Research of Heat Flow Simulation by the Lattice Boltzmann Method

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1 A Background and Purpose

In computational fluid dynamics, the main method is Finite Difference Method, Finite Element Method utilizing discrete equation derived from Navier-Stokes equation today.

On the other hand, there is Particle Method as a method of seeing the flow from a microscopic standpoint. It is assumed that there is a possibillity that the phenomenon with a difficult achivement(immiscible two-phace flow as water and oil, flow through porous media etc.). A fluid consists of many particles, the configuration of particles at each time step evolves in two step, streaming and collision. It takes time to judge which particle collided.

The method of overcoming such a respect is lattice gas automaton method (LGA). The particle move on the lattice, and collide without fail every one step. The movement of the particle limited as this. Therefore, the collision judgment of each particle becomes useless. And, the calculation is simplicity (Boolean operation). But, the calculation lattice is needed more than other methods when accuracy is improved, becouse the space average is taken in the calculation of a physical amount of the flow.

The increase of this calculation lattice is suppressed, and the method of making the calculation rule a real number calculation is Lattice Boltzmann Method (LBM). This composes the lattice, too. It is a method of analyzing the flow from the distribution probability of the particle with each velocity vector on the node. It is based on the Boltzmann equation by which the movement of the particle is shown in a microscopic standpoint. It is possible the basic equation of fluid to approximate from discrete equation of this equation. The behavior of the particle in microscope can be caught also with

LBM. Characteristic of particle method of possibility that phenomenon with difficult achievement can be expressed in past difference method etc. And such a try are some reported.

LBM is a technique designed in recent years. It is recent that the theory has been maintained. The thesis which treats concrete numerical calculation of the heat flow phenomenon is still few. Especially, heat flow in the system where body force (gravity) exists is not handled. So, the Lattice Boltzmann Method by which the flow with heat can be treated is examined. In addition, the effect of external force is put.

The purpose of this research is to simulate the natural convection phenomenon which heat and flow.

2 Scheme

As the state of the particle in the Lattice Boltzmann Method heat flow decided to be handled by 25 kinds of particle which were.

I assumed as a equilibrium distribution function The expression of the low speed Taylor expansion(up to third order) of Maxwell-Boltzmann distribution which was the equilibrium solution of the Boltzmann equation.

To satisfy the law of energy conservation almost completely, the scheme is composed of the condition like two points above. In that case, conditions such as newton fluid, incompressibility, and ideal gases are imposed.

To approximates to the NS equation by the Lattice Boltzmann Method in this research, The relational expression of an undecided coefficient of the equilibrium distribution function is obtained by the technique which uses the Chapman-Enskog expansion procedure. However, because the number of relational expressions is fewer than the number of coefficients, the equilibrium distribution function has arbitrariness. Then, to approach the Boultzmann distribution of energy, mathematical planning is done. The equilibrium distribution function was uniquely requested to a physical amount.

About body force, There is the announced LBM which contains body force. Numerical steady simulation can have been done by changing some expressions of this.

In the boundary condition, the two condition of boundary on the node and boundary between the nodes was mounted.

3 Result

The result of obtaining for this research is shown as follows.

1. By taking Boltzmann distribution of energy into consideration, The equilibrium distribution function for the 25 kinds of particle state is obtained. This is satisfyed NS equation, has appropriate particle distribution in physics (The distribution of the particle with high energy increases when becoming a high temperature).

2. The treatment of body force for LBM is somewhat changed. It was suppressed to take a negative particle distribution by calculations process, and stabilized numerical.

   Moreover, the behavior of the thermohydrodynamic (natural convection) in the gravity field was able to be simulated almost.

3. About the treatment of the boundary condition, The system of the Couette flow if boundary is on the node or between the nodes was tried.

   There is defferent behavier of heat flow as this two kind of boundary position. The result that the calculation by the boundary between the nodes was few the error with analytic solution (heat distribution) than the other one was obtained.

4 Problem to be solved

To simulate concrete numerical problem, I thought that the method of treatment of boundary condition is as important as the scheme. I should study particular analysis to boundary condition for the LBM of heat flow.

The rusult around boundary of simulation in this research be different from the one of FDM. Especially, it is the on in the boundary by which the condition of insulation is imposed. A detailed analysis to the boundary condition might have to be examined with LBM of heat flow.

And, To calculate problem in hard condition as natural convection of high Ra number (the paper didn't treat this problem.). It need to research about parameter ajusted problem condition carefully, which relates numerical stability condition for LBM(CFL condition for FEM) and relation between unit time step and unit velocity length, transport cofficient.