FLOW AROUND A PAIR OF SIDE BY SIDE SQUARE CYLINDER IN TANDEM ARRANGEMENT USING LATTICE BOLTZMANN METHOD

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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LIST OF SYMBOLS

u	Velocity of the fluid parcel
P	Pressure
ρ	Fluid density
τ	Time relaxation
υ	Viscosity of fluid
$\Omega_{(x\ t)}$	Single relaxation time
f_{α}	Current distribution of particles
$f_{\alpha}^{(eq)}$	Equilibrium distribution function
Ω	Collision integral
Δt	Time change
η	Navier stokes constant
S	Pre collision
g	Radial distribution function
κ	Collision coefficient
J	Enskog collision term
x_i	Characteristic length
b	Number of discrete body in the model
Re	Reynolds number
α	Represent particle number

a	Acceleration
d	Depth of the chamber
δ	Thickness
L	Length
e_α	Discrete velocity
ω_α	Corresponding weight
t	Time taken
∂_t	Partial derivative of time
∇	Change of
c_s	Speed of sound
ξ	Abscissas
δ_t	Time step
λ	Wavelength
D_t	Time step (ODE function)
ψ	Cartesian (velocity) space
ζ	Momentum
I	Integral of moment
m	Boltzmann constant

LIST OF ABBREVIATIONS

BGK	Bhatnagar Groos Krook
CFD	Computational fluid dynamics
D2Q4	Two dimensionals four velocities model
D2Q6	Two dimensional six velocities model
D2Q7	Two dimensional seven velocities model
D2Q9	Two dimensional nine velocities model
D3Q27	Three dimensional twenty seven velocities model
LB	Lattice Boltzmann
LBE	Lattice Boltzmann equation
LBM	Lattice Boltzmann method
LGA	Lattice gas approach
MD	Molecular dynamics

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ABSTRACT

This thesis introduces a method which is Lattice Boltzmann Method. Flow around square cylinder has been carried out in this project using LBM. The project consisting two-dimensional numerical simulation of isothermal fluid flow around a couple of different size of cylinder aligned along to the main flow direction, at several distances. Vorticity and recirculation zone is studied in detail to find what are parameters affected it. The vorticity and the recirculation zone are obtained and compared with other existing results. The simulation is carried out by using FORTRAN and AVS software. This project has been done for low Reynolds Number ranging 10 to 60. The result obtained is well agreed with other researcher by using of simulation software.

ABSTRAK

Tesis ini memperkenalkan suatu kaedah iaitu kaedah kekisi Boltzmann. Pengaliran di sekeliling silinder bersegi telah dijalanakan di dalam projek ini dengan menggunakan kaedah kekisi Boltzmann. Projek ini merangkumi simulasi perangkaan dua dimensi aliran air isoterma disekeliling pasangan silinder bersegi dengan saiz yang berbeza yang disusun hujung ke hujung pada beberapa jarak. Kajian terperinci dijalankan terhadap pusaran dan zon peredaran dan apa yang menyebabkannya. Pelbagai keputusan terhadap pusaran dan zon peredaran akan di bandingkan satu sama lain. Simulasi dijalankan dengan menggunakan perisian FORTRAN dan AVS. Projek ini akan menumpukan nombor Reynolds yang rendah sahaja dalam lingkungan 10 hingga 60. Keputusan yang diperoleh adalah bersesuaian dengan pengkaji-pengkaji lain yang menggunakan perisian simulasi.

CHAPTER 1

INTRODUCTION

1.1 Project Background

This project involves the study of isothermal Lattice Boltzmann cases. Lattice Boltzmann Method (LBM) would be an alternative approach technique for solving the fluid flow problem as it has found recent successes in solve many fluid dynamics problems. Other method before Lattice Boltzmann Method arise which is Molecular Dynamics (MD) and Lattice Gas Approach (LGA) tend to get some problem or cannot get an accurate result needed. So, the better way to use LBM instead of MD or LA. The primary goal of this approach is to build a bridge between the microscopic and macroscopic dynamics, rather than to deal with macroscopic dynamics directly. In the simple word, is the derivation of macroscopic equation to microscopic dynamics. There have a number of advantages by using LBM. The algorithm is simple and can be implemented with a kernel of just a few hundred lines. The algorithm can also be easily modified to allow for the application of other more complex simulation components plus shorter time needed and lower computer speed.

