2019-01307 - PhD Position F/M Numerical modelling of coupled liquid gas Darcy flow and mechanical deformation in fractured porous media

Contract type : Public service fixed-term contract
Level of qualifications required : Graduate degree or equivalent
Fonction : PhD Position

About the research centre or Inria department

The Inria Sophia Antipolis - Méditerranée center counts 37 research teams and 9 support departments. The center's staff (about 600 people including 400 Inria employees) is composed of scientists of different nationalities (250 foreigners of 50 nationalities), engineers, technicians and administrators. 1/3 of the staff are civil servants, the others are contractual. The majority of the research teams at the center are located in Sophia Antipolis and Nice in the Alpes-Maritimes. Six teams are based in Montpellier and a team is hosted by the computer science department of the University of Bologna in Italy. The Center is a member of the University and Institution Community (ComUE) "Université Côte d'Azur (UCA)".

Context

The PhD proposal is part of a project in collaboration between Andra, Monash University and l'Universit\'e C\^ote d'Azur (laboratoire de Math\'ematiques J.A. Dieudonn\'e (LJAD) and joint LJAD-Inria team Coffee). The PhD will be co-supervised by Roland Masson, Laurent Monasse, Konstantin Brenner from joint LJAD-Inria team Coffee and by Laurent Trenty from Andra. J\'erome Droniou, from the department of Mathematics of Monash University, Melbourne, Australia, will also be involved in this project. The PhD will be held at LJAD on the Campus of Valrose in Nice with periodic meetings with Andra and also includes stays at Monash University.

Assignment

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 PhD 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.

The application targeted in this PhD 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.

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.

Bibliography:

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Main activities

This PhD project 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. It will also explore spatial discretizations combining a nodal approximation of the flow and mechanical models in the matrix with a face based approximation in the fractures and at the matrix fracture interfaces. This will provide both the locality of the transmission conditions at the matrix fracture interfaces and a low number of degrees of freedom on simplicial meshes. An essential enabler of the convergence analyses carried out on the schemes designed during the PhD project lies in the 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.

Skills

Applicant should have a Master degree in applied mathematics with a good knowledge of the discretization of partial differential equations. She/he should be familiar with a scientific programming language such as Fortran, C or C++, have a first experience in scientific computing and be interested in physics and team working.

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Remuneration

Monthly gross salary : 1st and 2nd year : 1.982 euros

Monthly gross salary : 3rd year : 2 085 euros

General Information

- **Theme/Domain :** Numerical schemes and simulations
  Scientific computing (BAP E)
- **Town/city :** Nice
- **Inria Center :** CRI Sophia Antipolis - Méditerranée
- **Starting date :** 2019-09-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2019-06-30

Contacts

- **Inria Team :** COFFEE
- **PhD Supervisor :**
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About Inria

Inria, the French national research institute for the digital sciences, promotes scientific excellence and technology transfer to maximise its impact. It employs 2,400 people. Its 200 agile project teams, generally with academic partners, involve more than 3,000 scientists in meeting the challenges of computer science and mathematics, often at the interface of other disciplines. Inria works with many companies and has assisted in the creation of over 160 startups. It strives to meet the challenges of the digital transformation of science, society and the economy.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of

the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.