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Simulation of Different Behaviors of the Blowing Air through Air Conditioner Using Lattice Boltzmann Method

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Abstract*—Nature has a very efficient way to process information. Processes studied by natural scientists involve systems that are either continuous, stochastic, spatially extended, or any combination of these, and fall strictly outside the range of discrete computation theory. The study of information processing in complex dynamical multi scale systems is, therefore, still in its infancy. Our aim is to understand how nature processes information. We can detect and describe the complex computational structure in natural processes and we can provide a quantitative characterization of essential aspects of heat convection in the room which is the typical features of effect of Air conditioner in conference room. Aim of the study deal with the two different behaviors of the blowing air through air conditioner, first, to Fixed air-condition in which cold air blow with a constant angle and second swiping air-condition in which the cold air blow with the swiping up and down. This research is driven by the ever increasing amount of experimental data as delivered, to find out which process is more efficient to cool down the room

***Index Terms*—Lattice Boltzmann Method, Air Conditioner, Heat Convection.**

I. INTRODUCTION

This work is inspired from the wide complexity of the physical systems and consequently by the necessity to simplify their complexity into fundamental processes. In recent years, the lattice Boltzmann method (LBM) has developed into an alternative and promising numerical scheme for simulating fluid flows and modelling physics in fluids. The scheme is particularly successful in fluid flow applications involving interfacial dynamics and complex boundaries. Unlike conventional numerical schemes based on discretization of macroscopic continuum equations, the lattice Boltzmann method is based on microscopic models and mesoscopic kinetic equations. The fundamental idea of the LBM is to construct simplified kinetic models that incorporate the essential physics of microscopic or mesoscopic processes so that the macroscopic averaged properties obey the desired macroscopic equations. Historically originating from the lattice gas automata (LGA) introduced by Frisch, Hasslacher, and Pomeau [3], the lattice Boltzmann equation (LBE) has recently become an alternative method for computational fluid dynamics. The essential ingredients in any lattice Boltzmann models which are required to be completely specified are: (i) a discrete lattice space on which fluid particles reside; (ii) a set of discrete velocities to represent particle advection; and (iii) a set of rules for the redistribution of particles residing on a node to simulate collision processes in a real fluid. Fluid-boundary interactions are usually approximated by simple reflections of the particles by solid interfaces. In a hydrodynamic simulation by using the lattice Boltzmann equation, one solves the evolution equations of the distribution functions of pretended fluid particles colliding and moving synchronously on a highly symmetric lattice space. The highly symmetric lattice space is a result of the discretization of particle velocity space and the condition for synchronous motions That is, the discretizations of time and particle phase space are coherently coupled together. This makes the evolution of the lattice Boltzmann equation very simple, it consists in only two steps: collision and advection. One immediate limitation of the LBE method is due to its use of highly symmetric regular lattice mesh, which is usually triangular or square lattices in two dimensions and cubic in three dimensions. Obviously this is a serious obstacle to its applications in many areas of computational fluid dynamics. To deal with complex computational domains, various proposals have been made to use grids that are better suited to fit boundaries or to adapt meshes according to the physics of the system. It has been shown recently that the lattice Boltzmann equation is indeed a special finite difference form of the continuous Boltzmann equation with some drastic approximations tailored for hydrodynamic simulations [4, 5, 7]. This makes the lattice Boltzmann method more amenable to incorporate body-fitted meshes [8, 9] or grid refinement techniques [10]. In most cases the regular lattice mesh is abandoned by decoupling the spatial-temporal discretization and the discrete velocity set, so that interpolations can be used in addition to the advection on a non-regular or non-uniform mesh. In this work Lattice Boltzmann Equation is used to simulate the flow through air conditioner. Here we take two different phenomena for judge the better cooling process. First, fixed initial velocity with fixed inlet geometry and the second is the fixed initial velocity with moving inlet geometry to fluctuate the inlet velocity direction. Most of the work is done with the fixed complex geometry or the geometry changes with the time but our model is capable to simulate the varying the inlet location for better understand the working patent of Air Conditioner at different conditions. Very accurate results could be obtained which are much better than those obtain by the conventional macroscopic method. For consider the process we take some assumptions to simplify the model complexity. We take room air is

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passive so the initial momentum of the particle is set to zero and having no velocity of its own, only the Air conditioner generate the momentum in the air. We consider as the miscible fluid because the no phase difference between the cold air of AC's and room air. We also consider the insulated room to avoid the exchange of temperatures between the insides and outside the room and gravity difference between cold air and native air is ignored. Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. **Do not change the font sizes or line spacing to squeeze more text into a limited number of pages.** Use italics for emphasis; do not underline.

