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A visco-poroelastic damage model for modelling compaction and brittle failure of porous rocks

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Hydraulic stimulation of geothermal wells is often used to increase heat extraction from deep geothermal reservoirs. Initiation and propagation of fractures due to pore pressure build-up increase the effective permeability of the porous medium. Understanding the processes controlling the initiation of fractures, the evolution of their geometries and the hydro-mechanical impact on transport properties of the porous medium is therefore of great interest for geothermal energy production.

In this contribution, we will present a thermodynamically consistent visco-poroelastic damage model which can deal with the multi-scale and multi-physics nature of the physical processes occurring during deformation of a porous rock. Deformation of a porous medium is crucially influenced by the changes in the effective stress. Considering a strain-formulated yield cap and the compaction-dilation transition, three different regimes can be identified: quasi-elastic deformation, cataclastic compaction with microcracking (damage accumulation) and macroscopic brittle failure with dilation.
The governing equations for deformation, damage accumulation/healing and fluid flow have been implemented in a fully-coupled finite-element-method based framework (MOOSE). The MOOSE framework provides a powerful and flexible platform to solve multiphysics problems implicitly and in a tightly coupled manner on unstructured meshes which is of interest for such non-linear context.

To validate and illustrate the model, simulations of the deformation behaviour of cylindrical porous Bentheimer sandstone samples under different confining pressures are compared to experiments. The first experiment under low confining pressure leads to shear failure, the second for high confining pressure leads to cataclastic compaction and the third one with intermediate confining pressure correspond to a transitional regime between the two firsts.
Finally, we will demonstrate that this approach can also be used at the field scale to simulate hydraulic stimulation of geothermal wells including fracture initiation and propagation.