PSL UNIVERSITÉ PARIS

THÈSE DE DOCTORAT DE L'UNIVERSITÉ PSL

Préparée à MINES ParisTech

Composition du jury :

Patrick, SELVADURAI Professeur, McGill University	*Rapporteur*
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Hervré, CHAURIS Professeur, MINES ParisTech	*Examinateur*
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Numerical modeling of hydraulic stimulation and induced seismicity in deep geothermal reservoirs

Dac Thuong NGO

June 27, 14h00, Mines ParisTech, 60 boulevard Saint Michel, Paris, Amphitheatre L 109

Geothermal energy is a renewable resource that can provide base-load energy for electricity production or heating purposes without, or with limited, emission of green house gases. However, the development and the exploitation of deep geothermal power plants is usually accompanied by induced seismicity – a side effect that can raise serious concerns to the public and may prevent large-scale application of geothermal energy. The centerpiece of a deep geothermal power plant is a heat exchanger, i.e., a reservoir, located in hot rocks at depth. This rock reservoir is created using a hydraulic stimulation technique, which essentially consists of injecting fluid at high pressures to create new hydraulic fractures that will connect with pre-existing fractures/faults, thus multiplying possible pathways for fluid circulation. Multiple physical processes are involved during the stimulation and exploitation of the rock reservoir, including fluid flow, rock deformation of the rock, and temperature changes. These processes are the origin of the rock failure (e.g., fracture propagation, fault reactivation) that is responsible for the induced seismicity. In return, the induced seismicity can be regarded as a real-time indicator of the spatial progress of the reservoir during hydraulic stimulation.

This doctoral research focuses on the use of numerical simulations to better understand the behavior of fractured geothermal reservoirs and the potential of induced seismicity. The propagation of hydraulic fractures and the reactivation of pre-existing faults are modeled using the cohesive material concept in combination with finite cohesive elements and taking into account the underlying physical processes (e.g., fluid flow, rock deformation). Various factors that may have a major impact on fracture propagation and fault reactivation are investigated, such as the friction condition of the pre-existing faults, the fluid injection rate, and the fault orientation. Temperature changes resulting from fluid injection and circulation that may have a long term effect are also separately investigated.

The induced seismicity is first studied from the standpoint of using the law of energy conservation in order to explain the mechanism of elastic waves generation due to failure. The process of converting the strain energy accumulated in a system prior to the failure into kinetic energy during failure, regardless of how slowly the external load is applied to the system, is clearly demonstrated. This approach provides a good understanding of the factors that have a major impact on the intensity of the induced seismic waves. A modeling procedure is then proposed to calculate the peak ground accelerations that are induced by the fault slip. The computed accelerations on the ground surface are used to assess the earthquake intensity, the human perception of the seismic waves, and the damage potential to infrastructures.

Scientific papers from the candidate:

Ngo, D.T., Pellet, F.L., Bruel, D. (2019) Modeling of fault slip during hydraulic stimulation in naturally fractured medium, Geomechanics and Geophysics for Geo-Energy and Geo-Resources, In Press, (*doi.org/10.1007/s40948-019-00108-1)*

Ngo, D.T., Pellet, F.L. (2018) Numerical modeling of thermally-induced fractures in a large rock salt mass, Journal of Rock Mechanics and Geotechnical Engineering, vol 10, 5 : 844 - 855 *(doi.org/10.1016/j.jrmge.2018.04.008)*

Ngo, D.T., Pellet, F.L., Bruel, D. (2017), Modeling of dynamic crack propagation under quasi-static loading, Proc. 15th International Conference of the International Association of Computer Methods and Advances in Geomechanics, IACMAG, Wuhan, China.