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Identification of viscoelastic properties from numerical model reduction of pressure diffusion in porous rock with fractures

Ralf Jänicke[1,*], Beatriz Quintal[2], Fredrik Larsson[1] and Kenneth Runesson[1]

[1] Chalmers University of Technology, Division Material and Computational Mechanics, SE-41296 Gothenburg, Sweden, ralf.janicke@chalmers.se

[2] University of Lausanne, Institute of Earth Sciences, Ch-1015 Lausanne, Switzerland

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This presentation deals with the computational homogenization and numerical model reduction of deformation-driven pressure diffusion in fractured porous rock. Exposed to seismic waves, the heterogeneity of the material leads to local fluid pressure gradients which are equilibrated via pressure diffusion. However, a macroscopic observer is not able to measure the diffusion process directly but senses the intrinsic attenuation of an apparently monophasic viscoelastic solid. The aim of this contribution is to establish a reliable, yet numerically efficient, computational homogenization method to identify the viscoelastic properties of the macroscopic substitute model. We use a hybrid-dimensional discretization of the fluid-filled fractures incorporating the hydro-mechanical coupling between fracture and rock matrix. We incorporate a Numerical Model Reduction procedure similar to the Nonuniform Transformation Field Analysis. Hence, we decompose the fluid pressure distribution additively and interpret it as a linear combination of N pressure modes p_a according to

$$p(\mathbf{x},t) \approx \sum_{a=1}^{N} \bar{\xi}_a(t)\, p_a(\mathbf{x}).$$

The weights $\bar{\xi}_a$ are called mode activity parameters and serve as the history variables of the viscoelastic substitute model. The proposed method is validated for several scenarios ranging from pressure diffusion in a poroelastic matrix without fractures to the coupled pressure diffusion in interconnected fractures and the embedding poroelastic matrix. Strategies for an adaptive enrichment of the basis during a two-scale simulation will be discussed.

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