Thermal Lattice Boltzmann simulation of forced convection using the double MRT model

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ABSTRACT

The Lattice-Boltzmann method (LBM) is an alternative and flexible approach for computational fluid dynamics (CFD). Unlike other direct numerical simulations (DNS) LBM is not solving Navier-Stokes equations but is based on kinetic theory and the discrete Boltzmann equation. LBM utilizes a Cartesian mesh and hence does not require a complex mesh derivation or a re-meshing in case of moving boundaries. Thermal LBM (TLBM) relies on a set of two distribution functions, the so called double distribution function (DDF) approach [1]; one for the fluid density and one for the internal energy. For the carried out numerical investigations a 3D TLBM framework is derived. Both, the fluid field and the temperature field are represented by a multiple-relaxation-time (MRT) [2-4] collision operator. For the hydrodynamic boundary conditions, a scheme introduced by Bouzidi et al. [5] is applied with quadratic interpolation. Thermal boundary conditions are prescribed according to Li et al. [6] with linear interpolation. The used boundary conditions are superior to the standard half way bounce back and are suitable for curved boundaries. The derived TLBM framework is applied to diffusion and convection-diffusion problems (e.g. forced convection) for plane and curved boundaries and is validated against analytical solutions, if avialiable or compared to established correlations [7] for forced convection problems. The thermal MRT operator is further compared against the Bhatnagar-Gross-Krook (BGK) operator regarding accuracy, computational effiency and numerical stability. Results for averaged and local heat transfer coefficients are presented. The findings indicate that the double MRT framework with interpolated boundary conditions offers an accurate and efficient approach for heat transfer problems under resolved flow.

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