GPU-based numerical solution of thermal multiphase flow in porous media

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Abstract

In this work, a numerical thermal multiphase flow in porous media is studied. We consider a porous media filled with three phases (water, oil and gas) and steam injection to investigate the effects of temperature rise on viscosity reduction. The mathematical model is based on the mass conservation equations for water, oil and gas, and an equation for the energy is considered to account for heat transport [1] [2]. These conditions give us a system of four non-linear and coupled partial differential equations that need to be solved numerically using some linearization strategy [3] [4] [5] [6] [7] [8]. The finite volume technique is used to develop a numerical model and to linearize the equations we apply the Newton-Raphson method [9]. The linear systems generated by the combination of both numerical techniques are large and difficult to solve. Some problems arise in the Jacobian construction, which takes considerable time to be generated. Also, the solution of the systems is expensive and requires a large amount of time for high number of unknowns. For this reason, it is necessary to apply new technologies to implement solution algorithms in parallel, since accelerating the computation time allows us to save time. Within these new technologies is the computation using Graphics Processing Units (GPU's) which allows to construct massively parallel numerical algorithms. The numerical solution of the systems was implemented in parallel and the strategy was to reduce the amount of information that needs to be exchanged between CPU and GPU memories. We used libraries that already include GPU Krylov methods [10] [11]. Also, we study the possibility of to construct the Jacobian directly on the GPU, which could reduce the communication information. Numerical results indicate very good acceleration using the GPU parallelization for our steam injection numerical code and we present some examples for regular domains and structured meshes.

Keywords: Multiphase flow, Porous media, GPUs, Finite volume, Newton-Raphson.

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