

Optimization of the Lattice Boltzmann Thermal Model for Simulation of Liquid-Vapor Phase Change

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The pseudo-potential lattice Boltzmann (LB) phase change model has been widely applied in the simulation of liquid-vapor phase change problem. In the simulation, the LB method are applied in modeling of both two-phase flow and the energy transition. However, Li et al. [Physical Reviews E 96, 063303 (2017)] pointed out that the LB thermal equations cause errors when applied with pseudo-potential model. To eliminate these errors, they proposed an improved model by adding correction terms in the LB thermal equation. In their research, the treatment of these correction terms is quite complex and several finite-difference (FD) computations are adopted to discretize these correction terms. Hence, they suggested to solve the energy equation directly with the FD method. However, it is found the stability and efficiency of the FD method are highly dependent on the time step and the thermal parameters of the object, while these influence is much smaller when LB method is applied in the diffusion-convection simulation. Hence, it is necessary to develop a LB thermal model free of error terms with minimum finite-difference (FD) computations.

To achieve this goal, in this work, a lattice Boltzmann thermal model is proposed to solve the energy equation in the pseudo-potential phase change model. Chapman-Enskog expansion shows that the error terms existed in the former LB thermal models can be avoided in this model without adding correction terms. Compared with the LB model proposed by Li et al., this model is free of additional temporal discretion treatment and the spatial discretion is also reduced by introduction of a local discrete scheme. The proposed model is then verified in several benchmark simulations and numerical compared with results obtained by the FD schemes. The simulation results agree well with the analytical and standard results, and the stability of the model is also improved compared with the FD schemes.

Keywords: lattice Boltzmann thermal model; phase change; pseudo-potential