II. THEORETICAL BACKGROUND

In this Lattice Boltzmann model we use the kinetic theory as a fundamental of Lattice Boltzmann equation. In kinetic theory we consider the hard sphere model with elastic collision. The position and the momentum of the molecules are defined as $x = (x, y, z)$ and $p = (p_x, p_y, p_z)$. Then $f(x, p, t)$ is the probability density function for the presence of molecule in six – dimensional phase space. The probable no of molecules with position coordinates in the range $x \mapsto x \pm dx$ and momentum coordinates $p \longmapsto p \pm dp$ is given by $f(x, p, t)dxdp$. We introduce an external force F that is small relative intermolecular forces. If there are no collisions, then at time $t + dt$, the new positions of molecules starting at x are $x + \left(\frac{dx}{dt}\right) dt = x + dx$ and the new momentum is $p + Fdt = p + \left(\frac{dp}{dt}\right) dt = p + dp$. Thus, when the position and momentum are known at a particular time t, incrementing them allows us to determine at a future time $t + dt$. Then the updated particle velocity distribution function is defined as $f(x + dx, p + dp, t + dt)$. If the collision in not occurs then the particle velocity is not change then $f(x + dx, p + dp, t + dt) - f(x, p, t) = 0$ and if the collision occur then there is a change in velocity distribution function and it is described as $f(x + dx, p + dp, t + dt) - f(x, p, t) \neq 0$. The Boltzmann Equation Expresses a balance between transport of a particle and collision between particles then

$$\frac{Df}{Dt}_{Transport} = \frac{Df}{Dt}_{Collision}$$

$$\therefore \frac{\partial f}{\partial t} + p_\alpha \frac{\partial f}{\partial x_\alpha} = C(f)$$

Where $C(f)$ models the pair wise collision between particles.

$C(f)$is evaluated by the Tailor's expansion of the updated velocity distribution function

$$dx\frac{\partial f}{\partial x} + dp\frac{\partial f}{\partial p} + dt\frac{\partial f}{\partial t} + \frac{(dx)^2}{2}\frac{\partial^2 f}{\partial x^2} + \frac{(dp)^2}{2}\frac{\partial^2 f}{\partial p^2} + \frac{(dt)^2}{2}\frac{\partial^2 f}{\partial t^2} + \frac{dxdp}{2}\frac{\partial^2 f}{dxdp} \frac{dpdt}{2}\frac{\partial^2 f}{dpdt} + \frac{dtdx}{2}\frac{\partial^2 f}{dtdx} = \Gamma^+ - \Gamma^-$$

$$dx\frac{\partial f}{\partial x} + dp\frac{\partial f}{\partial p} + dt\frac{\partial f}{\partial t} + \frac{(dx)^2}{2}\frac{\partial^2 f}{\partial x^2} + \frac{(dp)^2}{2}\frac{\partial^2 f}{\partial p^2} + \frac{(dt)^2}{2}\frac{\partial^2 f}{\partial t^2} + \frac{dxdp}{2}\frac{\partial^2 f}{dxdp} \frac{dpdt}{2}\frac{\partial^2 f}{dpdt} + \frac{dtdx}{2}\frac{\partial^2 f}{dtdx} = -\frac{f - f^{eq}}{\tau}$$

Then the equilibrium function is defined as $f^{eq} = \rho w_i \left[1 + \frac{3}{c^2} c_i u + \frac{9}{2c^4}(c_i u)^2 - \frac{3}{2c^2} u^2\right]$

