XIX International Conference on Water Resources
CMWR 2012
University of Illinois at Urbana-Champaign
June 17-22, 2012

Mass conservative domain decomposition for fractured porous media

Tor Harald Sandve, Department of Mathematics, University of Bergen, +4741106542, tor.sandve@math.uib.no

1. Tor Harald Sandve, Department of Mathematics, University of Bergen
2. Eirik Keilegavlen, Department of Mathematics, University of Bergen
3. Jan M. Nordbotten, Department of Mathematics, University of Bergen

Simulation of flow and transport in fractured porous media is important for applications such as recovery of geothermal energy, petroleum production and geological waste disposal. The large contrast in characteristic properties (length scale and permeability), together with geometrical discontinuities and anisotropy presents great challenges to numerical simulation of the flow. Even though the global flow field most often is dominated by flow in the fractures, a proper representation of the interaction between fracture and matrix is crucial for e.g. estimating the potential for energy recovery. If the numerical grid does not conform to the fractures, upscaling is needed to represent the fracture flow. This is a highly challenging task. As an alternative, conforming grids can offer better approximation properties, to the price of a higher number of unknowns, and also an unstructured linear system to solve for the pressure. Thus if conforming grids are to offer a viable option, it is important to study efficient linear solvers for this problem.

In this work, we propose to apply a mass conservative domain decomposition (MCDD) type of multiscale linear solver, and study its performance for solving the pressure equation stemming from a fractured porous media. The MCDD method can be considered a reformulation of the multiscale finite volume method (MSFV) into a domain decomposition framework, allowing it to benefit from the domain decomposition literature, for instance in designing approximations on the interface between subdomains. In this work we investigate how the flexibility offered in the MCDD framework can be utilized to construct accurate coarse scale operators, and thus efficient linear solvers.
We apply triangular grids that conform to the fractures on both the coarse scale and the fine scale. This is to our knowledge the first application of a MSFV-type method to an unstructured grids; previous work has only considered logically Cartesian grids. That the coarse grid conforms to the main heterogeneities has two important consequences. First, it allows the main flow paths (the fractures) to be directly represented on the coarse scale, yielding good approximation properties for this part of the solution. Second, when the subdomains are divided by a highly permeable flow path, it is easier to give a physical interpretation to the interface approximations. Clever design of these interface approximations may greatly reduce the number of iterations needed to solve the linear system.

The coarse scale approximation of fracture flow can be further improved by associating more coarse scale degrees of freedom with the fractures, with the effect of enriching the coarse space. These auxiliary coarse variables have been studied within a domain decomposition context; however, few applications within multiscale methods have been reported so far.

We investigate how to best combine conforming grids, interface approximations and auxiliary coarse variables. Our aim is to design a linear solver which, when possible, resembles a discrete fracture network system, that is, the coarse scale approximation is sufficient for describing the global flow. If this is not the case, the linear solver should detect this, and resolve the coupling between the fractures and the rest of the domain