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A mass conserving boundary condition for the lattice Boltzmann method for tangentially moving walls

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Abstract

In the present discussion a no-slip boundary condition for walls with a tangential movement is derived. The resulting closure is local, conserves mass exactly and is second order accurate with respect to the grid spacing. In addition it avoids the numerical instabilities observed for other types of boundary conditions. Therefore the resulting boundary condition is stable for relaxation frequencies close to two. The present boundary condition is verified for Couette flow, half Poiseuille flow, the second problem of Stokes and flow in a lid-driven square cavity.

Keywords: Numerical stability; Mass conservation; Numerical accuracy

1. Introduction

The lattice Boltzmann method has become increasingly popular for computing fluid flows [11,13,4]. It is based on a particle approach, meaning that a fluid is rather considered as an ensemble of particles than as continuous matter. These particles can travel from one grid node to the other, where they undergo collisions with each other. These two principles are materialized in the streaming and collision step of the lattice Boltzmann method. Macroscopic quantities, such as density or momentum, are then recovered as statistical moments of the particle distribution function, the central object of the lattice Boltzmann method. From a numerical point of view, the lattice Boltzmann method is a second order ACCURATE scheme in space and time, if compressibility effects can be made negligible.

As mentioned in [8], boundary conditions are still an open issue. The difficulty of boundary conditions in lattice Boltzmann methods is to find a formulation for the particle distribution functions leaving into the bulk fluid domain, but which do not stem from the computational domain. The lattice Boltzmann boundary conditions can be divided into two families, the bounce back [10] and the so-called wet boundary conditions [3]. For the former, boundary nodes lie outside of the fluid domain, whereas for the latter ones, they are at the boundary but still part of the fluid domain. Therefore the former ones only formulate a closure for the unknown populations whereas the later ones still apply a collision step before streaming, similar to a bulk node.

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