Peer-reviewed Conference Contribution

Thermo-hydro-mechanical modelling of geothermal energy extraction in deep mines in spatially heterogeneous settings

Le Zhang[1], Alexandros Daniilidis[2], Anne-Catherine Dieudonné[2] and Thomas Hermans[1,*]

[1] Ghent University, Ghent, Belgium
[2] Delft University of Technology, Delft, The Netherlands
* Corresponding author: Thomas.Hermans@UGent.be

With the increasing demand for mineral and alternative energy resources, as well as the gradual depletion of shallow resources, the exploitation and utilization of mineral resources and geothermal energy in deep strata is an effective way to solve the problem of resource shortage [1]. In recent years, as a new type of resource mining mode, the co-mining of deep mineral and geothermal energy has developed rapidly [2, 3]. This method can make use of the original equipment of the mine for geothermal exploitation. However, the deep co-mining system faces two significant challenges: the first is the significant uncertainty inherent in subsurface properties, while the second is the high levels of geostress and temperature associated with deep mining. These challenges are adding some constraints on the practicality of exploiting such systems and limit the feasibility of deep resource co-mining, so that modelling efforts are needed for actual risk assessment.

Consequently, we developed a Thermo-Hydro-Mechanical (THM) coupling framework for geothermal energy exploitation in deep mines using COMSOL to quantitatively characterize the temperature field of the geothermal system and predict the stress field of the mining system, considering the joint effects of large uncertainties and THM coupling. Through SGeMS, the uncertainty and spatial heterogeneity distribution of porosity are first generated. Then, the uncertainty of the hydraulic parameter [4] (permeability), mechanical parameter [5] (elastic modulus), and thermal parameter [6] (heat capacity and heat conductivity) was derived from the porosity. 500 samples were generated within a given uncertainty range, by means of Monte Carlo simulations. The spatial and temporal distributions of the temperature field of the geothermal system, and the stress field of the mining system were simulated, for each sample with COMSOL. Using the distance-based global sensitivity analysis [6], the most sensitive parameters for deep mining are identified, the heat storage capacity of the system and evolution of the maximum stress ratio are evaluated, including uncertainty.

Contributor statement

Le Zhang: Conceptualization, Software, Visualization, Writing - original draft, Writing - review & editing. Alexandros Daniilidis: Supervision, Software, Visualization, Writing - review & editing. Anne-Catherine Dieudonné: Supervision, Software, Visualization, Writing - review & editing. Thomas Hermans: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing.

References

[1] Hartai, É., Bodosi, B., Madarász, T., Földessy, J., Németh, N., Tóth, A., ... & CHPM2030, T. (2017). Combining energy production and mineral extraction–The CHPM2030 project. *European Geologist*, (43), 6-9.
[2] Li, B., Zhang, J., Ghoreishi-Madiseh, S. A., de Brito, M. A. R., Deng, X., & Kuyuk, A. F. (2020). Energy performance of seasonal thermal energy storage in underground backfilled stopes of coal mines. *Journal of Cleaner Production*, *275*, 122647.
[3] Xu, Y., Li, Z., Chen, Y., Jia, M., Zhang, M., & Li, R. (2022). Synergetic mining of geothermal energy in deep mines: An innovative method for heat hazard control. *Applied Thermal Engineering*, *210*, 118398.
[4] Chapuis, R. P., & Aubertin, M. (2003). On the use of the Kozeny Carman equation to predict the hydraulic conductivity of soils. *Canadian Geotechnical Journal*, *40*(3), 616-628.
[5] Choren, J. A., Heinrich, S. M., & Silver-Thorn, M. B. (2013). Young's modulus and volume porosity relationships for additive manufacturing applications. *Journal of Materials Science*, *48*, 5103-5112.
[6] Hermans, T., Nguyen, F., Klepikova, M., Dassargues, A., & Caers, J. (2018). Uncertainty quantification of medium-term heat storage from short-term geophysical experiments using Bayesian evidential learning. *Water Resources Research*, *54*(4), 2931-2948.

DOI: https://doi.org/10.59490/seg23.2023.554