Uncertanity analysis of the material properties of rock in hydrualic fracturing process

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Hydraulic fracturing is mostly controversial on the account of the potential risk of contaminating groundwater issues. Hydraulic fracturing is a challenging process to simulate, as it involves the coupling of various models: a solid model which describes the deformation of the rock induced by the fluid; a fluid flow model within the fracture, including a model for the representation of fluid leak off to the rock formation; a fracture propagation model. Besides, hydraulic fracturing processes are surrounded by uncertainty, as available data on e.g. rock formations is scant and available models are still rudimentary. In this contribution, an uncertainty analysis is carried out by considering rock properties to be non-deterministic as a step in the direction of uncertainty quantification in hydraulic fracturing.

We consider the Perkins-Kern-Nordgren (PKN) model [1][2] for hydraulic fracturing, which is one of the most commonly used models for well design in engineering practice [3]. The assumptions made in this model enable its application within a stochastic framework. Albeit simplified, the PKN model is still characterized by a moving boundary, strong non-linearities, and the presence of a singularity at the moving tip due to vanishing of the fracture aperture. The employed simulation technique is discussed, with a particular focus on the enrichment of the computational basis to represent the singular tip behavior.

The stochastic framework considered herein is discussed in specific to rock properties which are modeled as random fields. The random fields are generated using the Karhunen−Loéve expansion. On one hand our study will present a direct analysis of the propagation of heterogeneities in the hydraulic fracturing process, while on the other hand it will enable the study of the influence of heterogeneities in the model parameters. The Monte Carlo method is used to quantify these heterogeneities. These simulations show the appropriateness of uncertainty analysis in hydraulic fracturing for determination of the probability of occurrence of undesired phenomenon such as interference of fracture geometry with the groundwater resources.

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