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Lattice Boltzmann modeling of rotating channel flows

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The lattice Boltzmann method (LBM) is recognised as a well-established numerical technique, capable of solving a wide variety of fluid flow problems [1]. This study will focus on a very specific application: *the LBM modeling of rotating channel flows* [2]. Despite the apparent simplicity of this problem, current CFD commercial codes still show difficulties in solving it [3], and LBM is no exception [2]. This study will tackle this problem, starting from a standard LBM-BGK model [4] subject to a popular force scheme [5] on a cubic lattice [6]. Then, by taking a step-by-step analysis, based on simple numerical examples, we will progressively unfold which difficulties the method is expected to face and which strategies can be adopted to overcome them. The points under analysis will cover almost every element of the LBM algorithm, namely:

1. LBM collision model: Is a single-relaxation-time model (LBM-BGK) able to support physically consistent numerical solutions? Should a two-relaxation-time model (LBM-TRT) [7] be preferred?

2. LBM forcing model: Is the popular Guo et al. [5] force scheme able to reproduce consistent external body forces in incompressible hydrodynamics [8]? Should we be expecting the inevitable presence of LBM force errors? What are their consequences? Is there any strategy to correct/mitigate them?

3. LBM lattice and equilibrium models: Do all cubic lattices (D3Q15, D3Q19 and D3Q27) perform identically, when the same equilibrium [6] is adopted? What might explain their differences? Can we correct them by tailoring the equilibrium according to the lattice [9]?

This work will address each of these questions and, at the same time, provide an improved LBM scheme, capable of competing with (or even outperforming) traditional CFD strategies for this problem class.

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