April 21, 2019

Postdoctoral position

Numerical modelling of coupled liquid gas Darcy flow and mechanical deformation in fractured porous media.

Many real life applications in the geosciences involve processes like multi-phase flow and hydro-mechanical coupling in heterogeneous porous media. Such mathematical models are coupled systems of partial differential equations, including nonlinear and degenerate parabolic ones. Next to the inherent difficulties posed by such equations, further challenges are due to the heterogeneity of the medium and the presence of discontinuities like fractures. This has a strong impact on the complexity of the models, challenging their mathematical and numerical analysis and the development of efficient simulation tools.

This project focuses on the so called hybrid-dimensional matrix fracture models obtained by averaging both the unknowns and the equations in the fracture width and by imposing appropriate transmission conditions at both sides of the matrix fracture interfaces. Given the high geometrical complexity of real life fracture networks, the main advantages of these hybrid-dimensional compared with full-dimensional models are to both facilitate the mesh generation and the discretisation of the model, and to reduce the computational cost of the resulting schemes. This type of hybrid-dimensional models has been the object of intensive researches since the last 15 years due to the ubiquity of fractures in geology and their considerable impact on the flow and transport of mass and energy in porous media, and on the mechanical behavior of the rocks, see [1, 2] for single phase Darcy flows, [3, 4] for two-phase Darcy flows, and [5, 6, 7] for poro-elastic models.

The application targeted in this postdoctoral project deals with the simulation of the liquid gas transient flow coupled with the rock mechanical deformation in the deep Callovo-Oxfordian geological storage studied by Andra. The fracture network is initially induced by the drilling of the underground tunnels resulting in a damaged zone in the neighbourhood of the excavated galleries with fractures of variable connectivity, sizes and widths. The objective is to study the impact of the gas pressure on the width of the fractures and finally on the homogenized permeability and porosity at the scale of the damaged zone.

Program

Hybrid-dimensional matrix fracture models combine geometrical complexity with highly contrasted properties and constitutive laws at the matrix fracture interfaces leading to strong nonlinear couplings and a large range of space and time scales. It leads to new challenges in terms of mathematical analysis, discretization and nonlinear solvers.

We will consider hydro-mechanical models that couple the hybrid-dimensional porous media liquid gas flow with the rock mechanical deformation. For such models, the flow in the fractures has a strong nonlinear dependence upon the fracture width, resulting from the rock mechanical deformation which itself depends on the fluid pressure in the fractures. This type of models involves many challenges, some of which are listed here. First, the mathematical formulation of the problem involves weighted spaces with weights which depend on the unknown fracture width. The discretization should also find a compromise between robustness, accuracy and cost, while being able to adapt to heterogeneities. The numerical scheme should ensure conservation and avoid locking and inf-sup instabilities. At the tip of the fractures, the mechanical stress exhibits singularities which should be resolved. This is especially important in the case when the fractures propagate, since their dynamics is driven by the crack tip stress concentration. The convergence analysis is hindered by the severe non-linearities, and similarly, the fully nonlinear schemes are difficult to solve.

This project will explore spatial discretization methods adapted to the coupling between the hybrid-dimensional two-phase Darcy flow model and the mechanical model. It will investigate time splitting and nonlinear solver strategies to solve the strong nonlinear coupling between the liquid gas Darcy flow and the rock mechanical deformation. An essential enabler of the convergence analyses carried out on the schemes designed during the project will rely on a series of works around discrete functional analysis (current topic of the Australian Research Council-funded project of J. Droniou), and in particular its application to fully non-linear and possibly degenerate models [8, 9].

Applicant background: Applicant should have a PhD in applied mathematics related to the discretization of partial differential equations and scientific computing. She/he should be experienced with a scientific programming language such as Fortran, C or C++ and be interested in applications and team working.

Organisation of the project : The postdoctoral project is part of a project in collaboration between Andra, Monash University and l'Université Côte d'Azur (laboratoire de Mathématiques J.A. Dieudonné (LJAD) and joint LJAD-Inria team Coffee). It will be co-supervised by Roland Masson, Laurent Monasse, Konstantin Brenner from joint LJAD-Inria team Coffee and by Laurent Trenty from Andra. Jérome Droniou, from the department of Mathematics of Monash University, Melbourne, Australia, will also be involved in this project. The position will be held at LJAD on the Campus of Valrose in Nice with periodic meetings with Andra and also includes a stay at Monash University.

Duration and starting date : the duration is for 2 years and the starting date before the end of 2019.

Salary: About 2150 Euros net/month

Application : Send application with CV, letter of motivation, and references to roland.masson@univ-cotedazur.fr

References

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[6] Hanowski, K.K., Sander, O.: Simulation of Deformation and Flow in Fractured, Poroelastic Materials (2016). URL http://arxiv.org/abs/1606.05765

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[8] J. Droniou, R. Eymard, T. Gallouët, C. Guichard, and R. Herbin, *The gradient discretisation method*. Mathematics & Applications, vol. 82. Springer, 2018, 511p. doi: 10.1007/978-3-319-79042-8. `https://hal.archives-ouvertes.fr/hal-01382358`.

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