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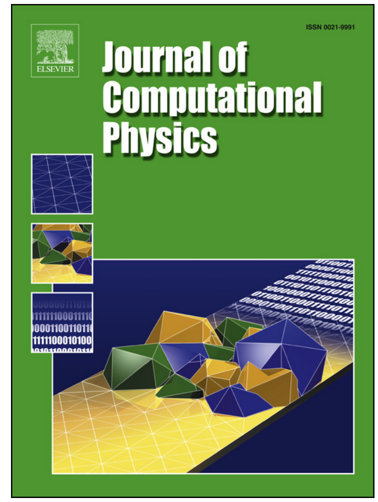

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Direct numerical simulation of turbulent pipe flow using the lattice Boltzmann method

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Abstract

In this paper, we present a first direct numerical simulation (DNS) of a turbulent pipe flow using the mesoscopic lattice Boltzmann method (LBM) on both a D3Q19 lattice grid and a D3Q27 lattice grid. DNS of turbulent pipe flows using LBM has never been reported previously, perhaps due to inaccuracy and numerical stability associated with the previous implementations of LBM in the presence of a curved solid surface. In fact, it was even speculated that the D3Q19 lattice might be inappropriate as a DNS tool for turbulent pipe flows. In this paper, we show, through careful implementation, accurate turbulent statistics can be obtained using both D3Q19 and D3Q27 lattice grids. In the simulation with D3Q19 lattice, a few problems related to the numerical stability of the simulation are exposed. Discussions and solutions for those problems are provided. The simulation with D3Q27 lattice, on the other hand, is found to be more stable than its D3Q19 counterpart. The resulting turbulent flow statistics at a friction Reynolds number of $Re_\tau = 180$ are compared systematically with both published experimental and other DNS results based on solving the Navier-Stokes equations. The comparisons cover the mean-flow profile, the r.m.s. velocity and vorticity profiles, the mean and r.m.s. pressure profiles, the velocity skewness and flatness, and spatial correlations and energy spectra of velocity and vorticity. Overall, we conclude that both D3Q19 and D3Q27 sim-

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