Modelling of natural hydraulic fracturing in sandstone cylinders

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Natural Hydraulic Fractures (NHFs) exist predominantly *in situ*. Compared with Induced Hydraulic Fractures (IHFs), NHFs do not have an increasing but rather experience a decreasing pore pressure in the fracture zone [1]. Numerous studies have been conducted on the interaction between NHFs and IHFs, while rare research has addressed why the former exist and how they grow. This work aims to provide a theoretical basis for their generation and intends to justify the fracture criteria of geomaterials, within the framework of the Theory of Porous Media (TPM) constituted with the phase field method [2, 3].

For this purpose, a numerical model is developed to simulate the natural hydraulic fracturing behavior of sandstone. The numerical test scheme is designed to first model the steady-state flow of deep groundwater within the sandstone (rock), and then the changes in loading conditions at deep subsurface foundations, e. g. during sandstone drilling, where the external vertical load is removed, or e. g. due to tunneling, where the load on the tunnel foundation is significantly reduced under water-saturated conditions. These two states will be modelled using (i) a classical biphasic model and (ii) a biphasic model with an integrated phase-field approach to fracture. From (i), we expect a better understanding of the stress and pressure states occurring *in situ*. From (ii), we intend to justify the failure criteria and estimate material parameters of the TPM phase-field model.

Through this study, permeability was identified as a key parameter for the generation of tensile stresses that would cause fracture or damage within the sandstone via a basic biphasic model [4]. Furthermore, the influence of an important fracture material parameter, the energy release rate, G_c, on the growth of NHFs, was studied. An estimated critical range of $G_c > 110$ N/mm, which does not allow NHFs growth, is given as a reference for future studies. In addition, the growth of NHFs shows a strong dependence on permeability. With higher permeability the material is only damaged and does not produce any fracture, while NHFs tend to grow with lower permeability, even though the external force in both cases remains the same.

The study of NHFs provides relevant insights for engineering practice, e.g. measures to increase either the permeability or the energy release rate of the material in order to avoid excessive fracture growth within geomaterials. The TPM frameworks, along with the phase-field method, can also serve as a powerful tool for engineering practice *in situ*.

References

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