Crack initiation and propagation in anisotropic medium accounting for Hydro-Mechanical couplings

The aim of the PhD thesis is to consider the influence of anisotropy on the initiation and propagation of fractures within rock masses. Indeed, the intrinsic anisotropy of the material, in association to the anisotropy induced by the stress field, plays a significant role in the hydro-mechanical behavior of rocks and directly influences the way damage develops in the medium. This project aims at developing a representative model and a powerful predictive tool whose applications will resonate both in geotechnics (stability of underground structures and cliffs) and in the operation and management of natural resources (geothermal, CO2 capture, extraction of hydrocarbons).

A so-called HM-XFEM model is currently developed at GeoRessources laboratory through two PhD theses (M. Faivre: 2012-2015 and B. Paul: 2013-2016). The HM-XFEM model integrates the formalism of poromechanics (as defined by Coussy) within the extended finite element method (XFEM) but is limited, in its present form, to the description of isotropic poro-elastic behaviors. The objective of the thesis proposed here is to anchor the model in a more realistic context, more representative of the actual behavior of rocks, by taking into account the anisotropy on one hand, and, the plastic behavior on the other hand. The final aim is to improve the model predictive capabilities regarding the potential scientific and industrial applications (tunnel stability, radioactive waste disposal, CO2 storage, geothermal energy, mineral resources, natural resources, etc...). Beyond the applications to engineering structures, taking into account the intrinsic anisotropy is of fundamental importance to better reproduce the behavior of sedimentary rocks, most of which are transverse isotropic due to the presence of plans of cleavage and stratification joints in their texture. Indeed, these structural properties gives the rock matrix preferred directions of flow and deformation that must be taken into account in the modeling. The PhD will thus be devoted to the integration of the structural anisotropy of the rock matrix into the constitutive laws of the HM-XFEM model and to the study of its consequences on the initiation and propagation of fractures.

The thesis work will involve numerical developments within a finite element code (Code_Aster, Edf) which will be compared to discrete elements simulations forming part of a complementary study on the same topic (postdoctoral fellowship due to begin by the end of 2015). The PhD student will thus have the opportunity to judge the respective contributions and limitations of both approaches to tackle fracturing processes in anisotropic media. After validating the model through sound analytical solutions acquired from literature, the model will be calibrated from laboratory tests performed in the laboratory. The model will then be applied to dedicated in situ experiments.

The candidate should have a formation in solid and fluid mechanics, and, good knowledge in geomechanics (rock mechanics) and mechanics of porous media (poromechanics). Moreover, the candidate should present strong skills in numerical modeling and computer programming. Familiarity with computer language such as C++ will be an advantage.

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