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Simulation of Thermal Binary Components Flow by the Lattice Boltzmann Method

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1 Background and Purpose

Since Finite Difference Method and Finite Element Method consisted with discrtizations of Navier-Stokes Equation and Poisson Equation are often used in Computational Fluid Dynamics, these methods require phase boundary to simulate binary components fluid and therfore these methods are hard to apply mixture of immiscible binary components fluid.

In contrast, algorithms based on particle method which analyze flow field by particle dynamics need not to describe the entire flow field with a system of equation. So, particle method can apply mixture of immiscible binary components fluid, which is hard for FDM and FEM to be applied, and can simulate phase separation in self organizing way without explicit phase boundary.

There are many methods based on partcile method: Molcular Dynamcs, Monte Carlo Method. These methods have a limit number of particles which depends on resources of computer, because these methods have to solve force effected on particle at each timestep.

In case of no requirements of particle motion in detail, lattice Boltzmann method (LBM), which uses statistics of particles, is effective. LBM is a modified model of Lattice Gas Automata (LGA), LGA limits particle velocity in order to hold particle on lattice and sets collision pattern of particle in advance. LGA has a high efficiency on caluculation because of particle velocity limit and rurled collision pattern. Then, LGA is unable to have more than 2 particles of the equal velocity on each lattice point due to determination of collision pattern. For reasons of this, macroscopic quantites includes noize essentially.

LBM is the same method as LGA in point of having particle velocity limit, LBM uses Boltzmann Equation to govern particle translational movement and collision. Therfore, LBM has no exclution of particle like LGA, and LBM can exclude noize which LGA includes from macroscopic quantities.

In research of LBM, there has been analysis of nonthermal binary components flow, thermal single component liqiud-gas flow, and so on. But, there exists a few research of thermal binary components flow by means of LBM.

In this research, an expansion method of many thermal/nonthermal lattice Boltzmann models is presented. Then simulation of natural convection under gravity is examined with this expaneded lattice boltzmann model.

2 Scheme

In this research, after an extension to thermal/nonthermal multiple components LBM with thermal/nonthermal single component LBM is presented, these modified LBM is examined. First, to verify modified LBM, an modifed model of 2D9V nonthermal LBM proposed by S.Hou et.al with the identical component is examined whether result of this modefied LBM is equal to that of original LBM. Then, an modifed model of 2D21V thermal LBM proposed by M.Tsutahara, N.Takada with the identical component is examined whether result of this modified LBM is equal to that of original LBM. Finally, an modifed model of 2D21V thermal LBM proposed by M.Tsutahara, N.Takada with particle mass of different virtually is applied to simulation of natural convetion under gravity.

3 Result

1. An modifed model of 2D9V nonthermal LBM proposed by S.Hou et.al is applied to simulate 2D cavity flow. The result equal to result of original 2D9V LBM is given without difference between components.

2. An modifed model of 2D21V thermal LBM proposed by M.Tsutahara and N.Takada is applied to simulate 2D Benard convection. In case of no difference between components, the result equal to result of original 2D21V LBM is given.

3. An modifed model of 2D21V thermal LBM proposed by M.Tsutahara and N.Takada is applied to simulate 2D natural convection such as Benard convection. As a result, it is possible to simulate phenomenon that with a initial mixture state of immiscrible binary components and virtual particle mass difference, a mixture of immiscrible fluids separate in self organaizing way, and a phase of light mass particle which is cooled at low temperature wall, causing an increase of local density of that phase, sinks down to a phase of heavy mass particle.