ICCCD 2011

2011 International Conference on Computer and Communication Devices

April 1-3, 2011

Bali Island, Indonesia

Editor: Yang Li

IEEE

ICCCD 2011

2011 International Conference on Computer and Communication Devices

1-3, April, 2011

Bali Island, Indonesia

Volume 2

PROCEEDING

PREFACE

Dear Distinguished Delegates and Guests,

The Organizing Committee warmly welcomes our distinguished delegates and guests to the 2011 International Conference on Computer and Communication Devices (ICCCD 2011), and the workshops—2011 International Conference on Industrial and Intelligent Information (ICIII 2011) and 2011 International Conference on Fluid Dynamics and Thermodynamics Technologies (FDTT 2011) held on Bali Island, Indonesia during April 1-3, 2011.

ICCCD 2011 is Co-sponsored by International Association of Computer Science and Information Technology (IACSIT) and IEEE, and supported by IACSIT Members and scholars from universities all round the world. If you have attended a conference sponsored by IACSIT before, you are aware that the conferences together report the results of research efforts in a broad range of computer science and information technology. The conferences are aimed at discussing with all of you the wide range of problems encountered in present and future high technologies. The ICCCD 2011 is organized to gather members of our international community scientists so that researchers from around the world can present their leading-edge work, expanding our community's knowledge and insight into the significant challenges currently being addressed in that research. The conference Program Committee is itself quite diverse and truly international, with membership from the Americas, Europe, Asia, Africa and Oceania.

This proceeding records the fully refereed papers presented at the conference. The main conferences' themes and tracks are all aspects of Computer & Communication Devices, Industrial & Intelligent Information, and Fluid Dynamics & Thermodynamics Technology. The main goal of this event is to provide international scientific forums for exchange of new ideas in a number of fields that interact in-depth through discussions with their peers from around the world. Both inward research, core areas of Computer & Communication Devices, Industrial & Intelligent Information, and Fluid Dynamics & Thermodynamics Technology, and outward research, multi-disciplinary, inter-disciplinary, and applications will be covered during this event.

The conference has solicited and gathered technical research submissions related to all aspects of major conference themes and tracks. All the submitted papers in the proceeding have been peer reviewed by the reviewers drawn from the scientific committee, external reviewers and editorial board depending on the subject matter of the paper. Reviewing and initial selection were undertaken electronically. After the rigorous peer-review process, the submitted papers were selected on the basis of originality, significance, and clarity for the purpose of the conference. The selected papers and additional late-breaking contributions to be presented as lectures will make an exiting technical program. The conference program is extremely rich, featuring high-impact presentations.

The high quality of the program – guaranteed by the presence of an unparalleled number of internationally recognized top experts – can be assessed when reading the contents of the program. The conference will therefore be a unique event, where attendees will be able to appreciate the latest results in their field of expertise, and to acquire additional knowledge in other fields. The program has been structured to favor interactions among attendees coming from many diverse horizons, scientifically, geographically, from academia and from industry. Included in this will to favor interactions are social event at prestigious sites.

We would like to thank the program chairs, organization staff, and the members of the program committees for their work. Thanks also go to Editor Ms. Yang Li, International Association of Computer Science and Information Technology, for her wonderful editorial service to this proceeding.

We are grateful to all those who have contributed to the success of ICCCD 2011. We hope that all participants

Mesoscale Simulation of Natural Convection in Square Cavity Driven by Discrete Two Source–Sink Pairs On One Sidewall

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Abstract—**Lattice Boltzmann method (LBM) was applied to predict fluid flow and heat transfer characteristics of natural convection in a two-dimensional square cavity driven by two discrete source-sink pairs on one vertical sidewall. The size of sources and sinks was L/4. The arrangement of the sources and sinks were alternately located. Simulations were conducted at Rayleigh number 103 to 105. The characteristics were represented by streamlines and isotherms. It was found that the solution is comparatively acceptable with other previous study applying conventional approach.**

Keywords-lattice Boltzmann method (LBM); discrete source-sink pairs; natural convection

I. INTRODUCTION

Benchmark solution for natural convection in square geometry has been developed nearly three decades ago [1]. Due to industrial demand for numerical solutions, the problem has been progressively extended to simulate various engineering applications.

