129d Lattice Boltzmann Simulations of Non-Newtonian and Viscoelastic Flows

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The simulation and modeling of non-Newtonian and viscoelastic fluids are of high interest in both science and technology due to their broad applications in studying the flow behaviors of complex fluids containing polymers, surfactants, and/or colloids. Lattice Boltzmann (LB) method for specific models descriptive for non-Newtonian and viscoelastic fluids are developed. Unlike conventional numerical methods which discretize the macroscopic equations, LB method constructs simplified kinetic models incorporating the essential physics of microscopic processes so that the macroscopic properties obey the desired equations. Due to inherently transient nature, fully parallel algorithms, and easy incorporation of complex geometries, LB method has become an alternative and promising numerical scheme for simulating fluid flows and modeling complex physics in fluid systems.

The truncated power law and Carreau-Yasuda models are incorporated into lattice Boltzmann Bhatnagar-Gross-Krook (LBGK) method by generalizing the single relaxation time as a function of shear rate, which is space and time dependent. The Poiseuille flows are first simulated in 2D channels using modified LBGK method and the simulated velocity profiles obtained from truncated power law as well as Carreau-Yasuda models agree well with analytic solutions. To further demonstrate our simulation capability, we examined the hemodynamics. The pulsatile flow in the 2D channel was considered to mimic the blood flows in the artery induced by the heartbeat. Cosine wave changing flow rate is used as the inlet boundary, and bounce back boundary condition is used at the solid boundaries. The velocity and wall shear stress profiles are obtained.

LB method is further generalized to simulate the viscoelastic model including Maxwell's model. The Maxwell elastic stress is incorporated as an extra body force, which is calculated by discretizing time and spatial domain. The model includes memory of accumulated shear strain, which is a necessary and natural feature of viscoelasticity. As a case study, a transverse wave traveling in the viscoelastic fluid is simulated. Via using moving boundary and periodical boundary conditions, the velocity distribution is obtained, which agrees very well with the previous numerical studies.

In summary, we developed LB methods for non-Newtonian and viscoelastic fluids, which give accurate results in complex geometries. It is suggested that LB method is a powerful computational tool and can accurately simulate complex fluid flows including complex biological system.