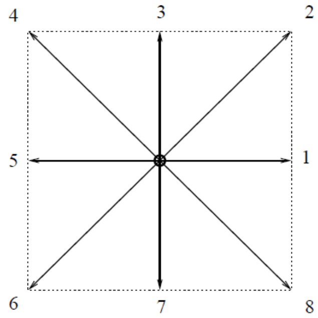

Fig 1: The lattice pattern of the D2Q9 model

Wherew_i, the weight factor corresponds to set of particles for D2Q9 lattice for rest particle $w_0 = \frac{4}{9}$, nearest neighbors have $w_i = \frac{1}{9}$ for $i = 1,3,5,7$ and farthest neighbors having $w_i = \frac{1}{36}$ for $i = 2,4,6,8$. $c_i$is the discrete sets of velocities for D2Q9 lattice and is defined as $c_0 = 0$, nearest neighbors $c_i = c\left(\cos(i-1)\frac{\pi}{4}, \sin(i-1)\frac{\pi}{4}\right)$ for $i = 1,3,5,7$ and farthest neighbors $c_i = \sqrt{2}c\left(\cos(i-1)\frac{\pi}{4}, \sin(i-1)\frac{\pi}{4}\right)$ for $i = 2,4,6,8$. We take the speed of light in the media $c = \sqrt{3w_0}\frac{\Delta x}{\Delta t}$ where Δx and Δt is the lattice spacing and time spacing respectively. For these models we take single time relaxation parameter $\tau = 1$. The macroscopic variables are defined as a velocity moments of the velocity distribution function

- Mass density: $\rho(x,t) = m\int f(x,p,t)\,d^3p$
- Flow velocity: $u(x,t) = \frac{m}{\rho}\int p\, f(x,p,t)\,d^3p$
- Temperature: $T = \frac{m}{2R\rho}\int |p|^2\, f(x,p,t)\,d^3p$
- Stress Tensor$p_{\alpha,\beta} = m \int f(x,p,t)(p_\alpha - u_\beta)\, f(x,p,t)\,d^3p$

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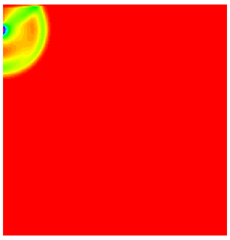
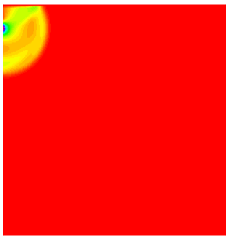
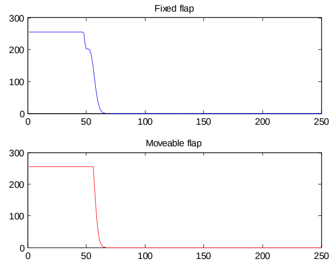
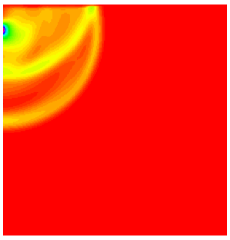
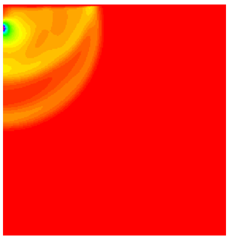
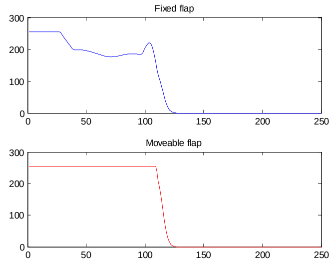
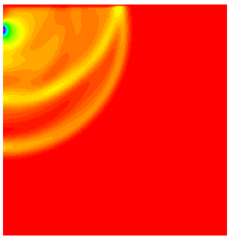
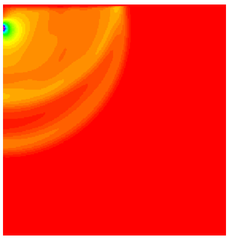
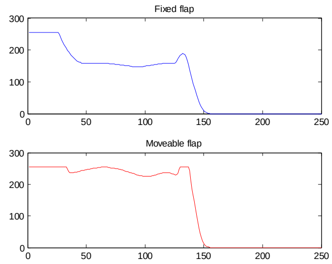
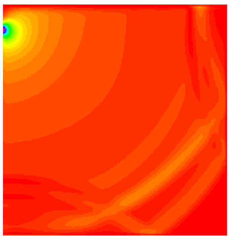
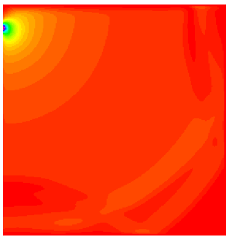
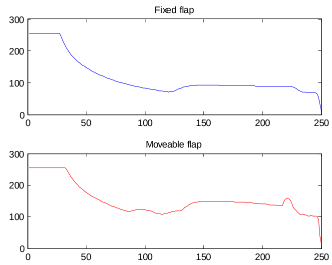
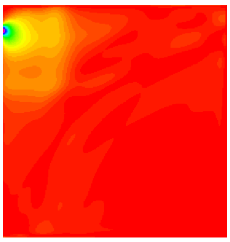
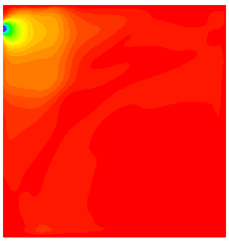
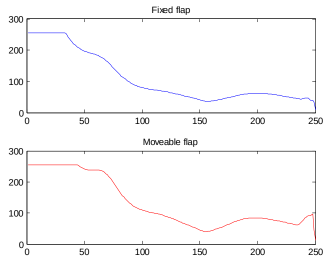
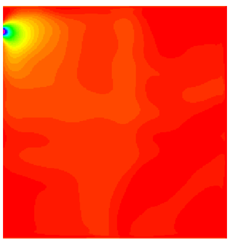
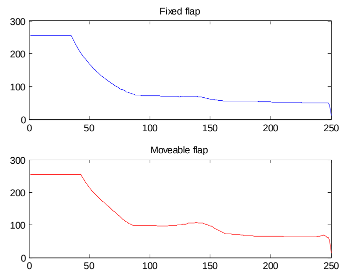
III. SIMULATION RESULTS