This work is related to natural convection in square cavity. Earlier studies concentrate on this topic with one source and one sink [2, 3]. It was found that both the size and location of the discrete heat source significantly influence the behavior of heat transfer. Recently, researches in this type of problem have been extended to investigate the behavior of natural convection due to mulitiple discrete source-sink pairs [4].

Mesoscopic approach for fluid flows have been extensively used with the advancement of lattice Boltzmann method [5]. However, simulations for thermal related problem such as natural convection require additional thermal equilibrium distribution function [6]. Such simulations have also been done which yields comparatively good results with conventional direct way of solving Navier-Stokes equation.

The objective of this work is to study the reliability of this mesoscopic approach specifically lattice Boltzmann method (LBM) for natural convective heat transfer simulation in a square cavity driven by discrete two source-sink pairs on one vertical sidewall. The size of sources and sinks are set to be L/4. The arrangement of the sources and sinks are alternately located. Simulations are conducted at Rayleigh number, Ra = 10^3 to 10^5. The characteristics are discussed in terms of the streamlines and isotherms.

II. PROBLEM PHYSICS AND BOUNDARY CONDITIONS

The physical domain of the problem is represented in Fig.1. Thermal boundary conditions are T = 1 for sources and T = 0 for sinks. The temperature difference between the sources and sinks on the left vertical wall creates a temperature gradient in the flow field, which will then introduce density difference. This difference in density will cause the fluid to move. This movement is not initiated by any external force, therefore it is widely known as natural convection. The other walls are assumed to be in adiabatic condition. The square cavity contains fluid with Prandtl number, Pr = 0.71. No slip condition is imposed for all velocities on the walls.

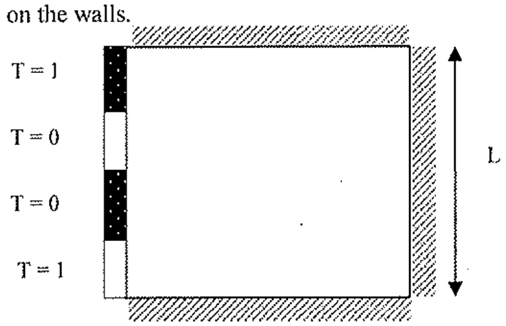


Figure 1. Physical domain of the problem

Boussinesq approximation is applied to the buoyancy force term. With this approximation, it is assumed that all fluid properties are constant except for density change with temperature.

$$\mathbf{G} = \beta g(T - T_m)\mathbf{j} \quad (1)$$

where β is the thermal expansion coefficient, g is the acceleration due to gravity, T_m is the average temperature and **j** is the vertical direction opposite to that of gravity. The dynamical similarity depends on two dimensionless parameters: the Prandtl number, *Pr* and Rayleigh number, *Ra*:

$$Pr = \frac{\nu}{\chi} \quad (2)$$

$$Ra = \frac{\rho\beta(T_H - T_C)L^3}{\nu\chi} \quad (3)$$

where ν, X and L are the fluid kinematic viscosity, thermal diffusivity and width of the cavity respectively.

III. Numerical Method

The Boltzmann equation discretized in space and time is given as follows:

$$f_i(\mathbf{x} + \mathbf{c}_i\Delta t, t + \Delta t) - f_i(\mathbf{x}, t) = -\frac{1}{\tau_f}(f_i - f_i^{eq}) + F_i\Delta t \quad (4)$$

$$g_i(\mathbf{x} + \mathbf{c}_i\Delta t, t + \Delta t) - g_i(\mathbf{x}, t) = -\frac{1}{\tau_g}(g_i - g_i^{eq}) \quad (5)$$

