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A fully parallel Pore Network Simulator for plug size pore scale simulations

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Pore scale simulation is increasingly used to study various phenomena that cannot be reproduced by conventional Darcy-based simulators. Direct Numerical Simulation (DNS) on systems larger than few millimeters is too computationally demanding. Pore Network Modeling (PNM) is a practical way to study the flow at pore scale on larger volumes while keeping reasonable running times.

Recent advances have improved the speed of Pore Network Models (Regaieg et al, 2017, Petrovsky et al, 2020), while interesting speed-ups have been achieved, they are still not enough for tens of million pores simulations and memory starts to become the limiting factor. In order to accelerate our pore network simulations and to overcome memory limitations, we propose TOTAL's fully parallel pore network simulator DynaPNM used in quasi-static mode.

In this talk, we first describe the parallel pore network simulator. Then, we present several test cases where we show that this parallelization improves the computational performance without losing the accuracy of the solution. All the simulations were run on TOTAL's supercomputer PANGEA on networks of real rocks. Each network represents an upscaled version of the 3D segmented image of the rock in the form of a network of pore elements where the single-phase flow conductances in each pore are derived by solving the Stokes equation in the original geometry (Raeini et al, 2017). The extraction of large volumes became possible using a newly developed stitching algorithm (Varloteaux et al, 2021).

We then describe how simulation runs in parallel mode allow to perform large uncertainty studies (thousands simulations / day) on networks extracted from images that represent a size as large as (10000x8000x8000) voxels representing a rock volume of 46 cm3 which is a typical size of a plug used in capillary pressure measurements. We document the very large statistical dispersion in relative permeability results (due to the microscopic arrangement of oil-water contact angles) that is normally achieved when images as small as 1000x1000x1000 are used in simulation. We show how this finite size effect can be drastically reduced by simulating much larger and representative images, greatly improving the precision of the numerical result.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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Primary authors: REGAIEG, Mohamed (Total SE); VARLOTEAUX, Clément (Computational Hydrocarbon Laboratory for Optimized Energy Efficiency); MONCORGÉ, Arthur (Total SE); FARHANA FAISAL , Titly (Inria); BONDINO, Igor (Total SE)

Presenter: REGAIEG, Mohamed (Total SE)

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