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Two-phase flow simulation in the large digital rock by using high performance cluster

JIANG, Fei[1] ; TSUJI, Takeshi[1*]

[1]I2CNER, Kyushu University

A numerical implementation based on a Graphics Processing Unit (GPU) is proposed for the acceleration of the two-phase simulation using Lattice Boltzmann Method (LBM). The LBM yields regular, data-parallel computations; therefore, it is especially well fitted to GPU calculations. This study focuses on the application of the LBM for fluid displacement computations in real rock sample. For this purpose, the digital rock model is reconstructed from the micro-CT scanned images of reservoir sample with a resolution of 2.0 um. In order to obtain reliable and accurate results from the developed numerical model, the computational domain must be large enough to cover the representative element size (REV) of sample rock. As a result, pore scale LBM simulation of multiphase porous medium systems with sufficient resolution and large grid-number are very computationally challenging. To achieve this extremely large-scale simulation, multi-GPU parallel scheme by using CUDA and MPI is developed. Careful optimizations include sparse storage scheme, efficient domain decomposition and non-blocking communication are desired for algorithm implementation. Finally, we succeeded to perform a two-phase simulation with 10 billion (1000 x1000x1000) mesh sizes using a small-scale GPU cluster. The developed large-scale simulation method enables the direct upscaling from pore scale to core scale which is a very powerful tool for many engineering applications such as enhanced oil recovery (EOR) and Carbon Capture and Storage (CCS).

Keywords: Digital rock, lattice Boltzmann method, two-phase simulation, GPU, CO2 storage