where distribution function f_i is used to calculate density and velocity fields and distribution function g_i to calculate temperature field. F_i is the forcing term which includes the buoyancy effect. τ_f and τ_g are the relaxation times carried by the momentum and energy respectively. The equilibrium function for the density and temperature distribution function for a D2Q9 model [6] respectively is:

$$f_i^{eq} = \omega_i\rho[1 + 3\mathbf{c}_i \cdot \mathbf{u} + 4.5(\mathbf{c}_i \cdot \mathbf{u})^2 - 1.5\mathbf{u}^2] \quad (6)$$

$$g_1^{eq} = -\frac{2\rho T}{3}\mathbf{u}^2 \quad (7)$$

$$g_{2,3,4,5}^{eq} = \omega_i\rho T[1.5 + 1.5\mathbf{c}_i \cdot \mathbf{u} + 4.5(\mathbf{c}_i \cdot \mathbf{u})^2 - 1.5\mathbf{u}^2] \quad (8)$$

$$g_{6,7,8,9}^{eq} = \omega_i\rho T[3 + 6\mathbf{c}_i \cdot \mathbf{u} + 4.5(\mathbf{c}_i \cdot \mathbf{u})^2 - 1.5\mathbf{u}^2] \quad (9)$$

The bounce back-rule of the non equilibrium distribution function is used for all the walls. The lattice configuration for D2Q9 is shown in Fig.2.

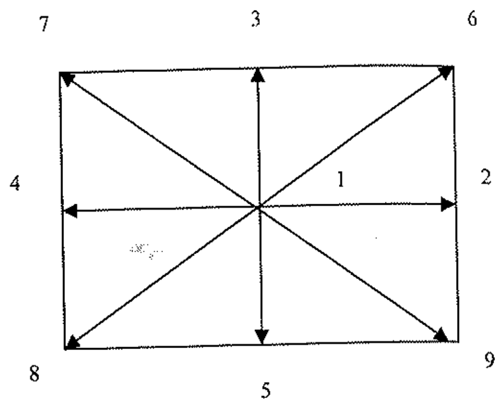


Figure 2. D2Q9, a nine-velocity lattice model with ω_1=4/9, $\omega_{2,3,4,5}$= 1/9 and $\omega_{6,7,8,9}$= 1/36

The macroscopic variables such as density, velocity and temperature can be calculated by taking moment to the distribution functions as follows:

$$\rho = \sum_1^9 f_i, \rho\mathbf{u} = \sum_1^9 \mathbf{c}_i f_i, \rho T = \sum_1^9 \mathbf{c}_i g_i \quad (10)$$

The time relaxations can be related to the macroscopic fluid kinematic viscosity and thermal diffusivity using the following equations:

