Multsacle Modeling of Poroelasticity in Highly Deformable Fractured Reservoirs

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In this work a new class of methods for upscaling fluid-structure interaction problems from the pore-level to a macroscale is proposed. We consider a fully coupled fluid-structure interaction problem for stokes fluid and an elastic solid at the pore-level. The solid, due to coupling with the fluid, material nonlinearities, as well as macroscopic boundary conditions, can deform enough so that the pore-space is altered significantly. As a result, macroscopic properties such as the permeability of the porous media become nonlinearly dependent on the fine-scale displacements. Therefore, classical upscaled models, such as Biot's equations, can no longer be applied. We propose a series of numerical upscaling models which couple this fine-scale FSI problem to a nonlinear elliptic equation for the averaged pressure and displacements at the coase scale. The proposed multiscale methods correclty transfer the appropriate physics from the fine to the coarse scale. Moreoever they are intrinsically parallelizable on a wide variety of computer architectures. The models are applied to a two-scale media with a fracture network embedded in elastic, impermeable solid at the finer scale. We use the proposed models to upscale the fracture network to the coarse nonlinear poroelasticity. It is shown that the coarse permeability is a highly sensitive function of pressure and displacements due to their effects on changing the aperture of the fractures at the fine scale. Several numerical examples which demonstrate the method are also presented.