Thermal Lattice Boltzmann simulation of fluid flow through a packed bed

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ABSTRACT

The lattice Boltzmann method is a flexible approach for computational fluid dynamics. Based on combined distribution functions for the density as well as for the internal energy combined problems with thermal and fluid flow can be addressed [1]. For the carried out numerical investigations a LBM framework is derived. A D3Q19 model is applied in which the fluid flow is calculated by a multiple-relaxation-time (MRT) [2] and the thermal flow by a Bhatnagar-Gross-Krook (BGK) collision operator [1]. For the fluid boundary conditions a scheme introduced by Bouzidi et al. [3] is used with linear and quadratic interpolation. Thermal boundary conditions are prescribed according to Lin et al. [5] also with linear and quadratic interpolation. The numerical framework is used to investigate the behavior of fluid flow which passes a fixed particle-bed regarding momenta and thermal phenomena. For the simulation validation a set of a single sphere and three spheres arranged in a row passed by a fluid at different Reynolds-numbers is chosen. The obtained drag coefficient and Nusselt number which represent forces and heat transfer respectively were compared to results from established correlations [6,7] and to finite volume CFD simulations. The deviation between the LBM approach and the scientific correlations lies in a maximum range of five percent (5%). After benchmarking and validation, the LBM framework is used to simulate a fixed bed flown through by a fluid at varying Reynolds numbers. Forces and heat transfer are regarded and compared to finite volume simulations and to correlations from scientific literature. The results are in good agreement with established correlations available.

REFERENCES

[1] S.J. Almalovi, A. Oztekin, *Flow Simulations Using Two Dimensional Thermal Lattice Boltzmann Method*, J. Appl. Math., **2012**, 1-12, (2012)

[2] D. D'Humières, I.Ginzburg, M. Krafczyk, P. Lallemand, L. Luo, *Multiple-relaxation-time lattice Boltzmann models in three dimensions*, Philos. Trans. A. Math. Phys. Eng. Sci., **360**, 437–51, (2002)

[3] M. Bouzidi, M. Firdaouss, P. Lallemand, *Momentum transfer of a Boltzmann-lattice fluid with boundaries*, Phys. Fluids, **13**, 3452-3459, (2001)

[4] K. Lin, C. Liao, S. Lien, C. Lin, *Thermal lattice Boltzmann simulations of natural convection with complex geometry*, Comp. Fluids, **69**, 35-44, (2012)

[5] D.J. Gunn, *Transfer of heat or mass to particles in fixed and fluidised beds*, Int. J. Heat Mass Transf., **21**, 467–476, (1978)

[6] P.P. Brown, D.F. Lawler, *Sphere Drag and Settling Velocity Revisited*, J. Environ. Eng., **129**, 222-231, (2003)

[7] S.D. Dhole, R.P. Chhabra, V. Eswaran, *A numerical study on the forced convection heat transfer from an isothermal and isoflux sphere in the steady symmetric flow regime*, Int. J. Heat Mass Transf., **49**, 984-994, (2006)