Δt	Moving flap (model – 2)	Fixed flap (model – 1)	No of particle with velocity
100			
200			
300			
500			
1000			
2000			

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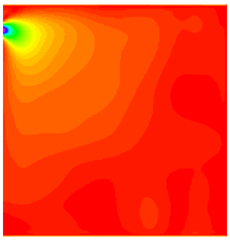
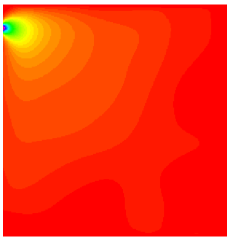
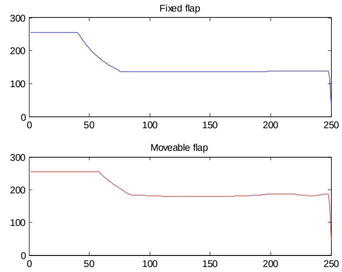
5000			

Table 1: simulation of model – 2 and model – 1 with the different time interval and in the last column gives the no of particles with the given velocity

We simulate 2 models, namely model – 1, the fixed flap in Air conditioner and model – 2, the moving flap in Air conditioner. In model – 1 fixed flap the flap is steady at the constant angle 45o and model – 2, the moving flap changes its position form 30o to 45o after seven iterations. In both the model simulation we took mesh of 1250 x 1250 and the results are based on the equilibrium distribution and hydrodynamic boundary conditions. We consider the Reynolds number Re = 100 and the initial velocity taken as 0.2 for the simulations. In the last column of the Table we observed that the area covered by the red curve has more area then blue line so, model – 2 having more active (velocity) particles as compare model – 1. In this work we consider equilibrium function in the Lattice Boltzmann equation is considered up to the second order with can be good arguments between the accuracy of the solution and computational needs.

IV. CONCLUSION

A lattice Boltzmann equation was successfully applied to simulate the Air Conditioner flow. The result obtain by the model 2 are in good agreement with those of model 1. As compared with model – 1, the model – 2 gives more efficient cooling because of additional mobility provide to the particle by the moving flap. For the comparison with both models, it can provide the same order of accuracy but require more computational effort. The major advantage of model 2 over the model 1 is that it can be applied to problems with complex inlet geometry.

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