Abstract

The present thesis explores the applicability of the lattice Boltzmann Method (LBM) to validate the turbulent flow simulation in the various complex flow domains. LBM in recent years has emerged as an alternative Computational Fluid Dynamics (CFD) approach other than traditional Navier-Stokes (NS) solvers. The method is based on the discrete numerical approach and solves the kinetic equations to discretize the fluid domain. The fluid in LBM is defined as the particle distribution functions. The computational domain of the fluid flow represents the Eulerian grid nodes, each of which consists of a lattice structure. The lattice structure is comprised of the particle distribution functions, which are restricted to move in specific directions.

The research work mainly focuses on modeling large turbulent structures on a grid-scale for high Reynolds number flows with the Large Eddy Simulation (LES) model in the frame of LBM. The turbulent motions smaller than grid size are resolved using the popular Smagorinsky subgrid-scale (SGS) model. The study also gives special attention to investigate the effect of the different discrete velocity models of LBM and boundary conditions on the turbulent flow behavior. The results are presented for various turbulent statistics, including phase-averaged velocities, root-mean-square (RMS) velocity, Reynolds stresses, and turbulent kinetic energy (TKE).

Moreover, another important work reported in the thesis is the turbulent flow simulation in the stirred tank reactor equipped with dual-Rushton impellers. The study shows the LBM capability to simulate the turbulent flow in such complex geometry. The work also investigates the effect of baffles on the flow hydrodynamics at different impeller clearance. The study compares the results at different impeller clearance in the presence and absence of baffles. The obtained results are validated with the experimental data available in the literature.

The thesis work also presents the efficiency of the LBM algorithm on multi-core computer hardware. A highly parallelized computer code was developed using Compute Unified Device Architecture (CUDA) programming language to execute on Graphics Processing Units (GPUs) parallel platform. The computational performance of the algorithm is measured from the Millions Lattice Updates Per Second (MLUPS) parameter. This is obtained from the simulation run-time of the code on the multi-cores of the GPU. The computational scaling of the code is addressed in the study by executing the code at varying numbers of cores. The three-dimensional (3-D) approach of the domain decomposition is employed to increase the scalability.

In conclusion, the research studies performed in the present thesis show the LBM viability as a feasible tool for the turbulent flow simulation at high Reynolds numbers with good accuracy and high computational efficiency for various simple to complex flow domains.

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