SIMULATION OF PARTICLE MOTION IN INCOMPRESSIBLE FLUID BY LATTICE BOLTZMANN MRT MODEL

MOHAMMAD POURTOUSI

A dissertation submitted in partial fulfilment of the

requirements for the award of the degree of

master of mechanical engineering

Faculty of Mechanical Engineering

Universiti Teknologi Malaysia

JANUARY 2012

To my beloved mother and father

ACKNOWLEDGMENT

I would like to thank Dr. Nor Azwadi Che Sidik for his direction, assistance, and guidance. Special thanks should be given to my friends in UTM university who helped me in this project.

Finally as far as there is a limit time and paper , it is impossible to mention all of my friends that have had good impact on my master project . only I would like to warmly appreciate my parents supports during doing this project and other friends helps to toward my work.

ABSTRACT

As far as these days developing simulation fluid flow in different geometries are one the main concern of thermo fluid researchers , This study are going to employ Lattice Boltzmann Method as a computational method to solve some different geometries. This approach tends to demonstrate different accuracy and stability in two Relaxation time for Lattice Boltzmann Method(LBM) in lid driven cavity .Velocity field for different Reynolds number and aspect ratio in channel fluid flow are systematically presented to interpret developed vortex in different time. In this geometries multi particles are simulated for different Reynolds number and it is found that the percentage of removal particles in different time after stability is decreased by growing aspect ratio . In final section Multi-relaxation-time based on Lattice Boltzmann method is applied for simulation of backward-facing step .The obtained results shows position and length of the vortex. The numerical results obtained in this paper are in good agreement with the published experimental and numerical results.

ABSTRAK

Setakat yang hari ini, pembangunkan simulasi aliran bendalir dalam geometri yang berlainan adalah satu kebimbangan utama penyelidik bendalir termo. Kajian ini akan menggunakan Kaedah Kekisi Boltzmann sebagai satu kaedah pengiraan untuk menyelesaikan beberapa geometri yang berbeza. Pendekatan ini cenderung untuk menunjukkan ketepatan dan kestabilan yang berbeza dalam dua masa Kelonggaran untuk Kaedah Kekisi Boltzmann dalam yang aliran didorong oleh rongga tudung. Medan halaju untuk nombor Reynolds yang berbeza dan nisbah aspek dalam aliran bendalir saluran secara sistematik dibentangkan untuk mentafsir vorteks dibangunkan dalam masa yang berbeza. Dalam geometri ini, simulasi pelbagai zarah dilakukan untuk nombor Reynolds yang berbeza dan mendapati bahawa peratusan penyingkiran zarah dalam masa yang berbeza selepas kestabilan berkurang dengan penambahan nisbah aspek. Dalam seksyen akhir kelonggaran masa pelbagai yang berdasarkan kaedah Boltzmann kekisi digunakan untuk simulasi langkah menghadap ke belakang. Keputusan yang diperolehi menunjukkan kedudukan dan panjang vorteks. Keputusan berangka yang diperolehi dalam kertas ini adalah dalam persetujuan yang baik dengan keputusan uji kaji dan berangka penerbitan.

TABLE OF CONTENTS

LIST OF FIGURES

Figures **Title** **pages**

NOMENCLATURE

f	distribution function in discrete Boltzmann equation and in the LB fluid flow model
ν	Kinematic viscosity in the lattice Boltzmann method
ρ	Dimensionless fluid density in the lattice Boltzmann method
τ	Single Relaxation time of Boltzmann equation
u	Macroscopic flow velocity in the lattice Boltzmann method
c_i	Discrete particle velocity in each discrete direction
C_s	Speed of sound
t	Time
m	Physical molecular mass
Ma	Mach number
f_d	Drag Force
F_e	External Force
F_b	Buoyancy Force
C_d	Drag Force Coefficient
CFL	Courant- Friedrichs - Lewy number
AR	Aspect ratio of the channel cavity
d_p	Particle diameter
Re	Channel Reynolds number

Re_p	Particle Reynolds number
BGK	Bhatnagar-Gross-Krook
CFD	Computational Fluid Dynamics
D2Q9	Two Dimensions nine velocities lattice Boltzmann method
FEM	Finite Element Method
FDM	Finite Difference Method
FVM	Finite Volume Method
LB	Lattice Boltzmann
LBE	Lattice Boltzmann Equation
LBM	Lattice Boltzmann Method
LGA	Lattice Gas Approach
PDE	Partial Differential Equations
MRT	Multi Relaxaion Tim

CHAPTER 1

INTRODUCTION

1.Introduction

Many methods have been recently introduced in order to analyze a laminar flow and its modeling of hydrodynamic or aerodynamic removal of particles from the internal surfaces . They have tended to solve physical problems for different geometries in industries and research laboratories . In this case Lattice Boltzmann method (LBM) is one of the newest method that has been vastly studied by a huge number of papers. As a matter of fact, Lattice Boltzmann scheme is one of the numerical techniques that is normally used to solve the equation of turbulent and laminar flow which is represented time –dependent fluid flow [1].

Also it should be noted that, LBM is one of the most effective numerical ways for simulating and modeling complicated physical chemical system with complex geometry. LBM has introduced as a microscopic numerical method and has a certainly effect on simulating fluid flow . In particular, the easy implementation of boundary conditions makes LBM very interesting for the simulation of multiphase flows and specially flow in complex geometries[2].

To solve Lattice Boltzmann equation partial differential must be considered. In this regard partial differential equation presents fluid flow through the space and

time .As a matter of fact ,certain solutions only exist for a few specific cases with simple geometries and suitable boundary conditions. It is certainly true that to obtain simplified equation , the complex phenomena must be ignored. However, nowadays digital computers have rapidly developed and many researchers prefer to use high performance computers in their field of study.

Many papers have been presented Lattice Boltzmann in different groups by researchers and indeed , three groups of them have been broadly developed in their field of studies . First of all different type of fluid flow respect to the fluid regime consist of laminar, turbulent and incompressible flow and therefore, different Reynolds number and changing characteristic of fluid are used by seintic .The second group wants to indicate different geometries and different aspect ratio in 2D and 3D modeling patterns.

Finally last group of papers are clearly represented by engineers which discuss a bout different theoretical ,numerical and experimental methods of solving the equation and simulation fluid flow in different shapes. Moreover, their results are compared by exits ones to show the validation.

Many years ago, the modeling of incompressible Laminar fluid flow inside the different kind of geometries was investigated and there are number of articles published by researchers in entire the world . The current study tends to present the incompressible fluid flow in case of laminar by MRT-LB method for different physical problems such as cavity and channel flow. Furthermore it shows the discrepancy between this numerical modeling with SRT method.

The present work is going to consider the difference between Multi relaxation time and single relaxation time in terms of accuracy and stability in cavity. Moreover , the instability of fluid flow is performed by different meshes and Reynolds numbers.

Since a plotting vortex and streamlines for fluid flow are one of the important concern for scientists ,this study investigates a prediction of vortex structure and different position of vortex with particle trajectory in channel to show clearly this phenomenon .

Also a reattachment area for vortex inside the backward facing step flow is carried out and verified with available benchmark in different time and Reynolds numbers. To extend this work Multi particles with Lattice Boltzmann based on Multi Relaxation Time inside the channel are simulated and then agree well with a existing numerical results.