Contribution ID: **687**   Type: **Oral Presentation**

A Flow Discretization for Conforming Discrete Fracture Matrix Models with Upscaling of Microscale Fractures

Wednesday, 2 June 2021 20:05 (15 minutes)

Natural occurring fractures can dominate fluid flow in subsurface rock and thus be crucial for engineering operations such as energy recovery and waste disposal. The fractures occur on multiple length scale with no scale separation, forming a challenge for their incorporation into mathematical models for fluid flow [1], as well as for discretizations.

Among the several classes of conceptual models for representing fractures [2], our interest is in the so-called Discrete Fracture Matrix (DFM) models. In DFM models, fractures that are deemed important (here termed macroscale fractures) are explicitly represented allowing for detailed representation of dynamics in these fractures, while the remaining (herein microscale) fractures are upscaled into equivalent continuum properties. We further consider DFM models where the fractures are represented as lower-dimensional objects and where the computational mesh conforms to these objects. This approach allows for high modeling and discretization of complex multiphysics processes [3], to the price of relatively high computational cost due to the high cell count needed to resolve the fractures.

The high computational cost makes the task of fracture upscaling critical for the feasibility of DFM methods with conforming grids. While discretization methods for this class of models have received much attention over the last decade, techniques for upscaling those fractures that are not explicitly represented have not been much studied.

In this work, we present a conforming DFM approach for the flow problem with a discretization that is tailored for upscaling of microscale fractures. The computational mesh is constructed to conform with the macroscale fractures. Inspired by the Multiscale Finite Volume [4] method, the basis functions for discretization on this macro mesh are constructed by solving local (to small patches of macro cells) problems where the microscale fractures are explicitly represented. This approach allows us to represent complex fracture networks at a reasonable computational cost. Moreover, relabeling of fractures between macro and micro is relatively straightforward, allowing for the study of the interplay between computational cost and errors due to upscaling and macro- and micro discretization. The implementation is open source [5] and is based on a standard workflow for meshing and discretization of conforming DFM models [6].

We present numerical examples for complex fracture networks in 2d and 3d, with emphasis on accuracy, convergence and robustness of the numerical methods. We also illustrate the impact of upscaling versus explicit representation on fracture networks where there is no separation of fracture length scales.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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Session Classification: MS3

Track Classification: (MS3) Flow, transport and mechanics in fractured porous media