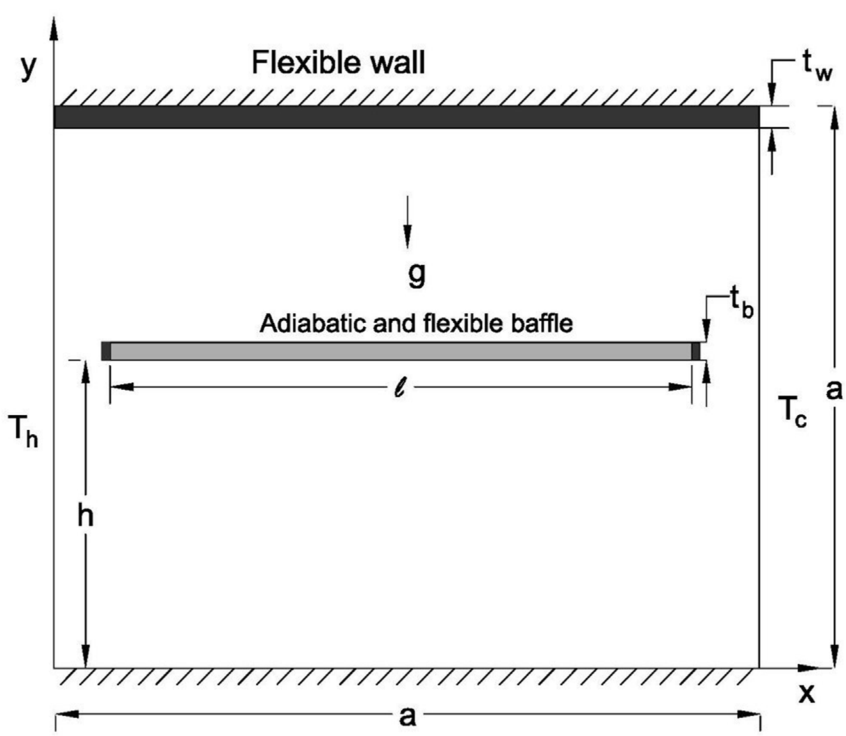

Fig. 1. Schematic diagram of the physical model and boundary conditions.

Download English Version:

https://daneshyari.com/en/article/7060708

Download Persian Version:

https://daneshyari.com/article/7060708

Daneshyari.com