A LOCAL EMBEDDED METHOD FOR FLOW IN FRACTURED POROUS MEDIA WITH NUMERICAL UPSCALING AND MACHINE LEARNING

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The study of flow in fractured porous media is a key ingredient for many geoscience applications, such as reservoir management. Modelling and simulation of these highly heterogeneous and geometrically complex systems require the adoption of non-standard numerical schemes.

The Embedded Discrete Fracture Model (EDFM) [1] is a simple and effective way to account for fractures with coarse and regular grids, but it suffers from some limitations: the expression for the flux interaction terms between porous matrix and fractures comes from the assumption of linear pressure distribution around fractures, which holds true only far from the tips and fracture intersections, and it can be employed for highly permeable fractures only.

We propose an improvement of EDFM, i.e. the Local Embedded Discrete Fracture Model (LEDFM), which aims at overcoming both its limitations computing an improved coupling between fractures and the surrounding porous medium by a) relaxing the linear pressure distribution assumption, b) accounting for impermeable fractures modifying near-fracture transmissibilities.

These results are achieved by adopting local flow-based upscaling methods to compute new transmissibilities for matrix-fracture and near-fracture matrix-matrix connections. Here the coarse model coincides with an embedded model, whereas in the numerical upscaling techniques for fracture networks found in the literature the coarse model typically belongs to the family of Continuum Fracture Models (CFM), that are not capable of explicitly representing fractures. The definitions of the local fine scale problems for transmissibility computation are inspired from the aforementioned techniques, and a conforming method is used to solve them.

In some cases, a higher accuracy for the description of the near fracture flow is needed, so that the local problems for the computation of matrix-matrix transmissibilities are replaced with a multiscale approach.

Generally, a high number of local problems should be solved. Hence, to speed up an otherwise very costly procedure, neural networks are integrated in the model to provide a fast evaluation of the local flow problems. Indeed, these are solved in an offline stage, where different fracture configurations and matrix-fracture permeability contrasts are examined. The results obtained are then used to train two feedforward neural networks, whose goal is that of learning the transmissibility functions relative to the two different local problems. The transmissibilities are then obtained by evaluating the networks instead of solving the local problems directly, resulting in a dramatic reduction of the computational cost of the method.

The results obtained from several numerical tests, comparing the solutions of different embedded methods, including the newly developed LEDFM, with the reference ones, show that the local method overcomes both the limitations mentioned before pertaining to the classic EDFM method.

This is a joint work with Anna Scotti.

References

[1] L. Li and S.H. Lee, *Efficient field-scale simulation of black oil in a naturally fractured reservoir through discrete fracture networks and homogenized media*, SPE Reservoir Evaluation and Engineering, Vol. 11, pp. 750–758, 2008.

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