$$\tau_f = 3\nu + 0.5 \quad (11)$$

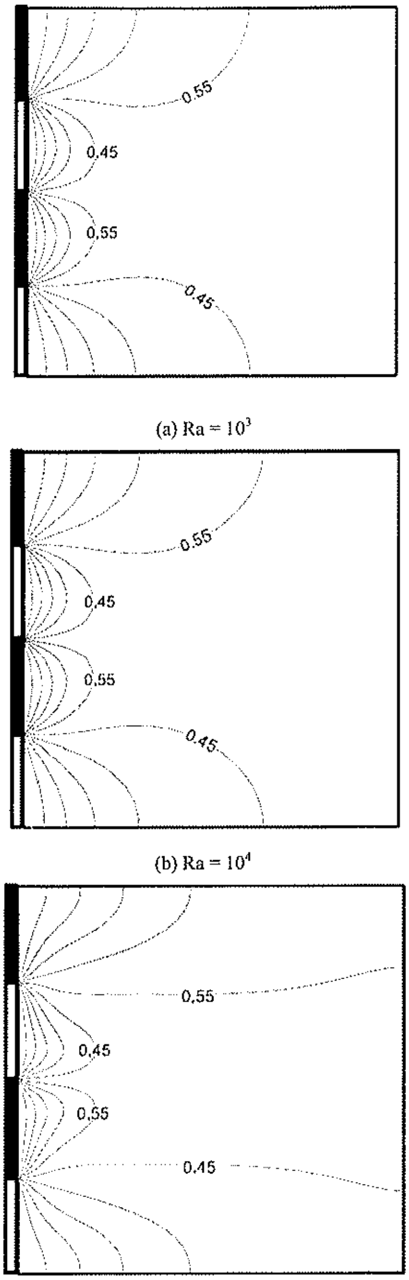
$$\tau_g = \chi + 0.5 \quad (12)$$

IV. Results And Discussion

Fig.3 and Fig.4 shows the plots of streamline and isotherms obtained for Ra = 10^3, 10^4 and 10^5. In this study, FORTRAN code was developed to solve the discretized equation. These streamlines and isotherms are found to be identical with macroscale solution obtained by other previous studies by solving the Navier-Stokes solution directly.

It can be observed that heat transfer is dominated by conduction when the sources and sinks are placed alternately on the same sidewall. This is due to the buoyancy effects which are now working independently. Large number of eddies are generated in the cavity. Due to mixing between these eddies; the fluid in the region away from the sources and sinks is at an averaged temperature. Therefore, it can be concluded that significant heat transfer only occur at the region close to the sources and sinks.

As Rayleigh number increases, the convective effect also slowly increases. However, heat transfer mode is still dominated by conduction.

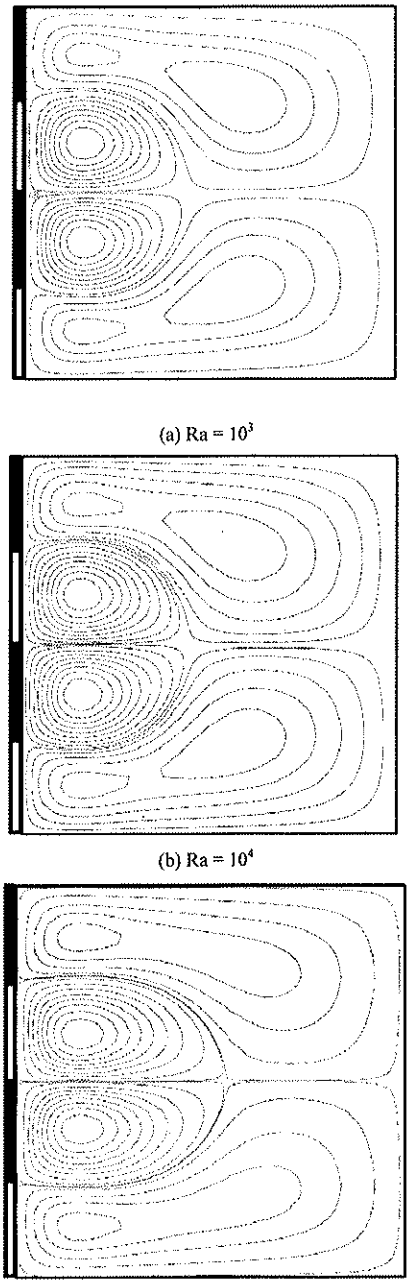


(a) Ra = 10^3

(b) Ra = 10^4

(c) Ra = 10^5

Figure 3. Isotherms for Ra = 10^3-10^5



(a) Ra = 10^3

(b) Ra = 10^4

(c) Ra = 10^5

Figure 4. Streamlines for Ra = 10^3-10^5

V. CONCLUSION

Natural convection in a two-dimensional square cavity driven by two discrete source-sink pairs on one vertical sidewall was studied by applying mesoscopic approach namely LBM.

The dominant heat transfer mode is conduction although convective effect slowly increases with Rayleigh number increment. Significant heat transfer activities only occur at the region close to the sources and sinks. This study proves that mesoscopic approach can be used as an alternative approach to solve this type of simulation problem.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and the Malaysian government for supporting this study.

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IEEE Catalog Number: CFP1195M-PRT
ISBN: 978-1-4244-9829-1