Flow over a cylinder has been studied extensively. It exhibits vastly different behaviour as the Reynolds number, based on free stream velocity, cylinder diameter and kinematic velocity, increase from zero to large values. Flow around a pair of circular cylinders could provide an in-depth understanding of vortex dynamics, pressure distribution and fluid forces associated with multiple cylinders. Aerodynamic interference between two cylinders may result in flow separation, reattachment, vortex impingement, recirculation and quasi-periodic vortices, involving most generic flow features associated with multiple cylinders. As such, the flow around two cylindrical bluff bodies has been extensively investigated in the past. In the current investigation, we are interest in the problem of flow interference when two square cylinders are place side by side in tandem arrangement in a steady flow. Williamson (1983), who discovers the same problem but it has three cylinders and vertical arrangement observe that when more than one body is placed in a fluid flow, the resulting forces and vortex shedding pattern maybe completely different from those found at the same Reynolds number. A variety flow pattern characterized by the behaviour of the wake region may be discerned as the spacing between three cylinders is changed. When the three cylinders are arranged, the flow behaviour is characterized by the two ratios L_j/d, where L_j are centre to centre cylinder spacing and *d* is the cylinder diameter. Flow visualisations by Williamson (1983), found that with three side-by-side cylinders subject to a uniform cross flow, the wake flow strongly depends upon Reynolds number and the gap between cylinders. When the gaps are equal, the flow is symmetric about the centreline, with a wide wake behind the central cylinder and two wakes behind the outer cylinders.

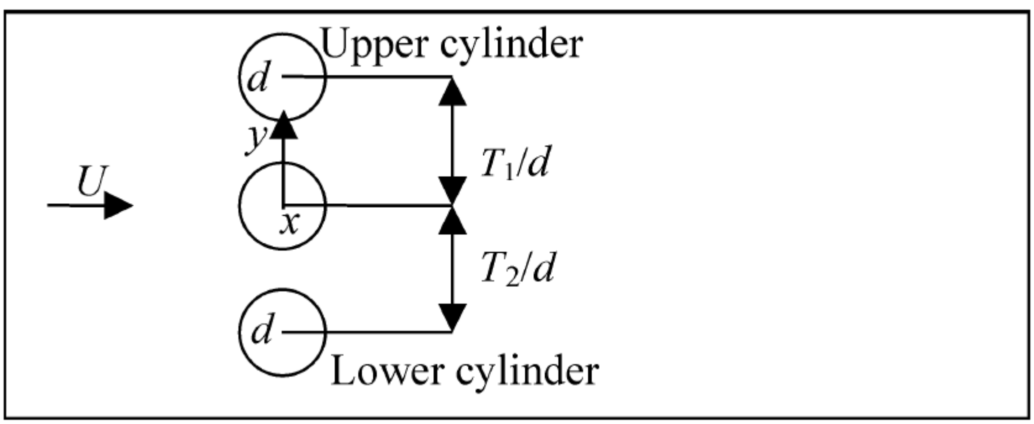

Figure 1.1: Schematic description of three side-by-side cylinder

(H. K. Virahsawmy et al, 2004)

However, when the two gaps are different, deflection of the gap flow occurs, forming a wide wake behind the lower/upper cylinder and two narrow wakes behind the lower/upper and central cylinder respectively, depending on the gap spacing. They observe that the deflected gap flows were stable, but nonlinear interaction between two wakes may generate pressure fluctuation that cause reorientation of both gap flow.

The numerical technique employed is a recently developed lattice Boltzmann method (LBM), as introduced by Chen and Doolen, (1998) with a BGK, single relaxation time, collision model. LBM is characterized by a clear picture of the physics of fluids, the natural parallelism, and ease to handle interactions between fluids and structures. The reliability and efficiency of LBM have been well demonstrated by a number of studies in various fields. The use of lattice Boltzmann as a working method in this class of problems has some important, well-known advantages: (i) programming is very easy and (ii) the method is intrinsically parallel. Nevertheless, it appears that the most important advantage of the LB method with respect to classical CFD methods is related to the needless of velocity field numerical derivatives in calculating the drag force. In fact, due to its mesoscale nature, drag force can be directly calculated in LB methods by, simply, considering the momentum exchanged between the lattice particles and the solid body.

1.2 Project Objective

1) Investigate the effect of flow pattern under different Reynolds Number, gap between two cylinders and size of the cylinder.
2) Investigate the flow pattern under combination of different Reynolds Number with different gap and size of the cylinders.
3) Study the methods of Lattice Boltzmann in order to apply in the isothermal fluid flow problem.

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