Numerical assessment of the near-wellbore rock matrix permeability gain due to thermal stimulation

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Introduction

EGS (Enhanced/Engineered Geothermal System) constitutes a promising renewable energy technology to produce heat and electricity from deep geothermal energy (several kilometers deep). In this context, the DEEPEGS project aims at demonstrating the feasibility of EGS in different geological contexts, in order to deliver new innovative solutions and models for wider deployments of EGS. The evaluation of the increase of the well injectivity thanks to stimulation processes is one of the ongoing challenges that need to be addressed. In this paper we propose a first assessment of the permeability gain of the rock matrix around deep geothermal wellbores following numerical simulation of thermal stimulation. In a first step, the rock fracturing induced by the host rock cooling during thermal stimulation of the deep geothermal wellbore is modelled using a "micro-macro" Discrete Element Method approach (PFC ©Itasca). Then, in a second step, we propose an estimation of the subsequent near-wellbore rock permeability variation.

Thermal stimulation of the deep geothermal wellbore

The objective is to build a realistic model, corresponding to the beginning of thermal stimulation of the demonstrator well RN-15/IDDP-2 (Reykanes, Iceland). We assume that a cold fluid (30°C) is injected in the wellbore surrounded by a dolerite. The injection takes place at 4650 m-depth, where the rock temperature is around 430°C; no overpressure is considered in the well as a first evaluation of the impact of the thermal loading. We study the initiation of the failure in the rock mass in the near-well area in a 2D plan perpendicular to the wellbore [Peter-Borie, 2017; Peter-Borie et al., soumis].

Figure 1 illustrates the kind of results that will be further analysed during the presentation: cracks and possible associated fractures (cracks coalescence) are recorded depending on time, as well as the temperature field.

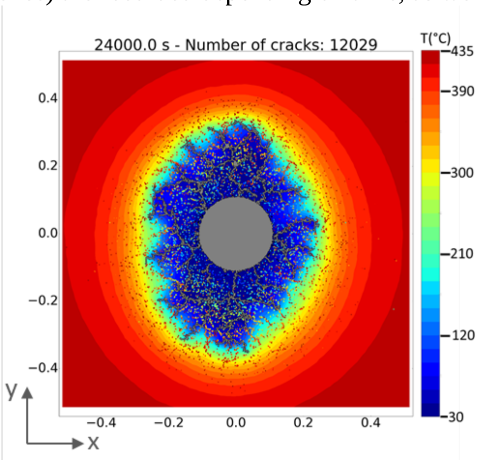


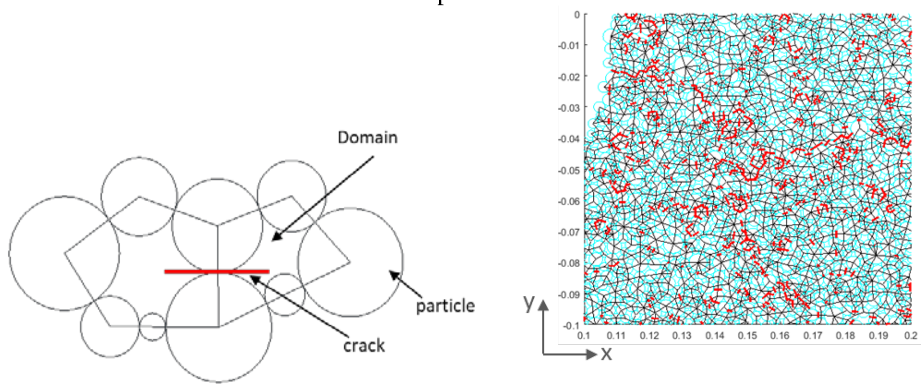
Fig. 1: The temperature field with cracks represented by points

Estimation of the rock permeability variation in the near-wellbore area

In the second step, from the results of numerical simulation of the thermal stimulation, a method of estimation of permeability evolution in the near-wellbore is proposed. The rock permeability increases with the apparition of thermomechanical cracks. On the one hand, we propose to evaluate the permeability in the rock matrix linked to all the cracks, and, on the other hand, to characterize the fracture created by the crack coalescence from the wellbore. At first hand, in the initial state, we assume that the permeability of the medium k_d^{ini} is constant. At the cracking state, the length of microcracks is sufficiently large compared to the size of the domain. Therefore, assuming that we can get the mechanism of parallel transfer in the domain containing cracks and the rock permeability in a domain k_d is determined by the sum of the initial permeability k_d^{ini} and the permeability of the microcracks k_d^{crk} :

$$k_d = k_d^{ini} + k_d^{crk}$$

The permeability of cracks k_d^{crk} is estimated by the Poiseuille law in the "local domains" [Zhou, 2016]. The "local domains" are established by the connectivity of the particles of the numerical model. Figure 2 presents the local domains in the near-wellbore area at the microscopic scale.

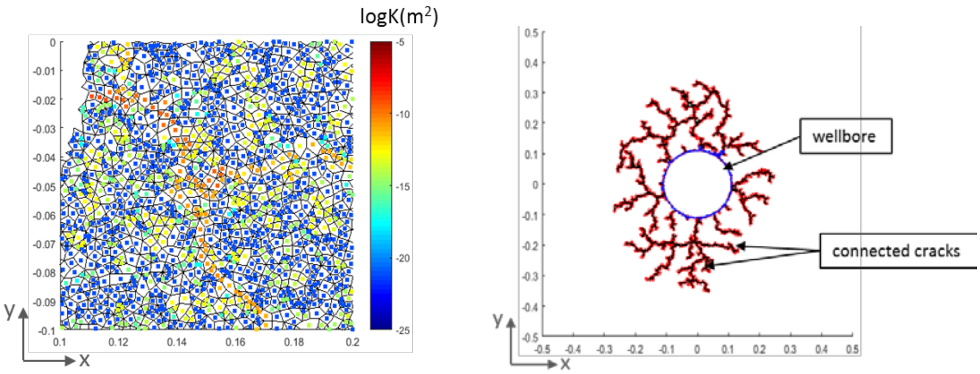


(a) (b)

Fig. 2: a. Domain containing crack; b. Zoom of domains at the microscopic scale

Figure 3a shows the variation of permeability k_d at the cracking state. This value increases depending on the number of cracks and on its aperture in the local domains. The permeability of the medium varies from 10^{-21} to 10^{-11} m^2.

Assuming that cracks in a domain are connected, we can determine the propagation of fractures from the wellbore into the rock. Figure 3b shows the new wellbore boundary and the propagation of cracks from this wellbore.



(a) (b)

Fig. 3: a. Logarithm of permeability in domains containing cracks; b. Connectivity of cracks near-wells

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References

Peter-Borie M (coord), and DEEPEGS team (2017) On the different stimulation methods for EGS and recommended methods for stimulation scenarios based on numerical modelling at each site. Applied to Reykjanes, Deliverable D4.2 of the DEEPEGS project, Confidential document

Peter-Borie M et al. (soumis) Borehole damaging under thermo-mechanical loading in the IDDP2/RN-15 well: numerical modelling and feedback from wellbore logging. Geothermal energy special issue

Zhou J, Zhang L and Pan Z (2016) Numerical investigation of fluid-driven near-borehole fracture propagation in laminated reservoir rock using PFC 2D. Journal of Natural Gas Science and Engineering, pp. 36, 719-733