Choosing Optimal L-BGK Simulation Parameters for Time Harmonic Flows

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We explore simulations of time harmonic flows by the lattice Boltzmann method (LBM), and extend the work by Artoli et al. [1], [2]. We propose a general scheme to choose simulation parameters, under the constraints of fixed Reynolds and Womersley numbers, and with a specified simulation error. Under these constraints four free parameters must be specified: the spatial and temporal discretization, the relaxation parameter τ (or related viscosity ν) and the Mach number Ma. The choice of these four parameters not only influences the accuracy of the method, but also other features such as stability, convergence and execution time. Under the constraints of a fixed Reynolds and Womersley number and a specified simulation error, we choose the simulation parameters such that the execution time of the simulation is minimized. We have formulated an asymptotic error theory, where we assume three sources of error, due to spatial and temporal discretization and due to compressibility. The errors due to spatial and temporal discretizations are of first or second order, depending on the boundary conditions and the compressibility error is known to be of second order in Ma. We derive iso-error contours in the $\tau - Ma$ plane (for fixed Reynolds and Womersley numbers). We have also measured errors in L-BGK simulations of three dimensional Womersley flow, from which experimental iso-error curves were extracted. The theoretical expressions fit the experimental results very well. From the fits we examine the relevance of each error component on the accuracy of simulations. Next we obtain (both theoretically and experimentally) the execution time along the iso-error curves, again yielding a good agreement between asymptotic error theory and experiment. Finally, we choose Ma and τ such that the execution time is minimized along the iso-error contour. In our case of harmonic 3D tube flow, and in the range of Reynolds and Womersley number that we covered, the minimum is reached for rather high Ma.

References

[1] A. M. Artoli, A. G. Hoekstra and P. M. A. Sloot *Comput. Fluids*, **35**, 227 (2006)

[2] A. M. Artoli, A. G. Hoekstra and P. M. A. Sloot *J. Biom.*, **39**, 873 (2005)

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