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Shear Displacement Predictions in Fractured Rock Based on Global vs. Resolved Stress

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Shear displacement of fractures in porous rock leads to fracture dilation influencing the flow field. This is an important mechanism in e.g. enhanced geothermal systems, where the fracture aperture determines the heat extraction performance of the reservoir. To predict shear dilation in a fractured reservoir, the shear displacement needs to be calculated first, since the dilation directly depends on it. This can be done using analytical solutions depending on far field stresses, or with mechanical solvers. Analytical solutions exist for simple test cases of isolated fractures, and approximations from far field stresses calculate the local shear and normal stress on the fracture with Cauchy's equation. However, we expect that using these two leads to wrong results in complicated fracture patterns, because the interaction between fractures is neglected. This is the main reason why mechanical solvers like boundary element methods, extended finite element methods (XFEM) and extended finite volume methods (XFVM), all of which resolve the mechanics locally by solving for stress equilibrium, were developed.

We compare results based on approximating the local stress at the fractures by the far field stress with those relying on spatially resolved stress fields obtained with a mechanical solver. While the former are computationally much cheaper, the latter are more accurate and more flexible. Our goal is to describe the accuracy and range of application of current cheap approximations regarding shear displacement. To obtain reference solutions we used a solver based on XFVM, in which the fractures are embedded manifolds of lower dimension represented by special discontinuous basis functions. These functions have the property that the displacement gradient is continuous over the fracture segments, which simplifies the computation of traction and compressive forces across the manifold.

The results show that the shear displacement of a single fracture in a rock matrix is well represented by far field stress approximations. In two intersecting fractures the behavior of the fracture slipping at higher pressures is approximated well by using an adaptation depending on the fracture length. In conjugate fractures, on the other hand, the far field approximation overestimates the shear displacements. The importance of locally resolved stresses is highlighted by simulation results of a model with a layer-restricted fracture pattern mapped in the Hornelen basin in Norway, that is, large differences can be observed in the resulting aperture distributions obtained with resolved vs. global stress field approximations.

Participation

In-Person

References

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